FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Environmental Assessment and Restoration, Bureau of Watershed Restoration

NORTHWEST DISTRICT • CHOCTAWHATCHEE–ST. ANDREW BAY BASINS

FINAL TMDL Report

Dissolved Oxygen TMDL for Sikes Creek (WBID 142)

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October 12, 2010

Acknowledgments

This Total Maximum Daily Load (TMDL) analysis could not have been accomplished without significant contributions from staff in the Florida Department of Environmental Protection's (Department) Northwest District Office, and its Watershed Evaluation and TMDL Section. Map production assistance was provided by Janis Paulsen, System Project Administrator with the Department's Division of Environmental Assessment and Restoration.

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Contents

List of Tables

List of Figures

Websites

Florida Department of Environmental Protection, Bureau of Watershed Management

TMDL Program

http://www.dep.state.fl.us/water/tmdl/index.htm

Identification of Impaired Surface Waters Rule

http://www.dep.state.fl.us/legal/Rules/shared/62-303/62-303.pdf

Florida STORET Program

http://www.dep.state.fl.us/water/storet/index.htm

2010 Integrated Report

http://www.dep.state.fl.us/water/docs/2010_Integrated_Report.pdf

Criteria for Surface Water Quality Classifications

http://www.dep.state.fl.us/legal/Rules/shared/62-302/62-302.pdf

Basin Status Report: Choctawhatchee–St. Andrew Bay

http://tlhdwf2.dep.state.fl.us/basin411/csa/status/ChoctawhatcheeWEB.pdf

Water Quality Assessment Report: Choctawhatchee–St. Andrew Bay

http://tlhdwf2.dep.state.fl.us/basin411/csa/assessment/G3AS-Chocta-LR-Merge.pdf

U.S. Environmental Protection Agency

Region 4: TMDLs in Florida

http://www.epa.gov/region4/water/tmdl/florida/

National STORET Program

http://www.epa.gov/storet/

Chapter 1: INTRODUCTION

1.1 Purpose of Report

This report presents the Total Maximum Daily Load (TMDL) for dissolved oxygen (DO) and nutrients for Sikes Creek in the Choctawhatchee–St. Andrew Bay Basins. This waterbody was verified as impaired for low DO and therefore was included on the Verified List of impaired waters for the Choctawhatchee–St. Andrew Bay Basins that was adopted by Secretarial Order on January 15, 2010. This TMDL establishes the allowable nutrient loadings to Sikes Creek that would restore the waterbody so that it meets the applicable water quality criteria for DO and nutrients.

1.2 Identification of Waterbody

For assessment purposes, the Florida Department of Environmental Protection (Department) has divided the Choctawhatchee–St. Andrew Bay Basins into water assessment polygons with a unique **w**ater**b**ody **id**entification (WBID) number for each watershed or stream reach. This TMDL addresses WBID 142, Sikes Creek (**Figure 1.1**).

Sikes Creek is 1 of 172 waterbody segments in the Choctawhatchee Basin and one of 8 waterbody segments in the basin included on the 1998 303(d) list for Florida. **Figure 1.2** depicts the main channel of Sikes Creek.

The headwaters of Sikes Creek are situated in the mid-central portion of Holmes County. The creek flows southwest for approximately 12.5 miles to the Choctawhatchee River. The upper northwest portion of the watershed is drained by Tiger Ford Branch, which flows into upper Sikes Creek. Sikes Creek also receives flow from a number of smaller branches (**Figure 1.2**).

The drainage area within the Sikes Creek WBID boundary is approximately 16.9 square miles (mi^2) (10,830 acres) and is predominantly made up of forested land and wetlands. Additional information about the hydrology and geology of this area is available in the Basin Status Report for Choctawhatchee–St. Andrew Bay (Department, 2003).

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 1999 Florida Watershed Restoration Act (FWRA) (Chapter 99-223, Laws of Florida).

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. They provide important water quality restoration goals that will guide restoration activities.

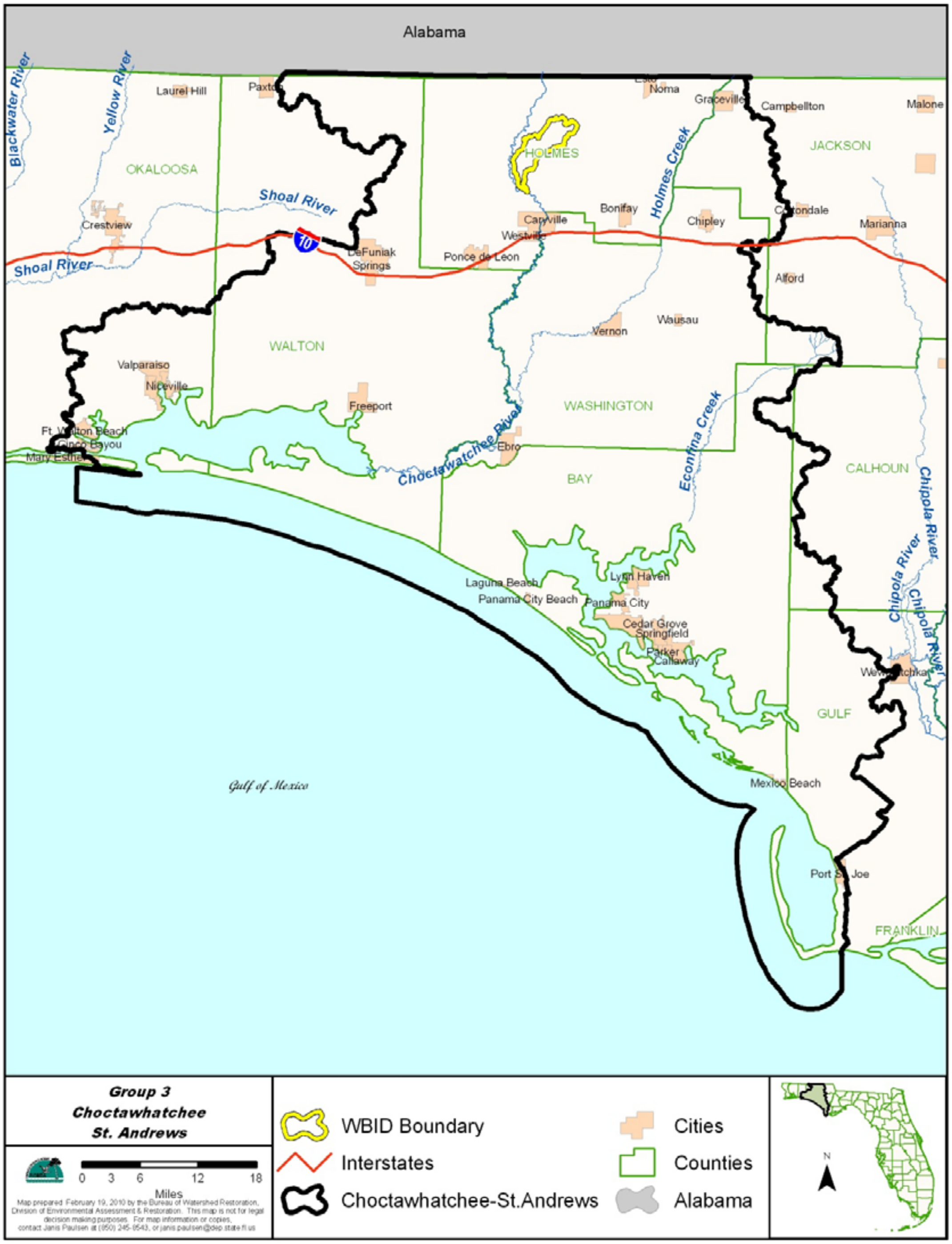
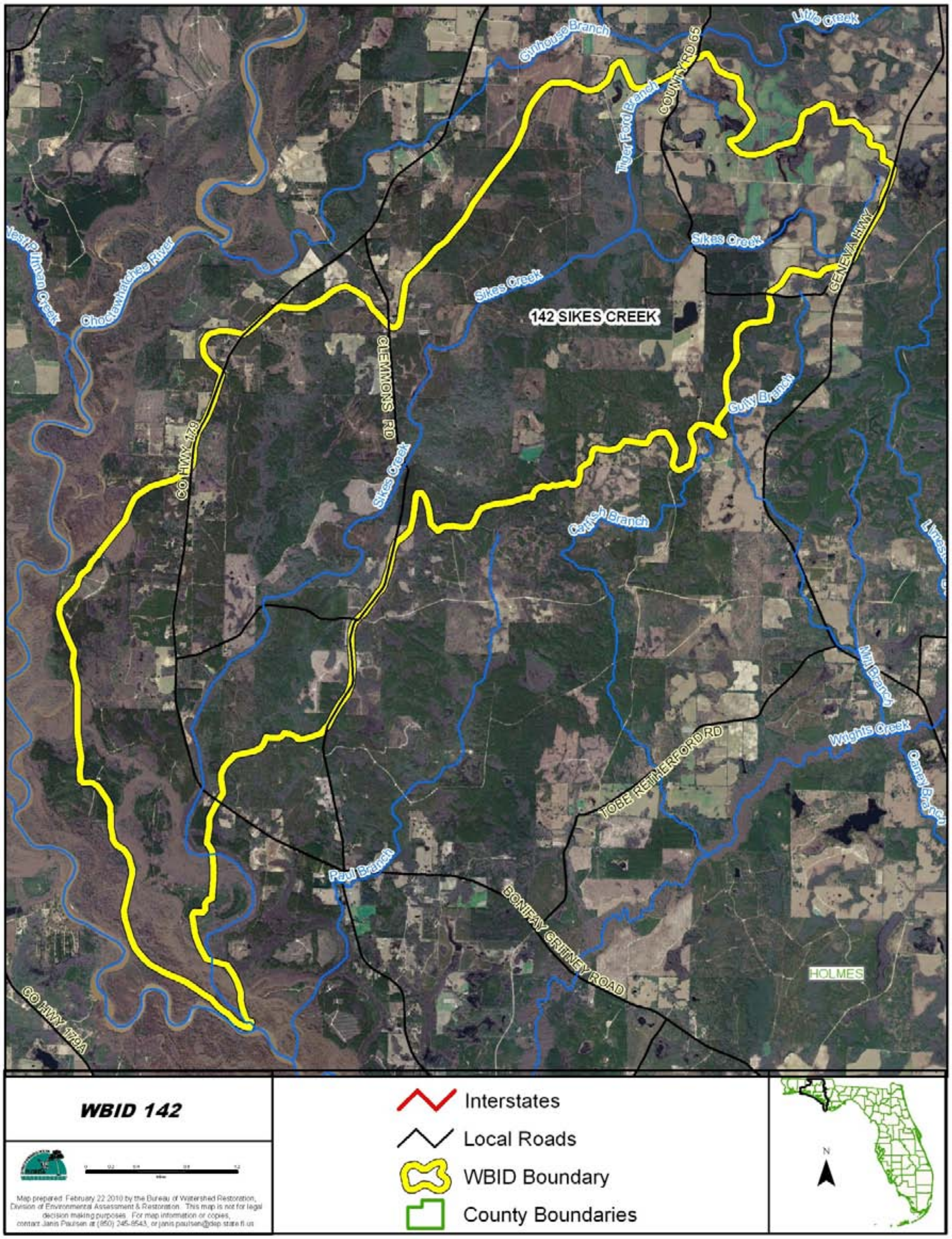


