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FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Water Resource Management, Bureau of Watershed Management

CENTRAL DISTRICT • MIDDLE ST. JOHNS BASIN

TMDL Report

Nutrient TMDLs for the Wekiva River (WBIDs 2956, 2956A, and 2956C) and Rock Springs Run (WBID 2967)

Xueqing Gao

April 18, 2008

Acknowledgments

This TMDL was based on the Pollutant Load Reduction Goal (PLRG) for nitrate and total phosphorus developed by the St. Johns River Water Management District. The Florida Department of Environmental Protection (the Department) appreciates the instrumental help provided by Rob Mattson, and valuable suggestions from Ed Lowe, Larry Battoe, and Eric Marzolf. Special thanks also go to Dr. Xufeng Niu, who helped to define the nitrate target using the change-point analysis. We deeply appreciate the kind help provided by the Department's Central District Office staff, especially Chris Ferraro, Dennise Judy, Pat Young, and Ali Kazi, who helped greatly in providing data, valuable insight, and understanding of the point sources identified in the Wekiva River drainage basin. We also deeply appreciate the help from Sarah Jozwiak (NPDES Stormwater Section of the department) in providing information related to MS4 permits, and CDM, Inc for providing information about septic tanks for the Wekiva River Drainage basin.

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Chapter 1: INTRODUCTION

1.1 Purpose of Report

This report presents the nutrient Total Maximum Daily Loads (TMDLs) for Rock Springs Run (RSR) and the Wekiva River, in the Middle St. Johns River Basin. These waters were verified as impaired due to total phosphorus (TP) and nitrate based on evidence of imbalance in aquatic flora provided by the St. Johns River Water Management District (SJRWMD) and were added to the Verified List of impaired waters for the Middle St. Johns River Basin by Secretarial Order on January 3, 2007. The purpose of this TMDL is to establish the allowable loadings of pollutants to RSR and Wekiva River that would restore these waterbodies such that they meet their applicable water quality criteria for nutrients.

1.2 Identification of Waterbody

The Wekiva River Study Area ("WSA"; **Figure 1-1**) is located in central Florida. The boundary of the area was delineated in the Wekiva Parkway and Protection Act (WPPA, 2004) and encompasses 473 square miles. The river is a major hydrological feature of the WSA, which receives discharges from thirty springs and several major tributaries, including Little Wekiva River from the south, Rock Springs Run in the middle, and Blackwater Creek from the north, and discharges into the St. Johns River downstream of Lake Monroe. The eastern and southern parts of the WSA are highly urbanized areas occupied by several municipalities, including the City of Orlando, Winter Park, Casselberry, Winter Spring, Lake Mary, and Sanford. More rural areas are located in the northwestern part of the WSA.

The Wekiva River and RSR and their headsprings currently provide a variety of recreational opportunities, including canoeing, swimming, snorkeling, tubing, boating, and fishing. In addition to being protected under the WPPA, the Wekiva River system (including the main stem and Rock Springs Run) is designated as an Outstanding Florida Water (OFW). The river is also in the Wekiva River Aquatic Preserve, first designated by the Florida Legislature (Chapter 258.36, FS) in 1975. Most recently, the Wekiva River and portions of its major tributaries were designated Florida's third National Wild and Scenic River system (U.S. House of Representatives Bill H. R. 3155). This is a federal designation applied to rivers considered worthy of protection due to their ecological and aesthetic attributes and recreational value.

The Wekiva River basin is also part of the SJRWMD's Surface Water Improvement and Management (SWIM) program for the Middle St. Johns River Basin. The SJRWMD was required to develop a pollutant load reduction goal (PLRG) for the river, and the PLRG development schedule was expedited per the WPPA.

The area that includes the Wekiva River surface water basin and "springshed" lies within portions of the Marion Upland, Orlando Ridge, and Osceola Plain physiographic regions (Schmidt 1997). Land elevations range from 175 feet above mean sea level (MSL) in the western part of the region to about 10 feet above MSL at the confluence of the Wekiva River and Blackwater Creek (WSI 2004). In the western and southern portions of the region, the land is a series of high (>75 feet above MSL) terraces and ridges, with well-draining sandy soils. In the eastern and northeastern portions of the region, land elevations are generally < 25 feet above MSL, with poorly draining wetland and flatwoods soils.

The Wekiva River basin and springshed lie in a karst-influenced landscape. The Floridan Aquifer is the main water source for springs that discharge to the Wekiva River and its tributaries (Toth and Fortich 2002; Osburn et al. 2002). The principal recharge areas to the Floridan Aquifer are in the western and southern portions of the region (Osburn et al. 2002), with recharge of up to 12” of rainfall annually. Much of the lengths of the Wekiva River and Rock Springs Run lie within the discharge zone of the Floridan Aquifer, resulting in a predominance of spring flow in these streams. Based on Hupalo et al. (1994), spring flow represents at least 67% of the base flow of the Wekiva River. Because of the predominance of spring flow in these streams, the water quality in the springs exerts a major influence on water quality in the spring-run streams.

More detailed information regarding the physiogeography, hydrology, hydrogeology, and climate of the WPPA area can be obtained by consulting the “*Wekiva River and Rock Springs Run Pollutant Load Reduction Goals*” developed by the SJRWMD (Mattson, et al. 2006).

For assessment purposes, the Department has divided the Middle St. Johns Basin into water assessment polygons with a unique **w**ater**b**ody **id**entification (WBID) number for each watershed or stream reach. This TMDL report addresses four WBIDs: WBIDs 2956 and 2956A for the main stem of the Wekiva River, WBID 2956C for Wekiva Spring, and WBID 2967 for Rock Springs Run. **Figure 1.1** shows the locations of the WBIDs covered in this TMDL report.

1.3 Background

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

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

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

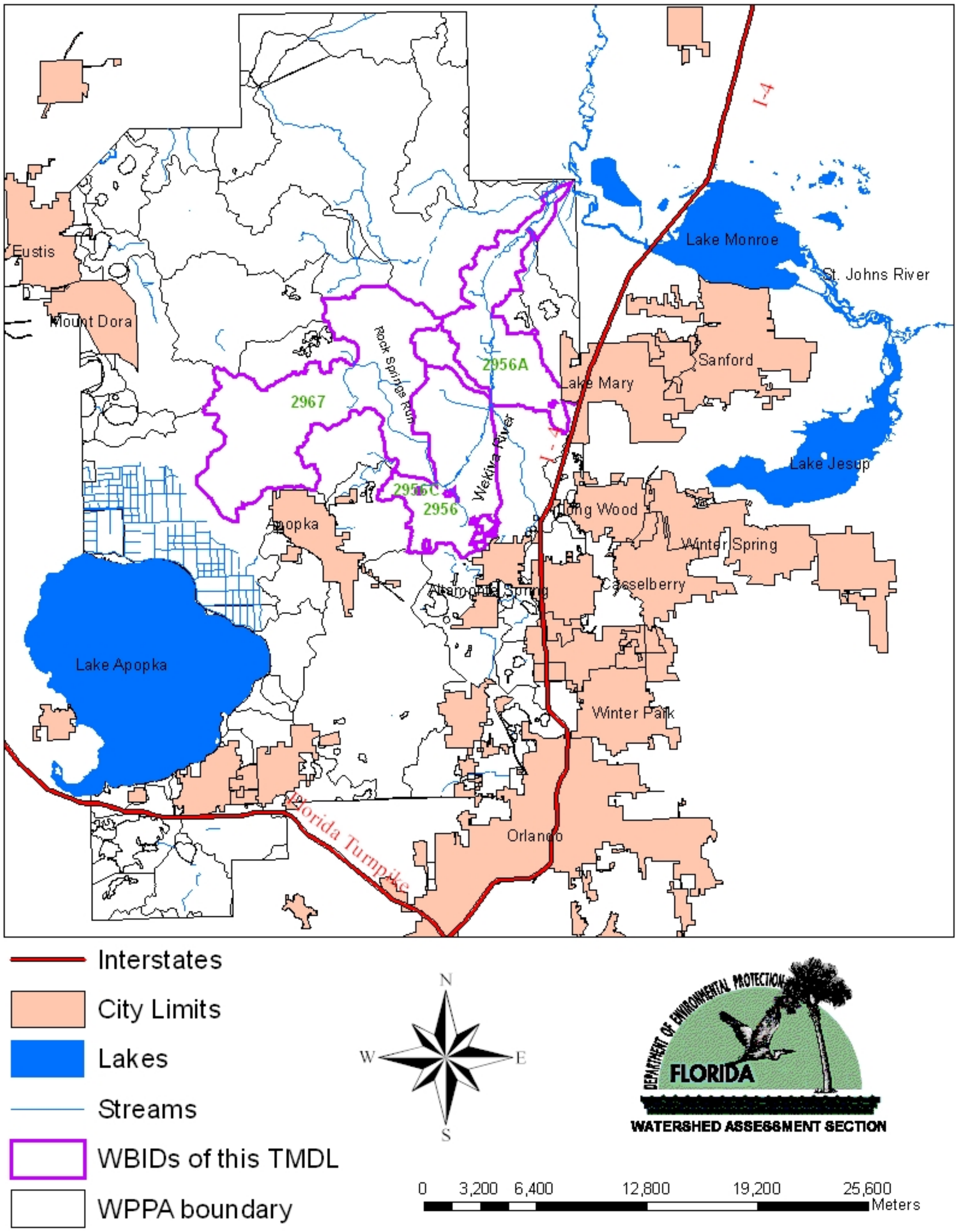


Figure 1.1. Locations of Wekiva Parkway Protection Area (WPPA), main stem of the Wekiva River and Rock Springs Run, waterbody IDs (WBIDs) covered in this TMDL, and major cities located around the waterbodies under question.

Chapter 2: DESCRIPTION OF WATER QUALITY PROBLEM

2.1 Statutory Requirements and Rulemaking History

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

Florida's 1998 303(d) list included 22 waterbodies in the Middle St. Johns 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 the Department to develop, and adopt by rule, a new science-based methodology to identify impaired waters. After a long rulemaking process, the Environmental Regulation Commission adopted the new methodology as Chapter 62-303, Florida Administrative Code (F.A.C.) (Identification of Impaired Surface Waters Rule, or IWR), in April 2001, and modified in 2006. The list of waters for which impairments have been verified using the methodology in the IWR is referred to as the Verified List.

2.2 Information on Verified Impairment

The Wekiva River (WBIDs 2956 and 2956A for the main stem and WBID 2956C for Wekiva Spring) and Rock Springs Run (WBID 2967) were not on the Verified List signed by Secretarial Order on May 27, 2004 because annual average *Chl a* concentrations of these WBIDs did not exceed the 20 µg/L threshold for eutrophication assessment at the time these waters were assessed. However, the Florida Impaired Waters Rule (Chapter 62-303, F.A.C) allows the use of information other than *Chl a* concentration to verify nutrient impairment. Recently, the SJRWMD provided to the Department several lines of evidence, indicating that these waters are impaired for nutrients, with the causative pollutants being nitrate[1] and phosphorus compounds.

According to the basin rotation schedule, when waterbodies in the Middle St. Johns River basin are assessed in the second water quality assessment cycle in 2008, these waters could be included on the Verified Listed, based on the evidence provided by the SJRWMD. However, the Florida Legislature passed the Wekiva Parkway and Protection Act (WPPA) in 2004 (Chapter 369, Part III, FS), which requires that:

> *"By December 1, 2005, the St. Johns River Water Management District shall establish pollution load reduction goals for the Wekiva Study Area to assist the Department of Environmental Protection in adopting total maximum daily loads for impaired waters*

[1] Nitrate is typically measured and reported as NO3+NO2. However, because the majority of this measurement is in the form of nitrate, NO3+NO2 is referred to as nitrate in this report.

within the Wekiva Study Area by December 1, 2006" (Chapter 369.318 [8], FS)

Because Rock Springs Run and the Wekiva River main stem are both located within the boundary of the Wekiva Study Area defined by the WPPA, based on the expedited timeline required by the WPPA, the Department conducted an off-cycle water quality assessment for these waterbodies using the recent information provided by the SJRWMD and verified their impairments for nutrients (TP and nitrate). According to the 1999 Florida Watershed Restoration Act (FWRA), Chapter 99-223, Laws of Florida, once a waterbody is included on the Verified List, a TMDL must be developed.

One way that the SJRWMD and its contractors used to identify the impairment was to compare the distribution of periphyton in the Wekiva River and Rock Springs Run with periphyton in two reference spring creeks [Alexander Springs Creek (ASC) and Juniper Creek (JC)]. These two reference creeks are located about 32 to 54 km (20 to 33 miles) north of the Wekiva River System in south Marion and north Lake Counties. Juniper Creek receives inflows from Juniper Springs and Fern Hammock Springs and travels for about 9 km (5.6 miles) before entering the southwest corner of Lake George. Alexander Springs Creek receives inflow from Alexander Springs and travels for about 17 km (10.5 miles) before entering the St. Johns River near Lake Dexter. **Figure 2.1** shows the location of these two creeks. **Table 2.1** shows the landuse categories in the watershed of these two creeks. The dominant landuse in watersheds of both reference creeks is upland forest. Development is insignificant in these watersheds.

Table 2.1. Landuse of Juniper Creek and Alexander Springs Creek basins.

Landuse Description	Juniper Creek		Alexander Springs Creek	
	Acreage	Percent Area	Acreage	Percent Area
Urban and Built-Up	98	0.2%	197	1.7%
Rangeland	488	1.1%	4.0	0.0%
Upland Forest	39495	85.5%	7679	68.1%
Water	457	1.0%	131	1.2%
Wetlands	5603	12.1%	3261	28.9%
Barren Land	3	0.0%	0	0.0%
Transportation, Communication, and Utilities.	23	0.1%	0	0.0%
Total	46,167	100.0%	11,272	100.0%

The SJRWMD compared the percent of stream bottom covered by periphyton[2] in the Wekiva River and Rock Springs Run to the two reference creeks and found that periphyton was more abundant in the Wekiva River and Rock Springs Run than in the two reference creeks. Specifically, periphyton (including benthic algae, filamentous algae, Nitella sp., and etc.) covered about 22.5% and 10.1% of the creek bottom in the Wekiva River and Rock Springs Run, respectively, while the percent of stream bottom covered by these algae was only about 1.8% in the two reference creeks (WSI, 2005). While some amount of periphyton growth is ecologically beneficial, excessive periphyton growth can inhibit the growth of submerged aquatic vegetation (SAV), which is considered the most important aquatic habitat for fish and other

[2] Periphyton refers to the community of attached organisms on submerged surfaces, which may include microsopic algae such as diatoms, green algae, blue-green algae, euglenophytes, as well as filamentous macrophytic algae (Mattson et al. 2006).

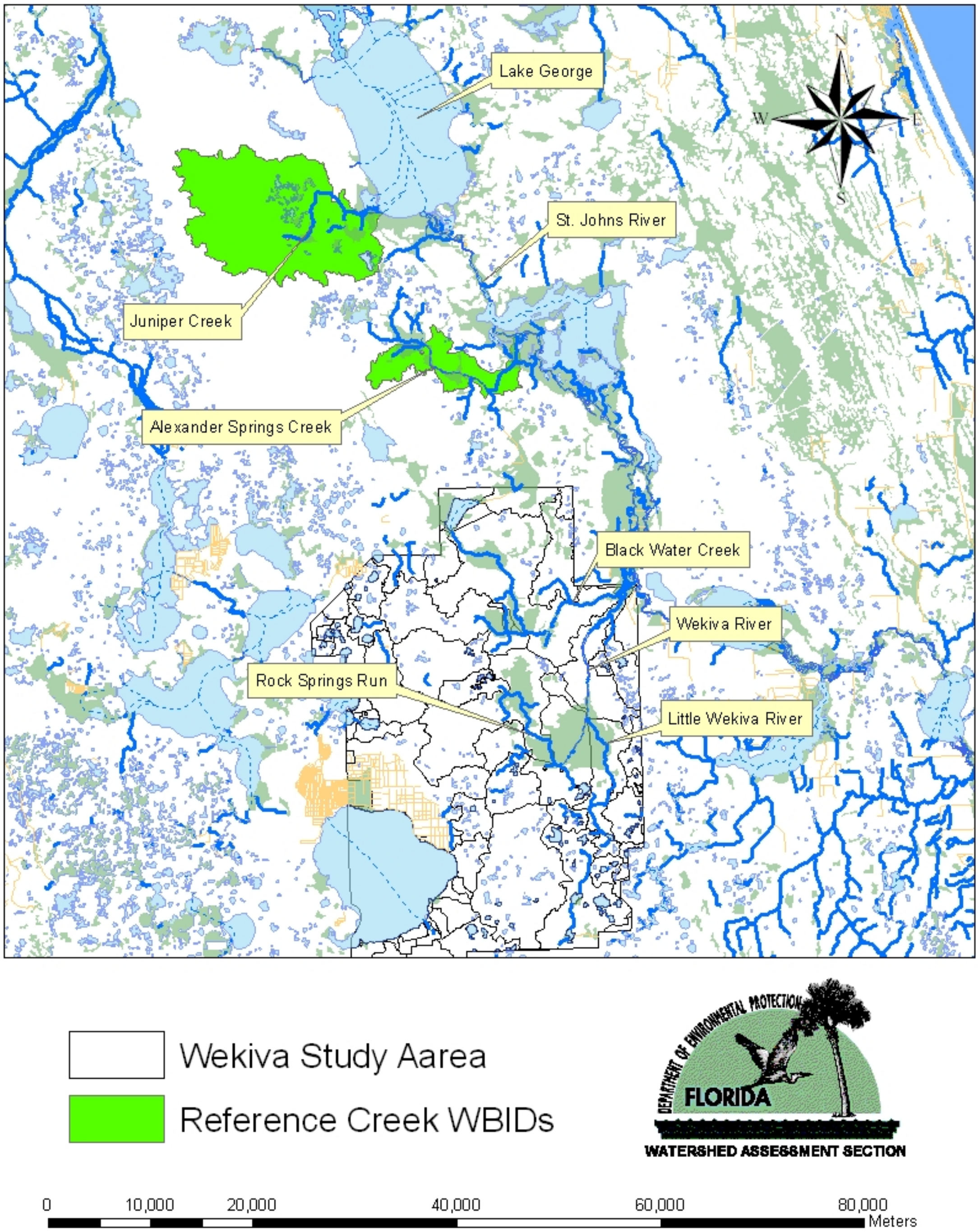


Figure 2.1. Locations of the two reference creeks used in this TMDL.

aquatic organisms in these spring creeks. For the case of the Wekiva River and Rock Springs Run, these high values indicate an imbalance in the flora of the creeks under question.

Another focus of the SJRWMD's studies was to examine the existence of algal species in the creeks that may cause harmful effects to fish and wildlife populations or human health concerns. One algal group of major concern in Florida springs is the filamentous Cyanobacteria, primarily in the genus *Lyngbya*. Studies have shown that, with increased nutrient loading to a waterbody, it is frequently the Cyanobacteria that respond most prolifically (Komarek 2003, Bronmark and Hansson 1998). Increases in *Lyngbya* biomass is a management issue in many Florida Springs (Stevenson et al. 2004). *Lyngbya*, and other Cyanobacteria, produce toxins that may be associated with skin reactions and respiratory distress in humans. Large mats of filamentous Cyanobacteria may also adversely affect macroinvertebrate and fish habitat, water quality and SAV.

Based on data collected by the Green Lab, Inc (contracted by the SJRWMD), Cyanobacteria were found to be the dominant or second largest contributors in the attached algal communities at the majority of the Wekiva River sites examined. The major Cyanobacteria species identified in the study were *Heteroleibleinia sp, Lyngbya wollei,* and *Phormidium sp.1*. Dominance of the attached algal communities by Cyanobacteria was also observed in Rock Springs Run, which was due primarily to the presence of *Lyngbya wolli* (Mattson, 2006). These observations are consistent with the conclusion that the Wekiva River and Rock Springs Run were impaired and the aquatic flora in these streams were imbalanced.

Information from an ecosystem level study conducted by the Wetland Solution, Inc (WSI, 2005) also suggested that the Wekiva River and Rock Springs Run aquatic flora were impaired. In this study, several ecosystem level indices, including gross primary productivity, net primary productivity, system respiration rate, and ecological efficiency, were measured for segments of Wekiva River and Rock Springs Run and compared to those measured in the two reference creeks. It was found that all these system indices were depressed in the Wekiva River and Rock Springs Run compared to the reference creeks, suggesting impairment on the ecosystem functions of the streams under question.

The SJRWMD provided several lines of evidences to show that nitrate and phosphorus compounds are the causative pollutants for observed impairments:

1. Laboratory experiments (Cowell and Dawes, 2004) and field studies (Hornsby et al. 2000) indicated that *Lyngbya* biomass and the biomass and diversity of Cyanobacteria population increased with elevated nitrate concentration, especially when the nitrate concentration increased above 0.30 mg/L.
2. Field studies indicated that the percent biovolume of Cyanobacteria in the algal community increased with increased total phosphorus (TP) concentrations, especially when the TP concentration was higher than 0.090 mg/L (Potapova and Charles, 2005).
3. The mean nitrate and TP concentrations in the Wekiva River and Rock Springs Run range between 0.60-0.70 mg/L and 0.12-0.14 mg/L, respectively, which are significantly higher than the threshold nitrate and TP concentrations identified in the above studies.
4. The percent stream bottom covered by algae was higher and overall ecosystem metabolic activities were lower in the Wekiva River and Rock Springs Run where nitrate and TP concentrations were higher compared to the two reference creeks where nitrate and TP concentrations were lower.

5. The highest biomass of attached algae was found at sites in and around the springs of both the Wekiva River and Rock Springs Run. Filamentous Cyanobacteria (particularly *Lyngbya wollei* and *Phormidium*) were most abundant in terms of biomass at spring vent sites. These spring vents typically have significantly higher nitrate and TP concentrations than sites farther downstream of the vent.

The above evidence indicated that the Wekiva River and Rock Springs Run are impaired and the causative pollutants are nitrate and phosphorus compounds.

Chapter 3. DESCRIPTION OF APPLICABLE WATER QUALITY STANDARDS AND TARGETS

3.1 Classification of the Waterbody and Criteria Applicable to the TMDL

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

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

Both the Wekiva River and Rock Springs Run are Class III waterbodies, with a designated use of recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife. The Class III water quality criteria applicable to the impairment addressed by this TMDL are for nutrients.

3.2 Applicable Water Quality Standards and Numeric Water Quality Target

3.2.1 Interpretation of Narrative Nutrient Criterion

Florida's nutrient criterion is narrative only—i.e., nutrient concentrations of a body of water shall not be altered so as to cause an imbalance in natural populations of aquatic flora or fauna. Accordingly, a nutrient-related target was needed to represent levels at which an imbalance in flora or fauna is expected to occur. A threshold commonly used for assessing the nutrient impairment in streams is the annual average *Chl a* concentration of 20 µg/L, which is defined in the Impaired Waters Rule (IWR, 62-303 F.A.C). In addition, the IWR also allows the use of other information indicating imbalance in flora or fauna due to nutrient enrichment, including, but not limited to, algal blooms, excessive macrophyte growth, decrease in the distribution (either in density or areal coverage) of seagrasses or other submerged aquatic vegetation, changes in algal species richness, and excessive dial oxygen swings.

As indicted in SJRWMD's PLRG (Mattson et al., 2006), the impairments of the Wekiva River and Rock Springs Run were primarily manifested through elevated algal biomass, dominance of benthic algal communities by blue-green algae such as *Lyngbya wolli* , and depressed ecosystem metabolic activities and that the impairments were due to the elevated nitrate and phosphorus concentrations. As such, target nitrate and TP concentrations are needed to address the imbalances of these structures and functions of aquatic communities.

3.2.1.1 Setting the nitrate target

The target nitrate concentration for the Wekiva River and Rock Springs Run was established based on several lines of evidence, including 1) laboratory nutrient amendment bioassays, 2) examining the relationship between periphyton biomass and cell density and the nitrate concentration in flow-through systems similar to the Wekiva River and Rock Springs Run, and 3) comparing metabolic rates, specifically, ecological efficiency, of aquatic communities in the Wekiva River and Rock Springs Run with those in reference creeks.

1) **Laboratory nutrient amendment bioassays**

The nutrient amendment bioassay work was conducted by Cowell and Dawes (2004), who examined the required nitrate concentration in the Rainbow River, Marion County, Florida to achieve a reduction of biomass of *Lyngbya wollei*. *L. wollei* is a nuisance blue-green benthic algal species that dominates the Rainbow River due to elevated nitrate concentrations, and is also frequently observed in the Wekiva River and Rock Springs Run where elevated nitrate concentrations exist (Mattson et al. 2006). Using *Lyngbya* cultures incubated in a series of nitrate amendments, Cowell and Dawes (2004) found that, at the end of the nutrient amendment experiments, both the biomasses and growth rates were low in treatment groups with nitrate concentration at or below 300 µg/L, while the growth rates and biomass were significantly higher in treatments with nitrate concentrations at or higher than 600 µg/L. In addition, the experiment also showed that the biomass and growth rate in 300 and 70 µg/L treatment groups were similar, suggesting that further reduction of nitrate concentration below the 300 µg/L level probably would not achieve dramatic further reduction of *L. wollei*. A nitrate concentration of 300 µg/L should be appropriate in controlling *L. wollei*.

2) **Relationship between periphyton biomass and cell density and nitrate concentration**

The nitrate target suggested by the Rainbow River study was corroborated by the findings of Hornsby et al. (2000), who evaluated periphyton and water quality data collected from the Suwannee River and two tributaries including the Withlacoochee River and Santa Fe River. Much of the length of the Suwannee River was heavily influenced by spring inflow, and the algal communities appeared to be generally similar in composition to those in the Wekiva River and Rock Springs Run. Therefore, results from this river were considered applicable to the Wekiva River and Rock Springs Run (Mattson et al., 2006). This study showed positive correlations for both periphyton biomass versus nitrate concentration and cell density versus nitrate concentration. The functional relationships of periphyton biomass (represented as ash free dry mass, or AFDM) versus nitrate concentration and cell density versus nitrate concentration are shown in **Figures 3.1-A**, and **–B,** respectively. Data presented in these figures represent long-term average biomass, cell densities, and nitrate concentrations measured at 13 stations across the Suwannee River system (including the Withlacoochee River and Santa Fe River). **Figure 3.2** shows locations of these stations. As shown in **Figures 3.1-A** and **–B,** both periphyton biomass and cell density per unit increase of nitrate concentration significantly increased when nitrate concentration reached a level between 200 – 300 µg/L.

To narrow down the nitrate concentration that may significantly impact the periphyton biomass and cell density per unit increase of nitrate concentration, the Department contracted Professor Xufeng Niu of the Department of Statistics, Florida State University, to conduct a change-point analysis. The applied method fits a step function through observed data by examining the probability of each data point as the change-point. A nitrate concentration change point was

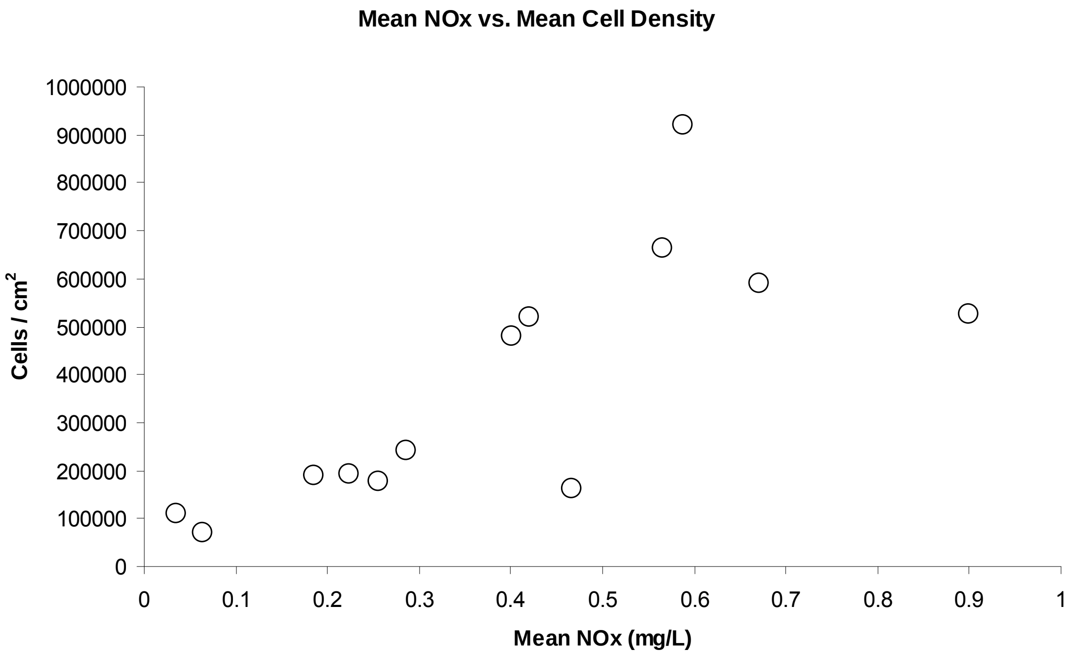


Figure 3.1-A Relationship between mean nitrate concentration and mean periphyton cell density from sampling sites on the Suwannee, Santa Fe, and Withlacoochee Rivers (Mattson et al. 2006).

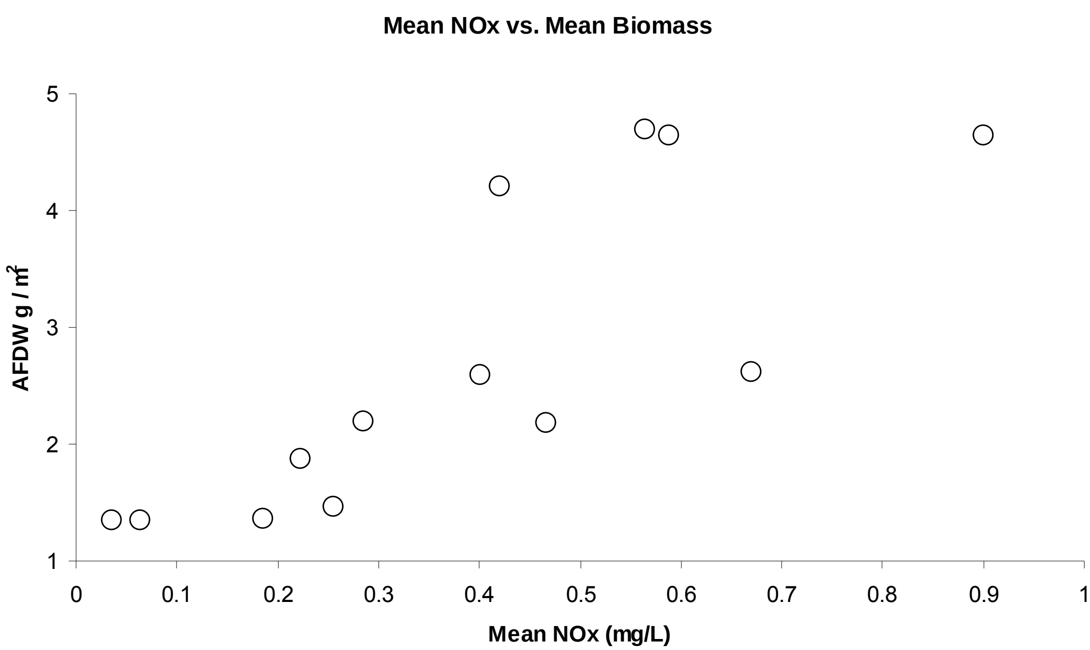


Figure 3.1-B Relationship between mean nitrate concentration and mean periphyton biomass from sampling sites on the Suwannee, Santa Fe, and Withlacoochee Rivers (Mattson, 2006).

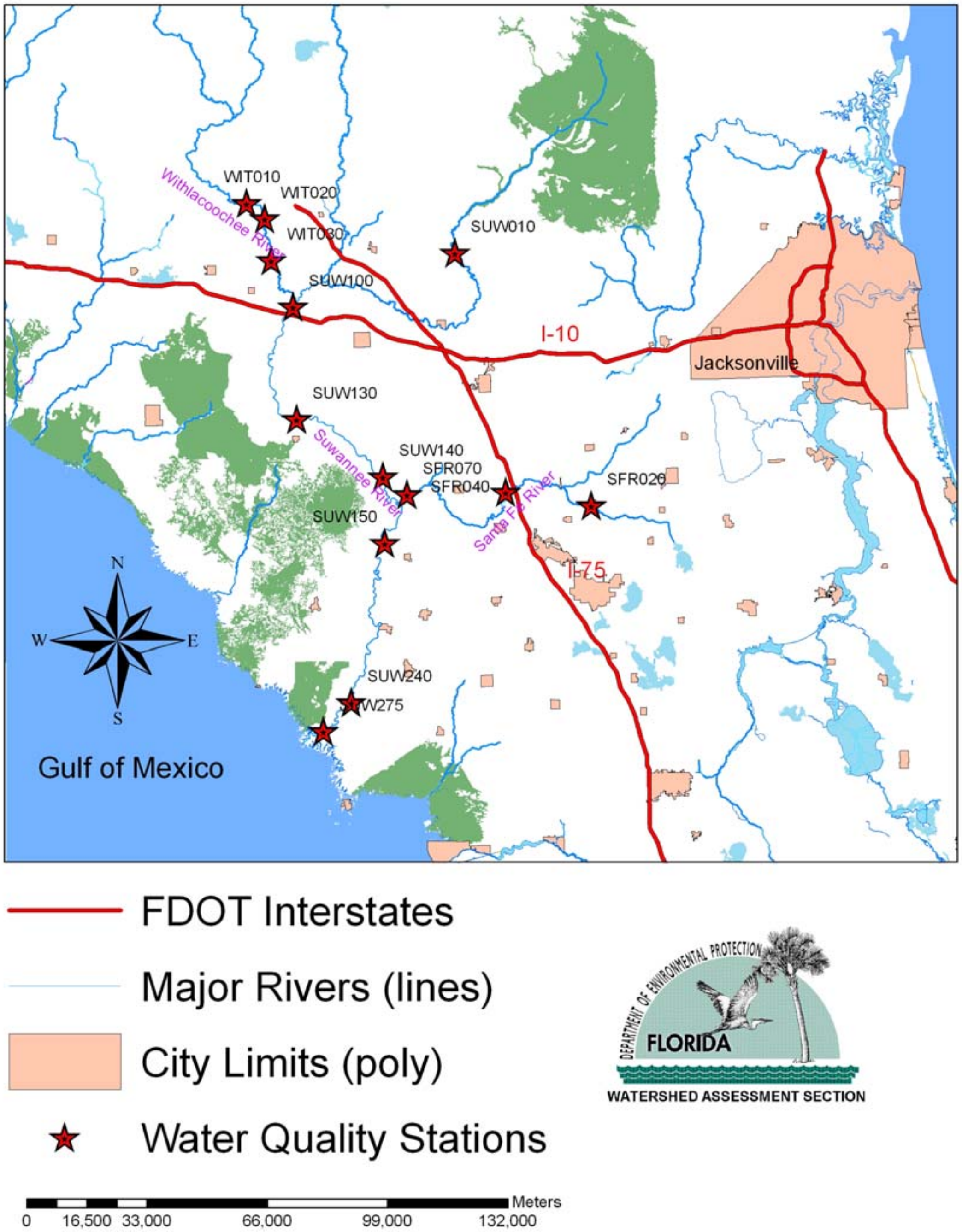


Figure 3.2. Locations of water quality stations from which nitrate and periphyton abundance samples were collected and used for the change-point analysis

identified at a 5% significant level if the change of cell density or periphyton biomass caused by the nitrate concentration was 3.5 times higher (the T test critical value) than the standard error of the change of cell density or periphyton biomass The identified step function (the change-point model) was also compared to linear regression and non-linear regression models for its goodness-of-fit and the extent of over-fitting based on the Bayesian Information Criterion (SBC). For both periphyton cell density and periphyton biomass, change-point step functions were shown to be the best model among the models tested. This supports the use of the change-point model identified in the T test. Details of the change-point analyses are provided in **Apendix B**.

For the functional relationship between cell density and nitrate concentration, the change-point step function identified two cell density levels (**Table 3** in **Apendix B**). One level is about 162,998 cells/cm^2 (P = 0.009), and the other is about 162,998 + 453,295 = 616,293 cells/cm^2 (P = 0.0001). In this study, the 162,998 cells/cm^2 was considered as the baseline condition under which no significant nitrate impact was detected. The nitrate concentration that significantly changed the cell density level from 162,998 cells/cm^2 to 616,293 cells/cm^2 was identified by the change-point step function as 0.401 mg/L (**Table 2** in **Apendix B**), indicating that, to prevent the periphyton cell density from switching to the higher level, the nitrate concentration should not exceed 0.401 mg/L. In addition, based on **Table 2** and **Figure 4** of **Appendix B**, the cell density switch occurred when the nitrate concentration reached between 0.286 mg/L and 0.401 mg/L. Although the nitrate concentration that started the cell density switch could be any nitrate concentration between 0.286 mg/L and 0.401 mg/L, 0.286 mg/L was chosen in this TMDL as the nitrate target to control periphyton cell density to make the nitrate target conservative.

For the functional relationship between periphyton biomass and nitrate concentration, the change-point step function identified two biomass levels (**Table 5** in **Apendix B**). One level is about 1.73 g/m^2 (P= 0.00), and the other level is about 1.73 + 2.42 = 4.15 g/m^2 (P = 0.0001). In this study, the 1.73 g/m^2 was considered as the baseline condition under which no significant nitrate impact was detected. The nitrate concentration that significantly changed the biomass level from 1.73 g/m^2 to 4.15 g/m^2 was identified by the change-point step function as 0.420 mg/L (**Table 4** in **Apendix B**), indicating that, to prevent the periphyton biomass from switching to the higher level, the nitrate concentration should not exceed 0.420 mg/L. In addition, based on **Table 4** and **Figure 6** of **Appendix B**, the highest observed nitrate concentration that allowed the biomass baseline condition was between 0.401 mg/L and 0.0.420 mg/L. Although the nitrate concentration that started the biomass switch could be any nitrate concentration between 0.401 mg/L and 0.420 mg/L, 0.401 mg/L was chosen in this TMDL as the nitrate target to control periphyton biomass to make the nitrate target conservative.

Based on the above discussion, nitrate concentrations lower than 0.286 mg/L and 0.401 mg/L should be appropriate to maintain periphyton cell density and biomass at baseline conditions, respectively. Because 0.286 mg/L is lower than 0.401 mg/L, 0.286 mg/L was selected for the TMDL target to maintain both cell density and biomass at baseline conditions. Choosing the lower nitrate concentration between 0.286 and 0.401 mg/L also adds to the margin of safety of the nitrate TMDL.

3) **Relationship between ecological efficiency and nitrate concentration**

Wetland Solutions, Inc (WSI, 2005) studied the effects of nutrient concentrations on the community metabolic rates in the Wekiva River, Rock Springs Run, and two reference creeks

(ASC and JC). The gross community primary production, community respiration, net primary production, and ecological efficiency were measured and examined. The community metabolic parameter shown to have a significant functional relationship with nutrient concentrations was ecological efficiency, which is defined as the quotient between the rate of gross primary productivity (GPP) and the incident photosynthetically active radiation (PAR) during a specified time interval. It is an ecosystem-level property that estimates the overall efficiency of an aquatic ecosystem to utilize incident solar radiation.

To examine the effect of nitrate concentrations on the ecological efficiency, experimental sites were set up in streams with different nitrate concentrations. **Figures 3.3 - 3.5** show locations of these segments. Two test stream segments were set up in both the Wekiva River and Rock Springs Run, and one test stream segment was set up for each of Alexander Springs Creek (ASC) and Juniper Creek (JC). As shown in **Figure 3.3,** the test segment RSR-SEG1 (one of the test segments for Rock Springs Run) is located close to the spring vent where high nitrate concentrations are typically observed. Segment RSR-SEG2 is a downstream site located close to the confluence of Rock Springs Run and the Wekiva River, and the average nitrate concentration at this site was lower than 300 µg/L at the time the study was conducted.

For the Wekiva River, WR-SEG1 is the test segment located close to the Wekiva Spring, where high nitrate concentrations were observed. Segment WR-SEG2 is the downstream segment where nitrate concentration decreased to about 300 µg/L at the time the study was conducted.

Table 3.1 lists ecological efficiency results and nitrate+nitrite concentrations from these test segments.

Table 3.1. Ecological efficiencies and nitrate concentrations at test segments in WRMS, RSR, JC, and ASC.

Test Segments	Ecological Efficiency (g O_2/mol)	Nitrate+Nitrite (mg/L)	Water Color (PCU)	Period of Record
WR-SEG1	0.11	1.09	8.75	4/29/2005 5/27/2005
WR-SEG2	0.22	0.300	40.0	4/28/2005 5/26/2005
RSR-SEG1	0.08	1.15	26.3	4/1/2005 4/20/2005
RSR-SEG2	0.05	0.270	193	4/1/2005 4/21/2005
ASC-SEG1*	0.36	0.009	58.8	4/29/2005 5/24/2005
JC-SEG1**	0.47	0.015	38.8	3/31/2005 4/18/2005
WR-SEG1	0.11	1.24	21.9	8/10/2005 8/31/2005
WR-SEG2	0.14	0.365	96.3	8/9/2005 9/1/2005
RSR-SEG1	0.05	1.03	77.5	7/12/2005 8/3/2005
RSR-SEG2	0.07	0.045	350	7/12/2005 8/4/2005
ASC-SEG1*	0.23	0.018	150	8/9/2005 8/29/2005
JC-SEG1**	0.26	0.023	65.0	7/11/2005 8/1/2005

*Test segment in Alexander Springs Creek.
**Test segment in Juniper Creek.

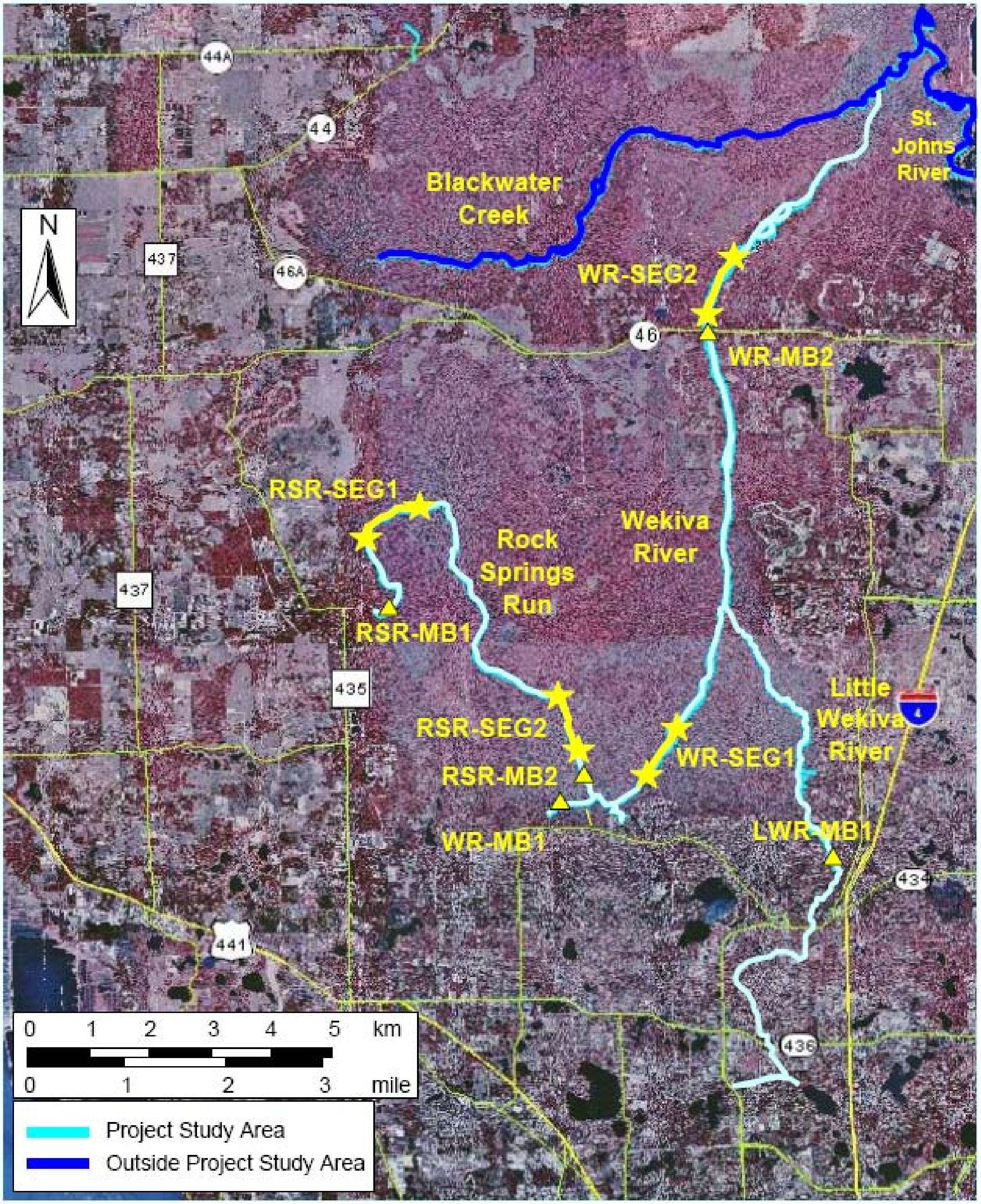


Figure 3.3. Wekiva River and Rock Springs Run stream segments for ecological evaluations. This figure was cited from Wetland Solution, Inc. (2005).

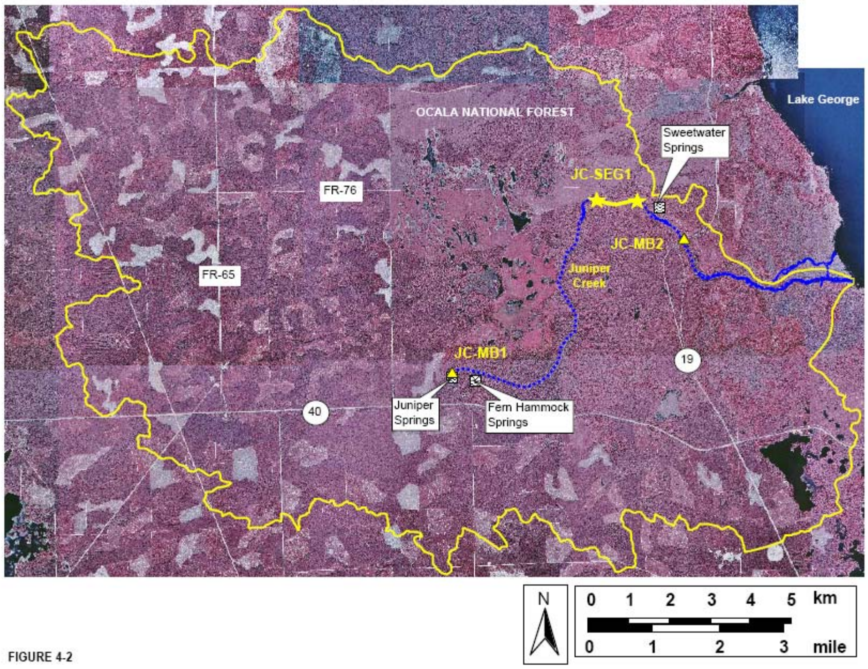


Figure 3.4. Juniper Creek stream segments for ecological evaluations. This figure was cited from Wetland Solution, Inc. (2005).

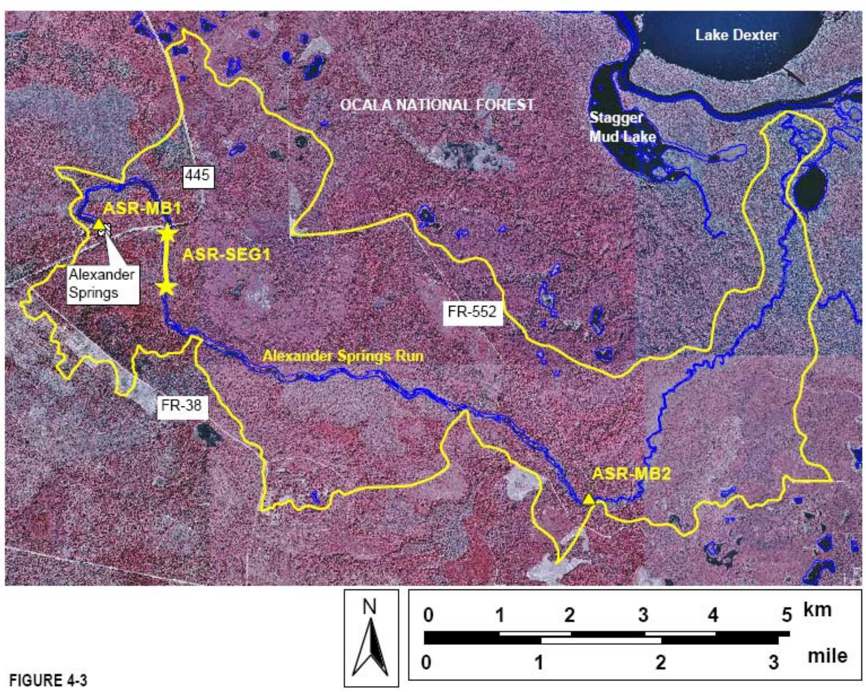


Figure 3.5. Alexander Springs Run stream segments for ecological evaluations. This figure was cited from Wetland Solution, Inc. (2005).

Table 3.1 shows a general trend that the ecological efficiencies of the test segments with high nitrate concentration, e.g. WR-SEG1 and RSR-SEG1 were significantly lower than test segments of reference streams, e.g. ASC-SEG1 and JC-SEG1. For the Wekiva River, ecological efficiency significantly increased at the downstream test segment WR-SEG2 where nitrate concentrations significantly decreased. However, similar increases in ecological efficiency was not observed at the downstream segment (RSR-SEG2) located in Rock Springs Run even when the nitrate concentration at this segment also significantly decreased. One possible reason for the suppressed ecological efficiency at RSR-SEG2 is the high water color. As shown in **Table 3.1**, water color at RSR-SEG2 was dramatically higher for both test events than color levels observed for the other segments. High color at RSR-SEG2 suggested that the gross primary production (GPP) at this segment could be depressed due to the low light availability and the community could be dominated by heterotrophic organisms. Therefore, the amount of organic carbon that can be fixed by the unit photosynthetically active radiation (PAR) could become naturally lower even when the nitrate concentration was not high.

Another explanation for the low observed ecological efficiency at RSR-SEG2 could be the type of aquatic flora dominating the community in this segment. **Table 3.2** lists the percent stream bottom covered by different vegetation types in different test segments. These data were collected by Wetland Solutions, Inc (2005). The plant community data were aggregated into several different functional groups, including benthic algae (ALG), emergent aquatic plants (EMA), floating aquatic plants (FAP), submerged aquatic plants (SAV), shrubs (SHR), and vines (VINE).

Table 3.2. Percent stream bottom covered by vegetation of different functional groups at different test segments.

Functional Vegetation Groups	Test Segments					
	WR-SEG1	WR-SEG2	RSR-SEG1	RSR-SEG2	ASC-SEG1	JC-SEG1
ALG	37.73	7.32	20.21	0.00	1.77	1.82
EMA	5.03	9.13	10.00	37.11	19.16	1.22
FAP	4.77	8.11	10.73	26.65	8.50	1.56
SAV	1.45	27.87	4.49	0.00	48.58	4.21
SHR	1.09	0.07	0.00	1.22	0.08	1.13
VINE	0.00	0.22	0.08	0.00	0.02	0.00

As shown in **Table 3.2**, unlike at any other sites, no benthic algae (ALG) or submerged aquatic vegetation (SAV) were observed at RSR-SEG2, the downstream site of the Rock Springs Run. This could be caused by the high water color observed at this segment. The dominant vegetation communities at RSR-SEG2 were emergent (EMA) and floating aquatic plants (FAP). As the measurement of ecological efficiency was based on measuring the water column dissolved oxygen concentration, and even if EMA and FAP can fix a significant amount of organic carbon using the PAR, less oxygen will be released into the water column than if the community is dominated by ALG and/or SAV. Therefore, it is not totally unexpected that low ecological efficiency was observed at RSR-SEG2. The low ecological efficiency observed at RSR-SEG2 might not be directly related to the nitrate concentration of this segment.

Based on the above discussion, data measured at RSR-SEG2 were excluded when analyzing the relationship between ecological efficiency and nitrate concentration. **Figure 3.6** shows the correlation between the ecological efficiency and nitrate concentration.

The target ecological efficiency for this TMDL was chosen as the average of summer time ecological efficiency measurements taken from the reference sites [ASC-SEG1 (8/9/2005 – 8/29/2005) and JC-SEG1 (7/11/2005 – 8/12/2005)] in the two sampling events (**Table 3.1**). As shown in **Table 3.1**, ecological efficiency varied greatly in the two reference creeks even when nitrate concentrations were low. Defining the target ecological efficiency based on summer data would address the influence of pollutant loadings from both springs and surface runoff (influence from nonpoint source loading is more significant in the summer rainy season than in the winter dry season). The target ecological efficiency defined using this method is 0.25 g O_2/mol. Using the ecological efficiency – nitrate concentration equation defined in **Figure 3.6**, the target nitrate concentration is 0.293 mg/L or 293 µg/L.