Figure 1.1. Location of Sikes Creek in the Choctawhatchee–St. Andrew Bay Basins and major geopolitical and hydrologic features in the area



Map prepared February 22 2010 by the Bureau of Watershed Restoration, Division of Environmental Assessment & Restoration. This map is not for legal decision making purposes. For map information or copies, contact Janis Paulsen at (850) 245-8543, or janis.paulsen@dep.state.fl.us

Figure 1.2. Location of Sikes Creek (WBID 142) in Holmes County and major geopolitical and hydrologic features in the area

This TMDL Report may be followed by the development and implementation of a Basin Management Action Plan, or BMAP, designed to reduce the amount of nutrients and increase the DO levels that caused the verified impairment of Sikes Creek. These activities will depend heavily on the active participation of the Northwest Florida Water Management District (NWFWMD), Holmes County, 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 the impaired waterbody.

Chapter 2: DESCRIPTION OF WATER QUALITY PROBLEM

2.1 Statutory Requirements and Rulemaking History

Section 303(d) of the federal Clean Water Act requires states to submit to the U.S. Environmental Protection Agency (EPA) lists of surface waters that do not meet applicable water quality standards (impaired waters) and establish a TMDL for each pollutant causing the impairment of listed waters on a schedule. The Department has developed such lists, commonly referred to as 303(d) lists, since 1992. The list of impaired waters in each basin, referred to as the Verified List, is also required by the FWRA (Subsection 403.067[4], Florida Statutes [F.S.]); the state's 303(d) list is amended annually to include basin updates.

Florida's 1998 303(d) list included eight waterbody segments (WBIDs) in the Choctawhatchee - St. Andrew Bay Basins. 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 Rule 62-303, Florida Administrative Code (F.A.C.) (Identification of Impaired Surface Waters Rule, or IWR), in April 2001; the rule was modified in 2006 and 2007.

2.2 Information on Verified Impairment

The Department used the IWR to assess water quality impairments in Sikes Creek and verified the impairments during Cycle 2 of the TMDL Program (**Table 2.1**). **Table 2.2** summarizes the DO and nutrient data collected during Cycle 2 of the verified period (January 1, 2002, through June 30, 2009). The projected year for the 1998 303(d)–listed DO TMDL for the creek was 2009, but the Settlement Agreement between the EPA and Earthjustice, which drives the TMDL development schedule for waters on the 1998 303(d) list, allows an additional nine months to complete the TMDLs. As such, this TMDL must be adopted and submitted to EPA by September 30, 2010.

This waterbody was verified as impaired based on low DO because, using the IWR methodology, more than 10 percent of the values exceeded the Class III freshwater criterion of 5.0 mg/L in the verified period (14 out of 25 samples) (**Table 2.2**). Nitrogen (N) was identified as the causative pollutant due to an elevated median value in 2008 (0.99 milligrams per liter [mg/L]) and a significant correlation with DO. Given a median total phosphorus (TP) of 0.021 mg/L, the fact that over 50 percent of the TP results were less than detection, and that there was no significant correlation between TP and DO, total phosphorus (TP) was not considered as causing or contributing to the DO impairment.

The data used in this report that formed the basis of the verified listing are contained within the IWR Run38 database. The water quality data shown in **Table 2.3** were collected during 3 trips to Sikes Creek in early 2010. The data collected during this time for TN, 5-day biochemical oxygen demand (BOD_5), TP, and corrected chlorophyll *a* (cchl*a*) are all lower than the data collected during 2008. DO at Station PN0114 (R1) during early 2010 averaged about 2 mg/L higher than the average of the data collected during 2008. The color data, at 160 platinum cobalt units (PCU), are similar to the 2008 average of 150 PCU.

Table 2.1. Verified Impairments for Sikes Creek (WBID 142)

This is a six-column table. Column 1 lists the WBID number, Column 2 lists the waterbody segment, Column 3 lists the waterbody type, Column 4 lists the waterbody class, Column 5 lists the 1998 303(d) parameter of concern, and Column 6 lists the parameter causing impairment.

[1] IIIF = Class III fresh water

WBID	Waterbody Segment	Waterbody Type[1]	Waterbody Class	1998 303(d) Parameters of Concern	Parameter Causing Impairment
142	Sikes Creek	Stream	IIIF	DO	TN

Table 2.2. Summary of data for Sikes Creek (WBID 142) during the verified period (January 1, 2002–December 31, 2009)

This is an 11-column table. Column 1 lists the WBID number, Column 2 lists the parameter, Column 3 lists the total number of samples, Column 4 lists the IWR-required number of exceedances, Column 5 lists the number of observed exceedances, Column 6 lists the number of observed nonexceedances, Column 7 lists the number of seasons data were collected, Column 8 lists the mean value, Column 9 lists the median value, Column 10 lists the minimum value, and Column 11 lists the maximum value.

N/A = Not applicable

WBID	Parameter/ Unit of Measurement	Total Number of Samples	IWR-required Number of Exceedances	Number of Observed Exceedances	Number of Observed Non-exceedances	Number of Seasons Data Were Collected	Mean	Median	Minimum	Maximum
142	DO (mg/L)	25	5	14	11	4	4.25	4.38	0.40	8.38
142	TN (mg/L	18	N/A	N/A	N/A	4	1.13	0.99	0.47	2.7
142	TP (mg/L)	20	N/A	N/A	N/A	4	0.027	0.021	0.020	0.052
142	BOD_5 (mg/L)	19	N/A	N/A	N/A	4	1.58	1.60	0.30	4.0
142	Chl*a* (µg/L)	20	1 annual average	0	0	4	1.55	1	1	9.3
142	Color (PCU)	19	N/A	N/A	N/A	4	149.5	150	60	300

Table 2.3. Water quality data for Sikes Creek, 2010

This is a 10-column table. Column 1 lists the station, Column 2 lists the sampling date, Column 3 lists the total depth, Column 4 lists the water temperature, Column 5 lists the data for DO, Column 6 lists the data for TN, Column 7 lists the data for TP, Column 8 lists the data for cchla, Column 9 lists the data for BOD_5, and Column 10 lists the data color.

\- = Empty cell/no data

Station	Date	Total Depth (feet [ft])	Water Temperature (C.°)	DO (mg/L)	TN (mg/L)	TP (mg/L)	Cchl*a* (µg/L)	BOD_5 (mg/L)	Color (PCU)
PN0114 (R1)	2/10/2010	5.3	6.75	6.3	-	-	-	-	-
PN0114 (R1)	3/16/2010	1.93	10.92	6.29	0.76	0.024	0.64	1.1	160
PN0114 (R1)	4/6/2010	1.68	21.32	6.41	-	-	-	-	-

The verified impairments were based on data collected by the Department at four STORET stations in WBID 142 (21FLPNS 32020114, 21FLPNS 32020154, 21FLPNS 32020155, and 21FLPNS 32020156) (**Table 2.4** and **Figure 2.1**).

In all subsequent tables and graphs, the water quality stations are "nicknamed" as follows to maximize the graphic portion of each plot, and stations are plotted on the graphs (legend) from downstream to upstream:

- *Station 21FLPNS 32020114, the most downstream station, is titled PN0114 for data presentation and R1 on all model graphs in Chapter 5;*
- *Station 21FLPNS 32020156, located midstream, is titled PN0156;*
- *Station 21FLPNS 32020155, also located midstream, is titled PN0155; and*
- *Station 21FLPNS 32020154, the most upstream station, is titled PN0154.*

Figure 2.2 depicts lower Sikes Creek, Station PN0114 (R1), at County Road 179 during flood conditions (February 2010); the creek is out of its banks. In this portion of the watershed, the creek is constrained within the 60-foot contour interval.

Figure 2.3 depicts the upstream side of the bridge at Station PN0114 (February 2010) showing debris on the bridge. This indicates that the creek was recently flowing over the bridge. The creek is scoured out just upstream and downstream of the bridge and exposed to full sunlight, with the potential to form a pool under low-flow conditions. This pooling under the bridge could influence water quality data collected at the bridge under low-flow conditions in such a way that some of the data (especially DO and temperature) might not be characteristic of the stream, which is mostly free-flowing (not pooled) and canopied by trees upstream and downstream of the bridge.

Table 2.4. Nicknames for water quality stations in Sikes Creek (WBID 142)

This is a two-column table. Column 1 lists the station, and Column 2 lists the nickname.