The target nitrate concentration based on ecological efficiency is very close to the target nitrate concentrations suggested by the results from the Rainbow River and Suwannee River studies, which are about 300 µg/L and 286 µg/L, respectively. Therefore, the Department established a final target concentration of 286 µg/L, which is the nitrate target derived from the change – point analysis based on periphyton data. This target is lower than both 293 µg/L and 300 µg/L and therefore is the most conservative target. It is protective of the structure and function of aquatic flora in the Wekiva River and Rock Springs Run and adds to the margin of safety (MOS) of this TMDL.

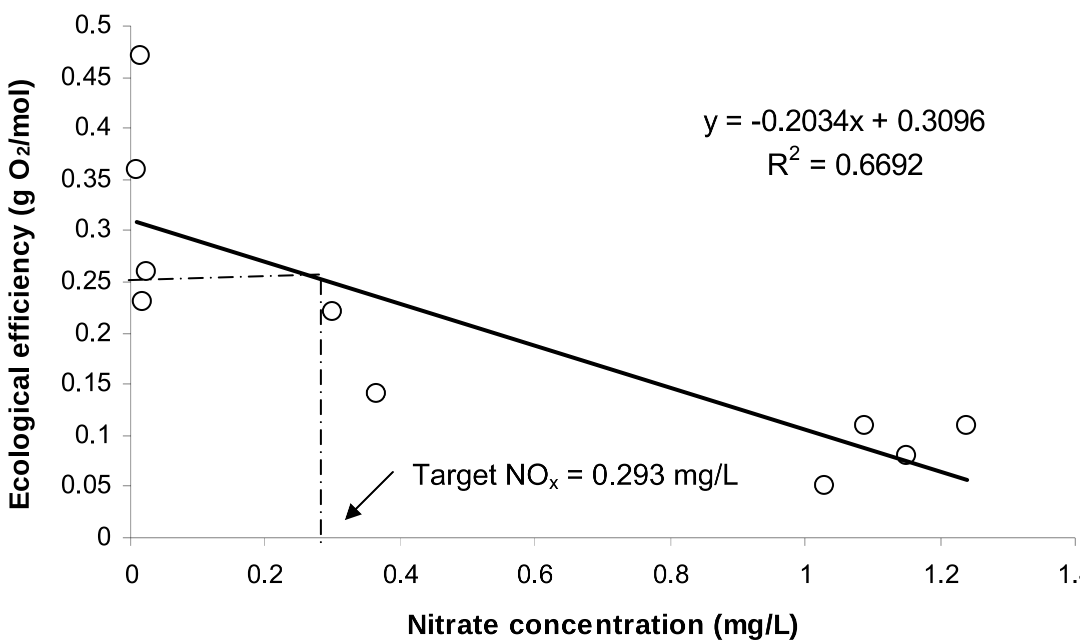


Figure 3.6. Correlation between ecological efficiency and nitrate concentration in WR, RSR, ASC, and JC.

The SJRWMD proposed a biologically effective nitrate concentration of 250 µg/L based on the Rainbow River *Lyngbya wollei* nutrient amendment experiment. Given the natural variation of nitrate concentrations in ambient water, the SJRWMD, when proposed 250 µg/L as the nitrate effective concentration, conducted a statistical analysis to determine a nitrate target concentration that would ensure that the 250 ug/L target would be met the majority of the time. The SJRWMD concluded that the targets should ensure compliance with the 250 ug/L target at least 90% of the time and the statistical analysis indicated that the nitrate target should be 216 µg/L for Wekiva River and 221 µg/L for Rock Springs Run. A detailed description of the statistical method used by the SJRWMD is provided by Mattson et al. (2006).

After carefully reviewing all the above studies from which the SJRWMD's nitrate target (250 µg/L) was derived, the Department believes that it is not necessary to limit the percentage of time the 250 µg/L target can be exceeded and instead established the target as a monthly average concentration. This is mainly because the changes in aquatic vegetation biomass do not respond to the change of nutrient concentration in an instantaneous manner. Therefore, short-term exceedence of this target concentration may not produce negative biological or ecological effects. The 286 µg/L nitrate range obtained from the Suwannee River study was based on the correlation between the long-term average nitrate concentration and long-term average cell density and biomass. Therefore the 286 µg/L should be considered as a long-term average target instead of an instantaneous value. The nitrate range suggested by the *Lyngbya* study was from a nutrient amendment experiment. The value can be considered as a threshold. However, the significant differences in growth rate and biomass between the above 600 µg/L treatment groups and below 300 µg/L treatment groups were not observed until 8 to 12 days after the nutrient amendment study started. This apparently suggested a time lag between the change of the nitrate concentration and the response from *Lyngbya*. In addition, the Lyngbya nutrient amendment study was conducted under the tightly controlled laboratory condition with no competition from other periphyton and plants, no grazing from aquatic animals, no removal effects from the shearing force of the stream flow, and no light attenuation from changing of water color. These factors are very common in natural stream systems such as the Wekiva River and RSR. All these natural processes could significantly slow down the response of *Lyngbya* to the change of nitrate concentration and further elongate the response time delay. Therefore, treating the 300 µg/L nitrate concentration obtained from the *Lyngbya* study as an exact instantaneous value is not necessary.

The same concept also applies to the target nitrate value obtained from the correlation between the ecological efficiency and the nitrate concentration. The ecological efficiency shown in **Table 3.1** and **Figure 3.6** are average values for a period from three to four weeks (WSI, 2005). The nitrate target value derived from an equation, based on average ecological efficiency, should not be treated as an exact instantaneous value. It is more appropriate that the target number be treated as an average target, over a certain time period.

Based on above discussions, the Department established the 286 µg/L threshold as a monthly average target concentration. To address the temporal variation of nitrate concentration in the Wekiva River, the Department analyzed the monthly variation of nitrate concentration in a Wekiva River WBID with high nitrate concentrations (WBID 2956) using the data collected during 1999 through 2005. The monthly variation of nitrate concentration in this WBID is shown in **Figure 3.7**. It appears that the high nitrate concentrations typically appear during the winter, early spring, and later fall, while concentrations are typically lower during the summer season. This observation is not a surprise because one of the major nitrate contributors to the Wekiva River is springs, and summer months typically have higher rainfall and dilution by the surface runoff could play an important role in reducing the in-stream nitrate concentration. Expressing the target as a monthly average provides a margin of safety because restoration activities designed to address the higher winter nitrate concentrations should help ensure that summer nitrate concentrations are even lower.

Toxicity effects of nitrate concentration in the Wekiva River and Rock Springs Run were also discussed by the SJRWMD in the nutrient PLRG. However, all the discussions were based on literature published nitrate toxicity studies conducted in other waterbodies. All these studies concentrated on the acute toxicity effects of nitrate, and chronic effects were only implied by multiplying the acute toxicity results by various safety factors. At the time this TMDL was developed, no information or measurements specific to the Wekiva River and Rock Springs Run indicated that the existing nitrate concentration has caused any toxic effects to aquatic fauna in these waterbodies. In contrast, results from 10 Stream Condition Index (SCI) conducted in the upper reach of Wekiva River (WBID 2956) from 1999 through 2004 showed that benthic macroinvertebrate communities were in good or excellent condition. Results from 2 BIORECON and 8 SCIs for the Rock Springs Run (WBID 2967) in 1997, 1999, and 2002 through 2004 also showed benthic macroinvertebrate communities were in good or excellent condition. Apparently, even under the existing high nitrate concentrations, no direct toxic impacts were observed with the benthic macroinvertebrates communities, which are typically considered sensitive index organisms to toxic materials. The 286 µg/L target nitrate concentration therefore should be sufficient to protect the aquatic fauna in the Wekiva system.

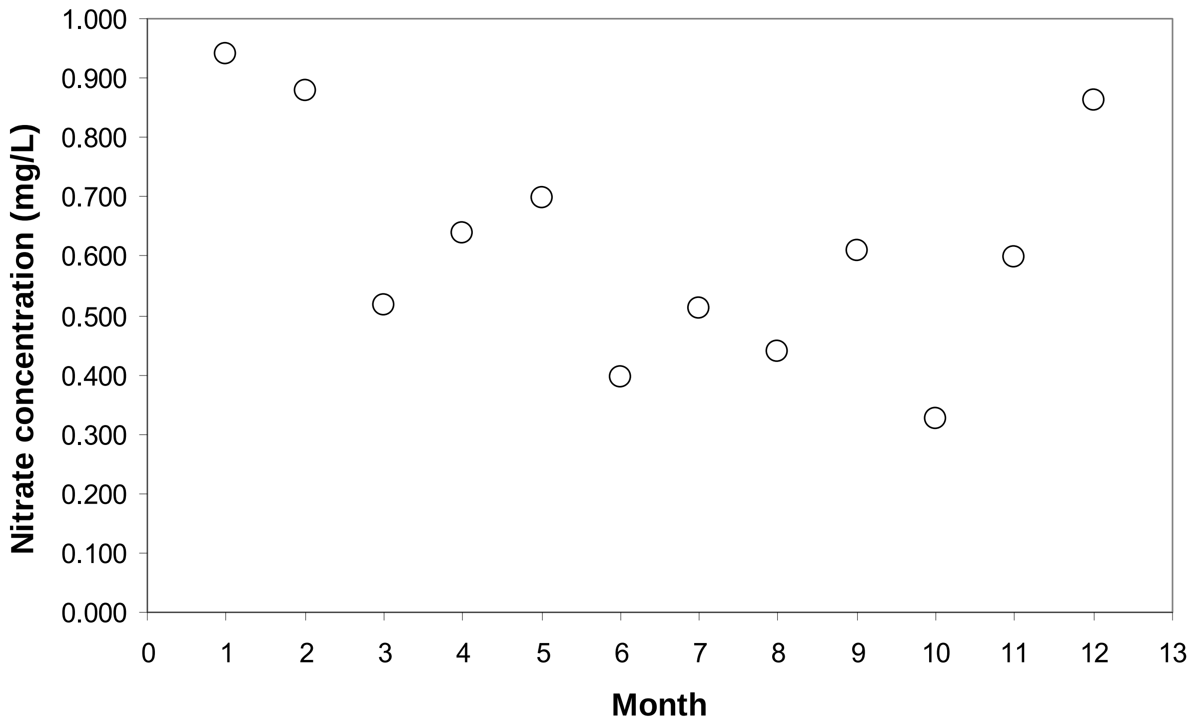


Figure 3.7. Monthly variation of nitrate concentration in upstream WRMS

In conclusion, based on the information currently available, the Department believes that a monthly average nitrate concentration of 286 µg/L should be sufficiently protective of the aquatic flora and fauna in the Wekiva system. This target concentration is higher than long-term median nitrate concentrations of the two reference streams – ASC and JC, which are 50 and 80 µg/L, respectively (Mattson et al. 2006). However, TMDL targets are designed to identify the threshold above which impairment is expected to occur, and natural aquatic systems have assimilative capacities for nutrients. An elevated pollutant concentration in the system alone does not necessarily constitute impairment as long as there is no negative response from the local aquatic flora or fauna. Based on information provided above, 286 µg/L nitrate is the target concentration that will not cause an imbalance in the aquatic flora and fauna in the Wekiva River and Rock Springs Run.

3.2.2.2. Setting the total phosphorus target

The total phosphorus target (TP) for the Wekiva River and Rock Springs Run was established based on the studies on the attached algal communities conducted by the GreenWater Labs (2005) and the ecosystem metabolism studies conducted by the Wetland Solution, Inc. (2005).

The GreenWater Labs collected attached algal samples from 15 sampling sites along the Wekiwa Spring/Wekiva River and 9 sites along Rock Springs/Rock Springs Run. Each site was sampled in winter during December 2004-January 2005 and in summer in June of 2005. At each site, nutrient (include nitrogen and phosphorus) samples were collected at the same time that attached algal samples were collected and analyzed. **Figure 3.8** shows the locations of these sampling sites in the Wekiva River and Rock Springs Run.

The SJRWMD analyzed the relationship between *Chl* a concentration, algal biovolume, ash free dry mass of algal samples, and percent blue-green and green algal biovolume in the total algal biovolume and TP concentration. These analyses yield a threshold relationship between percent biovolume of blue-green and green algae and TP concentration (**Figure 3.9**). High percent biovolumes of blue-green and green algae were observed when the TP concentration increased above 90 µg/L.

The Department also analyzed the relationship between the ecological efficiency and TP data collected by the Wetland Solutions, Inc. **Table 3.3** lists the ecological efficiency and TP data used in this analysis and test stream segments from which these data were collected. Again, because of the high color and the vegetation communities dominated by emergent and floating aquatic vegetation at RSR-SEG2, data from this sampling site were excluded from the analysis. **Figure 3.10** shows the correlation between the ecological coefficient and TP concentration at these test segments. Again, 0.25 g O_2/mol was chosen as the target ecological efficiency. Based on this target and the correlation equation shown in **Figure 3.10**, the target TP concentration should be 65 µg/L. Because the 65 µg/L TP target is lower than the 90 µg/L concentration derived from GreenWater labs attached algal studies, it should addresse both the ecological efficiency and blue-green and green algae dominance issues. Therefore, 65 µg/L was chosen as the final TP target for this TMDL.

There was no seasonal pattern for the percentage blue-green and green algae indicating a critical season or month. There were not enough data to determine when would be the critical season for the low ecological efficiency. Analysis on the monthly distribution of TP concentration in the Wekiva River indicated that high TP concentrations were typically observed during the summer months, which is the typical growth season. Therefore, there is not enough information to determine whether establishing the 65 µg/L as the annual average target would be sufficiently protective. As the 65 µg/L target was derived from the ecological efficiency studies and these studies had a time scale of close to one month, theTP threshold of 65 µg/L was expressed as a monthly target for this TMDL.

Figure 3.8. Sampling stations used by the GreenWater Labs for attached algal studies in the Wekiva River and Rock Springs Run (GreenWater Labs, 2005)

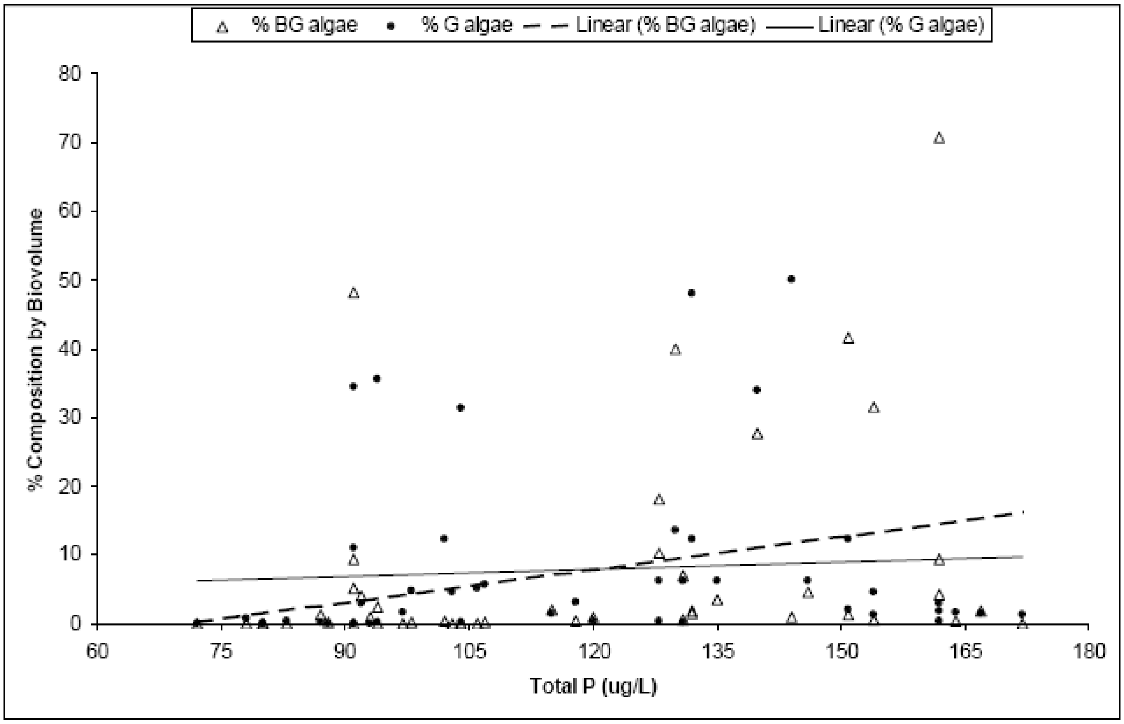


Figure 3.9. Relationship between TP concentration and percent biovolume of blue-green and green algae in the Wekiva River and Rrock Springs Run (Mattson et al. 2006)

Table 3.3. Ecological efficiencies and TP concentrations at test segments in theWekiva River (WR), Rock Springs Run (RSR), Juniper Creek (JC), and Alexander Springs Creek (ASC)

Test segments	Ecological efficiency (g O_2/mol)	TP concentration (mg/L)	Water color (pcu)	Period of Record	
WR-SEG1	0.11	03125	8.75	4/29/2005	5/27/2005
WR-SEG2	0.22	0.118	40.0	4/28/2005	5/26/2005
RSR-SEG1	0.08	0.091	26.3	4/1/2005	4/20/2005
RSR-SEG2	0.05	0.096	193	4/1/2005	4/21/2005
ASC-SEG1*	0.36	0.045	58.8	4/29/2005	5/24/2005
JC-SEG1**	0.47	0.024	38.8	3/31/2005	4/18/2005
WR-SEG1	0.11	0.158	21.9	8/10/2005	8/31/2005
WR-SEG2	0.14	0.141	96.3	8/9/2005	9/1/2005
RSR-SEG1	0.05	0.097	77.5	7/12/2005	8/3/2005
RSR-SEG2	0.07	0.180	350	7/12/2005	8/4/2005
ASC-SEG1*	0.23	0.055	150	8/9/2005	8/29/2005
JC-SEG1**	0.26	0.025	65.0	7/11/2005	8/1/2005

*Test segment in Alexander Springs Creek.
**Test segment in Juniper Creek.

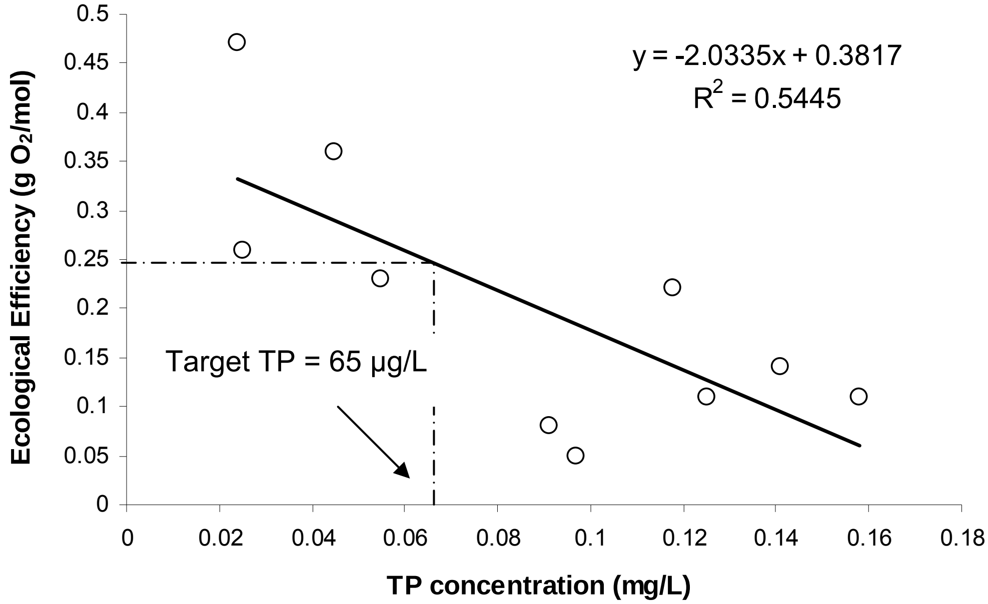


Figure 3.10. Correlation between ecological efficiency and TP concentration in the Wekiva River, Rock Springs Run, Alexander Springs Creek, and Juniper Creek.

3.2.2.3. Summary on the water quality targets

Based on above analyses, the nutrient targets for this TMDL are monthly averages of 286 µg/L for nitrate and 65 µg/L for TP. These water quality targets apply to both the Wekiva River and Rock Springs Run. These targets will protect the structure and functions of the aquatic vegetation communities and also protect the aquatic fauna based on historic SCI and BIORECON results for benthic macroinvertebrates.

Chapter 4: ASSESSMENT OF SOURCES

4.1 Types of Sources

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

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

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

4.2. Potential Sources of pollutants in Watersheds of the Wekiva River and RSR

4.2.1 Point Sources

4.2.1.1 Wastewater Point Sources

There are eight wastewater facilities that are authorized to discharge to surface waters within the drainage basin of the Wekiva River. No NPDES permitted facilities were identified in the subbasin of Rock Springs Run. **Table 4.1** lists the permit numbers, names, business types, and permit types of these facilities, and **Figure 4.1** shows the locations of these facilities. Five of the facilities are concrete batch plants and operate under generic permits. These facilities may discharge wastewater with high pH, high dissolved and total suspended solids, but elevated nitrate and TP concentrations from these facilities are typically not expected. The other three are domestic wastewater facilities: the Wekiva Hunt Club WWTF (FL0036251), Altamonte Springs Regional Water Reclamation Facility (FL0033251), and SCES/Yankee Lake WRF

(FL0042625). These facilities have the potential to contribute nitrate and TP to Wekiva River and, as such, are described in more detail below, however they are not considered significant sources of nutrient loading to the Wekiva River

Table 4.1. NPDES permitted facilities identified in the drainage basin discharge to Wekiva River.

Permit Number	Facility Name	Wastewater Type	Permittee
FL0042625	SCES/Yankee Lake WRF	Domestic Wastewater	Seminole County Environmental Services
FL0033251	Altamonte Springs Regional Water Reclamation Facility	Domestic Wastewater	City of Altamonte Springs
FL0036251	Wekiva Hunt Club WWTF	Domestic Wastewater	Sanlando Utilities Corporation
FLG110301	Florida Rock Industries – Carder Road CBP	Industrial Wastewater	Florida Rock Industries
FLG110557	Rinker Materials – Lockhart Concrete Batch	Industrial Wastewater	Rinker Materials
FLG110231	Action Ready Mix CBP	Industrial Wastewater	Action Ready Mix CBP
FLG110672	CEMEX – Lockhart CBP	Industrial Wastewater	CEMEX – Lockhart CBP
FLG110464	Inland Materials – Orlando CBP	Industrial Wastewater	Inland Materials

SCES/Yankee Lake WRF is located in Sanford, close to the most downstream segment of Wekiva River (**Figure 4.1**). It has a 2.5 MGD annual average daily flow (AADF) permitted capacity, with advanced wastewater treatment facilities, including influent screening, grit removal, anoxic basin followed by aeration chamber, chemical feed, clarification, tertiary filtration, disinfection by chlorination, and aerobic digestion of residuals. Residuals of the facility are hauled to the SCES Greenwood Lakes WWTF for additional treatment.

The majority of the treated wastewater from SCES/Yankee Lake WRF is reused. The facility has a slow rate land application system with an anticipated capacity of 3.707 MGD AADF, consisting of a reclaimed water transmission/distribution system for public access irrigation of recreational areas, residential lawns, golf course, urban landscapes, road medians, nurseries and citrus groves within its Reuse Service Area. Wet-weather or reject flows are sent to three backup systems including 1) a 0.35 MGD AADF permitted capacity slow-rate restricted public access system that consists of a 72.6 acre sprayfield, 2) a 0.36 MGD AADF permitted capacity rapid infiltration basin system that consists of five rapid infiltration basins (RIBs) with a total wetted area of 800,000 square feet, and 3) a 0.75 MGD AADF permitted capacity wet-weather back-up discharge to an upland/receiving wetland system.

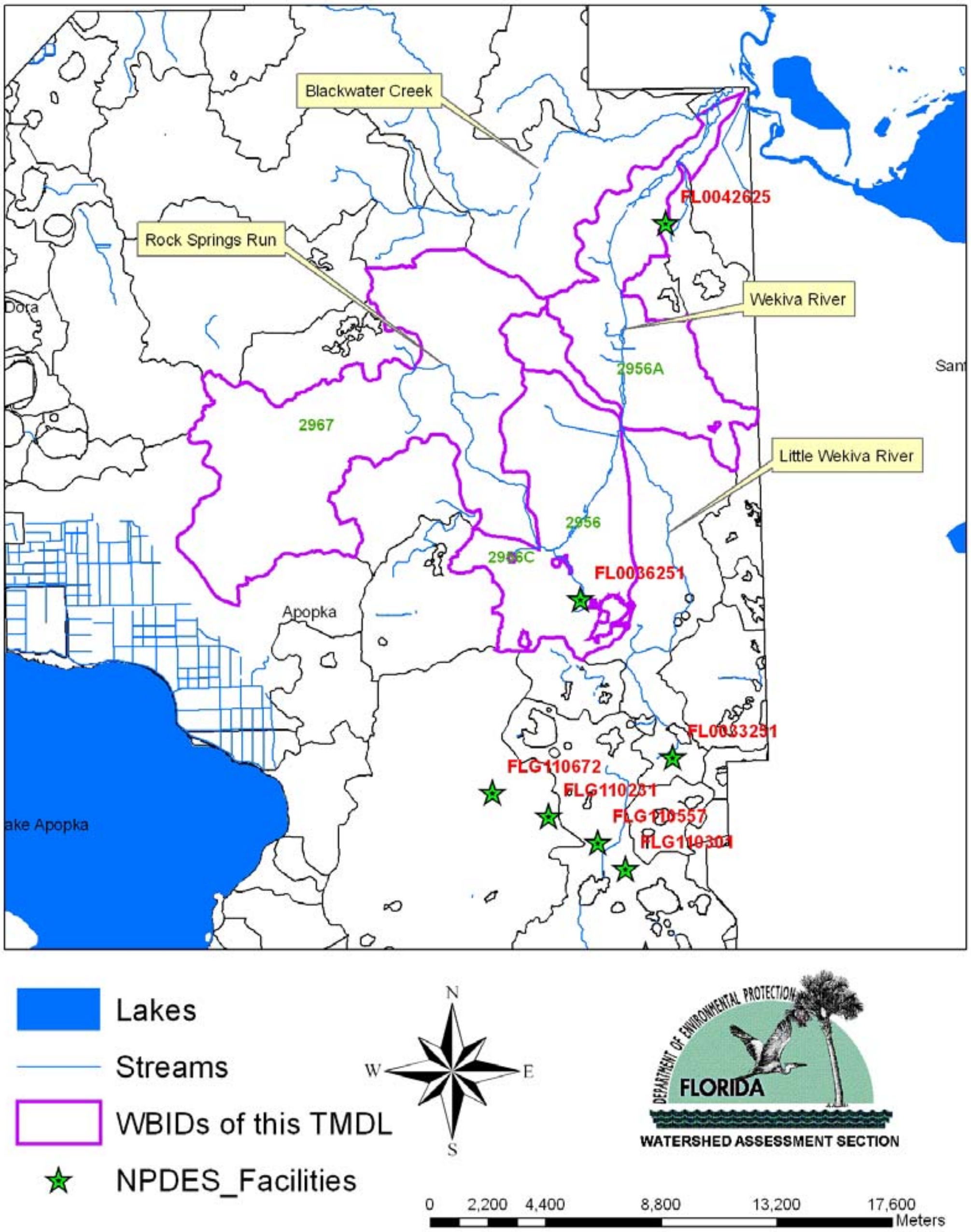


Figure 4.1. NPDES permitted facilities located in the Wekiva River drainage area.

The upland/receiving wetland system is not anticipated to discharge to other surface waters except under extreme wet-weather conditions, which may create intermittent flow through Sulfur Creek, which discharges from Yankee Lake through the receiving wetlands. This infrequent discharge may eventually reach the lower reach of the Wekiva River close to its confluence with St. Johns River. The permit issued to the facility requires the permittee to monitor the water quality in Sulfur Creek monthly when there is flow through Sulfur Creek to ensure that the wetland operation does not adversely impact the water quality of the creek. Based on the information from the Department's Central District Office, there have only been four months when there was flow in Sulfur Creek since July 2005, when the facility started to discharge to the upland/receiving wetland system. **Table 4.2** shows monitoring results in Sulfur Creek upstream and downstream of the effluent point and at the effluent point during the four months period.

Table 4.2. Results of water quality monitoring in Sulfur Creek upstream and downstream of the effluent point and at the effluent point when flow appeared in the creek.

Parameter	August 3, 2005			October 5, 2005			November 9, 2005			March 1, 2006		
	Upst	Downst	Efflu	Upst	Downst	Efflut	Upst	Downst	Efflu	Upst	Downst	Efflu
ammonia, mg/L	0.055	0.052	0.026	0.037	0.036	0.024	0.027	0.023	0.043	0.026		0.043
TKN, mg/L	1.1	0.97		1.1	1.2		1	0.93		0.81		
TN, mg/L	1.1	0.97	0.840	1.1	1.2	1.2	1	0.93	1.400	0.81		2.5
nitrite+nitrate, mg/L	0.020 U	0.020 U		0.0075 U	0.0075 U		0.0075 U	0.0075 U		0.0075 U	0.0075 U	
nitrate			0.200	0.056	0.048	0.46			0.560			1.636
TP, mg/L	0.050 U	0.050 U	0.320			0.22	0.09	0.071	0.180	0.017	0.012 U	0.15
Flow, day MGD			1.757			1.588			0.512			0.853

As shown in **Table 4.2**, in no cases for the four monitoring events were the nitrate and TP concentrations downstream of the effluent point significantly higher than those upstream of the effluent point, indicating that the discharge did not have any significant negative impact on Sulfur Creek water quality. This also indicates that the occasional backup discharge from the SCES/Yankee Lake WRF into the upland/receiving wetland system is not a significant source of nitrate or TP to the WR and RSR.

<u>The Altamonte Springs Regional Water Reclamation Facility</u> is located in the southeastern part of the Wekiva Study Area. The facility currently has a 12.5 MGD AADF permitted discharge to Little Wekiva River (**Figure 4.1**). However, the majority of the treated wastewater from the facility has been directed to reuse by the City of Altamonte Springs for purposes of irrigation within the 5,900 acre Reuse Service Area consisting of city parks, street, and highway medians, city-owned nurseries, residential and commercial lawns. Reclaimed water is also used for street cleaning, dust control, fire protection, water-to-air heat pumps, chillers (cooling water towers), and at automatic car washes. The actual discharge from the facility to the Little Wekiva River is significantly lower than the permitted 12.5 MGD (**Table 4.3**), with a long-term annual average discharge of 1.2 MGD. In addition, the facility also has a planned project that would take the excess reclaimed water to the City of Apopka for reuse and recharge, which will further decrease the discharge to the surface water. **Table 4.3** lists the long-term monthly average daily discharge rate from the facility to the Little Wekiva River, the monthly average TP

concentration of the discharge, and monthly TP loadings from the facility to surface waters. This summary was based on the discharge rate measured in 1999 through 2006, and TP concentrations in 2000 through 2002. No routine monitoring results of nitrate for the facility were available to the Department at the time this TMDL was developed.

Table 4.3. Long-term monthly average daily discharge rate, TP monthly average concentrations, and long-term TP monthly average loading for Altamonte Springs Regional Water Reclamation Facility.

Month	Monthly Average Daily Flow (MGD)	Monthly flow (million gallons/month)	TP (mg/L)	TP loading (lbs/month)
January	0.80	24.88	1.39	287.9
February	0.87	24.40	1.24	252.3
March	1.54	47.82	1.46	583.4
April	1.08	32.25	1.53	412.4
May	1.15	35.61	1.71	508.8
June	1.04	31.07	1.70	440.6
July	1.08	33.44	1.51	422.0
August	1.41	43.67	1.44	524.3
September	2.03	60.86	1.35	686.6
October	1.45	45.08	1.67	630.4
November	0.89	26.57	1.52	337.5
December	1.40	43.53	1.52	554.2
Mean	1.23	38.07	1.50	470.0

Influence of the discharge on the TP concentration of the Little Wekiva River is shown in **Figure 4.2**. TP concentrations measured at water quality stations upstream and downstream of the discharge point were analyzed. As shown in **Figure 4.2**, upstream of the WRF discharge point, the long-term average TP concentration of Lake Lotus, which is located within the Little Wekiva Canal basin and is close to the confluence of Little Wekiva Canal and the Little Wekiva River, is about 70 µg/L. This TP concentration is very close to the TP concentration measured from a water quality station (21FLORANLWD) located close to the inlet of the lake, which is about 60 µg/L. On the Little Wekiva River side, the long-term average TP concentration of Spring Lake, which is also located upstream of the WRF discharge point, is about 40 µg/L. The TP concentrations from all the stations upstream of the discharge point are significantly lower than the TP concentrations of the WRF's efflluent, which is about 1500 µg/L (**Table 4.3)**. Immediately downstream of the discharge point, the long-term average TP concentrations of the Little Wekiva River increases to about 190 µg/L (based on data from 21FLSEM WET, **Figure 4.2**), indicating a significant impact of the discharge on the river TP concentration. This high TP concentration, plus high TP concentrations in the discharges from several springs (**Table 4.11** of this report), including Starbuck Springs (a second magnitude spring, with a long-term average discharge 14.3 cfs, and TP concentration 160 µg/L), Sanlando Springs (a second magnitude spring, with a long-term average discharge 19.6 cfs, and TP concentration 180 µg/L), and Palm Springs (a third magnitude spring, with a long-term average discharge 6.88 cfs, and TP concentration 120 µg/L), result in a long-term average TP concentration of 170 µg/L measured from a station (21FLSJWMLW-WUR) located at the outlet of the Little Wekiva River into the main stem of the Wekiva River, indicating the influence of the WRF discharge on the TP concentration of the main stem of the Wekiva River.

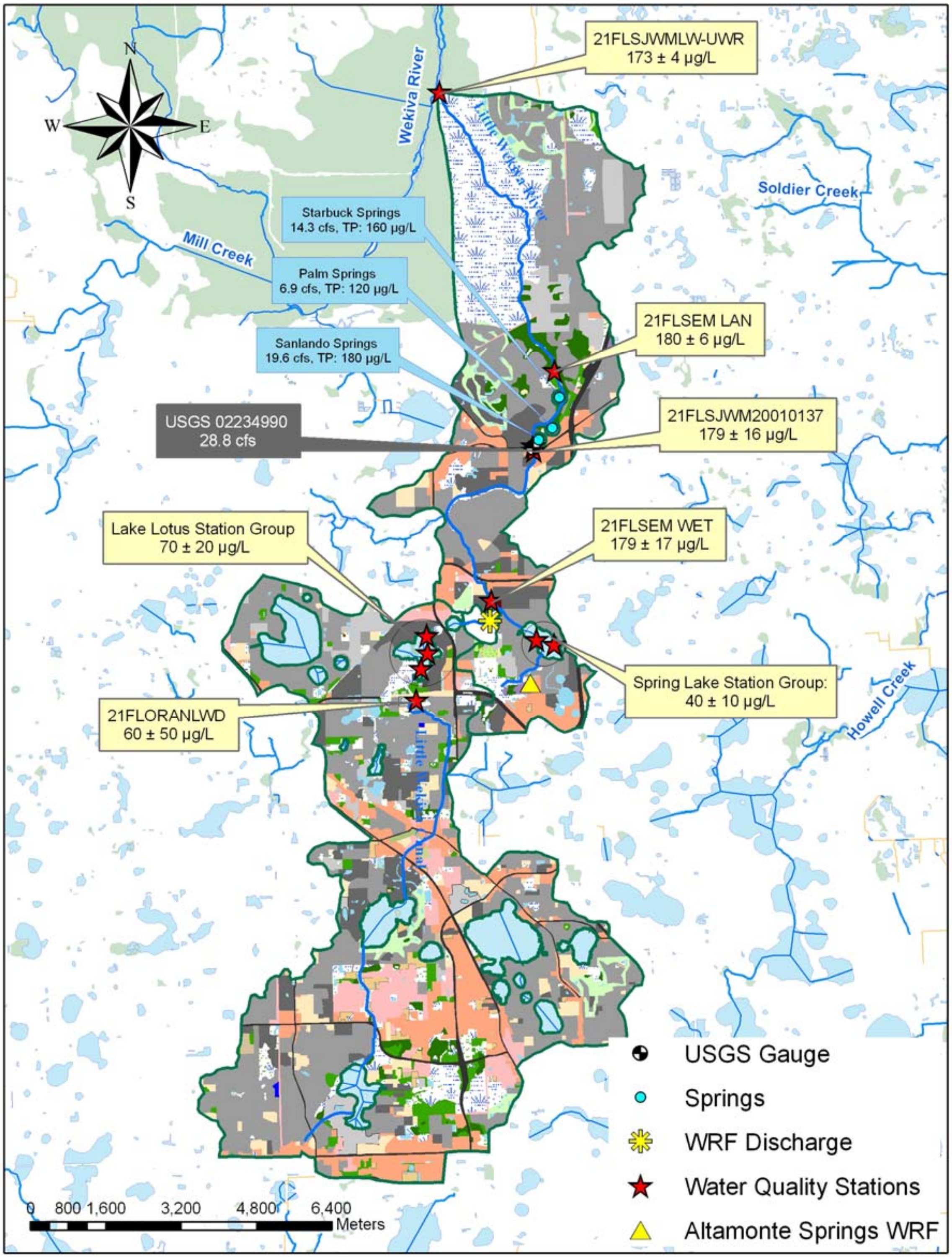


Figure 4.2. Influence of the Altamonte Springs Regional WRF on the spatial distribution of TP concentration in the Little Wekiva River.

Subsequent removal of TP discharged from the WRF during stream transport may not be significant. As was shown in **Figure 4.2**, from the station immediately downstream of the effluent point (21FLSEM WET) to the outlet of the Little Wekiva River to the Wekiva River main stem, the TP concentration did not change significantly. It appears that, to achieve the TP target of the Wekiva River main stem, TP loading from the WRF needs to be reduced significantly.

Wekiva Hunt Club WWTF is located about 1.3 miles east of the confluence of Rock Springs Run and the Wekiva River. The facility has a 2.9 mgd AADF permit to Sweetwater Creek, which in turn discharges to Cove Lake in the northwest, and then to the Wekiva River about 0.4 mile downstream of the Rock Springs Run and the Wekiva River confluence. The facility currently does not have effluent limits for either TN or nitrate. The TP effluent limits for the facility are 0.4 mg/L monthly average and 0.5 mg/L for any single sample.

Long-term monthly average nitrate and TP concentrations of the effluents from the facility were analyzed based on effluent data for the period of 1999 through 2006 retrieved from the Permit Compliance System (PCS) database and tabulated in **Table 4.4**. Compared to the annual average nitrate target and the monthly average TP target established for the Wekiva River and Rock Springs Run, discharge concentrations from the facility are considered very high. **Table 4.4 also** lists the long-term monthly average nitrate and TP loadings from the facility.

While the mean nutrient loads discharged are fairly significant, the discharge nitrate and TP concentrations can be significantly attenuated in the process of transport through the Sweetwater Creek – Cove Lake system before it reaches the Wekiva River. Based on information from the Department's Central District Office (Chris Ferraro, personal communication), the SJRWMD has been working on restoration projects to clean up Cove Lake. The SJRWMD funded a project where a deep area south of Cove Lake and Wekiva Springs Road was dredged deeper to create a sedimentation basin to allow eroded materials from Sweetwater Creek to settle out before the flow reaches Cove Lake. The project may further attenuate the nitrate and TP concentrations of the discharge from Wekiva Hunt Club WWTF.

Table 4.4. Long-term monthly average nitrate and TP concentrations and loadings for the effluent discharge from Wekiva Hunt Club WWTF in the period from 1999 through 2006.

Month	Average monthly flow (million Gallon/month)	Nitrate concentration (mg/L)	TP concentration (mg/L)	Nitrate loading (lb/month)	TP loading (lb/month)
January	51	10.43	0.16	4445	68
February	46	10.67	0.21	4102	81
March	41	10.12	0.19	3467	65
April	39	12.12	0.19	3950	62
May	38	9.46	0.19	3004	60
June	39	11.35	0.24	3699	78
July	47	8.88	0.12	3488	47
August	48	8.45	0.19	3390	76
September	55	7.96	0.24	3659	110
October	47	9.74	0.20	3826	79

November	42	9.85	0.18	3457	63
December	52	9.12	0.17	3963	74
Mean	45	9.85	0.19	3704	72

To analyze the possible attenuation rates for nitrate and TP along the path from the facility discharge point to the WR, the Department examined the water quality data collected from several monitoring sites along the transport path. These sites include:

- Site #1: Background Sweetwater Creek, upstream of the outfall to Sweetwater Creek;
- Site #2: 2400 feet downstream of the outfall to Sweetwater Creek, and about 200 feet upstream of the southernmost tributary that enters from the creek from the east;
- Site #3: 1000 feet upstream of the Wekiva Springs Road bridge;
- Site #4: Downstream side of the Wekiva Springs Road bridge, 200 feet downstream of the northernmost tributary that enters from the west;
- Site #5: North end of Cove lake at the discharge culvert to Wekiva Marina;
- Site #6: Weir structure located at River Bend Road;
- Site #7: Miami Springs Road bridge, upstream of confluence with Sweetwater Creek;
- Site #8: Wekiva River, downstream of Sweetwater Creek discharge.

Figure 4.3 shows the locations of these water quality sites. **Tables 4.5** and **4.6** show measured nitrate and TP concentrations at each sampling site, respectively, during the period from January, 2005 through April, 2006. Nitrate and TP concentrations of the effluent discharge are also included in **Tables 4.5** and **4.6**. **Figures 4.4-A** and **-B** show the long-term average spatial trend of nitrate and TP concentrations at these sampling sites.

Table 4.5. Nitrate concentrations at different sampling sites along the Sweetwater Creek – Cove Lake system

Unit: mg/L

Sites	1/05	2/05	3/05	5/05	6/05	7/05	8/05	9/05	10/05	11/05	1/06	2/06	4/06	mean
Site #1	1.53	0.358	0.247	0.329	0.291	1.13	0.432	0.245	0.199	0.424	0.254	0.361	0.289	0.468
Effluent	11.00	7.050	4.740	6.600	9.050	4.300	7.800	8.700	8.600	6.350	9.060	10.080	N/A	7.778
Site #2	1.19	0.687	0.51	0.577	0.401	1.64	0.349	0.338	0.23	0.28	4.13	0.424	0.345	0.854
Site #3	1.05	0.815	0.459	0.589	0.202	1.23	0.374	0.35	0.201	0.286	4.04	0.424	0.389	0.801
Site #4	1.04	0.816	0.476	0.563	0.227	1.23	0.373	0.367	0.155	0.26	3.89	0.407	0.119	0.763
Site #5	1.04	1.3	0.327	0.243	0.019	0.385	0.019	0.402	0.178	0.321	0.574	1.74	0.000	0.504
Site #6	0.229	0.606	0.045	0.042	0.019	0.554	0.022	0.22	0.28	0.335	0.742	1.05	0.000	0.319
Site #7	0.641	0.701	0.504	0.569	0.384	0.273	0.838	0.741	0.705	0.398	0.841	0.739	0.881	0.632
Site #8	0.711	0.696	0.509	0.586	0.457	0.273	0.773	0.714	0.686	0.521	0.834	0.76	0.866	0.645

Table 4.6. TP concentrations at different sampling sites along the Sweetwater Creek – Cove Lake system

Unit: mg/L

Sites	1/05	2/05	3/05	5/05	6/05	7/05	8/05	9/05	10/05	11/05	1/06	2/06	4/06	mean
Site #1	0.224	0.096	0.093	0.148	0.22	0.28	0.229	0.208	0.136	0.214	0.064	0.09	0.05	0.158
Effluent	0.097	0.240	0.127	0.220	0.840	0.190	0.380	0.670	0.390	0.210	0.110	0.112	N/A	0.299
Site #2	0.196	0.134	0.134	0.115	0.26	0.202	0.279	0.111	0.122	0.119	0.128	0.124	0.102	0.156
Site #3	0.311	0.117	0.107	0.114	0.147	0.25	0.237	0.155	0.095	0.0988	0.134	0.096	0.12	0.152
Site #4	0.192	0.103	0.11	0.108	0.157	0.94	N/A	0.157	0.0841	0.102	0.148	0.092	0.116	0.192
Site #5	0.192	0.034	0.126	0.087	0.103	0.222	0.156	0.188	0.0686	0.133	0.106	0.062	0.174	0.127

Site #6	0.308	0.069	0.105	0.109	0.115	0.864	0.0686	0.127	0.0719	0.119	0.084	0.136	0.174	0.181
Site #7	0.199	0.065	0.085	0.085	0.074	0.22	0.084	0.02	0.0586	0.108	0.09	0.116	0.112	0.101
Site #8	0.09	0.017	0.098	0.089	0.144	0.22	0.0706	0.02	0.0592	0.114	0.094	0.118	0.104	0.095

As shown in **Table 4.5**, with the exception of one sampling event in January of 2006, nitrate concentrations dramatically decrease by the time the effluent reaches Site #2, which is about 2,400 feet downstream of the effluent point. A similar trend was also observed for TP (**Table 4.6**). In most cases, when the effluent TP concentration was significantly higher than the background condition measured at Site #1, a significant decrease in TP concentration was observed when the discharge reached Site #2. Nitrate concentration in the stream decreased more rapidly than TP, suggesting that nitrate is quickly assimilated by the Sweetwater Creek system, instead of being merely diluted by the flow in the creek.

These downstream trends are readily seen in **Figures 4.4-A** and **–B.** On the long-term average basis, nitrate concentrations decrease from 7.78 mg/L at the effluent point to about 0.319 mg/L at Site #5, while TP concentrations decrease from 0.299 mg/L to 0.127 mg/L at Site #5 (Site #5 is located at the outlet of Cove Lake and close to the discharge point of Sweekwater Creek into WRMS). The decreases in concentration between the effluent point and the outlet of Cove Lake represent attenuation rates of 96% for nitrate and 39% for TP. These attenuation rates will be used in a later chapter to estimate the wasteload allocation for the facility.

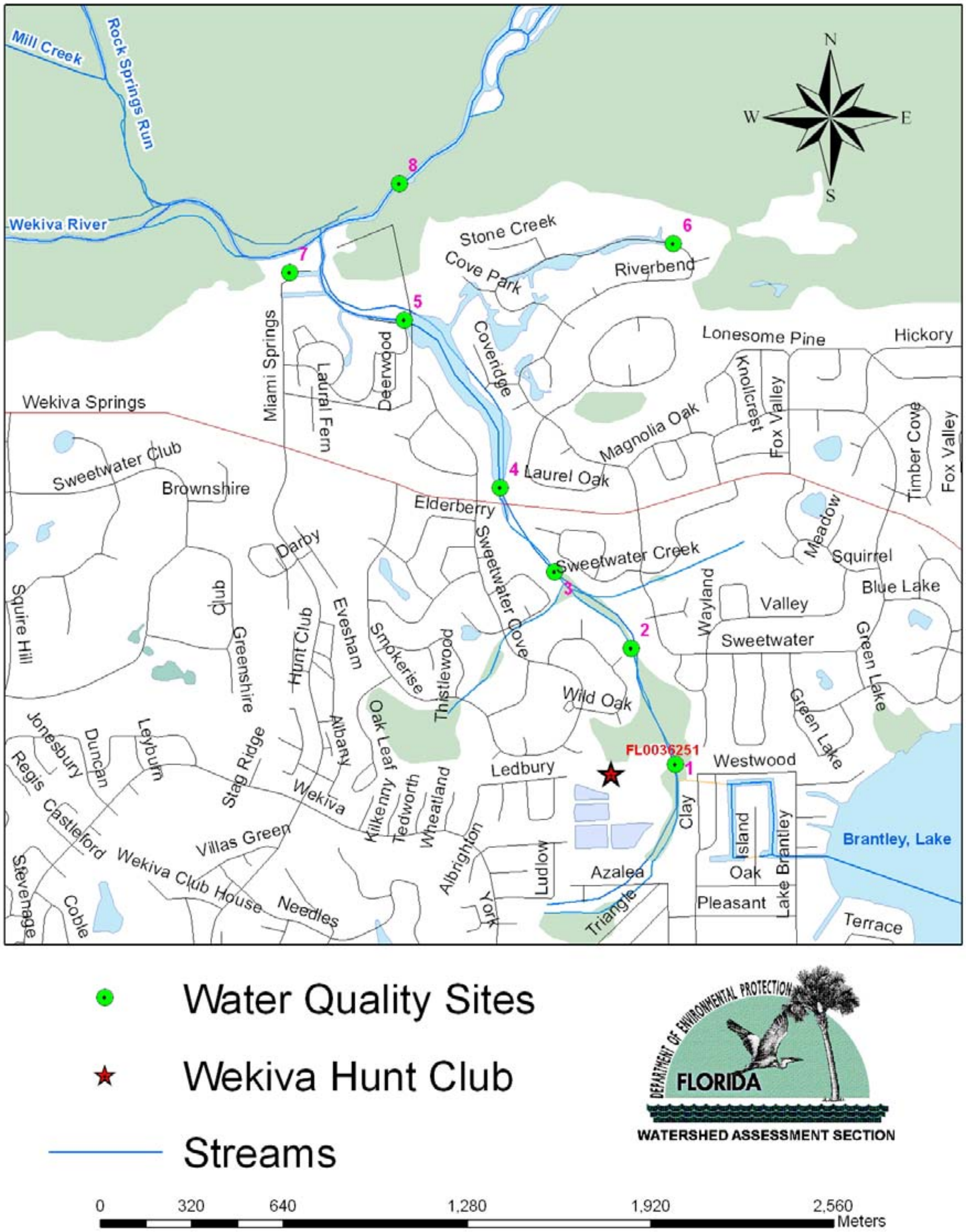
4.2.1.2 Municipal Separate Storm Sewer System Permittees

Within the drainage basin of the Wekiva River System, Orange County has a Phase I MS4 permit (FLS000011). The Florida Department of Transportation (FDOT) District 5 and City of Maitland are co-permittees for this permit. Seminole County also holds a Phase I MS4 permit (FLS000038) with FDOT District 5, City of Altamonte Springs, and City of Lake Mary being co-permittees for this permit. In addition, the City of Orlando holds a Phase I MS4 permit (FLS000014). Lake County does not have MS4 permit within the boundary of the drainage basin.

4.2.2 Nonpoint Sources

Additional nitrate and TP loadings to the Wekiva River system are primarily generated from nonpoint sources in the drainage basin. Major nonpoint sources may include, but are not limited to, loadings from surface runoff and ground water input from the surficial aquifer as stream seepage, as well as spring flows from the Floridan aquifer.

In this analysis, nitrate and TP loadings from the drainage basin to the Wekiva River system were estimated based on annual average rainfall, the area of different landuse categories summarized based on the SJRWMD's year 2000 landuse GIS coverage (scale 1:40,000), and runoff coefficients and event mean concentrations (EMCs) of nitrate and TP for different landuses (Harper, 2003). The nitrate and TP loadings estimated using this method reflect the potential amount of each pollutant that can be generated from different landuses in the drainage basin. These loading estimates did not take into consideration the attenuation during the pollutant transport across the drainage basin. The loading estimates therefore can be higher than the pollutant loadings that eventually reach the Wekiva River systems.