Station	Nickname
21FLPNS 32020114	PN0144 or R1 in Chapter 5
21FLPNS 32020156	PN0156
21FLPNS 32020155	PN0155
21FLPNS 32020154	PN0154

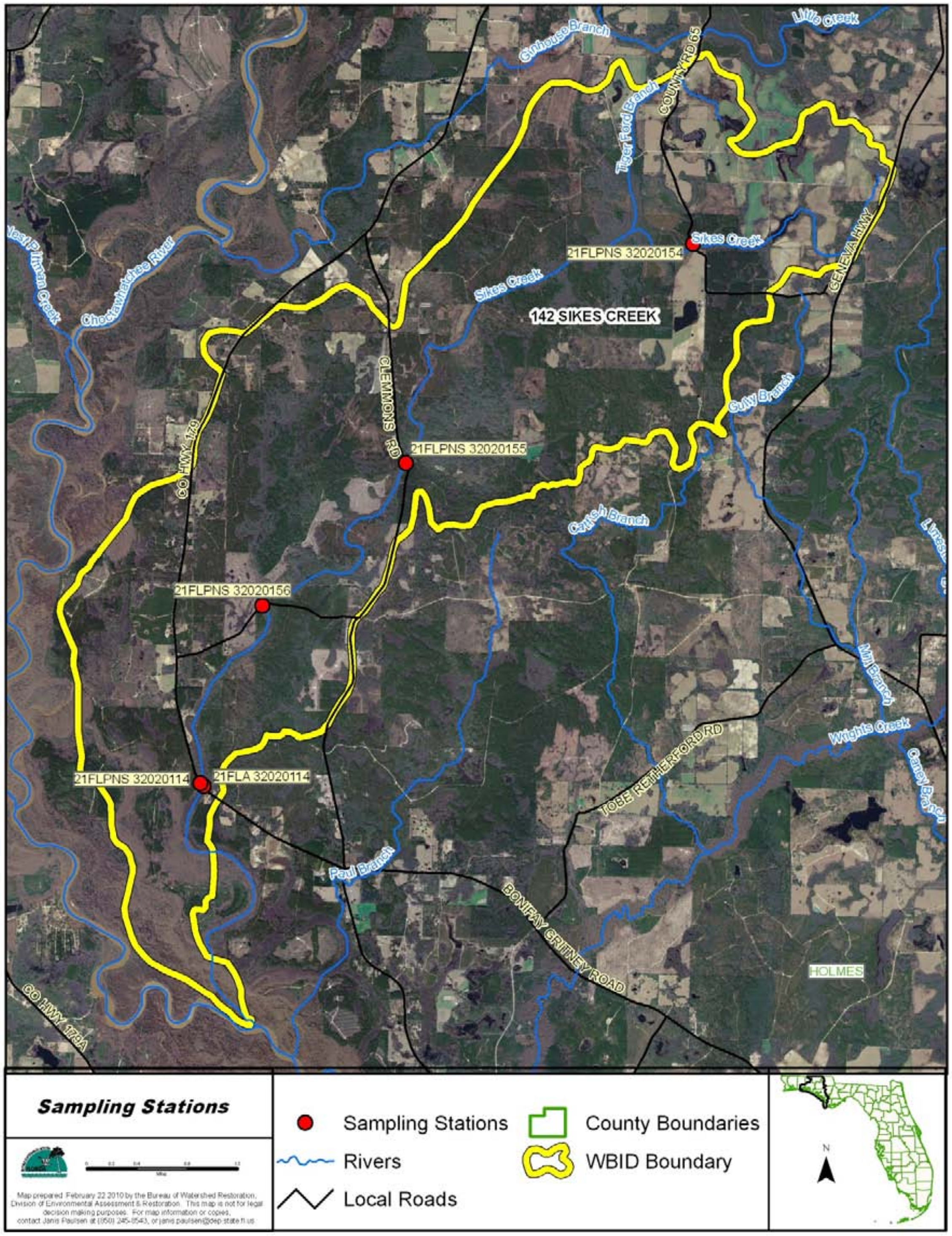


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Figure 2.1. Location of water quality monitoring stations in Sikes Creek (WBID 142)

Figure 2.2. Most downstream station, PN0114 (R1), February 2010

Figure 2.3. Station PN0114, February 2010

Figures 2.4 and **2.5** depict Station PN0156, located upstream of PN0114 (R1) at Harris Stevenson Road. In this portion of the watershed, the creek is constrained within the 70 foot contour interval. About 100 yards upstream of this location is a confluence with a tributary entering Sikes Creek from the west. Flows measured during April 2010 (after the stream was back within its banks) in the tributary (0.436 cubic feet per second [cfs]) and in Sikes Creek below the confluence (2.26 cfs) indicate that the tributary accounted for about 19 percent of the flow in Sikes Creek at Station PN0156 under these conditions. There are no water quality data for the tributary.

Figure 2.4. Station PN0156, February 2010

Figure 2.5. Station PN0156, upstream of bridge, February 2010

Figures 2.6 and **2.7** depict Station PN0155, located mid-watershed along Clemmons Road. Here the stream is constrained within the 90-foot contour interval. The station is scoured out around the culverts. This scouring and the pooling that could occur during low-flow conditions, as well as the lack of canopy over the stream, could influence the water quality data for DO and temperature during low-flow conditions. As illustrated in **Figure 2.6**, the stream is generally under heavy canopy, except at the road crossings.

Figure 2.6. Station PN0155, February 2010, downstream

Figure 2.7. Station PN0155, February 2010

Figures 2.8 and **2.9** depict the uppermost station, PN0154, located along County Road 65. In this portion of the watershed, the creek is constrained within the 100-foot contour interval. The station is scoured out on both sides of the culvert crossing and could form pools during low-flow conditions. DO and temperature measurements made during low-flow conditions may not be representative of conditions in the stream away from the road. **Figure 2.9** depicts typical conditions for the stream away from the culverts.

Figure 2.8. Station PN0154, February 2010

Figure 2.9. Sikes Creek downstream of Station PN0154, February 2010

Table 2.5 and **Figure 2.10** depict annual rainfall at the Marianna weather station, about 32 miles east of Sikes Creek. Weather data were collected here as it was the closest station with a complete set of meteorological information. The data show that the year resulting in the impairment of Sikes Creek (2008) had one of the highest annual rainfalls in the overall period (2003–08) following two dry years, and had higher rainfall than the average annual rainfall (in inches) for the period from 2003 to 2008.

Table 2.5. Annual rainfall (in inches) at the Marianna weather station, 2003–08

This is a two-column table. Column 1 lists the year, and Column 2 lists rainfall (in inches).

Year	Rainfall (inches)
2003	51.7
2004	52.9
2005	62.6
2006	39
2007	38.9
2008	62.0
Mean (2003–08)	**51.2**

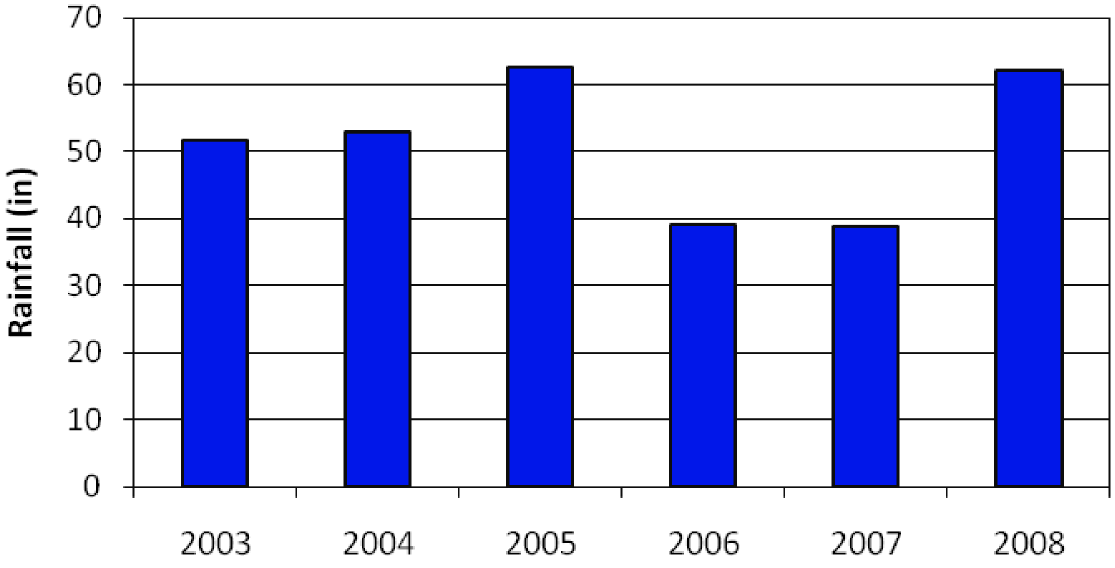


Figure 2.10. Annual rainfall (in inches) at the Marianna weather station, 2003–08

Table 2.6 and **Figure 2.11** depict monthly average rainfall at Marianna from 2003 to 2008. The data show that for the year resulting in the impairment of Sikes Creek (2008), the majority of the year (seven months) had higher monthly rainfall than the overall period (2003–08). During four months in 2008 (February, June, August, and December), rainfall was substantially higher than average. In May and September 2008, rainfall was substantially less than the long-term averages for these months.

The Cycle 2 verified period includes data collected from January 1, 2002, through June 30, 2009. All data for the Sikes Creek WBID were collected in 2008; as a result, this analysis focuses on data collected in the latter part of the Cycle 2 verified period. **Figures 2.12** through **2.16** display the raw data collected in 2008 for WBID 142.

Figure 2.12 shows that the majority (56 percent) of the DO samples collected in 2008 have a concentration less than the water quality criterion of 5.0 mg/L. The majority of data were collected at Stations PN0114 (R1) (n=10) and PN0155 (n=7). However, there are insufficient synoptic DO data at the upstream stations to determine spatial trends.

Table 2.6. Monthly average rainfall (in inches) at the Marianna weather station, 2003–08 and 2008

This is a three-column table. Column 1 lists the month, Column 2 lists the average rainfall from 2003 to 2008 (in inches), and Column 3 lists the 2008 average rainfall (in inches).