Mill Creek
Rock Springs Run
Wekiva River
Stone Creek
Cove Park
Riverbend
Lonesome Pine
Hickory
Miami Springs
Laural Fern
Deerwood
Coveridge
Wekiva Springs
Knollcrest
Fox Valley
Magnolia Oak
Timber Cove
Sweetwater Club
Brownshire
Laurel Oak
Elderberry
Meadow
Squirrel
Blue Lake
Darby
Sweetwater Creek
Sweetwater Cove
Wayland
Valley
Squire Hill
Club
Greenshire
Hunt Club
Evesham
Smokerise
Thistlewood
Sweetwater
Green Lake
Wild Oak
Jonesbury
Duncan
Leyburn
Regis
Stag Ridge
Albany
Oak Leaf
FL0036251
Westwood
Ledbury
Castleford
Wekiva
Kilkenny
Tedworth
Wheatland
Clay
Island
Brantley
Brantley, Lake
Villas Green
Albrighton
Ludlow
Azalea
Oak
Lake Brantley
Stevenage
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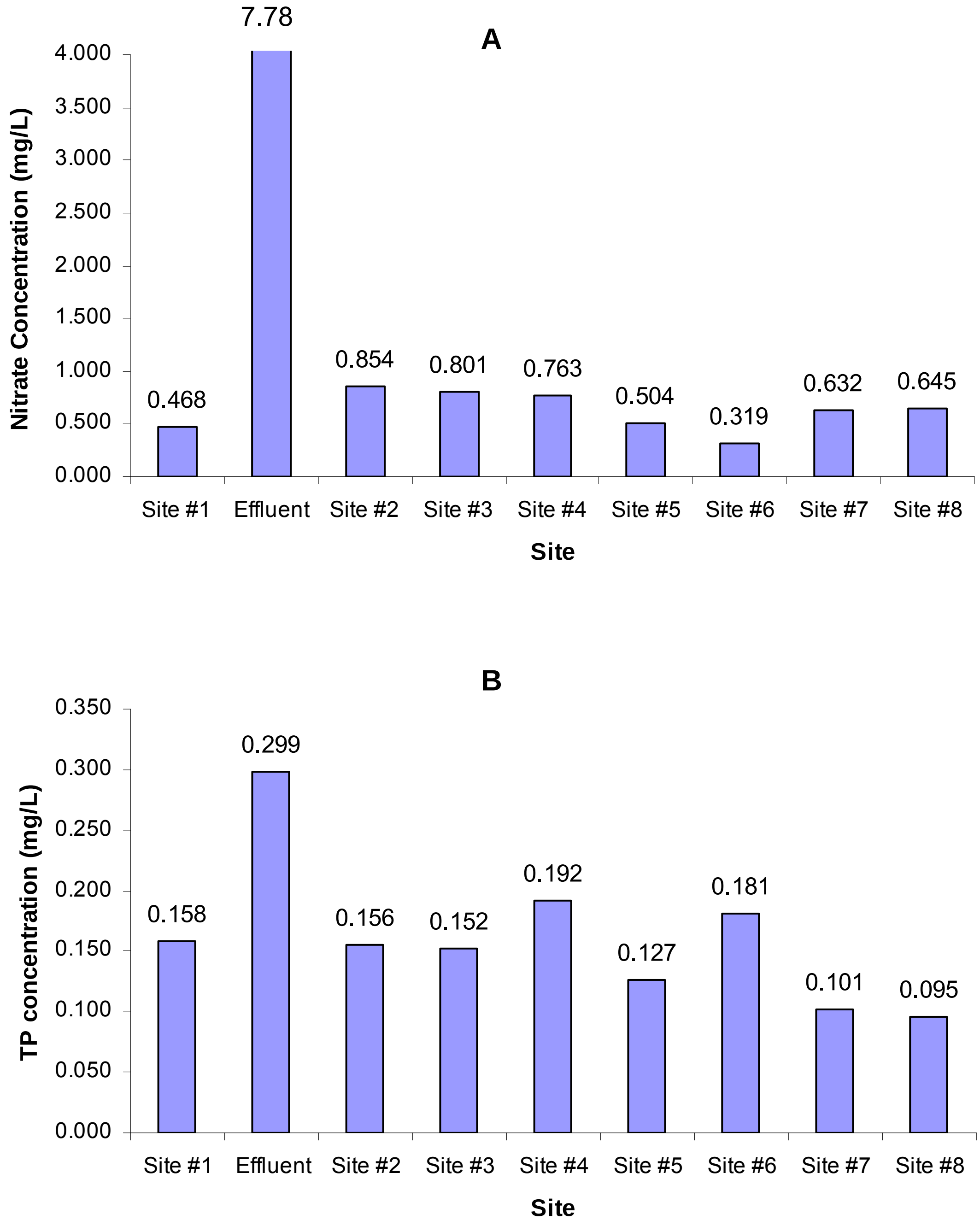

Figure 4.4. Long-term spatial trend of nitrate and TP concentration at different sampling sites along the Sweetwater Creek – Cove Lake system.

4.2.2.1 Land Uses

Based on the drainage basin delineation provided by the SJRWMD, the Wekiva River system drains a basin area of about 240,948 acres. **Figure 4.5** shows the boundary of the drainage basin and the landuse categories (SJRWMD year 2000 landuse GIS coverage) aggregated based on the Florida Landuse Classification Code System (FLUCCS) level one landuse classification. **Table 4.7** summarizes the landuse area from different landuse areas. According to **Table 4.7**, urban and built-up area occupies about 69,374 acres, which accounts for about 28.8% of the total drainage basin and ranks first among all the individual landuse categories for percent landuse acreage. About 32,464 acres of the basin land are used for various agricultural practices. Percent acreage for agricultural landuse is about 13.5%. Natural landuse, including rangeland, upland forest, water, and wetlands, when combined, occupy about 135,904 acres, which accounts for about 56.4% of the total area of the drainage basin. The remaining about 1.0% of the basin landuse is comprised of transportation, communications, and utilities.

Table 4.7. Acreages and percent acreages of different landuse categories for the Wekiva River system draingage basin

Landuse FLUCCS Code	Landuse Description	Acreages	Percent Acreages
1000	Urban and Built-Up	69,374	28.8%
2000	Agriculture	32,464	13.5%
3000	Rangeland	17,362	7.2%
4000	Upland Forest	55,867	23.2%
5000	Water	10,355	4.3%
6000	Wetlands	52,320	21.7%
7000	Barren Land	901	0.4%
8000	Transportation, Communications, Utilities.	2,305	1.0%
Total		240,948	100.0%

For loading estimation purposes, level 1 landuse categories were further divided into the sub-categories listed in **Table 4.8**. In addition, **Table 4.8** listed the acreage, runoff coefficients, nitrate and TP EMCs, and nitrate and TP loadings from these different landuses. A long-term annual average rainfall of 51 inches was used for estimating the long-term annual average pollutant loading. This number was calculated based on the rainfall data collected from a weather station located in Sanford. The period of record is from 1957 through 2002. **Table 4.9** lists the percent nitrate and TP loadings from different landuse categories.

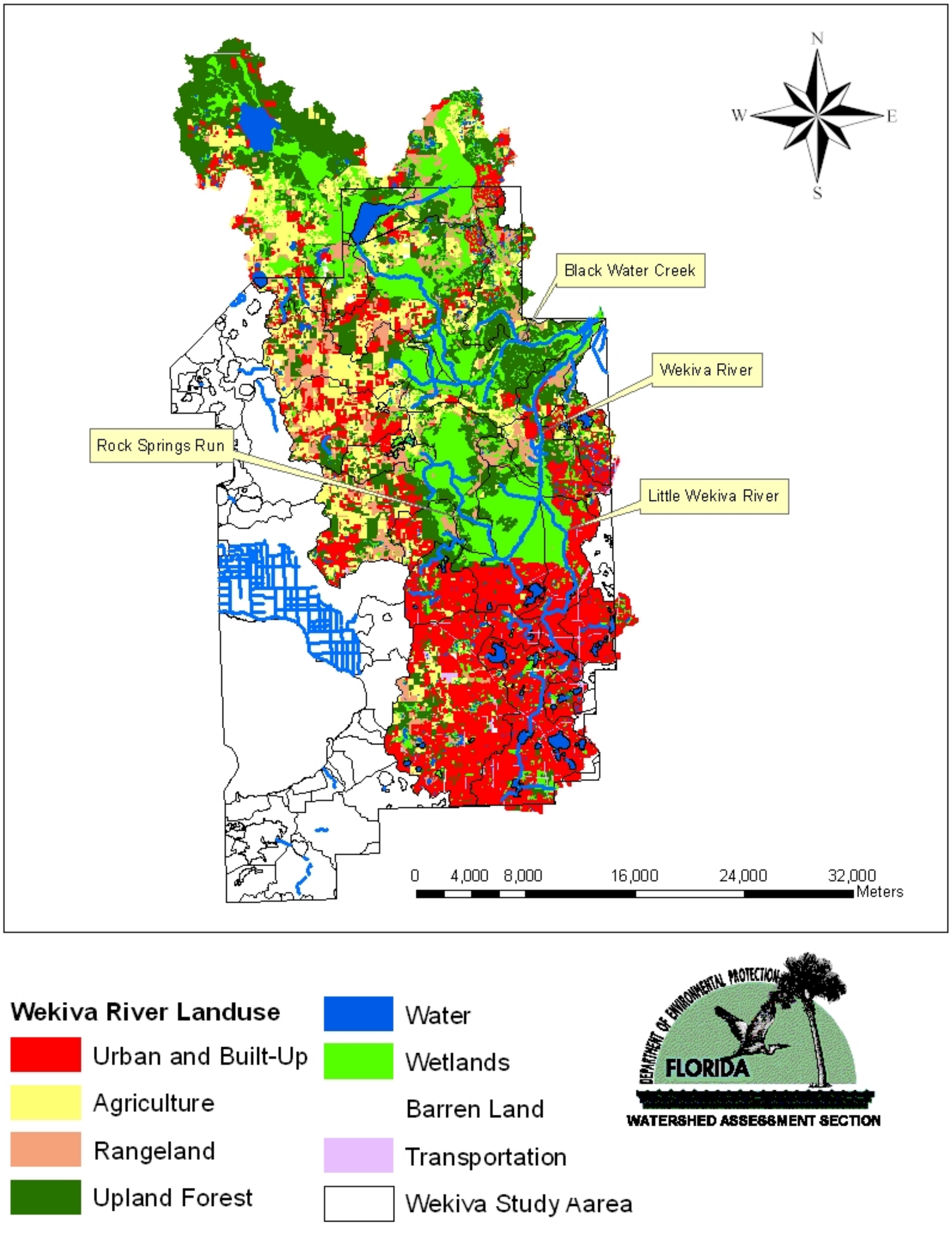

Figure 4.5. Principal land uses in the drainage basin of Wekiva River.

Table 4.8. Classification of land use categories in the Wekiva River watershed

Laduse	Acreage	Runoff Coefficie.	Annual Runoff (ac-ft/y.)	Monthly Runoff (ac-ft/m)	Event mean concentration (mg/L)		Nitrate loading		TP loading	
					nitrate	TP	Annual (lb/yr.)	Month (lbs/m.)	Annual (lb/yr.)	Monthly (lbs/m.)
Agriculture/ Golf Course	34615	0.3	44134	3678	0.58	0.34	69622	5802	41293	3441
Forest and Rural Open	55867	0.08	18995	1583	0.31	0.05	16015	1335	2583	215
Rangeland	17362	0.12	8855	738	0.4	0.34	9633	803	8188	682
Low-Density Residential	17668	0.27	20274	1690	0.63	0.3	34739	2895	16543	1379
Medium-Density Residential	29098	0.37	45757	3813	0.65	0.4	80893	6741	49780	4148
High-Density Residential	6551	0.68	18932	1578	0.67	0.49	34500	2875	25231	2103
Commercial	5376	0.85	19421	1618	0.67	0.29	35390	2949	15318	1277
Institutional	1532	0.84	5469	456	1.05	0.15	15619	1302	2231	186
Industrial/Utility	2499	0.79	8390	699	0.4	0.31	9128	761	7074	590
Transportation Facilities	2305	0.78	7641	637	0.4	0.34	8313	693	7066	589
Openland	5399	0.16	3671	306	0.31	0.05	3095	258	499	42
Water	10355	0.5	22004	1834	0.19	0.11	11371	948	6583	549
Wetlands	52320	0.23	51143	4262	0.4	0.19	55640	4637	26429	2202
Total	240948		274686	22891			383959	31997	208819	17402

*: Runoff coefficients were cited from Harper (2003).
**: EMCs were provided by the CDM.

Table 4.9. Percent pollutant contribution from different landuse categories

Landuse	Nitrate	TP
Agriculture/Golf Course	18.1%	19.8%
Forest and Rural Open	4.2%	1.2%
Rangeland	2.5%	3.9%
Low-Density Residential	9.0%	7.9%
Medium-Density Residential	21.1%	23.8%
High-Density Residential	9.0%	12.1%
Commercial	9.2%	7.3%
Institutional	4.1%	1.1%
Industrial/Utility	2.4%	3.4%
Transportation Facilities	2.2%	3.4%
Openland	0.8%	0.2%
Water	3.0%	3.2%
Wetlands	14.5%	12.7%
Total	100.0%	100.0%

As shown in **Table 4.9**, the most important nitrate and TP contributors in the drainage basin are urban landuses, which include low, medium, and high density residential, commercial, institutional, industrial/utility, transportation facilities, and other urban open lands. These landuses contribute about 218,583 lbs/year (18,215 lbs/month) and 123,244 lb/year (10270 lbs/month) of nitrate and TP, which account for about 57% and 59% of the total nitrate and TP from the entire drainage basin, respectively. In addition, agricultural landuses contribute about 18% of nitrate and 20% of TP, and wetlands contribute about 15% of the nitrate and 13% of the TP. Total human landuses contribute about 78% nitrate and 83% of TP, while natural landuses, including forest, waters, and wetlands, contribute about 22% of the nitrate and 17% of the TP through surface runoff.

Another possible nonpoint source of nitrate and TP to receiving waters is septic tank discharge. While properly installed and maintained septic tanks can remove phosphorus relatively effectively, significant amounts of nitrate can still be released into the ground water or surface runoff due to the low adsorption rate of nitrate by soil particles.

A GIS shapefile showing locations of septic tank-using land parcels within the boundary of the Wekiva River drainage basin was provided by the CDM (**Figure 4.6**). However, no data on the number of septic tanks located in the drainage basin were available to the Department at the time this TMDL was developed. To estimate the pollutant loading from septic tanks, the number of septic tanks in the basin is required. This number was estimated based on the following information:

(1) The total number of septic tanks located in the Lake County part of the Wekiva study Area was provided by the CDM, Inc., which is 9,286 septic tanks.
(2) The total acreage of the septic tank-using land parcels in Lake County part of the Wekiva Study Area was provided by the CDM, Inc. The total acreage is 20,599 acres.
(3) The number of septic tanks per acre of septic tank-using parcel were estimated as the quotient between the total number of septic tanks in (1) and the total acreage in (2), and is 0.45 septic tanks/per acre
(4) Assuming that septic tanks that contribute significant quantities of nutrients to receiving waters through surface runoff are typically located within 200 meters of receiving waters (Reckhow, 1980), the total acreage of septic tank-using land parcels in the Wekiva River drainage basin that could contribute significant quantities of nutrients to receiving waters through surface runoff is 458 acres.
(5) Multiplying 458 acres in (4) by the 0.45 septic tank/per acre in (3), the total number of septic tanks in the Wekiva River drainage basin that can contribute significant quantities of nutrients to receiving waters through surface runoff is 206 septic tanks.

The nitrate and TP loadings from septic tanks to the Wekiva River system were estimated using the following equation:

$$W = F * N * C * (1-R)$$

Where:

W is the total loading from septic tanks.
F is the number of people per household.
N is the number of septic tank-using households.
C is the per capita pollutant loading.
R is the pollutant removal efficiency.

Based on *Summary Population and Housing Characteristics in Florida* published by the United States Census Bureau in 2000 (http://www.census.gov/prod/cen2000/phc-1-11.pdf), the number

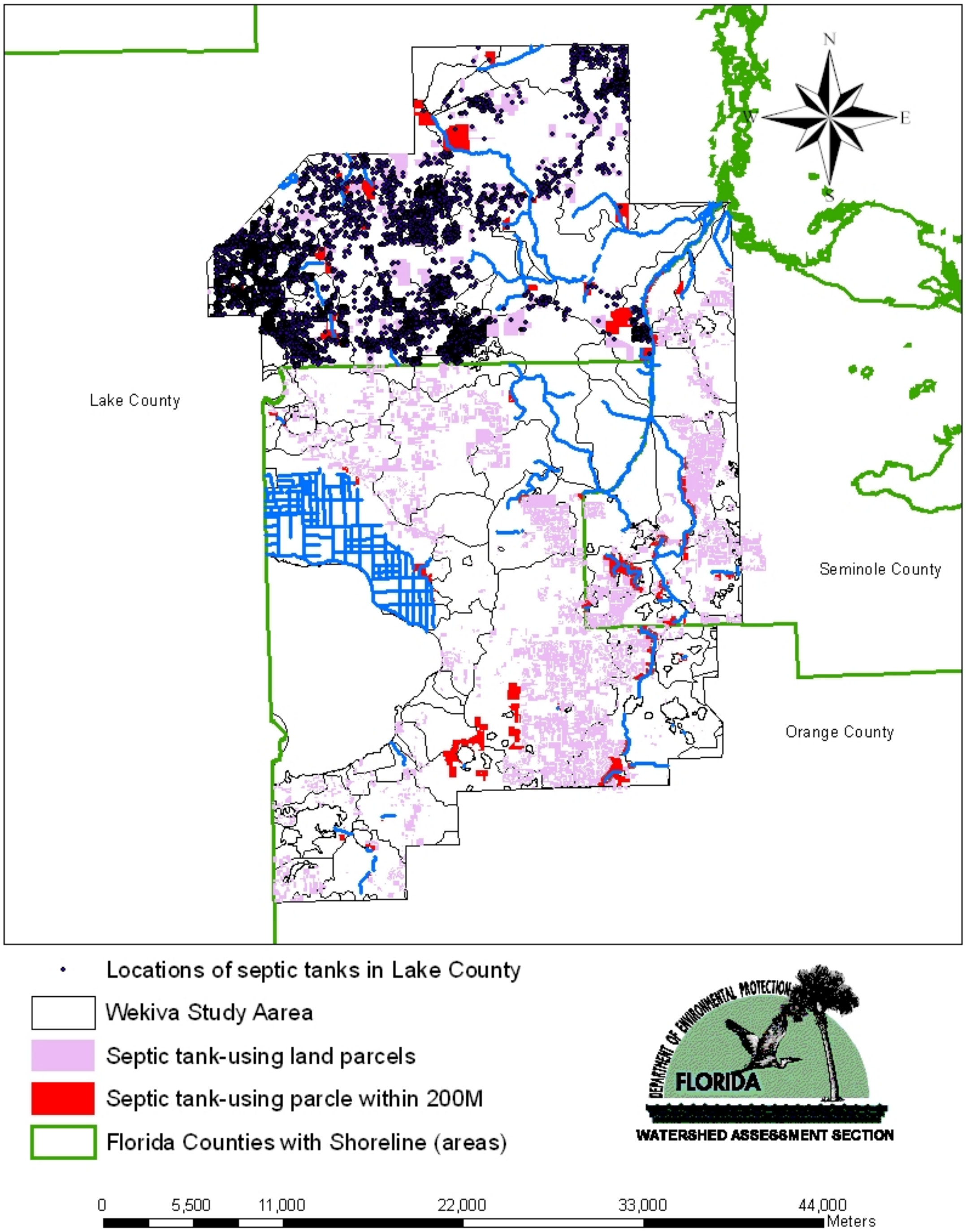

Figure 4.6. Location of septic tank-using land parcels in the Wekiva Study Area.

of people per household in Lake, Orange, and Seminole Counties are 2.34, 2.61, and 2.59, respectively. The average household size (F) for these three counties is 2.51.

The number of septic tank-using households within 200 meters to receiving waters could be considered the same as the number of septic tanks in the same area, assuming that each household uses one septic tank.

Per capita TP loading (**Table 4.10**) for raw sewage was cited from Reckhow (1980). It was a typical value calculated as the mean TP loading from various studies. Nitrate concentration in raw sewage is typically very low. Most of the nitrate appears in the drainage field of conventional septic tanks when organic nitrogen is mineralized through ammonification and ammonia is oxidized through nitrification. Typically, the physical and biochemical processes happening in septic tanks and drainage fields, including precipitation in the septic tank and denitrification in the drainage filed, can remove about 40 to 45% of the total nitrogen (Burton, 1991), and the remaining part of TN was assumed to be in the form of nitrate in this TMDL.

Pollutant removal efficiency (R) is the percent at which TP and nitrate is removed by the septic tank system (including the tank and the soil). In this case, it is assumed that within 200 meters, 70% of TP and 45% of the TN will be removed. The remaining 55% of TN will become nitrate and, together with the remaining 30% of TP, enter surface runoff or ground water.

Based on above information, the TP and nitrate loadings from septic tanks in the Wekvia River drainage basin that are within 200 meters to receiving water are about 499 lbs/year and 2,890 lbs/year, respectively. Compared to nitrate and TP loadings from various landuse categories, loadings from septic tank through surface runoff are relatively small.

Table 4.10. Nutrient load for household wastewater discharged into septic tanks (kilograms/capita/year) (cited from Reckhow, 1980)

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

N/A = Not available

The low nitrate and TP loadings from septic tanks estimated using the above method are mainly loadings through surface runoff, which is why a 200 meter distance limit was applied. However, septic tank pollutant loadings can also contribute to the surface water pollution via a ground water pathway, even for those septic tanks located beyond 200 meter distance limit. This is especially true for the Wekiva River drainage basin because this area is underlaid by a Karst geology characterized by limestone or dolostone bedrock with caves and springs. A study conducted by the Florida Department of Health indicated that using the conventional onsite sewage treatment and disposal system in Karst areas could produce nitrate concentrations as high as 60 mg/L in the groundwater adjacent to the drainage field (DOH 2004). The nitrate can be carried into surface waters through either baseflow, or more importantly in the Wekiva River system, through springs discharge.

At the time this TMDL was developed, not enough information was available for the Department to determinethe septic tank pollutant loading through ground water. Therefore, nitrate and TP loadings through spring discharges were estimated. Nitrate and TP loadings through spring discharges can include contribution form septic tanks, other human activities such as agricultural practices, and natural background.

There are about 30 springs located in the Wekiva River drainage area. These springs either discharge directly to the main stem of the Wekiva River or discharge to major tributaries, including RSR, Blackwater Creek (BWC), and Little Wekiva River (LWR), which in turn discharge into the WR. **Figure 4.6** shows the locations of these springs. **Table 4.11** shows the magnitude, discharge rate, and nitrate and TP concentrations of these springs. **Table 4.12** shows the nitrate and TP loadings and percent nitrate and TP loadings from these springs.

Among the 30 springs located in the Wekvia River drainage basin, Rock Springs and Wekiva Springs are the two largest springs. Both of them discharge at more than 50 cfs, while the majority of the other springs discharge at less than 10 cfs. Seminole Springs discharges at a rate of 35.2 cfs, ranking the third in discharge rate. This spring is located in Lake County and discharges into Blackwater Creek. Several other springs, including Messant Spring in Lake County (discharging to Blackwater Creek), Starbuck Springs located in Seminole County (discharging to Blackwater Creek), and Sanlando Springs located in Seminole County (discharging to Little Wekiva River) discharge at a long-term average rate of more than 10 cfs.

According to **Table 4.12**, the total nitrate and TP loading from all the 30 springs are about 511,433 lbs/year and 78,952 lbs/year, respectively. The total nitrate loading from springs is higher than the nitrate loading from surface runoff, which is about 383,959 lbs/year (**Table 4.8**). TP loading from springs are also significant compared to the TP loading from surface runoff, which is about 197,506 lbs/year. These numbers indicate that springs are a very important source of nitrate and TP in the Wekiva River system.

Among all the springs, Rock Springs and Wekiva Springs are the largest nitrate contributors. Combined nitrate loadings from these two springs account for about 70% of the spring nitrate. In addition, these two springs contribute about 59% of the spring TP, indicating that efforts to control nitrate and TP should be put on the recharge areas of these two springs. Other than these two springs, Seminole Spring contributes about 19% of the spring nitrate and 7% of spring TP. Sanlando Spring and Starbuck Springs contribute about 4.5% and 2.1 % of the spring nitrate and 8.8% and 5.7% of the spring TP, respectively. Considering the high nitrate and high TP concentrations observed in these springs, studies on the nitrate and TP loadings in recharge areas of these springs should also be stressed.

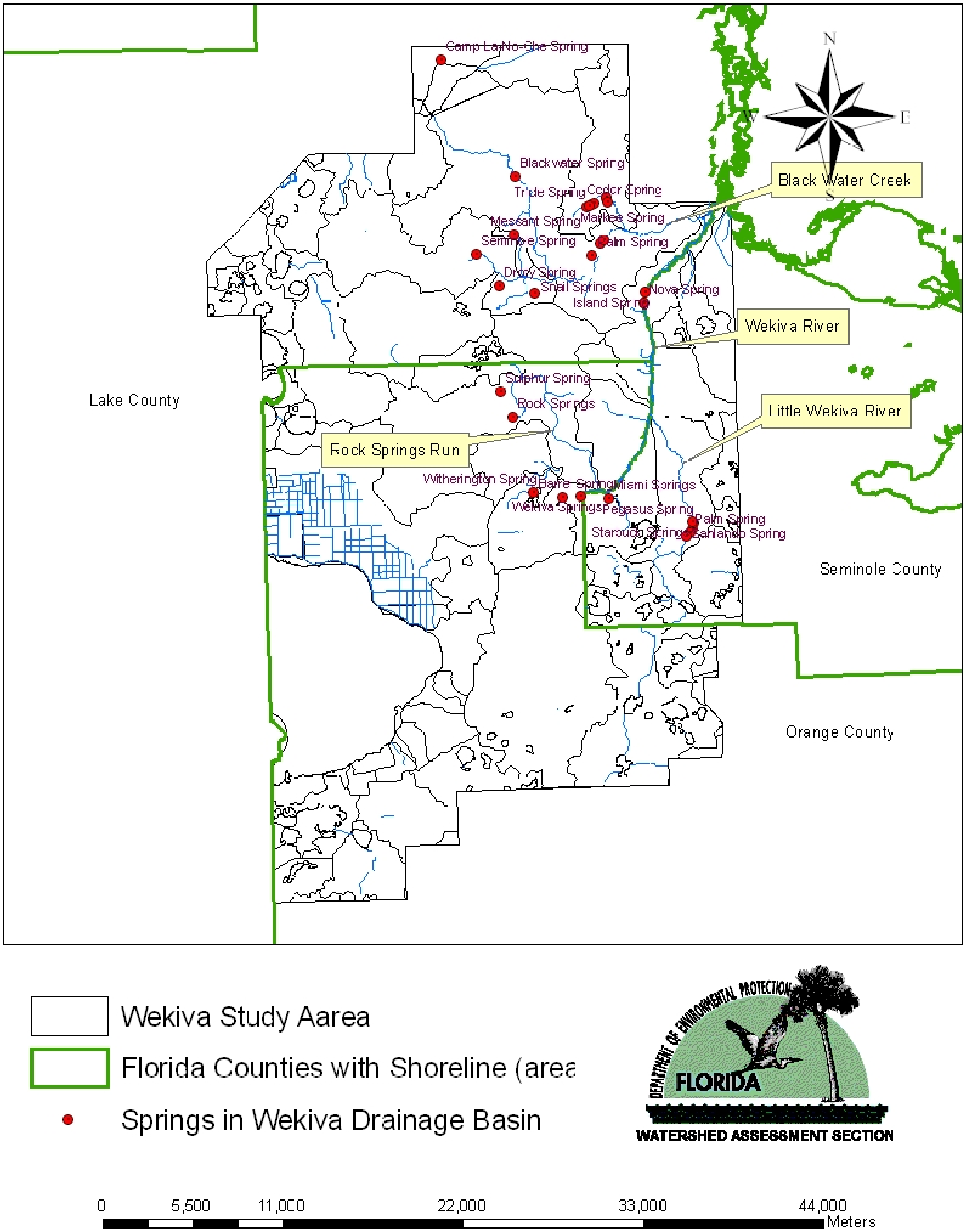

Figure 4.7. Locations of springs in the Wekiva River drainage area.