Month	2003–08 Average Rainfall (inches)	2008 Average Rainfall (inches)
January	3.7	4.4
February	5.3	9
March	3.8	3.2
April	3.9	4.4
May	2.4	1.5
June	5.8	9
July	5.4	4
August	6.4	9.3
September	2.7	0.7
October	3.5	5.1
November	3.5	3.2
December	4.8	8.2
Average	**4.3**	**5.2**

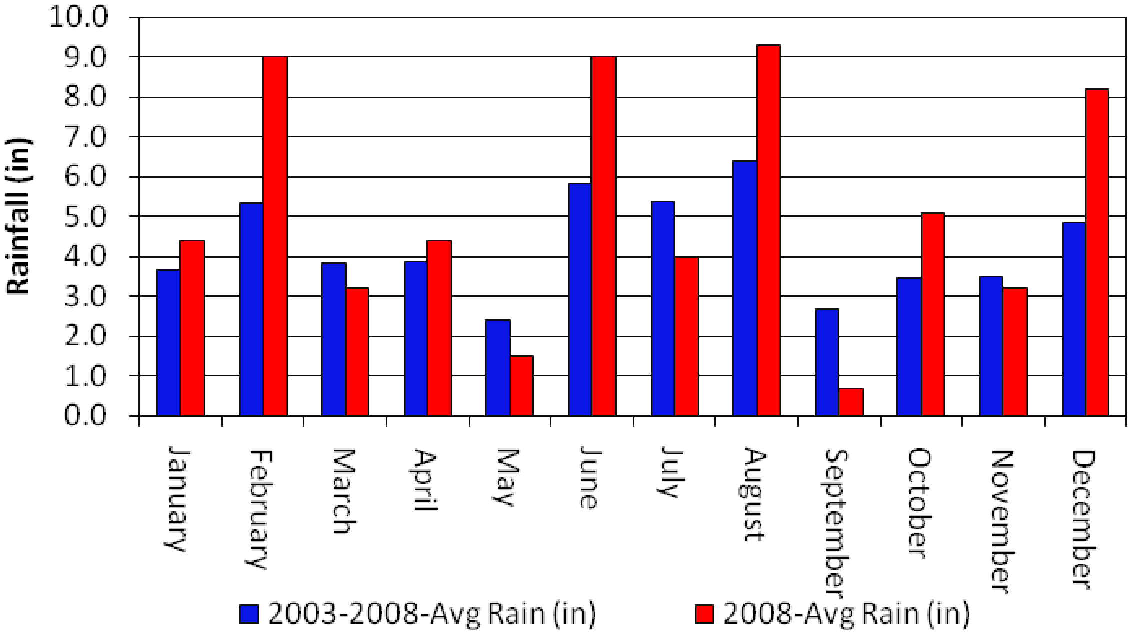


Figure 2.11. Monthly average rainfall (in inches) at the Marianna weather station, 2003–08 and 2008

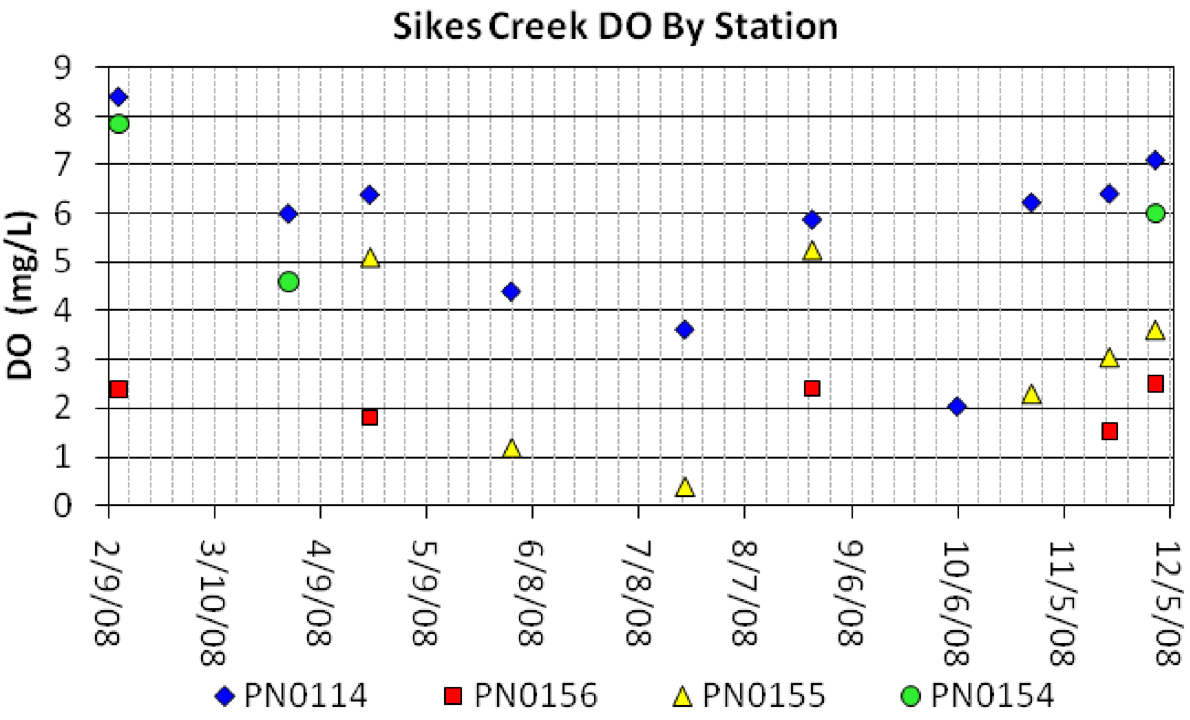


Figure 2.12. DO measurements for Sikes Creek (WBID 142) by station for 2008, during the Cycle 2 verified period. The red line indicates the target concentration (5 mg/L).

Figure 2.13 shows that the cchl*a* in Sikes Creek is low; the cchl*a* guidance (greater than 20 µg/L as an annual average) was not exceeded. Based on information from the Department's laboratory, a valid reporting limit for cchl*a* is 3 µg/L. In this case, all but 1 cchl*a* measurement was less than the 3.0 µg/L reporting limit, with most values at the detection limit of 1.0 µg/L. There are insufficient cchl*a* data at the upstream stations to determine spatial trends. The lowest (1 µg/L) and highest (9.3 µg/L) concentrations were recorded at the most downstream station, PN0114.

Figure 2.14 shows that BOD_5 is less than 2.0 mg/L in the majority of the samples (63 percent). The median BOD_5 was 1.6 mg/L. The highest BOD_5 recorded at Sikes Creek was 4.0 mg/L at Station PN0155, one of the midstream stations. There are insufficient BOD_5 data at the upstream stations to determine spatial trends.

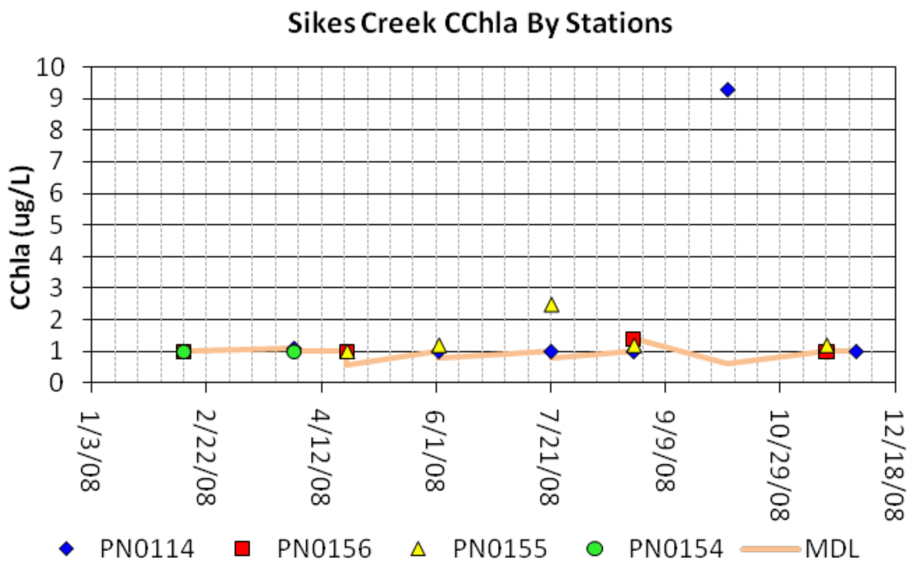


Figure 2.13. Cchl*a* measurements for Sikes Creek (WBID 142) by station, January 2008–December 2008

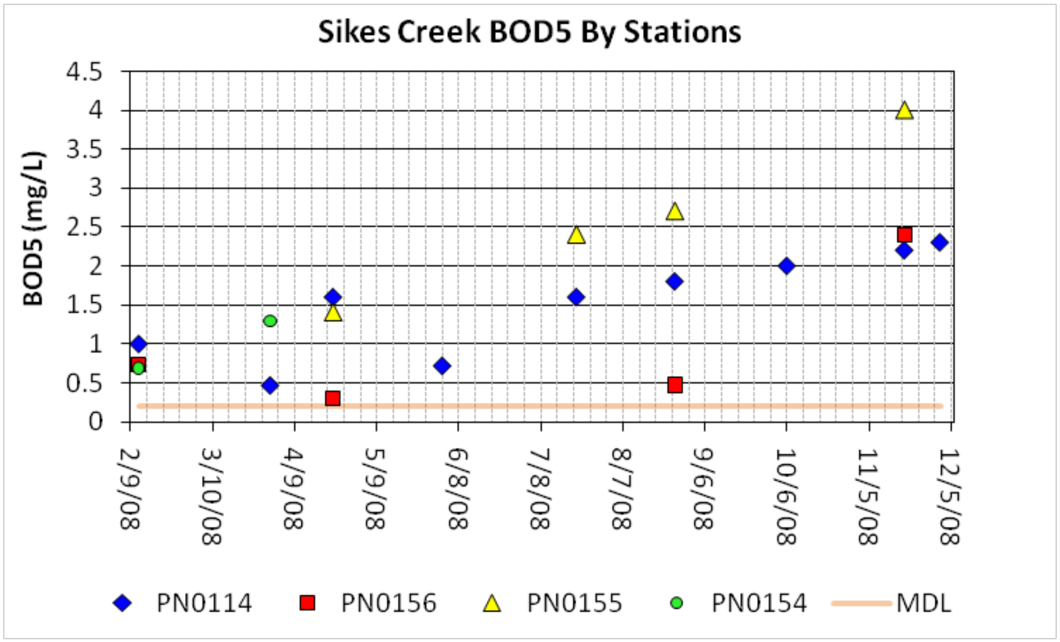


Figure 2.14. BOD_5 measurements for Sikes Creek (WBID 142) by station, January 2008–December 2008

Figure 2.15 shows that TN ranges from less than 0.5 to 2.7 mg/L. The highest TN value was recorded at Station PN0114. There are insufficient TN data at the upstream stations to determine spatial trends.

Figure 2.16 shows that the majority of TP concentrations (55 percent of samples) were at or below the minimum detection limit (MDL) (0.02 mg/L). Concentrations ranged from less than 0.02 to 0.05 mg/L, with the highest concentration (0.05 mg/L) recorded at Station PN0155 in 2 different sampling events.

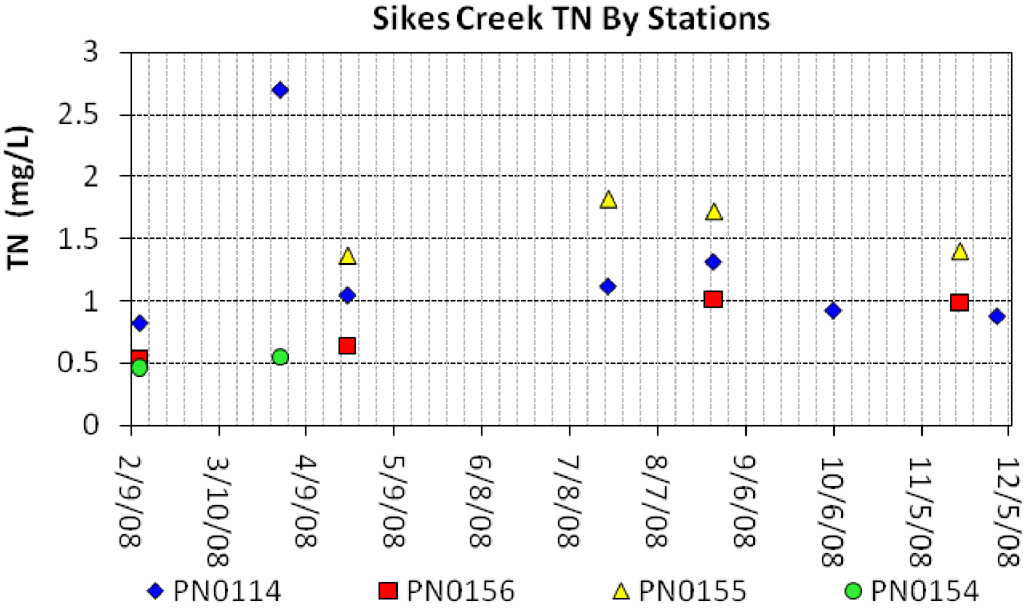


Figure 2.15. TN measurements for Sikes Creek (WBID 142) by station, January 2008–December 2008

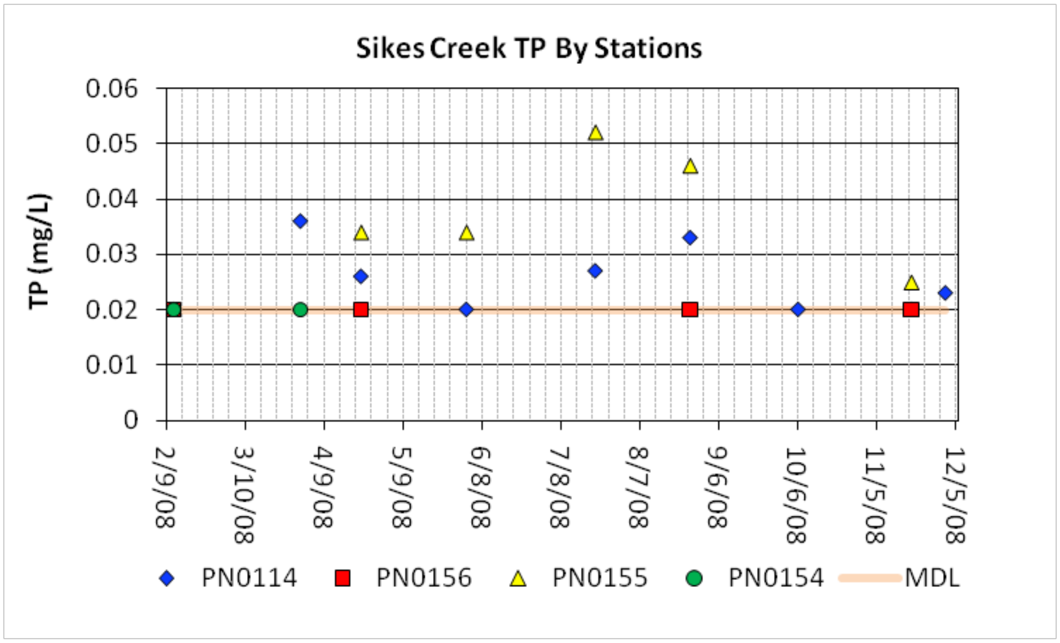


Figure 2.16. TP measurements for Sikes Creek (WBID 142) by station, January 2008–December 2008

Figures 2.17 through **2.21** display data collected in 2008 averaged across all stations as a single daily average value for the watershed. **Figure 2.17** depicts the daily average concentrations for DO in Sikes Creek. These data indicate either a problem with sampling locations, as discussed previously, and/or generally low DO in the watershed.

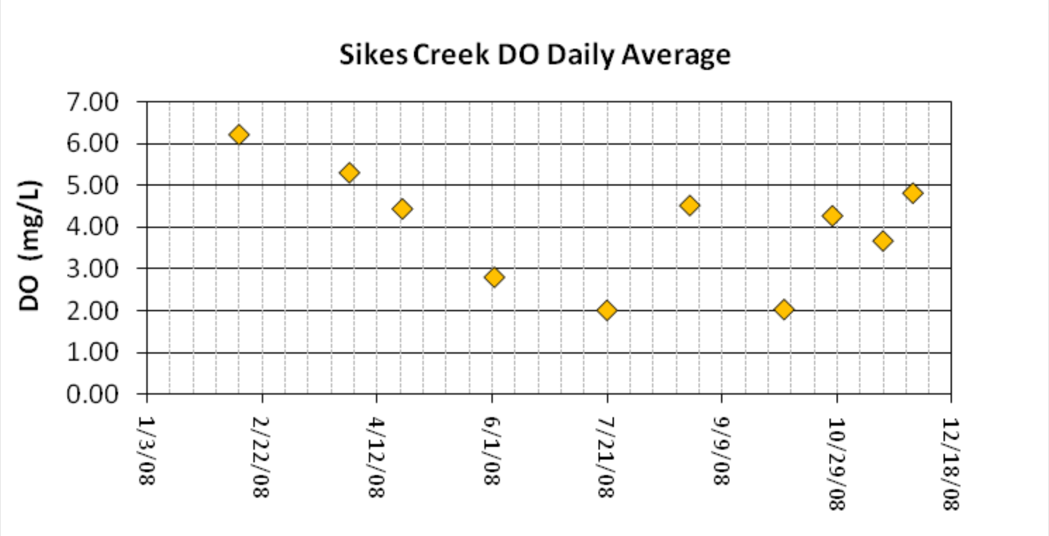


Figure 2.17. Daily average of DO measurements for all stations for Sikes Creek (WBID 142), January 2008–December 2008

Figure 2.18 depicts the daily average cchl*a* concentrations in the watershed. These data indicate that cchl*a* is not causing or contributing to the low measured DO concentrations. **Figure 2.19** depicts daily average BOD_5 data. These data indicate a general increase in BOD_5 over the year, with values less than 2.0 mg/L not considered as contributing to the low measured DO concentrations.

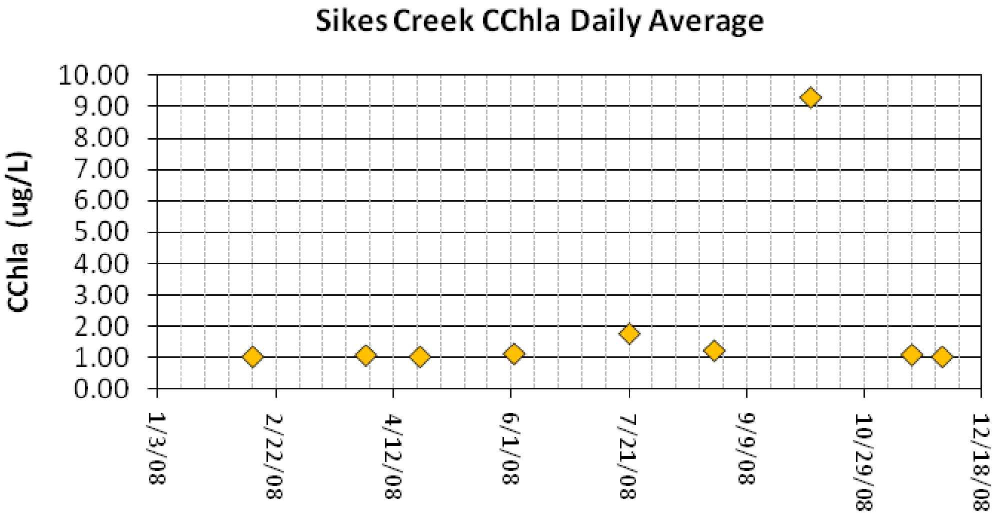


Figure 2.18. Daily average of cchl*a* measurements for all stations for Sikes Creek (WBID 142), January 2008–December 2008