Table 4.11. Characteristics of springs located in the Wekiva River drainage basin.

Spring Name	Spring Magnitude	Discharge (cfs)	NO3/NO2 (mg/L)	TP (mg/L)
Lake County				
Blackwater Spring	3rd	1.4	0.92	N/A
Blue Algae Boil	5th	0.14	0.03	0.05
Blueberry Spring	5th	0.07	0.03	N/A
Boulder Spring	5th	0.19	0.08	0.18
Camp La-No-Che Spring	4th	0.7	N/A	0.06
Cedar Spring	5th	0.03	0.03	0.05
Droty Spring	4th	0.62	0.03	0.08
Green Algae Boil	5th	0.14	N/A	0.06
Markee Spring	4th	0.25	0.02	0.06
Messant Spring	2nd	14.7	0.01	0.04
Mocassin Spring	4th	0.29	0.01	N/A
Palm Spring	4th	0.63	0.01	0.02
Seminole Spring	2nd	35.2	1.37	0.08
Sharks Tooth Spring	5th	0.15	0.09	0.05
Snail Springs	5th	0.09	0.02	0.15
Tricle Spring	N/A	N/A	N/A	N/A
Orange County				
Barrel Spring	4th	0.25	0.05	N/A
Rock Springs	2nd	57.9	1.5	0.08
Sulphur Spring	4th	0.74	0.02	0.03
Tram Springs	N/A	N/A	N/A	N/A
Wekiva Springs	2nd	67.1	1.43	0.28
Witherington Spring	3rd	4.7	0.38	N/A
Seminole County				
Gingar Ale Springs	5th	0.11	N/A	0.04
Island Spring	3rd	7.83	0.01	0.51
Miami Springs	3rd	5.05	0.17	0.12
Nova Spring	3rd	8.52	0.12	0.14
Palm Spring	3rd	6.88	0.69	0.12
Pegasus Spring	3rd	2.8	0.54	0.22
Sanlando Spring	2nd	19.6	0.59	0.18
Starbuck Springs	2nd	14.3	0.39	0.16

Data cited from SJRWMD's Springs website (http://sjrwmd.com/programs/plan_monitor/gw_assess/springs/).

Table 4.12. Nitrate and TP loadings from springs located in the Wekiva River drainage basin and percent loadings from these springs

Spring Name	**Loading**		**Percent loading**	
	NO3/NO (lbs/year)	TP (lbs/year)	NO3/NO	TP
Lake County				
Blackwater Spring	2536		0.5%	
Blue Algae Boil	8	14	0.0%	0.0%
Blueburry Spring	4		0.0%	
Boulder Spring	30	67	0.0%	0.1%
Camp La-No-Che Spring		83		0.1%
Cedar Spring	2	3	0.0%	0.0%
Droty Spring	37	98	0.0%	0.1%
Green Algae Boil		17		0.0%
Markee Spring	10	30	0.0%	0.0%
Messant Spring	289	1158	0.1%	1.5%
Mocassin Spring	6		0.0%	
Palm Spring	12	25	0.0%	0.0%
Seminole Spring	94967	5546	18.6%	7.0%
Sharks Tooth Spring	27	15	0.0%	0.0%
Snail Springs	4	27	0.0%	0.0%
Tricle Spring				
Orange County				
Barrel Spring	25		0.0%	
Rock Springs	171032	9122	33.4%	11.6%
Sulphur Spring	29	44	0.0%	0.1%
Tram Springs				
Wekiva Springs	188959	36999	36.9%	46.9%
Witherington Spring	3517		0.7%	
Seminole County				
Gingar Ale Springs		9		0.0%
Island Spring	154	7864	0.0%	10.0%
Miami Springs	1691	1193	0.3%	1.5%
Nova Spring	2013	2349	0.4%	3.0%
Palm Spring	9349	1626	1.8%	2.1%
Pegasus Spring	2978	1213	0.6%	1.5%
Sanlando Spring	22773	6948	4.5%	8.8%
Starbuck Springs	10983	4506	2.1%	5.7%
Total	511433	78952	100.0%	100.0%

Table 4.13 summarizes the possible nonpoint source contributors of nitrate and TP loadings in the Wekiva River drainage system considered in this TMDL. The contribution of nitrate and TP loads from septic tanks located with 200 meters to receiving water through surface runoff is not a major source. Nitrate loadings from different landuses through surface runoff and springs are comparable, and springs contribute slightly more nitrate than the surface runoff. The major contributor of TP apparently is the surface runoff from the drainage area. Spring TP contribution appears to be less important than the surface runoff.

Table 4.13. Summary of nitrate and TP loadings from possible nonpoint sources in the Wekiva River drainage areas.

Sources	Loading		Percent Loading	
	NO3/NO2 (lbs/year)	TP (lbs/year)	NO3/NO2	TP
Surface runoff from landuses	383,959	208,819	43%	73%
Spring contribution	511,433	78,952	57%	27%
Surface runoff from septic tanks	2,890	499	0%	0%
Total	898,282	288,270	100%	100%

Chapter 5: DETERMINATION OF ASSIMILATIVE CAPACITY

Ideally, existing loading and target loading reaching a given waterbody should be simulated using hydrologic and water quality models. However, there was not adequate time available to develop this TMDL using a modeling approach, and an alternative approach was used to estimate the existing and target loadings.

Existing stream loading can be estimated by multiplying the measured stream flow by the measured pollutant concentrations in the stream. To estimate the pollutant loading this way, flow measured at the outlet of each stream segment under question is required. Several USGS gauging stations were identified in the Wekiva River main stem and its major tributaries. However, none of these stations were located at outlets of the stream segments under question. The Department considered the feasibility of using the available flow measurements to estimate the flow at each segment outlet based on the drainage area ratio among these stream segments. This method would normally provide an approximation of flow estimates at the stream segment outlets. However, because of the ubiquitous existence of springs in the Wekiva River drainage area, flow estimation based on drainage area ratio will not give an accurate result. Therefore, the loads of nitrate and TP were not explicitly calculated. Instead, the percent load reduction required to achieve the nitrate and TP concentration targets were calculated assuming the percent loading reduction would be the same as the percent concentration reduction.

The percent reduction required to achieve the water quality target was calculated using the following formula:

[(existing mean concentration – target concentration) / existing mean concentration] x 100

As discussed in Chapter 3, both the nitrate target and the TP target were established as monthly averages in this TMDL. Therefore, long-term monthly average concentrations were calculated for each month for each parameter based on measured concentrations for the period of record. To make sure that the monthly average concentrations will meet the concentration target even under the worse case scenario, the highest monthly average nitrate and TP concentrations were used as existing monthly mean concentrations to calculate the percent reduction required to achieve the nitrate and TP targets. This approach adds to the margin of safety of the TMDL.

To make sure that the estimated existing mean concentrations represent the existing conditions of the stream, only recent data were used to estimate the existing mean concentration. Because the Verified Period for the Wekiva River basin water quality assessment started at 1996, no data earlier than 1996 were used in this analysis.

Because different nitrate and TP concentrations were observed in different stream segments, percent reduction requirements were calculated separately for each segment. The Wekiva

River was divided into three segments, including Wekiva Spring (WS, WBID 2956C), upstream Wekiva River (UWRMS, WBID 2956), and downstream Wekiva River (DWRMS, 2956A).

Rock Springs (RS) and Rock Springs Run (RSR) are currently combined in the same WBID (2967). To estimate the existing concentrations of RS, nitrate and TP concentration measurements collected from a water quality station located at the spring boil – station 21FLGW 11395, were excluded from the Rock Springs Run WBID and used specifically for existing nitrate and TP concentrations calculation for the spring.

Because nitrate and TP concentrations for Wekiva Spring (WBID 2956C) were only measured in 2002, 2003, and 2004 during very limited sampling events, monthly averages were not calculated for nitrate or TP for the spring and the highest observed concentrations were used as the existing condition**.** **Tables 5.1** and **5.2** show the existing mean concentrations, target concentration and percent reductions required for the stream segments (springs) mentioned above.

In addition to calculating required reductions in Rock Springs Run (WBID 2967), Wekiva Spring (WBID 2956C), and the Wekiva River (WBIDs 2956 and 2956A), the Department also calculated required reductions in nitrate and TP concentrations for the Little Wekiva River (LWR, WBID 2987), and Black Water Creek (BWC, WBID 2929A).

Table 5.1. Existing and target nitrate concentrations for related stream segments and percent concentration reduction required to achieve the nitrate target.

Unit: (mg/L)

Year	RS	RSR (2967)	WS (2956C)	UWRMS (2956)	DWRMS (2956A)	LWR (2987)	BWC (2929A)
January	1.50	0.62	1.30	0.88	0.54	0.70	0.29
February	N/A	0.65	N/A	0.88	0.38	0.59	0.21
March	N/A	0.52	N/A	0.52	0.41	0.26	0.29
April	1.50	0.58	1.25	0.63	0.39	0.36	0.35
May	1.30	0.77	N/A	0.70	0.33	0.39	0.46
June	N/A	0.77	N/A	0.40	0.35	0.44	0.32
July	1.40	0.57	1.34	0.52	0.30	0.25	0.59
August	N/A	0.08	N/A	0.44	0.24	0.26	0.12
September	N/A	0.57	N/A	0.61	0.29	0.36	0.24
October	1.50	0.53	0.94	0.42	0.27	0.17	0.29
November	N/A	0.43	N/A	0.60	0.47	0.28	0.27
December	N/A	0.73	N/A	0.86	0.30	0.49	0.14
Existing Mean (highest monthly mean)	**1.50**	**0.77**	**1.34**	**0.88**	**0.54**	**0.70**	**0.59**
Target Concentration	**0.286**	**0.286**	**0.286**	**0.286**	**0.286**	**0.286**	**0.286**
Percent Reduction	**81%**	**63%**	**79%**	**68%**	**47%**	**59%**	**52%**

Table 5.2. Existing and target TP concentrations for related stream segments and percent concentration reduction required to achieve the TP target.

Unit: mg/L

Month	RS	RSR (2967)	WS (2956C)	UWRMS (2956)	DWRMS (2956A)	LWR (2987)	BWC (2929A)
January	0.081	0.078	0.181	0.094	0.102	0.163	0.034
February	N/A	0.084	0.106	0.087	0.088	0.292	0.049
March	N/A	0.086	0.065	0.110	0.125	0.179	0.062
April	0.084	0.095	0.117	0.110	0.102	0.117	0.045
May	0.082	0.104	0.160	0.144	0.116	0.254	0.060
June	N/A	0.109	0.029	0.145	0.130	0.161	0.101
July	0.078	0.140	0.118	0.114	0.121	0.151	0.061
August	N/A	0.112	0.048	0.124	0.117	0.135	0.052
September	N/A	0.153	0.081	0.168	0.150	0.141	0.073
October	0.084	0.133	0.107	0.156	0.125	0.127	0.096
November	N/A	0.108	0.014	0.126	0.107	0.178	0.050
December	N/A	0.086	N/A	0.093	0.095	0.238	0.087
Existing Mean (highest monthly mean)	**0.084**	**0.153**	**0.181**	**0.168**	**0.150**	**0.292**	**0.101**
Target	**0.065**	**0.065**	**0.065**	**0.065**	**0.065**	**0.065**	**0.065**
Percent reduction	**23%**	**58%**	**64%**	**61%**	**57%**	**78%**	**36%**

Based on **Table 5.1**, the percent reduction required to achieve the nitrate target of 286 µg/L ranges from 47% for the downstream segment of the Wekiva River (WBID 2956A) to 81% for the spring vent of Rock Spring. The downstream segments of the river typically have relatively low nitrate concentrations, and therefore low percent required reduction. Upstream segments typically have higher nitrate concentrations than the downstream segments, and spring vents have the highest nitrate concentrations. Therefore, high percent reductions are usually required for the upstream segment and spring boil. This spatial trend indicates the importance of springs as the nitrate contributor. In addition to the Wekiva River and Rock Springs Run, 59% and 52% reductions are required Little Wekiva River and Blackwater Creek, respectively, to achieve the nitrate target for the main stem of the Wekiva River.

The required percent reduction for TP ranged from 23% for Rock Spring and 78% for the Little Wekiva River tributary. The spatial trend of the required percent reduction is not as consistent as that of nitrate. While required TP percent reductions differ significantly between Rock Spring and Rock Springs Run, the required TP percent reductions are not dramatically different among Wekiva Spring, the upstream segment of the Wekiva River, and the downstream segment of the Wekiva River. To achieve the TP target for the main stem of the Wekiva River, a 78% reduction is required for the Little Wekiva River tributary, indicating the relative importance of the Little Wekiva River tributary as the phosphorus contributor.

Chapter 6: DETERMINATION OF THE TMDL

6.1 Expression and Allocation of the TMDL

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

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

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

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

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

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

This approach is consistent with federal regulations (40 CFR § 130.2[I]), which state that TMDLs can be expressed in terms of mass per time (e.g., pounds per day), toxicity, or **other appropriate measure**. TMDLs for the Wekiva River, RSR and other related WBIDs in the drainage basin of the Wekiva River system are expressed in terms of pounds per month, pounds per day, and percent reduction of nitrate and TP, and represent the maximum long-term nitrate and TP loadings the WR and RSR can assimilate and maintain a balanced aquatic flora and fauna **(Table 6.1**). It should be noted that the expression of the TMDL on a mass per day basis is for information purposes only

Table 6.1. TMDL components for RSR, WRMS, and related WBIDs

WBID	Parameter	TMDL (percent reduction)	$WLA_{NPDES\ wastewater}$	$WLA_{NPDES\ Stormwater}$	LA	MOS
RS	Nitrate	81%	N/A	81%	81%	Implicit
RS	TP	23%	N/A	23%	23%	Implicit
RSR (2967)	Nitrate	63%	N/A	63%	63%	Implicit
RSR (2967)	TP	58%	N/A	58%	58%	Implicit
WS (2956C)	Nitrate	79%	N/A	79%	79%	Implicit
WS (2956C)	TP	64%	N/A	64%	64%	Implicit
UWRMS (2956)	Nitrate	68%	2,805 lbs/month	68%	68%	Implicit
UWRMS (2956)	TP	61%	40 lbs/month	61%	61%	Implicit
DWRMS (2956A)	Nitrate	47%	N/A*	47%	47%	Implicit
DWRMS (2956A)	TP	57%	191 lbs/month	57%	57%	Implicit

*While there is no WLA for nitrate for DWRMS, it should be noted that a WLA of 572 lbs/month has been established for Total Nitrogen for the SCES/Yankee Lake WRF (see Section 6.3.1). N/A in this table means not applicable.

Altamonte Springs Regional Water Reclamation Facility does not discharge directly into any of the above segments. However, the loading from the facility influences the main stem water quality through discharging into the Little Wekiva River. Therefore, WLA for TP was allocated to the facility as 26 lbs/month. A discharge limit of 286 µg/L was assigned to the facility for nitrate.

In addition to the percent load reductions described in **Table 6.1** that are needed to achieve the water quality in the main stem of the Wekiva River, nitrate loads from the Little Wekiva River and Blackwater Creek tributaries also need to be reduced by 59% and 52%, respectively. Similarly, TP loadings from the Little Wekiva River and Blackwater Creek should be reduced by 78% and 36%, respectively.

The percent load reductions listed on **Table 6.1** were established to achieve the monthly average nitrate concentration of 286 µg/L and the monthly average TP concentration of 65 µg/L. While these percent reductions are the expression of the TMDL that will be implemented, EPA[3] recommends that all TMDLs and associated load allocations and wasteload allocations include a daily time increment in conjunction with other appropriate temporal expressions that may be necessary to implement the relevant water quality standard. Daily maximum concentrations targets for nitrate and TP were established using the following equation[4], which assumes that the nitrate and TP data distributions are lognormal in Wekiva and Rock Springs Run:

$$MDL = LTA * \exp(Z_p\sigma_y - 0.5\sigma_y^2)$$

$$\sigma_y = \mathrm{sqrt}(\ln(CV^2 + 1))$$

[3] November 2006 U. S. Environmental Protection Agency (USEPA 2006) Memorandum "Establishing TMDL "Daily" Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. Circuit in Friends of the Earth, Inc. v. EPA et. al., No.05-5015 (D.C. Cir. 2006) and Implications for NPDES permits."
[4] EPA, "Options for Expressing Daily Load in TMDL (The Option)," June, 2007.

Where

LTA = long-term average
Z_p = pth percentage point of the standard normal distribution, which can be obtained from any statistics textbook.
σ = standard deviation
CV = coefficient of variance

For the daily maximum nitrate concentration, it was assumed that the average monthly target concentration should be the same as the average daily concentration. Also, assuming the target data set will have the same CV as the existing measured data set and allowing 10% exceedance, the daily maximum nitrate concentrations for Wekiva Upstream, Wekiva Downstream, and Rock Springs Run would be 0.47, 0.48, and 0.52 mg/L, respectively. The most conservative nitrate daily maximum target was chosen as the final daily maximum nitrate target for the Wekiva River – Rock Springs Run system, which is **0.47 mg/L (470 µg/L).** The means, STDEVs, and CVs of nitrate concentrations of different water segments are listed in **Table 6.2**.

Table 6.2. Daily maximum for target nitrate concentration (mg/L)

Statistics	Wekiva Upstream	Wekiva Downstream	Rock Springs Run
Mean	0.65	0.38	0.59
STDEV	0.33	0.2	0.4
CV	0.51	0.53	0.68
Daily Maximum	**0.47**	**0.48**	**0.52**

This same approach was used to calculate the TP daily maximum concentrations for Wekiva Upstream, Wekiva Downstream, and Rock Springs Run, which are 0.09, 0.09, and 0.11 mg/L, respectively. The most conservative TP daily maximum target was chosen as the final daily maximum TP target for the Wekiva River – Rock Springs Run system, which is **0.09 mg/L (90 µg/L).** The means, STDEVs, and CVs of TP concentrations of different water segments are listed in **Table 6.3**.

Table 6.3. Daily maximum for target TP concentration (mg/L)

Statistics	Wekiva Upstream	Wekiva Downstream	Rock Springs Run
Mean	0.12	0.116	0.107
STDEV	0.039	0.033	0.059
CV	0.33	0.28	0.55
Daily Maximum	**0.09**	**0.09**	**0.11**

It should be emphasized that these daily maximum targets were developed for illustrative purposes. Implementation of the TMDL will be based on the monthly average concentration targets.

6.2 Load Allocation

Because no target load was explicitly calculated in this TMDL report due to the lack of flow data at the outlet of each stream segment, TMDLs are represented as the percent reduction required to achieve the nitrate and TP targets. The percent reduction assigned to all the nonpoint sources areas (LA) are the same as those defined for the TMDL percent reduction. To achieve the annual average nitrate target of 250 µg/L in Rock Springs Run and the Wekiva River, the nitrate loads from the nonpoint source related to RS, RSR (2967), WS (2956C), UWRMS (2956), and DWRMS (2956A) need to be reduced by 81%, 63%, 79%, 68%, and 47%, respectively. In addition, nitrate contributions from nonpoint sources related to the LWR (2987) and BWC (2929A) should also be reduced by 59% and 52%, respectively, to ensure that the nitrate target of the Wekiva River will be met.

The required TP percent reductions to achieve the TP target of 65 µg/L are 23%, 58%, 64%, 61%, and 57% for RS, RSR, WS, UWRMS, and DWRMS, respectively. About 78% and 36% of the TP loadings from the LWR and BWC tributaries, respectively, should also be reduced to achieve the TP target of the main stem. The nonpoint sources covered in this allocation include runoff, septic discharge through surface runoff, and the anthropogenic load contained in the spring discharge. All the nonpoint sources covered in LA are restricted to those sources in non-MS4 areas.

6.3 Wasteload Allocation

6.3.1 National Pollutant Discharge Elimination System Wastewater Discharges

Three NPDES permitted facilities were identified in the Wekiva River system that may potentially contribute significant quantities of nitrate and TP to the Wekiva River. These facilities include SCES/Yankee Lake WRF (FL0042625), Wekiva Hunt Club WWTF (FL0036251), and Altamonte Springs Regional Water Reclamation Facility (FL0033251).

The **SCES/Yankee Lake WRF** discharges very little nutrient load to the WR via a backup upland/receiving wetlands surface water system, with the majority of their AWT treated wastewater going to reuse. As described in Chapter 4, the upland/receiving wetlands system typically does not discharge to any receiving surface water except to Sulfur Creek under wet weather conditions. Although Sulfur Creek discharges to the downstream section of the WR intermittently under wet weather, water quality monitoring results in Sulfur Creek upstream and downstream of the effluent point from SCES/Yankee Lake WRF did not show any significant impact from the facility. Therefore, the Department concluded that the existing permit limits for the wetlands discharge (0.75 mgd discharge, and TP and TN limits of 1.0 mg/l, and 3.0 mg/l) are adequately protective of the Wekiva River.

It should be noted that the facility currently does not have a nitrate effluent limit. The nitrate concentration of the effluent from this facility typically accounts for about 24 to 65% of the TN concentration, with an average percent nitrate concentration of 42% (**Table 4.2**). Because no negative impacts have been observed at the monitoring site downstream of the effluent point, the Department concluded that the a nitrate effluent limit was not needed. However, if the percent nitrate concentration from the effluent significantly increases in the future or negative impacts are detected in Sulfur Creek, the Department may require a permit limit for nitrate.

The wasteload allocation for TN was calculated in place of nitrate as follows:

TN allocation (lbs/month) = 8.36* monthly average TN limit * surface AADF limit *365/12

Where,

8.36 is the conversion factor;
The facility's monthly average TN limit is 3.0 mg/L;
The facility's surface discharge AADF limit is 0.75 mgd;
Three Hundred and sixty five days are assumed for each year; and
The monthly load was calculated by dividing the annual load by 12.

The monthly TN **wasteload allocation** is **572 lbs/month**. This allocation, when represented as daily loading, would be **18.8 lbs/day**, dividing the annual load by 365 days.

The TP wasteload allocation was calculated as follows:

TP allocation (lbs/month) = 8.36 * Annual average TP limit * surface AADF limit *365/12

8.35 is the conversion factor;
The facility's monthly average TP limit is 1.0 mg/L;
The facility's surface discharge AADF limit is 0.75 mgd;
Three hundred and sixty five days are assumed for all years; and
The monthly load was calculated by dividing the annual load by 12.

The monthly **TP allocation** is **191 lbs/month**. This allocation, when represented as daily loading, would be **6.3 lbs/day,** dividing the annual load by 365 days.

The Wekiva Hunt Club WWTF discharges into Sweetwater Creek, which in turn discharges to Cove Lake, and then the Wekiva River. The facility has a surface water discharge AADF of 2.9 mgd and a monthly average TP discharge limit of 0.4 mg/L. The facility does not have any nitrate or TN discharge limit. Based on PCS data, the facility is currently discharging at a long-term annual average discharge rate of 539 million gallon/year, with long-term annual averages of 0.19 mg/L TP and 9.94 mg/L nitrate. The long-term annual average nitrate and TP loadings from the facility are 46,751 lbs/year and 869 lbs/year, respectively. However, based on the surface water monitoring data collected during January of 2005 through April of 2006, the discharge nitrate and TP concentrations have attenuation rates of 96% and 39%, respectively, by the time the effluent reaches the sampling site closest to the Wekiva River (Site #5). Based on these attenuation rates, the long-term annual average nitrate and TP concentrations at Site #5 are:

Nitrate concentration = 9.94 mg/L * (1 – 96%) = 0.398 mg/L

TP concentration = 0.19 mg/L * (1 – 39) = 0.116 mg/L.

To achieve the nitrate and TP targets of 0.286 mg/L and 0.065 mg/L, respectively, at the discharge point of Sweetwater Creek to the Wekiva River, percent reductions required are:

Nitrate percent reduction = (0.398 – 0.286)/0.398 * 100% = 28%
TP percent reduction = (0.116 – 0.065)/0.116 * 100% = 44%.

Applying the nitrate and TP percent reductions to the long-term annual average nitrate and TP loadings discharged from the facility, the final wasteload allocations to the facility are:

Nitrate wasteload allocation = 46, 751 lbs/year * (1 – 0.28) = **33,661 lbs/year = 2,805 lbs/month**;
TP wasteload allocation = 860 lbs/year * (1 – 0.44) = **482 lbs/year = 40 lbs/month**;

When represented as daily loads, the nitrate and TP wasteload allocations are **80.5 lbs/day** and **1.3 lbs/day**, respectively.

The Altamonte Springs Regional Water Reclamation Facility discharges directly into the Little Wekiva River, which in turn discharges into the main stem of the Wekiva River. To achieve the 65 µg/L TP target for the Wekiva River main stem, this TMDL recommends that the discharge from the Little Wekiva River into the main stem meets the 65 µg/L target at the outlet of the Little Wekiva River (roughly at station 21FLSJWMLW-UWR, **Figure 4.2**). The TP concentration at this location is calculated using the following equation:

$$Cout = \frac{(Qusgs - Qwrf)*Clakelotus + Qwrf*Cwrf + Qsanlan*Csanlan + Qpalm*Cpalm + Qstar*Cstar}{(Qusgs - Qwrf) + Qwrf + Qsanlan + Qpalm + Qstar}$$

Where,

C_{out} is the TP concentration at the outlet of the Little Wekvia River,
Q_{usgs} is the flow measured at USGS gauge 02234990. The long-term average is **28.8 cfs**.
$C_{lakelotus}$ is the TP concentration of Lake Lotus, which is about **70 µg/L** and reflects the stream TP concentration from combined contribution of nonpoint sources.
Q_{wrf} is the discharge from the Altamonte Springs WRF. The long-term average is **1.9 cfs**.
C_{wrf} is the long-term average TP concentration of WRF's discharge, which is **1500 µg/L**.
$Q_{usgs} – Q_{wrf}$ is the total stream flow minus the flow from the WRF. The difference primarily represents the flow created by nonpoint sources.
Q_{sanlan} is the long-term average discharge rate from Sanlando Springs, which is **19.6 cfs**.
C_{sanlan} is the long-term average TP concentration in the discharge of Sanlando Springs, which is **180 µg/L**.
Q_{palm} is the long-term average discharge rate from Palm Springs, which is **6.9 cfs**.
C_{palm} is the long-term average TP concentration in the discharge of Palm Springs, which is **120 µg/L**.
Q_{star} is the long-term average discharge rate from Starbuck Springs, which is **14.3 cfs**.
C_{star} is the long-term average TP concentration in the discharge of Starbuck Springs, which is **160 µg/L**.