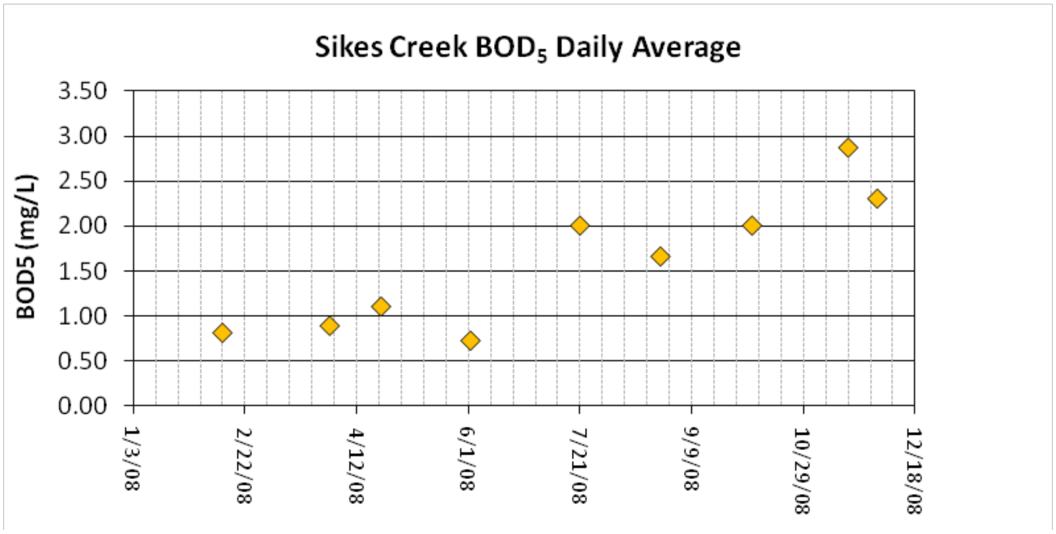


Figure 2.19. Daily average of BOD_5 measurements for all stations for Sikes Creek (WBID 142), January 2008–December 2008

Figure 2.20 depicts the daily average TN data, which indicate that TN is usually greater than 1.0 mg/L. TN in this range might cause or contribute to the increased growth of macrophytes and benthic attached algae, as well as phytoplankton in the water column. Increased growth in any of these ecosystem components could result in a depressed DO from an increase in respiration and the decomposition of organic matter. **Figure 2.21** depicts the daily average TP data. These indicate that TP should not be causing or contributing to the low measured DO concentrations.

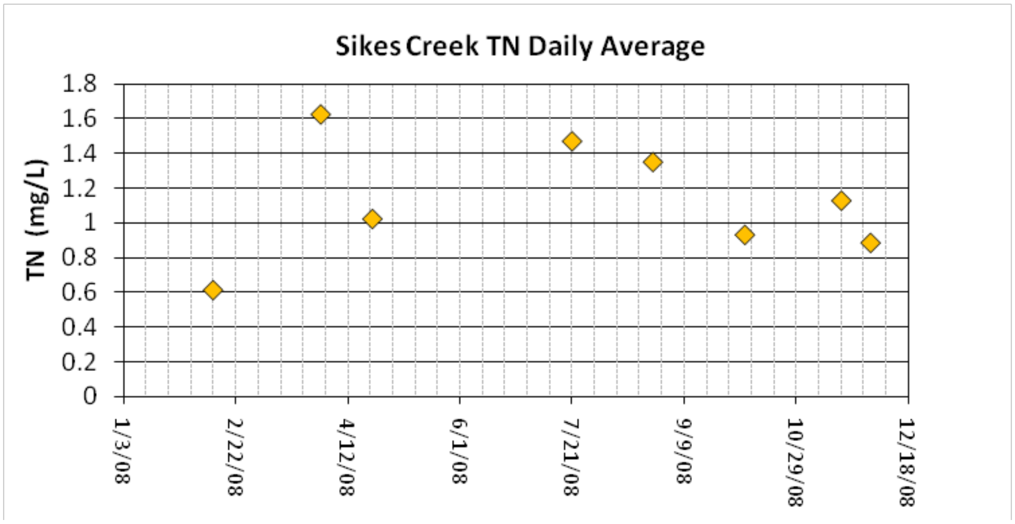


Figure 2.20. Daily average of TN measurements for all stations for Sikes Creek (WBID 142), January 2008–December 2008

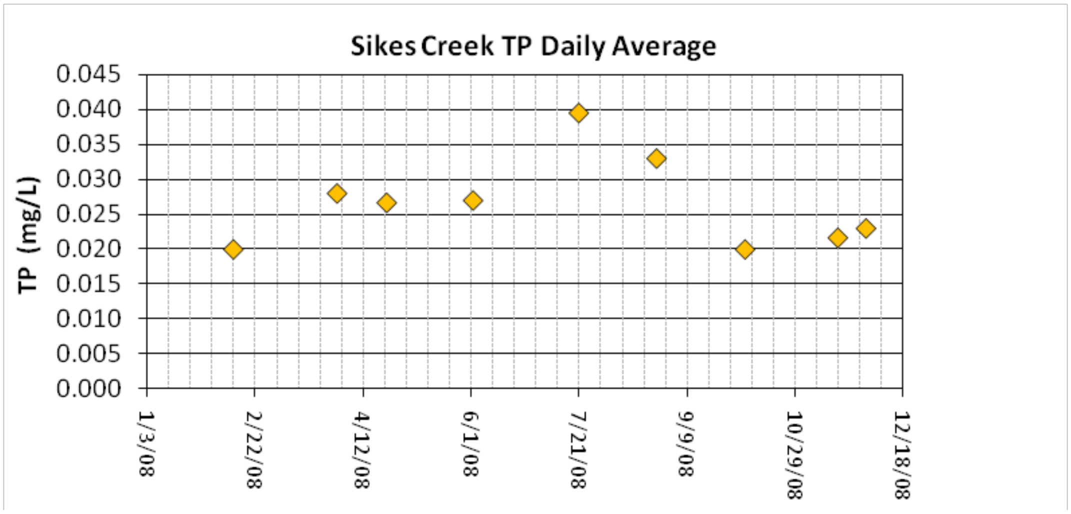


Figure 2.21. Daily average of TP measurements for all stations for Sikes Creek (WBID 142), January 2008–December 2008

Chapter 3. DESCRIPTION OF APPLICABLE WATER QUALITY STANDARDS AND TARGETS

3.1 Classification of the Waterbody and Criterion 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)**

Sikes Creek is a Class III fresh waterbody, with a designated use of recreation, propagation, and the maintenance of a healthy, well-balanced population of fish and wildlife. The criterion applicable to this TMDL is the Class III criterion for DO.

3.2 Narrative Nutrient Criteria Definitions

3.2.1 Chlorophyll a

Chlorophyll *a* (chl*a*), a green pigment found in plants, is an essential component in the process of converting light energy (sunlight) into chemical energy through the process of photosynthesis. In photosynthesis, the energy absorbed by chl*a* transforms carbon dioxide and water into carbohydrates and oxygen. The chemical energy stored by photosynthesis in carbohydrates drives biochemical reactions in nearly all living organisms. Thus, chl*a* is at the center of the photosynthetic oxidation-reduction reaction between carbon dioxide and water.

There are several types of chlorophyll; however, the predominant form is chl*a*. The measurement of chl*a* in a water sample is a useful indicator of phytoplankton biomass, especially when used in conjunction with an analysis of algal growth potential and species abundance. The greater the abundance of chl*a*, typically the greater the abundance of algae. Algae are the primary producers in the aquatic food web, and thus are very important in characterizing the productivity of aquatic systems.

3.2.2 Total Nitrogen as N

TN is the combined measurement of nitrate (NO_3), nitrite (NO_2), ammonia (NH_4), and organic nitrogen found in water. Nitrogen compounds function as important nutrients for many aquatic organisms and are essential to the chemical processes that occur between land, air, and water. The most readily bioavailable forms of nitrogen are ammonia and nitrate. These compounds, in conjunction with other nutrients, serve as an important base for primary productivity.

The major sources of excessive amounts of nitrogen in surface water are the effluent from municipal treatment plants and runoff from urban and agricultural sites. When nutrient concentrations consistently exceed natural levels, the resulting nutrient imbalance can cause undesirable changes in a waterbody's biological community and drive an aquatic system into an accelerated rate of eutrophication, or accelerated aging. Usually, the eutrophication process is observed as a change in the structure of the algal community and includes severe algal blooms that may cover large areas for extended periods. Large algal blooms are generally followed by depletion in DO concentrations as a result of algal decomposition.

3.2.3 Total Phosphorus as P

Phosphorus is one of the primary nutrients that regulate algal and macrophyte growth in natural waters, particularly in fresh water. Phosphate, the form in which almost all phosphorus is found in the water column, can enter the aquatic environment in a number of ways. Natural processes transport phosphate to water through atmospheric deposition, ground water percolation, and terrestrial runoff. Municipal treatment plants, industries, agriculture, and domestic activities also contribute to phosphate loading through direct discharge and natural transport mechanisms. The very high levels of phosphorus in some Florida streams and estuaries are usually caused by phosphate mining and fertilizer processing activities.

High phosphorus concentrations are frequently responsible for accelerating the eutrophication process. Once phosphorus and other important nutrients enter the ecosystem, they are extremely difficult to remove. They become tied up in biomass or deposited in sediments. Nutrients, particularly phosphates, deposited in sediments generally are redistributed to the water column. This type of cycling compounds the difficulty of halting the eutrophication process.

3.3 Applicable Water Quality Standards and Numeric Water Quality Target

3.3.1 Dissolved Oxygen

Florida’s DO criterion for Class III fresh waterbodies states that DO shall not be less than 5.0 mg/L. Normal daily and seasonal fluctuations above these levels shall be maintained. However, DO concentrations in ambient waters can be controlled by many factors, including DO solubility, which is controlled by temperature and salinity; DO enrichment processes influenced by reaeration, which is controlled by flow velocity; the photosynthesis of phytoplankton, periphyton, and other aquatic plants; DO consumption from the decomposition of organic materials in the water column and sediment, as well as the oxidation of some reductants such as ammonia and metals; and respiration by aquatic organisms. Sikes Creek was verified as impaired for DO because 14 of the 25 measured values were below the Class III freshwater criterion.

One of the major sources of DO consumption originates from organic sediments accumulated in the aquatic system over time. Bottom organic sediments can be deposited from different sources (i.e., wastewater effluents, nonpoint source runoff, and allochthonous particulates). Sediment oxygen demand (SOD) is a sum of DO needed for the oxidation of organic matter in bottom sediments via biological and chemical processes that take up DO. Major factors affecting SOD are temperature, the organic content of the sediment, and the oxygen concentration of the overlying waters (Chapra, 1997). Gardiner et al. (1984) reported that there is a square-root relationship between SOD and the organic content of sediments.

3.3.2 Nutrients

Florida’s nutrient criterion is narrative only—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. Under the IWR, nutrient impairment for freshwater streams is assessed by determining if annual average cchl*a* values exceed 20 µg/L, or if annual cchl*a* averages more than 50 percent greater than the historical value for at least 2 consecutive years.

While the IWR provides guidance values for nutrient impairment for streams based on annual average cchl*a* levels, these thresholds are not standards and need not be used as the nutrient-related water quality target for TMDLs. In fact, in recognition that the IWR thresholds were developed using statewide average conditions, the IWR (Section 62-303.450, F.A.C.) specifically allows the use of alternative, site-specific thresholds that more accurately reflect conditions beyond which an imbalance in flora or fauna occurs in the waterbody. The IWR used the guidance concentration of 20.0 µg/L cchl*a* for assessing Sikes Creek for nutrients and found no impairment based on this metric.

3.3.3 Nutrient Target Development

Numerous regressions were conducted on the data to examine the correlations between DO and TN, TP, and BOD_5. The relationship between TN and DO was used to establish a TN concentration (nutrient target) that would result in DO levels at or above 5.0 mg/L (water quality criterion). The Hydrological Simulation Program–Fortran (HSPF) Model (Bicknell et al., 2001) was then used to establish the relationship between nutrient load reductions and DO concentrations to establish the allowable nutrient loads.

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

However, the 1987 amendments to the Clean Water Act redefined certain nonpoint sources of pollution as point sources subject to regulation under the EPA’s National Pollutant Discharge Elimination System (NPDES) Program. These nonpoint sources included certain urban stormwater discharges, 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” will be used to describe traditional point sources (such as domestic and industrial wastewater discharges) ***and*** stormwater systems requiring an NPDES stormwater permit when allocating pollutant load reductions required by a TMDL (see **Section 6.1**). However, the methodologies used to estimate nonpoint source loads do not distinguish between NPDES stormwater discharges and non-NPDES stormwater discharges, and as such, this source assessment section does not make any distinction between the two types of stormwater.

4.2 Potential Sources of Nutrients and BOD_5 in the Sikes Creek Watershed

4.2.1 Overview of Modeling Process

A watershed is the land area that catches rainfall and eventually drains or seeps into a receiving waterbody such as a stream, lake, or ground water (EPA, 1997). Land use pollution loading models are often used to assess watershed impacts on the water quality of a receiving waterbody. A detailed watershed model is beneficial in estimating time series DO and nutrient loads from potential sources in the watershed, in order to predict algal responses in the receiving waterbody where the time scale of actual biological responses to nutrient loading from the watershed is at least equal to or less than that of the model prediction (EPA, 1997).

The external load assessment from the watershed and the resulting in-stream water quality conditions were evaluated using the Windows version of the HSPF Model (WinHSPF Version 2.3). Chapter 5 provides a detailed description of the model and discusses the results for calibration and TMDL development. Assessing the external load entailed assessing land use patterns, soils, topography, hydrography, point sources, service area coverages, climate, and rainfall to determine the volume, concentration, timing, location, and underlying nature of the point, nonpoint, and atmospheric sources of nutrients to the stream.

HSPF is a useful tool in the assessment of watershed-related properties. It was developed to allow engineers and planners to assess the water quantity and quality of both surface water and ground water (interflow and baseflow). The model simulates the primary physical processes important for watershed hydrologic and pollutant transport. HSPF (Duda et al., 2001; Bicknell et al., 2001) is a comprehensive package that can be used to develop a combined watershed and receiving water model. It can model various species of nitrogen and phosphorus, cchl*a*, coliform bacteria, and metals in receiving waters (bacteria and metals can be simulated as a "general" pollutant with potential in-stream processes, including first-order decay and adsorption/desorption with suspended and bed solids).

HSPF was developed and is maintained by Aqua Terra and the EPA. The PERLND (Pervious Land) Module performs detailed analyses of surface and subsurface flow for pervious land areas based on the Stanford Watershed Model. Water quality calculations for sediment in pervious land runoff can include sediment detachment during rainfall events and reattachment during dry periods, with the potential for washoff during runoff events. For other water quality constituents, runoff water quality can be determined using buildup-washoff algorithms (such as the Storm Water Management Model [SWMM]), potency factors (*e.g.,* factors relating constituent washoff to sediment washoff), or a combination of both. The IMPLND (Impervious Land) Module analyzes surface processes only and uses buildup-washoff algorithms to determine runoff quality. The Reach or Reservoir (RCHRES) Module is used to simulate flow routing and water quality in the receiving waters, which are assumed to be one-dimensional. Receiving water constituents can interact with suspended and bed sediments through soil-water partitioning. HSPF can incorporate "special actions" that use user-specified algorithms to account for occurrences such as the opening/closing of water control structures to maintain seasonal water stages, or other processes beyond the normal scope of the model code.

More information on the HSPF Model (Bicknell et al., 2001) and the Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) Model (EPA, 2007) is available at www.epa.gov/waterscience/basins/.

4.2.2 Point Sources

No NPDES-permitted facilities discharge directly or indirectly into Sikes Creek.

Municipal Separate Storm Sewer System Permittees

According to the Department's geographic information system (GIS) library, there are no NPDES municipal separate storm sewer system (MS4) permits that cover the Sikes Creek watershed.

4.2.3 Land Uses and Nonpoint Sources

Nonpoint source pollution, unlike pollution from industrial and sewage treatment plants, comes from many diffuse sources. Nonpoint pollution is caused by rainfall moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and even underground sources of drinking water (EPA, 1994).

Land Uses

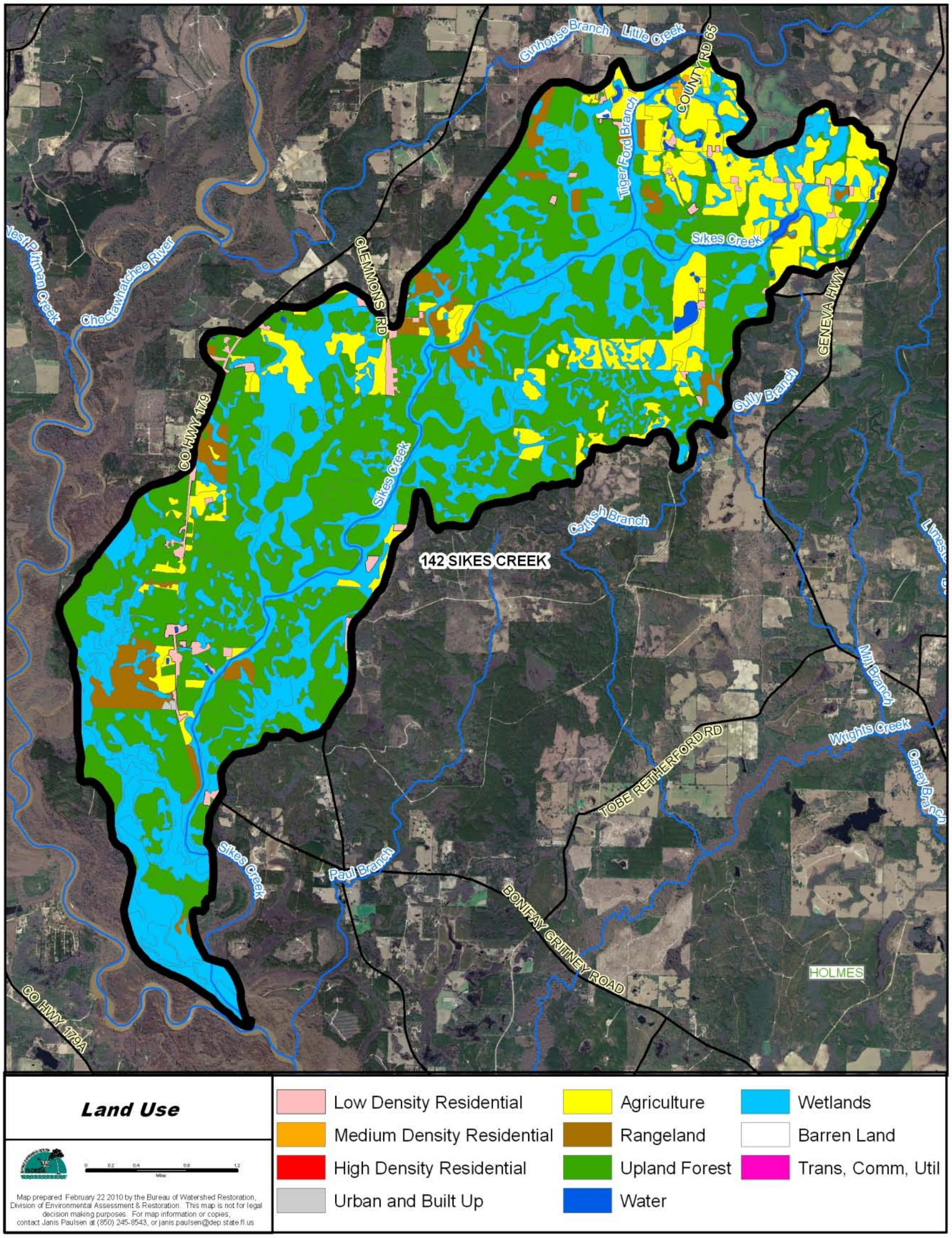
The spatial distribution and acreage of different land use categories were identified using the NWFWMDs 2004 land use coverage (scale 1:40,000) contained in the Department's GIS library. Land use categories in the watershed were aggregated using the Level 3 codes and tabulated in **Table 4.1.** **Figure 4.1** shows the acreage and spatial distribution of the principal land uses at the Level 1 land use scale.