Substituting the number for each of the items listed above into the equation, the final result of the C_{out} is 163 µg/L, which is close to the long-term average TP concentration of 173 µg/L measured at the outlet of the Little Wekiva River, suggesting that above equation, which represents only the mixing in the Little Wekiva River, reflects accurately the fate of TP in the stream. Loss of TP from the water column to the sediment through net deposition may not be a major factor in controlling the TP dynamics in the system.

Possible reasons for high TP concentrations in the discharge of the three springs listed above was also explored. **Table 4.11** listed nitrate and TP concentrations of all the springs located in the Wekiva Study Area. Nitrate and TP concentrations for the majority of these springs are relatively low. However, most of the springs located in the Seminole County, including the three springs listed above, have relatively high TP concentrations as well as high nitrate concentrations. These observations suggested that a significant portion of the high TP concentrations may have resulted from human activities instead of geological background. Therefore, to achieve the main stem TP target of 65 µg/L, TP concentrations from these springs also need to be reduced.

Assuming that we will reduce the TP concentrations from all the nonpoint sources to 65 µg/L (including the concentration at the outlet of Little Wekiva Canal, which is represented by the TP concentration of Lake Lotus, and TP concentrations of the spring discharges), the TP concentration allowable for the WRF discharge, based on above equation, would be 83 µg/L. If the existing discharge rate of the WRF is retained, the allowable monthly loading of TP from the WRF would be **26 lbs/month**. This represents about 94% reduction from its existing long-term average monthly loading of 470 lbs/month (**Table 4.3**). The daily allowable loading for the WRF would be **0.84 lbs/day**.

To estimate the target nitrate loading from the facility, the Department assumed that in-stream nitrate assimilation in the Little Wekiva River is insignificant comparing to the total watershed and point source loads, which adds to the margin of safety of this TMDL. Therefore, to achieve the nitrate target for the main stem of the Wekiva River, the Department recommend, at this point, to reduce the nitrate concentrations from all the nonpoint and point sources to 286 µg/L. This nitrate target also applies to the effluent of the WRF. Assuming that the facility's existing discharge rate is allowed to be kept, the target nitrate loading is **91 lbs/month** for monthly loading, and **2.9 lbs/day** for daily loading. The facility does not have a routine monitoring requirement for nitrate. Based on two Reclaimed Water Effluent Analyses conducted in 2006, the effluent nitrate concentrations from the facility were 4.66 mg/L and 3.96 mg/L. Assuming that the average of these two numbers (4.31 mg/L or 4310 µg/L) reflects the long-term average concentration of the discharge, under the existing discharge rate (1.23 MGD), the existing nitrate load from the facility is 1371 lbs/month. The target load of 91 lbs/month represents about 93% reduction of nitrate load from the existing condition.

6.3.2 National Pollutant Discharge Elimination System Stormwater Discharges

Because no information was available to the Department at the time this analysis was conducted regarding the boundaries and locations of all the NPDES stormwater dischargers, the exact stormwater nitrate and TP loadings from MS4 areas were not explicitly estimated. Within the Wekiva River drainage basin, Orange County has a Phase I MS4 permit (FLS000011), with the Florida Department of Transportation (FDOT) District 5 and City of Maitland as co-permittees. Seminole County also holds a Phase I MS4 permit (FLS000038) with FDOT District 5, City of Altamonte Springs, and City of Lake Mary being co-permittees for this permit. In addition, the City of Orlando holds a Phase I MS4 permit (FLS000014). Lake County does not have MS4 permit within the boundary of the drainage basin. The wasteload allocations for each of the MS4s are the same percent nitrate and TP reductions required for the LA assigned to the nonpoint sources in the river segments that belong to each county and municipality.

It should be noted that any MS4 permittee is only responsible for reducing the loads associated with stormwater outfalls that it owns or otherwise has responsible control over, and is not responsible for reducing other nonpoint source loads within its jurisdiction.

6.4 Margin of Safety

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

The MOS was created in several aspects of the analyses. For example, the nitrate target was established based on the most conservative concentration from the three lines of evidence (Suwannee River periphtyon result, Rainbow Creek Lyngbya result, and Rock Springs Run and the Wekiva River ecological efficiency experiment). Requiring that the 286 µg/L target be met every month should result in the nitrate concentration to be even lower than the target concentration during the summer algal growth season based on seasonal analysis on the nitrate concentration, and therefore adds to the margin of safety. In addition, when estimating the required percent load reduction to achieve the water quality target, the highest long-term monthly averages of measured nitrate concentrations, instead of average long-term monthly averages, were chosen to represent the existing condition. This will make estimating the required percent load reduction more conservative and therefore add to the margin of safety.

Similarly, the TP target concentration was established as a monthly average because no seasonal pattern could be identified for community structure and functions of aquatic flora in the system under question. Typically, if no seasonal pattern can be identified for biological responses to nutrient concentrations of the system, the time scale for the water quality target would be set as an annual average. For this TMDL, the Department found that TP concentrations in the system tend to be higher during the summer growth season and therefore established the TP target as a monthly average. This will not only address the growth season TP concentration properly, but also makes the in-stream TP concentration lower than the target TP concentration in other months of the year, which is more conservative and adds to the MOS. In addition, using the highest long-term monthly average instead of the average of long-term monthly average in calculating the required percent load reduction makes estimating the required percent load reduction more conservative and therefore adds to the margin of safety.

6.5 Recommendations for Further Studies

This TMDL is developed primarily based on the nitrate and TP PLRGs developed by the SJRWMD. Because of time limitations, the identification of impairments and development of water quality targets were based on data collected within one year. However, due to the varying nature of the local weather and hydrology, and the variation in responses from local flora and fauna to the change of nitrate and TP concentrations under different weather, hydrological, and hydraulic conditions, similar studies that could support the further identification of impairment and development of water quality targets should be conducted in the future for a longer time period to verify the conclusions and hypotheses used in this TMDL.

The SJRWMD also proposed future studies to further examine the dynamics of aquatic flora and fauna to environments with changing nitrate and TP concentrations. Proposed studies include studies on the effects of nutrient variation on the spring aquatic communities, the relationship between nutrient concentration and periphytic algal growth under varying conditions of current velocity and light availability, the inhibitory effects of periphyton on SAV growth, and the effects of filamentous algal growth on macroinvertebrate and fish habitat. In addition, the Department recommends that the hydrology, hydraulic, and water quality of the Wekiva River system be simulated using calibrated models to better understand the effects of nitrate and TP pollutants on the in-river nitrate and TP concentrations and influences on the structure and functions of aquatic communities. Because springs are major nitrate contributors for both the Wekiva River and RSR, it would be very important to identify and address the potential pollutant sources of nitrate in the ground water recharge area.

Chapter 7: NEXT STEPS: IMPLEMENTATION PLAN DEVELOPMENT AND BEYOND

7.1 Basin Management Action Plan

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

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

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

References

Bronmark, C and L. A. Hansson. 1998. The biology of lakes and ponds. Oxford University Press, New York, NY. 216 pp.

Burton, F. L. 1991. Wastewater Engineering, treatment, disposal, and resuse. 3rd Edition. Metcalf & Eddy, Inc. McGraw-Hill Publishing Company, New York. 1040 pp.

Cowell, B. C. and C. J. Dawes. 2004. Growth and nitrate-nitrogen uptake by the cyanobacterium *Lyngbya wollei*. J. Aquatic Plant Management 42: 69-71.

D.C. Cir. (United States Court of Appeals for the District of Columbia). 2006. *Friends of the Earth, Inc.v. EPA, et al*. No. 05-5015.

DOH. 2004. Wekiva basin onsite sewage treatment and disposal system study. Florida Department of Health.

Florida Administrative Code. *Chapter 62-302, Surface water quality standards.*

Florida Administrative Code. *Chapter 62-303, Identification of impaired surface waters*.

Florida Watershed Restoration Act. *Chapter 99-223, Laws of Florida.*

Florida Department of Environmental Protection. February 1, 2001. *A report to the governor and the legislature on the allocation of total maximum daily loads in Florida.* Tallahassee, Florida: Bureau of Watershed Management, Division of Water Resource Management. Available: http://www.dep.state.fl.us/water/tmdl/docs/Allocation.pdf.

Harper, H. H. and D. B. Baker. 2003. Evaluation of alternative stormwater regulations for southwest Florida. Submitted to: Water Enhancement & Restoration Coalition, Inc. Prepared by Environmental Research & Design, Inc.

Hornsby, D., R. A. Mattson, and T. Mirti. 2000. Surfacewater quality and biological monitoring. Annual Report. 1999. Suwannee River Water Management District Technical Report WR-00-04. iv, 148 pp.

Hupalo, R. B., C. P. Neubauer, L. W. Keenan, D. A. Clapp, and E. F. Lowe. 1994. Establishment of minimum flows and levels for the Wekiva River system. St. Johns River Water Management District Technical Publication SJ94-1. 86 pp.

Komarek, J. 2003. Coccoid and colonial cyanobacteria. Pp. 59-116 IN: J. D. Wehr and R. G. Sheath (eds.), Freshwater Algae of North America. Ecology and Classification. Academic Press, New York, NY.

Mattson, R. A., E. F. Lowe, C. L. Lippincott, and L. Battoe. 2006. Wekiva River and Rock Springs Run pollutant load reduction goals. Report to the Florida Department of Environmental Protectcion. St. Johns River Water Management District, Palatka, FL.

Osburn, W., D. Toth, and D. Boniol. 2002. Springs of the St. Johns River Water Management District. SJRWMD Technical Report SJ2002-5.

Potapova, M. and D. F. Charles. 2005. Choice of substrate in algae-based water quality assessment. J. North American Benthological Soc. 24(2): 415-427.

Reckhow, K. H., Beaulac, M. N., and Simpson, J. T. 1980. Modeling phosphorus loading and lake response under uncertainty: A manual and compilation of export coefficients. United States Environmental Protection Agency. EPA 440/5-80-011.

Schmidt, W. 1997. Geomorphology and physiography of Florida. Pp. 1-12 IN: A. F. Randazzo and D. S. Jones(eds.), The Geology of Florida. University Press of Florida, Gainesville, FL.

Stevenson, R. J., A. Pinowska, and Y-K Wang. 2004. Ecological condition of algae and nutrients in Florida Springs. Final Report to the Florida Department of Environmental Protection, Tallahassee, FL. 101pp.

Toth, D. J. and C. Fortich. 2002. Nitrate Concentrations in the Wekiva Groundwater Basin, With Emphasis on Wekiva Springs. St. Johns River Water Management District Technical Publication SJ2002-2. 84 pp.

United States Environmental Protection Agency. 2006a. Establishing TMDL "Daily" Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. Circuit in Friends of the Earth, Inc. v. EPA, et al., No.05-5015, (April 25, 2006) and Implications for NPDES permits. Memorandum from Benjamin Grumbles, assistant administrator, Office of Water. U.S. Environmental Protection Agency, Washington, DC.

United States Environmental Protection Agency. 2007. Options to expressing daily loads in TMDL (draft). Office of Wetlands, Oceans, and Watersheds.

WSI Inc. 2004. Work Plan. Pollutant load reduction goal (PLRG) analysis for the Wekiva River and Rock Springs Run, Florida. Report prepared for the St. Johns river Water management District, Palatka, FL. Pp. variously numbered.

WSI, 2005. Pollutant load reduction goal (PLRG) analysis for the wekiva River and Rock Springs Run, Florida. Final Report. Prepared for the St. Johns River Water Management District. Wetland Solutions, Inc.

Appendices

Appendix A: Background Information on Federal and State Stormwater Programs

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

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

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

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

Appendix B. Change Point Analysis of the Suwannee River Algal Data

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Technical Report Submitted to
the Florida Department of Environmental Protection

I. Background

Per the request of the Wekiva Parkway and Protection Act (WPPA) passed by the Florida Legislature in 2004 (Chapter 369, Part III, FS), the Florida Department Environmental Protection (the Department) is developing a nitrate Total Maximum Daily Load (TMDL) for the Wekiva River and Rock Springs Run in the central Florida area. Based on information provided by the St. Johns River Water Management District (SJRWMD), these two waterbodies showed elevated periphyton abundance compared to two reference creeks (Juniper Creek and Alexander Springs Run) located in the same region and were therefore considered impaired. After examining the distribution of various physical, chemical, and biological parameters in the Wekiva River and Rock Springs Run and in reference waterbodies, it was decided that elevated nitrate concentrations in the Wekiva River and Rock Springs Run is one of the major pollutants that caused this impairment. According to the 1999 Florida Watershed Restoration Act (FWRA), Chapter 99-223, Laws of Florida, once a waterbody is verified for impairment, a TMDL must be developed.

Establishing a nitrate target for the Wekiva River and Rock Springs Run is a critical part of the TMDL development. To define this target, a functional relationship between the periphyton abundance and nitrate concentration needs to be characterized. Ideally, the functional relationship would be built upon data collected from the Wekiva River and Rock Springs Run. Unfortunately, because of the limit amount of time available to this project, not enough data were available to establish the relationship in these two waterbodies. Therefore, this study uses nitrate and periphyton data collected from a monitoring network on the Suwannee River, which was established for the Surface Water Improvement and Management (SWIM) program by the Suwannee River Water Management District (Hornsby, et al. 2000). Much of the length of the Suwannee River is heavily influenced by spring inflow, and the algal communities appear to be generally similar in composition to those in the Wekvia River and Rock Springs Run. Therefore, results from the Suwannee River are considered applicable to the Wekiva River and Rock Springs Run (Mattson et al., 2006).

Nitrate and periphyton data were collected concurrently from 13 stations across the Suwannee River and two tributaries (Withlacoochee River and Santa Fe River) during the period from 1990 through 1998. **Figure 1** shows locations of these water quality stations. **Table 1** lists the period of records and number of samples for each station. Periphyton abundance was measured as both the cell density (cells/cm^2) and biomass density (ash free dry mass – AFDM/cm^2). Long-term average nitrate concentrations and periphyton measurements were calculated for each sampling station. Functional relationships between nitrate and periphyton abundance were established by plotting either long-term average cell densities or biomass density to long-term average nitrate concentrations from all water quality stations.

Significant relationships were found between nitrate concentration and algal abundance. **Figure 2** shows the correlation of mean nitrate concentrations versus mean periphyton biomass (r = 0.84; P<0.001). There is also a significant positive correlation between mean algal density and mean nitrate concentration (**Figure 3**: r = 0.77; P<0.01), indicating that increasing nitrate concentration in nature streams could result in elevated periphyton biomass (Mattson, 2006). In addition, both **Figures 2** and **3** suggest that there is a threshold nitrate concentration in the range between 0.2 and 0.4 mg/L, above which the increase of periphyton abundance per unit increase of nitrate concentration becomes significantly higher than below this threshold point.

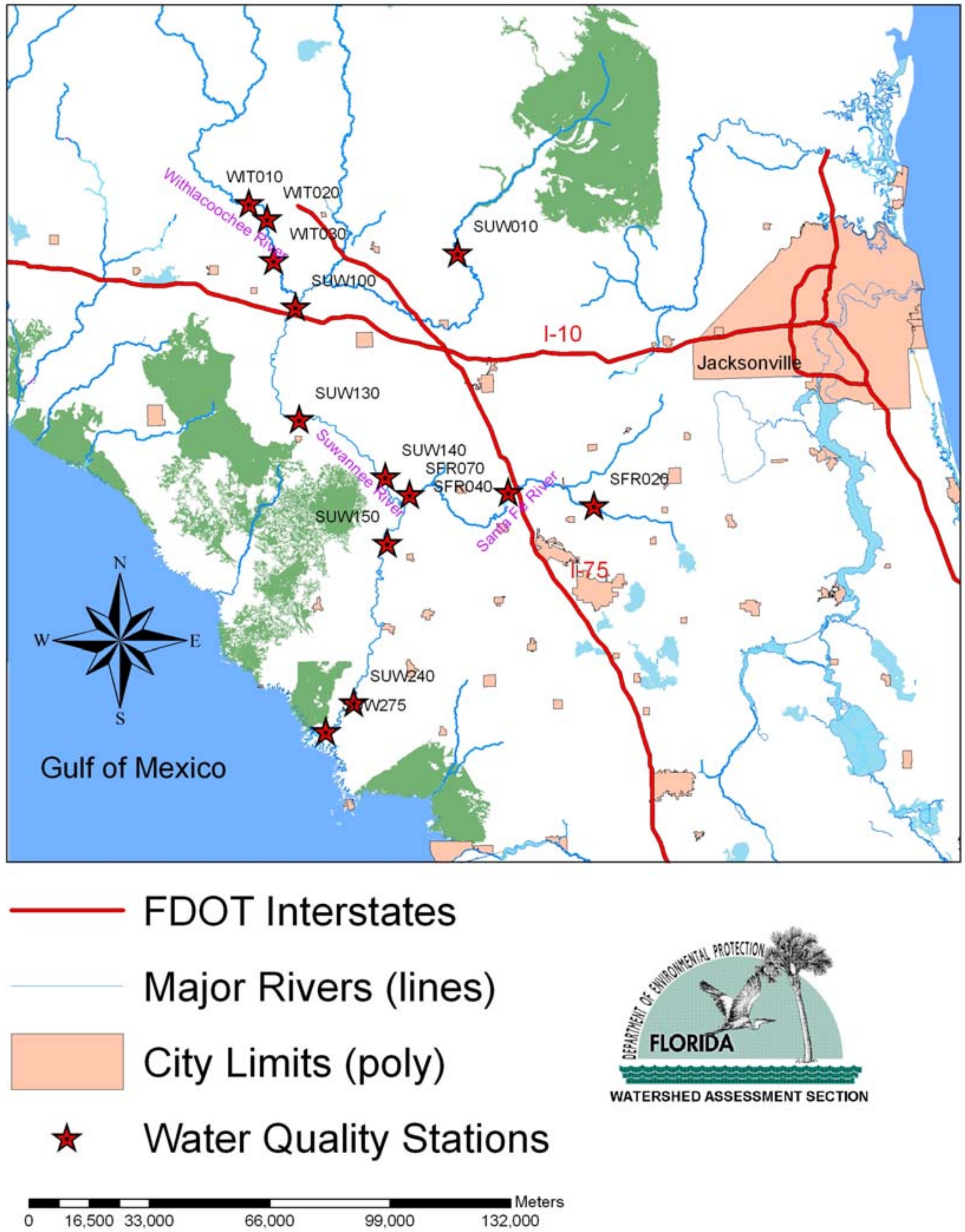

Figure 1. Locations of water quality stations from which measured nitrate and periphyton abundance were used for this analysis.

Table 1. Period of records and number of paired nitrate and periphyton samples from each station

Stations	Period of records	Number of samples
SUW010	06/1990 – 12/1998	24
SUW100	06/1990 – 12/1998	30
SUW130	06/1990 – 12/1998	33
SUW140	06/1996 – 12/1998	8
SUW150	06/1990 – 12/1998	30
SUW240	12/1992 – 12/1998	23
SUW275	03/1990 – 06/1992	10
SFR020	03/1990 – 12/1998	32
SFR040	03/1990 – 12/1998	34
SFR070	03/1990 – 12/1998	33
WIT010	03/1990 – 09/1991	6
WIT020	03/1990 – 09/1991	6
WIT030	03/1990 – 06/1991	5

The purpose of this study is to use change-point statistical analysis to identify the threshold nitrate concentration. This nitrate threshold, once being identified, can be used as the target nitrate concentration for the nitrate TMDL of the Wekiva River and Rock Springs Run.

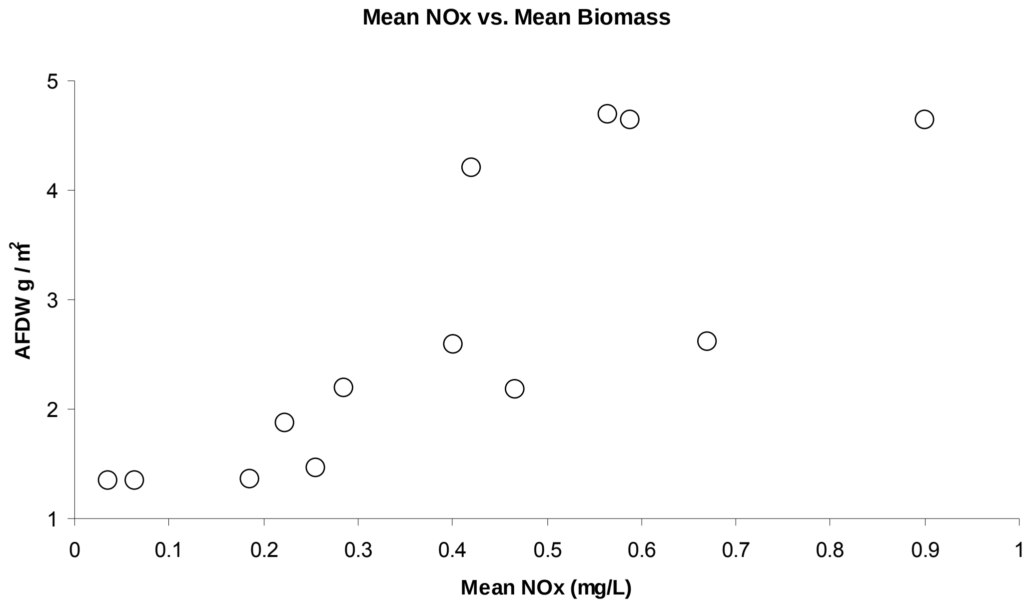

Figure 2. Relationship between mean nitrate concentration and mean periphyton biomass from sampling sites on the Suwannee, Santa Fe, and Withlacoochee Rivers.

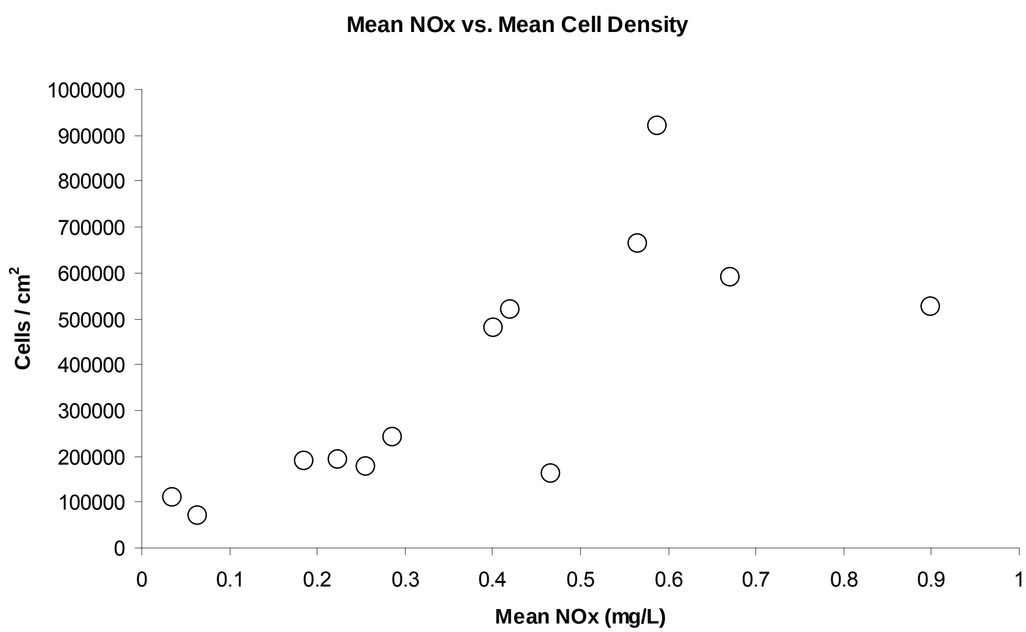

Figure 3. Relationship between mean nitrate concentration and mean periphyton cell density from sampling sites on the Suwannee, Santa Fe, and Withlacoochee Rivers.

The Detection Procedure

Niu et al. (2000) introduced an iterative procedure for detecting and modeling level-shift change points. Niu and Miller (2007) reported the change point analysis and a model comparison procedure for the Stream Condition Index (SCI) and Biological Condition Gradient (BCG) data. The change-point detection procedure in Niuet al. (2000) is similar to that suggested by Chang (1982) and further developed by Chang et al. (1988) for detecting outliers and level shifts in time series analysis. Statistical details of this procedure can also be found in Pankratz (1991, Chapter 8).

For simplicity, let us consider a response variable *Y*, after an appropriate transformation. Suppose that observations $\{(X_i, Y_i),\ i = 1, 2, \cdots, n\}$ are available where *n* is the sample size and *X* is an independent variable. Moreover, we assume that the observations are arranged in the following manner:

- The values $\{X_i,\quad i = 1, 2, \cdots, n\}$ are distinct. If several Y_i's are corresponding to a single *X* value, the median of the Y_i's is taken to be the response value for the *X* value.
- $\{(X_i, Y_i),\ i = 1, 2, \cdots, n\}$ are sorted according to the values of *X* from least to greatest.

For each integer $l > 1$, define the step variable $S_i(l) = 0$ for $i < l$ and $S_i(l) = 1$ for $i \geq l$.

Step 1. Fit the linear regression model:

$$Y_i = \beta_0(l) + \beta_1(l) S_i(l) + \varepsilon_i(l)\,, \qquad i = 1, 2, \cdots, n\,, \tag{1}$$

where for a fixed *l*, the $\varepsilon_i(l)$'s are assumed to be independent and identically distributed normal random variables with mean zero and variance $\sigma^2(l)$.

Step 2. Calculate the values $\{L(l) = \hat{\beta}_1(l) / se(\hat{\beta}_1(l)),\ l = 2, 3, \cdots, (n-1)\}$ where $se(\hat{\beta}_1(l))$ is the estimated standard error of $\hat{\beta}_1(l)$.

Step 3. Let $L(l_1) = \max\{L(2), L(3), \cdots, L(n-1)\}$ and compare $L(l_1)$ with the critical value *C*=3.0 (or *C*=3.5). The critical value *C*=3.0 (or *C*=3.5) corresponds roughly to $\alpha = 0.10$ (or $\alpha = 0.05$), or the 10% (or the 5%) significance level, based on the simulation results of Chang et al. (1988). If $L(l_1)$ is significant, we conclude that the response *Y* has a change point at X_{l_1} with a level-shift $\hat{\beta}_1(l)$.

Step 4. Let $Y_i^* = Y_i - \beta_1(l_1) S_i(l_1)$. Repeat Steps 1-3 on the new response variable Y_i^* for detecting a possible second change point. Continue the process until no further change point can be identified.

Step 5. Suppose that *k* change points are detected in the response variable *Y* and the corresponding *X* values are $\{X_{l_1}, X_{l_2}, \cdots, X_{l_k}\}$. Fit the model

$$Y_i = \beta_0 + \beta_1 S_i(l_1) + \beta_2 S_i(l_2) + \cdots + \beta_k S_i(l_k) + \varepsilon_i, \qquad i = 1, 2, \cdots, n. \tag{2}$$

Then the estimated coefficients $\{\widehat{\beta}_1, \widehat{\beta}_2, \cdots, \widehat{\beta}_k\}$ will be the *k* estimated level-shift values.

II. Model Comparison

Model (2) fits a step function $\beta_0 + \beta_1 S_i(l_1) + \beta_2 S_i(l_2) + \cdots + \beta_k S_i(l_k)$ to estimate the mean (or median) value of the response variable Y and the predictor variable X. In practice, many other models may be considered to describe the relationship between Y and X. In particular, if the scatter plot of observations $\{(X_i, Y_i),\ i = 1, 2, \cdots, n\}$ shows a straight line or a smooth curve pattern, a linear regression model or a nonlinear smooth-curve model should be fitted to the data instead of the step-function change point model in (2).

For the response variable Y and the predictor variable X, the linear regression model has the form:

$$Y_i = \beta_0 + \beta_1 X_i + \varepsilon_i, \qquad i = 1, 2, \cdots, n. \tag{3}$$

If the relationship between Y and X is nonlinear, many smooth-curve models may be considered. One of the choices is transforming the predictor variable X and fitting a regression model. For example, we may use the natural logarithm transformation log(X) instead of X as the predictor variable and fit the regression model:

$$Y_i = \beta_0 + \beta_1 \log(X_i) + \varepsilon_i, \qquad i = 1, 2, \cdots, n. \tag{4}$$

When different models are fitted to the observations $\{(X_i, Y_i),\ i = 1, 2, \cdots, n\}$, model selection techniques need to be used to decide which model fits the data better. Statistical inferences such as estimation and prediction will then be based on the best model selected. The Bayesian Information Criterion (SBC) suggested by Schwartz (1978) is one of the popular criteria for model comparison. For a fitted model (linear or nonlinear) with *p* parameters, the SBC is defined as

$$\text{SBC(p)} = -2\ \log(\text{maximum likelihood function}) + p \times \log(n),$$

where the likelihood function is based on the distribution assumption of the model such as normal or log-normal or other distribution families, and *n* is the sample size. When the random errors ε_i's have a normal distribution, the SBC(p) has the simplified form:

$$\text{SBC(p)} = n \times \log\left(\sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2 / (n - p - 1)\right) + p \times \log(n), \quad (5)$$

where $\hat{Y}_i$ is the fitted value based on one of the candidate models and $\sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2$ is the **Residual Sum of Squares (RSS)** based on the fitted candidate model.

Intuitively, there are two parts in (5), the first part is

$$n \times \log\left(\sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2 / (n - p - 1)\right) = n \times \log \hat{\sigma}^2,$$

which is a measure of the goodness-of-fit of the candidate model. In general, increasing the number of parameters in a model will improve the goodness-of-fit of the model to the data regardless how many parameters are in the **true model** that generated the data. When a model with too many predicators (significant or not significant ones) is fitted to a data set, we may get a perfect fit but the model will be useless for inference such as prediction. In statistics, fitting a model with too many unnecessary parameters is called *over-fitting*. The second part in SBC, $p \times \log(n)$, puts a penalty term on the complexity of a candidate model, which will increase when the number of parameters in a candidate model increases. Thus the criterion SBC requires a candidate model fitting the data well and penalizing the complexity of the model. **For a group of candidate models, the SBC value can be calculated for each of the models and the preferred model is the one with the lowest SBC value.**

III. Change Point Analysis of Suwannee River Algal Data

1. Mean Abundance (Cell Density) vs Mean NOx

a). Change Point Analysis

Table 2 presents the mean NOx and mean abundance data at stations along the Suwannee river and its two major tributaries (Withlacoochee and Santa Fe). The data were collected by the Suwannee River Water Management District (SRWMD). The first column of the table gives the station name. Columns 3 and 4 list the mean NOx and mean abundance at the 13 stations. Among stations with mean NOx above 0.4, it was noticed that station SUW275 reported much lower mean abundance (163243.90). The authors of this report consulted with Mr. Robert Mattson of SRWMD and learned that “the site SUW275 is ‘Suwannee River at Gopher River’ that is located way, way down on the river.” Mr. Mattson considers that SUW275 is the upper, tidal freshwater region of the Suwannee estuary. Current velocities there can be quite strong, and it also may be that the area got a short "shock" of salinity during the drought of 1990-91, even though it is usually a totally freshwater site. Furthermore, Mr. Mattson commented that “the site is a bit different and may not be entirely comparable to upstream, riverine sites such as SUW100 (Suwannee River at Ellaville - at the confluence with the Withlacoochee) and SUW130 (Suwannee River near Luraville, between Ellaville and Branford).”

Based on discussion between the authors of this report and Mr Mattson, we think that the data at station SUW275 is not comparable with those at other stations. Thus the data at SUW275 will be removed from the change point analysis in this report. After removing the data at Station

SUW275, the mean NOx and mean abundance data at the remaining 12 stations of the Suwannee River system are listed in the last two columns in Table 2.

Change point analysis was performed for mean abundance vs mean NOx. One change points was detected at the mean NOx values of 0.401, which was from the station SUW100. The change point has the statistic $L(l_1) = 6.39$ and is significant at the 5% level (95% confidence). Figure 4 presents the fitted step-function regression model to the mean abundance values. The R-square of the regression is 0.803, indicating that the step-function regression model fits the mean abundance values very well.

Table 2. Mean NOx and Mean Abundance Data at the Suwannee River Stations

	Original Data		Data Used in The Change Point Analysis	
Station	**Mean NOx**	**Mean abundance**	**Mean NOx**	**Mean abundance**
SUW010	0.035	109810.67	0.035	109810.67
SFR020	0.064	69202.03	0.064	69202.03
SFR040	0.186	189050.82	0.186	189050.82
WIT020	0.223	191812.50	0.223	191812.50
WIT010	0.256	176643.67	0.256	176643.67
WIT030	0.286	241469.20	0.286	241469.20
SUW100	0.401	479615.50	0.401	479615.50
SUW130	0.420	520475.42	0.420	520475.42
SUW275	**0.466**	**163243.90**		
SFR070	0.565	663744.24	0.565	663744.24
SUW150	0.589	920012.14	0.589	920012.14
SUW240	0.671	588875.04	0.671	588875.04
SUW140	0.900	525038.75	0.900	525038.75

Change Points: 1) Mean NOx = 0.401 with the test statistic of 6.39 and confidence level over 95%;
2) Highlighted numbers are the mean NOx-Abundance values at the change point.
3) Notice that the mean NOx value just before the change point is 0.286. Critical changes in mean abundance actually happened as the mean NOx changed from 0.286 to 0.401.

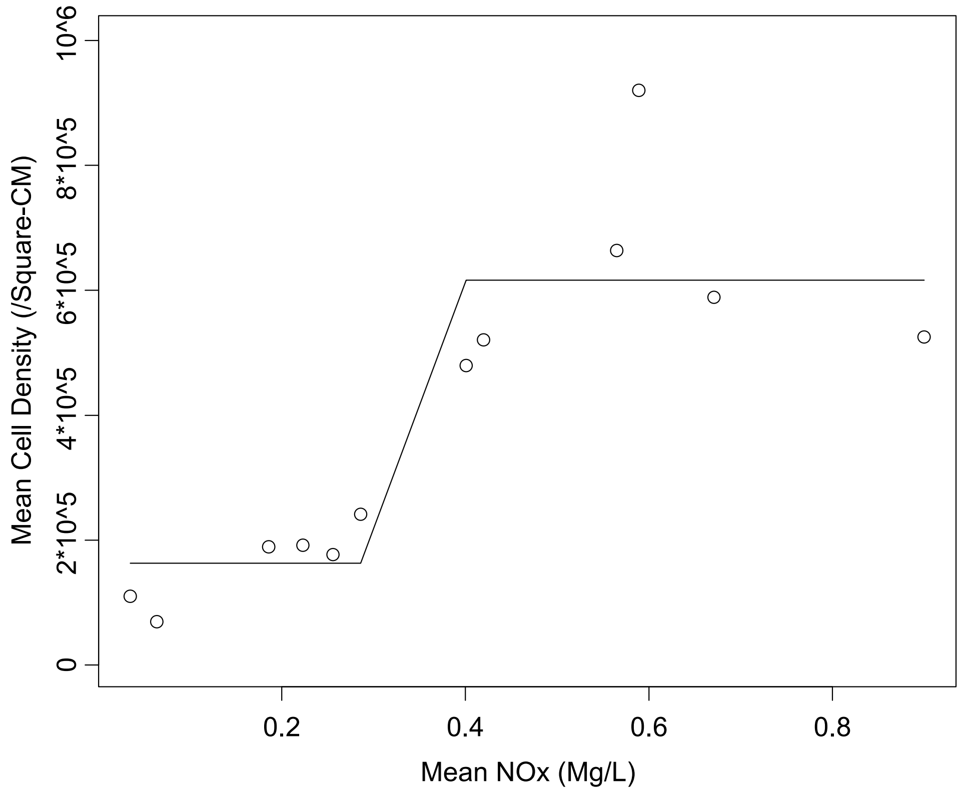

Figure 4. Mean Cell Density vs Mean NOx Change-Point Model (Step Function)

Change Points: Mean NOx=0.401 with the test statistic of 6.39 and confidence level over 95%;

b). Model Comparison

For the purpose of model comparison, two other models, the linear regression model in (3) and the non-linear regression model in (4), were also fitted to the data. Figure 5 presents the two fitted models.

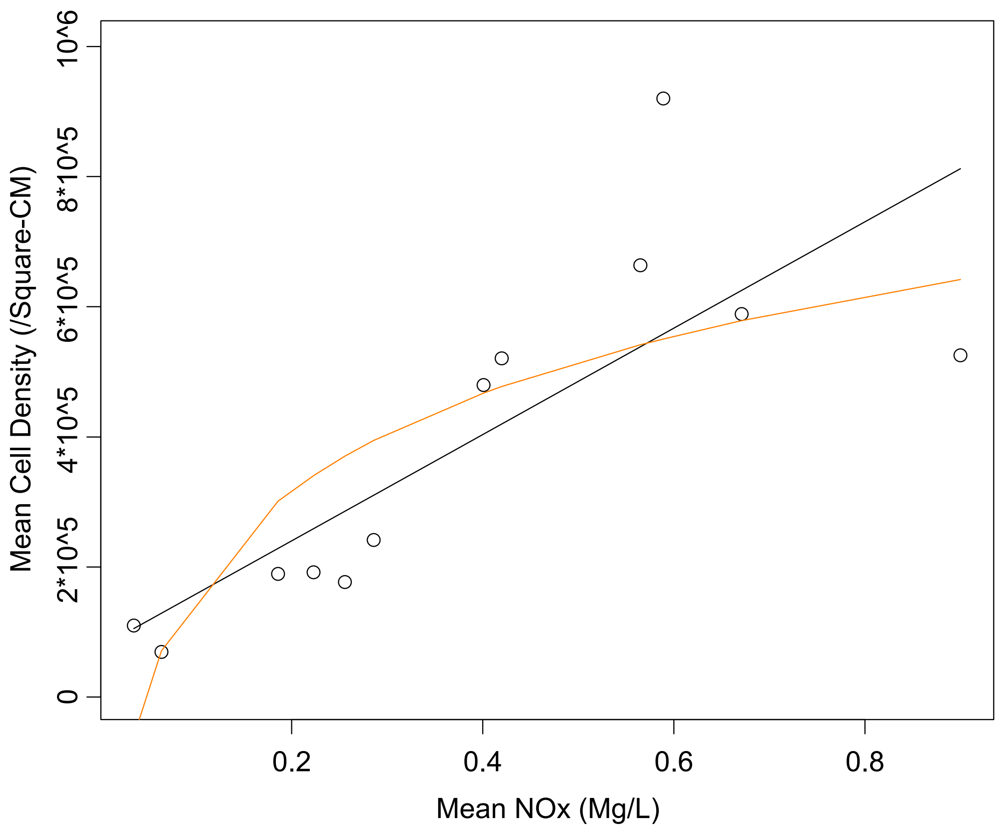

Figure 5. Linear Model (Solid Black), and Non-Linear Model (Mean Cell Density on log(Mean NO), Red)

The three fitted regression models are presented in Table 3. The SBC values for the change-point model, the linear regression model, and the non-linear regression model are 286.22, 293.32, and 294.13, respectively. Thus, the change-point model was the best model among the three models. Based on the fitted change-point model, the change point at Mean NOx of 0.401 is extremely significant (with p-values =0.0001). The mean abundance value at the change point increased 453295.37.

Table 3. Fitted Regression Models

Model 1. Step-Function Regression (Change Point Model) :

Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	162998.1482	50152.6502	3.2500	0.0087
NOx_0.401	453295.3680	70926.5581	6.3911	0.0001

Residual standard error: 122800 on 10 degrees of freedom
Multiple R-Squared: 0.8033
F-statistic: 40.85 on 1 and 10 degrees of freedom, the p-value is 0.00007923

SBC Value: 286.22

Model 2. Linear Regression Model:

Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	76552.0120	87601.4494	0.8739	0.4027
MN	817477.3373	191903.4375	4.2598	0.0017

Residual standard error: 165100 on 10 degrees of freedom
Multiple R-Squared: 0.6447
F-statistic: 18.15 on 1 and 10 degrees of freedom, the p-value is 0.001663

SBC Value: 293.32

Model 3. Non-Linear Regression Model:

Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	664741.5001	84092.3831	7.9049	0.0000
MN1	215985.5866	53485.6084	4.0382	0.0024

Residual standard error: 170800 on 10 degrees of freedom
Multiple R-Squared: 0.6199
F-statistic: 16.31 on 1 and 10 degrees of freedom, the p-value is 0.002368

SBC Value: 294.13

2. Mean Biomass vs Mean NOx

a). Change Point Analysis

Table 4 presents the mean NOx and mean biomass data at stations along the Suwannee river and its two major tributaries (Withlacoochee and Santa Fe). The first column of the table gives the station name. Columns 3 and 4 list the mean NOx and mean biomass at the 13 stations. Based on the discussion between the authors of this report and Mr Mattson, we decided to remove the data at the site SUW275 from the change point analysis in this report. After removing the data at Station SUW275, the mean NOx and mean Biomass data at the remaining 12 stations of the Suwannee River system are listed in the last two columns in Table 4.

Change point analysis was performed for mean biomass vs mean NOx. One change points was detected at the mean NOx values of 0.420, which was from the station SUW100. The change point has the statistic $L(l_1) = 6.10$ and is significant at the 5% level (95% confidence). Figure 6 presents the fitted step-function regression model to the mean abundance values. The R-square of the regression is 0.788, indicating that the step-function regression model fits the mean abundance values very well.

Table 4. Mean NOx and Mean Biomass Data at the Suwannee River Stations

	Original Data		Data Used in The Change Point Analysis	
Station	**Mean NOx**	**Mean abundance**	**Mean NOx**	**Mean Biomass**
SUW010	0.035	1.341	0.035	1.341
SFR020	0.064	1.348	0.064	1.348
SFR040	0.186	1.356	0.186	1.356
WIT020	0.223	1.867	0.223	1.867
WIT010	0.256	1.456	0.256	1.456
WIT030	0.286	2.187	0.286	2.187
SUW100	0.401	2.590	0.401	2.590
SUW130	0.420	4.205	0.420	4.205
SUW275	**0.466**	**2.173**		
SFR070	0.565	4.693	0.565	4.693
SUW150	0.589	4.636	0.589	4.636
SUW240	0.671	2.617	0.671	2.617
SUW140	0.900	4.644	0.900	4.644

Change Points: 1) Mean NOx=0.420 with the test statistic of 6.10 and confidence level over 95%;

2) Highlighted numbers are the mean NOx-Abundance values at the change point.

3) Notice that the mean NOx value just before the change point is 0.401. Critical changes in mean abundance actually happened as the mean NOx changed from 0.401 to 0.420.

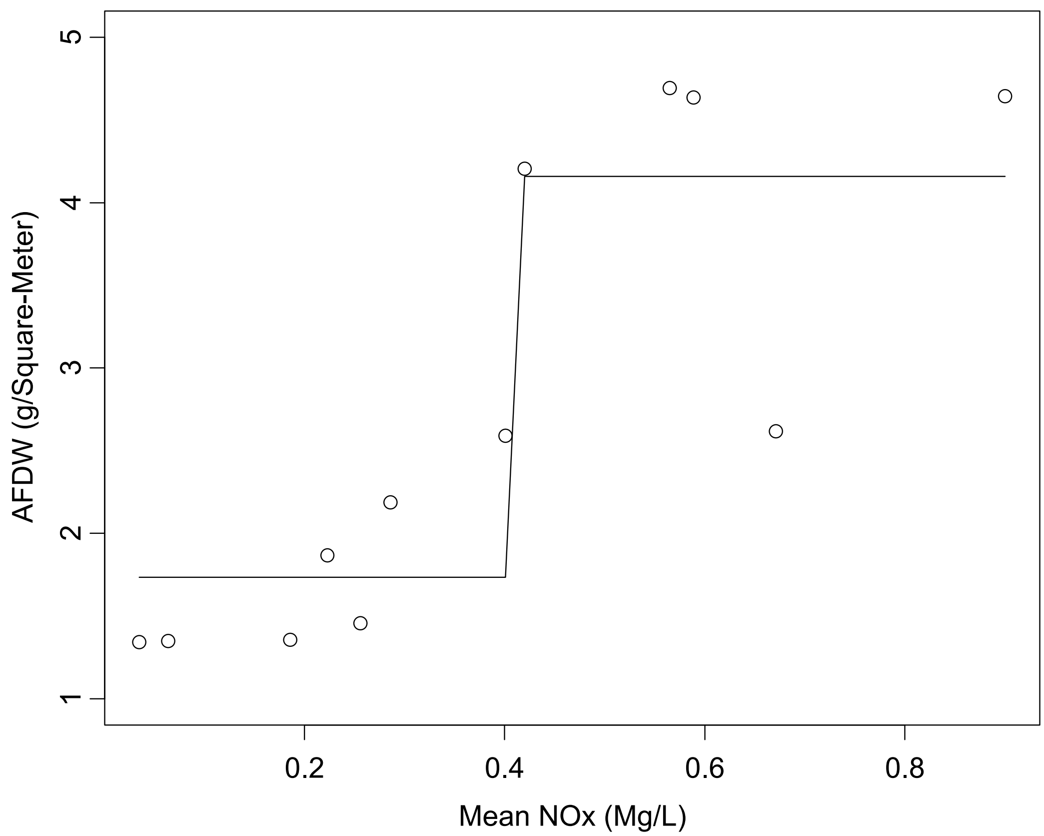

Figure 6. Mean Biomass vs Mean NOx Change-Point Model (Step Function)

Change Points: Mean NOx=0.420 with the test statistic of 6.10 and confidence level over 95%;

b). Model Comparison

For the purpose of model comparison, two other models, the linear regression model in (3) and the non-linear regression model in (4), were also fitted to the data. Figure 7 presents the two fitted models.

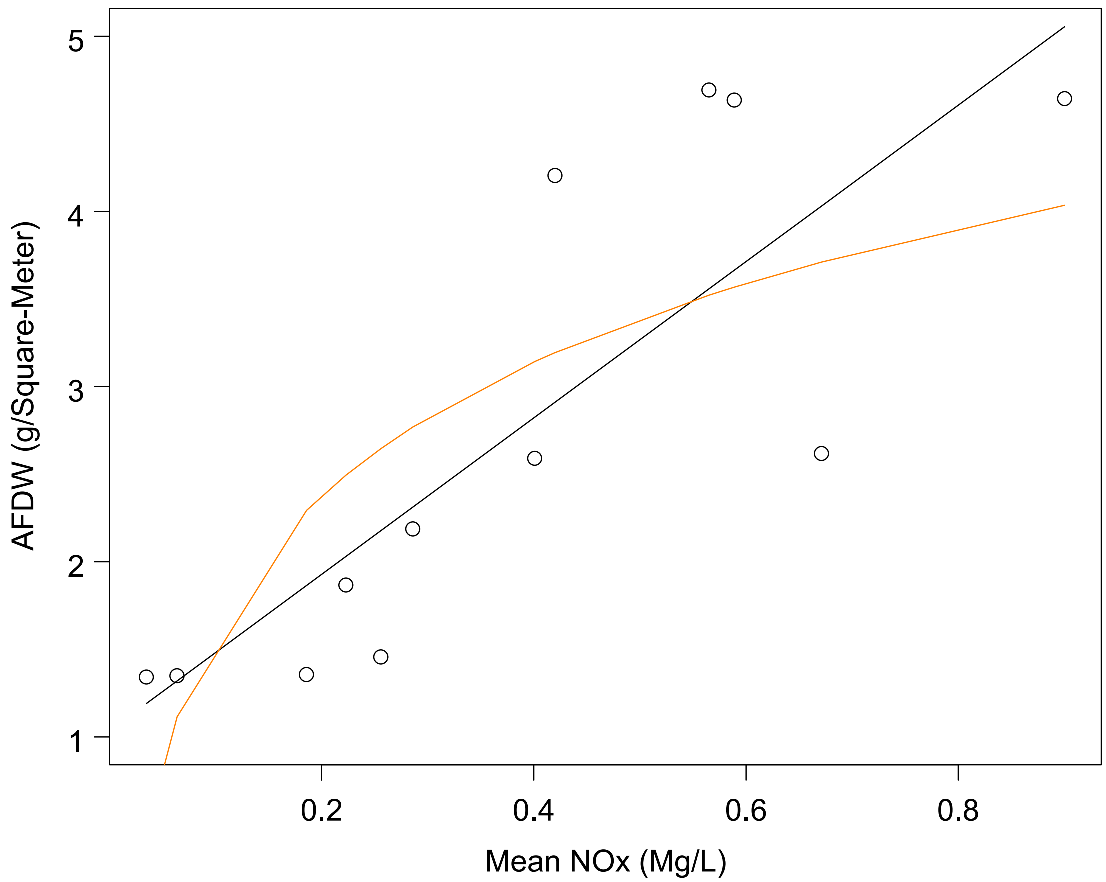

Figure 7. Linear Model (Solid Black) and Non-Linear Model (Mean Biomass on log(Mean NO), Red)

The three fitted regression models are presented in Table 5. The SBC values for the change-point model, the linear regression model, and the non-linear regression model are -4.33, 0.651, and 4.09, respectively. Thus, the change-point model was the best model among the three models. Based on the fitted change-point model, the change point at Mean NOx of 0.420 is extremely significant (with p-values =0.0001). The mean abundance value at the change point increased 2.424.

Table 5. Fitted Regression Models

Model 1. Step-Function Regression (Change Point Model) :

```
Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) 1.7350 0.2565     6.7630  0.0000
         x1 2.4240 0.3974     6.0991  0.0001

Residual standard error: 0.6788 on 10 degrees of freedom
Multiple R-Squared: 0.7881
F-statistic: 37.2 on 1 and 10 degrees of freedom, the p-value is
   0.0001158
```

SBC Value: -4.33

Model 2. Linear Regression Model:

```
Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) 1.0344 0.4432     2.3341  0.0418
         MN 4.4663 0.9708     4.6006  0.0010

Residual standard error: 0.8353 on 10 degrees of freedom
Multiple R-Squared: 0.6791
F-statistic: 21.17 on 1 and 10 degrees of freedom, the p-value is
   0.0009793
```

SBC Value: 0.651

Model 3. Non-Linear Regression Model:

```
Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) 4.1526 0.4746     8.7496  0.0000
        MN1 1.1052 0.3019     3.6611  0.0044

Residual standard error: 0.9639 on 10 degrees of freedom
Multiple R-Squared: 0.5727
F-statistic: 13.4 on 1 and 10 degrees of freedom, the p-value is
   0.004381
```

SBC Value: 4.09

3. Summary and Conclusions

In this report, change point analysis was preformed for the algal data at stations along the Suwannee river and its two major tributaries (Withlacoochee and Santa Fe). **The main findings in this report are the followings:**

1) **For the change point analysis of mean abundance vs mean NOx, one change point was detected at NOx=0.401 that is corresponding to the data at the site SUW100. The change point is significant at the confidence level 95%. Model comparison shows that the change point model fit the data better than the linear regression model and a nonlinear regression model. The mean NOx value just before the change point is 0.286, indicating that critical changes in mean abundance actually happened as the mean NOx changed from 0.286 to 0.401.**

2) **For the change point analysis of mean biomass vs mean NOx, one change point was detected at NOx=0.420 that is corresponding to the data at the site SUW130. The change point is significant at the confidence level 95%. Model comparison shows that the change point model fit the data better than the linear regression model and a nonlinear regression model. The mean NOx value just before the change point is 0.401, indicating that critical changes in mean abundance actually happened as the mean NOx changed from 0.401 to 0.420.**

Based on this analysis, we conclude that the major changes in mean abundance and mean biomass happened at mean NOx around 0.4. Further studies may be needed to confirm this finding.

References:

Chang, I. 1982. “Outliers in Time Series," Unpublished Ph.D. Dissertation, Department of Statistics, University of Wisconsin, Madison.

Chang, I., G.C. Tiao, and C. Chen. 1988. “Estimation of Time Series Parameters in the Presence of Outliers," *Technometrics*, 30: 193-204.

Hornsby, D., R. A. Mattson, and T. Mirti. 2000. Surface water quality and biological monitoring. Annual Report. 1999. Suwannee River Water Management District Technical Report WR-00-04. iv, 148 pp

Mattson, R. A., E. F. Lowe, C. L. Lippincott, J. Di, and L. Battoe. 2006. Wekiva River and Rock Springs Run pollutant load reduction goals. Report to the Florida Department of Environmental Protection. St. Johns River Water Management District.

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Niu, X., P. Lin, and D. Meeter. 2000. “Detecting Change Points in the Species Composition and Water Quality Data of WCA2A”. Department of Statistics, Florida State University, Tallahassee. Technical Report Submitted to the Florida Department of Environmental Protection.

Niu, X., and D. Miller 2007. “Change Point Analysis and Model Comparison of Stream Condition Index and Biological Condition Gradient Data.” Technical Report Submitted to the Florida Department of Environmental Protection.

Pankratz, A. 1991. *Forecasting with Dynamic Regression Models.* John Wiley & Sons Inc. New York.

Schwartz, G. 1978. Estimating the Dimension of a Model. *The Annals of Statistics*, 6: 461-464.

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