As shown in **Table 4.1,** the Sikes Creek watershed drains about 10,167 acres of land. The primary land uses are coniferous plantations (38.4 percent), followed by mixed wetland forest (22 percent), and upland coniferous forest (18 percent). Residential and other land uses with high imperviousness are less than 0.2 percent of the watershed.

Table 4.1. Classification of Level 3 land use categories for the Sikes Creek watershed (WBID 142) in 2004

This is a three-column table. Column 1 lists the land use, Column 2 lists the acreage, and Column 3 lists the percentage.

Level 3 Land Use	Acres	%
Low-density residential	198.6	1.8%
Medium-density residential	12.9	0.1%
High-density residential	0.0	0.0%
Improved pastures/crops/groves/poultry	1,004.0	9.3%
Unimproved pastures/woodland pastures	394.8	3.6%
Rangeland/upland forests	5,299.9	49.0%
Waters	153.5	1.4%
Wetlands	3,756.6	34.7%
Transportation/communication/utilities	4.4	0.0%
Total	**10,824.5**	**100.0%**



Map prepared February 22 2010 by the Bureau of Watershed Restoration, Division of Environmental Assessment & Restoration. This map is not for legal decision making purposes. For map information or copies, contact Janis Paulsen at (850) 245-8543, or janis.paulsen@dep.state.fl.us

Figure 4.1. Principal Level 1 land uses in the Sikes Creek watershed in 2004

Septic Tanks

Septic tanks are another potentially important source of nutrients in some watersheds. In areas with a relatively high ground water table, the drain field can be flooded during the rainy season, resulting in ponding, and can pollute the surface water through stormwater runoff. In these circumstances, a high water table can result in nutrient pollution reaching the receiving waters through baseflow. In addition, watersheds located in karst regions are extremely vulnerable to contamination. Karst terrain is characterized by springs, caves, sinkholes, and a unique hydrogeology that results in aquifers that are highly productive (U.S. Geological Survey [USGS], 2010). In comparison to nonkarst areas, the springs, caves, sinkholes, and other karst features act as direct pathways for pollutants to enter waterbodies.

Based on data obtained from the Florida Department of Health (FDOH), which is currently undertaking a project to inventory the use of onsite sewage treatment and disposal systems (OSTDS) (i.e., septic tanks) by determining the methods of wastewater disposal for developed property sites statewide, an estimated 102 housing units within the Sikes Creek WBID boundary are known or believed to be using septic tanks to treat their domestic wastewater. FDOH's parcel data were obtained from the Florida Department of Revenue 2008 tax roll. FDOH's wastewater disposal data were obtained from county Environmental Health Departments, WWTFs, Department domestic wastewater treatment permits, existing county and city inventories, and other available information. If there was not enough information to determine with certainty whether a property used a septic system, FDOH employed a probability model to analyze the characteristics of the property and estimate the probability that the property was served by a septic tank.

Within the Sikes Creek WBID boundary, 4 properties are known to use septic tanks and 98 are believed to use septic tanks. Given that the probability that these 98 properties are in fact served by septic tanks was 97 percent or higher, all 102 properties were assumed to be served by septic tanks. The discharge rate from each septic tank can be calculated by multiplying the average household size by the per capita wastewater production rate per day. A commonly cited value for per capita wastewater production rate is 70 gallons/day/person (EPA, 2001). Based on the information published by the Census Bureau, the average household size for Holmes County is about 2.43 people/household. The same population densities were assumed within the Sikes Creek WBID boundary. As only about 2 percent of the watershed has the potential for septic tanks (residential, institutional, etc.), septic tanks are not anticipated to be a significant contributor of pollution in this watershed.

Sanitary Sewer Overflows

Sanitary sewer overflows (SSOs) can also be a potential source of nutrient and/or bacterial pollution. Human sewage can be introduced into surface waters even when storm and sanitary sewers are separated. Leaks and overflows are common in many older sanitary sewers where capacity is exceeded, high rates of infiltration and inflow occur (i.e., outside water gets into pipes, reducing capacity), frequent blockages occur, or sewers are simply falling apart due to poor joints or pipe materials. Power failures at pumping stations are also a common cause of SSOs. The greatest risk of an SSO occurs during storm events; however, few comprehensive data are available to quantify SSO frequency and nutrient or bacteria loads in most watersheds. There is no evidence of sanitary sewers within the Sikes Creek watershed.

Livestock

Although agriculture is not one of the primary land uses in the WBID, a potentially important nonpoint source of nutrients could include livestock and other agricultural animals. Agricultural activities, including runoff from pastureland and cattle in streams, can affect water quality.

Urban Development

Although urban land use is not dominant within the Sikes Creek WBID boundary, nutrient contributions from residential areas could not be excluded based on current data, especially for the residential areas located immediately adjacent to Sikes Creek or its tributaries. Chapter 5 provides a preliminary quantification of the nutrient loadings from these sources.

Wildlife and Sediments

In addition to livestock, wildlife and sediments could also contribute to nutrients in the creek. Wildlife such as birds, raccoons, bobcats, rabbits, deer, and feral hogs have direct access to the stream, especially under low-flow conditions, and deposit their feces directly into the water or floodplain, where the nutrients can be transported during storm events to nearby streams.

Chapter 5: DETERMINATION OF ASSIMILATIVE CAPACITY

5.1 Determination of Loading Capacity

The DO and nutrient TMDL calculation was developed using a combination of an empirical equation to establish the concentration of nitrogen that would result in a DO of 5.0 mg/L and the HSPF Model to link reductions in nutrient loads from the watershed to the resulting in-stream nutrient and DO concentrations. The goal of this TMDL development is to identify the maximum allowable nutrient loadings from the watershed, so that Sikes Creek will meet the DO criterion and thus maintain its function and designated use as a Class III water. In order to achieve the goal, the Department selected the HSPF Model as the watershed and waterbody model. It was run dynamically to simulate DO responses in the creek to watershed nutrient loading and to ultimately estimate the assimilative capacity of the creek.

5.2 Model Approach

The HSPF Model was used to estimate the nutrient loads within and discharged from the Sikes Creek watershed. The model allows the Department to interactively simulate and assess the environmental effects of various land use changes and associated land use practices. The data analysis and evaluation were focused on the 7-year model simulation period from 2003 to June 2009 to represent recent and existing conditions. The only data available for calibration were collected during 2008. Model predictions for the period from 2003 to 2007 are presented to demonstrate how the model responds to changes in rainfall over this time. **Appendix D** contains additional information regarding the HSPF Model and calibration coefficients.

The IMPLND Module of HSPF accounts for surface runoff from impervious land areas (e.g., parking lots and highways). For the purposes of this model, each land use was assigned a typical percentage of directly connected impervious area (DCIA), as shown in **Table 5.1**, based on published values (CDM, 2002). Four of the nine land uses contain fractions of impervious lands.

The PERLND Module of HSPF accounts for surface runoff, interflow, and ground water flow (baseflow) from pervious land areas. For the purposes of modeling, the total amount of pervious tributary area was estimated as the total tributary area minus the impervious area.

Table 5.1. Percentage of impervious area

This is a two-column table. Column 1 lists the land use category, and Column 2 lists the percent DCIA.

Land Use Category	% DCIA
1. Commercial/industrial	80%
2. Cropland/improved pasture/tree crops	0%
3. High-density residential	50%
4. Low-density residential	10%
5. Medium-density residential	25%
6. Rangeland/upland forests	0%
7. Unimproved pasture/woodland pasture	0%
8. Wetlands	0%
9. Water	0%

The RCHRES module of HSPF conveys flows input from the PERLND and IMPLND Modules, together with rainfall directly on the water surface, and balances this with outflows from evaporation, and outflows based on a rating curve supplied by the modeler. This project consists of four sets of PERLND and IMPLND land uses representing the watershed, draining to four RCHRES, representing Sikes Creek. The RCHRES element defines the depth-area-volume relationship for the modeled waterbody. **Table 5.2** and **Figure 5.8** depict the land uses and acreage of each land use incorporated in the HSPF Model. Within the table, Reach 7 is the most upstream reach; Reach 3 is the middle part of Sikes Creek; Reach 4 is a major tributary to Sikes Creek that enters the creek at the junction of Reaches 3 and 1; and Reach 1 is the most downstream reach, terminating at County Road 179.

The domain does not include about 1,355 acres in the watershed located below County Road 179, as the hydrology below this point is unknown. Field surveys during January, March, and April 2010 documented that the creek below this point does not follow the path indicated by the GIS data used to set up the model domain and receives significant flow from an unnamed tributary just below the bridge. This unnamed tributary may convey overflow from the Choctawhatchee River floodplain when that river is out of its banks. For these reasons, the area below County Road 179 was not included in the model domain.

Table 5.2. Land use acreage used in the HSPF Model

This is a six-column table. Column 1 lists the category, Column 2 lists the acreage for Reach 7, Column 3 lists the acreage for Reach 3, Column 4 lists the acreage for Reach 4, Column 5 lists the acreage for Reach 1, and Column 6 lists the total acreage.

Categories	Reach 7	Reach 3	Reach 4	Reach 1	Total
Low-density residential	71.5	33.5	39.9	15.6	**161**
Medium-density residential	12.9	0.0	0.0	0.0	**13**
High-density residential	0.0	0.0	0.0	0.0	**0**
Improved pastures/crops/groves/poultry	855.1	26.3	85.2	0.0	**967**
Unimproved pastures/woodland pastures	266.9	7.6	78.9	20.1	**373**
Rangeland/upland forests	2,482.3	473.1	819.1	527.2	**4,302**
Waters	61.6	0.0	1.8	1.4	**65**
Wetlands	1,782.3	253.3	574.5	322.6	**2,933**
Transportation/communication/utilities	0.0	0.0	0.0	0.0	**0**
Total	**5,532.5**	**793.8**	**1,599.5**	**886.9**	**8,813**

5.3 Data Used in the Determination of the TMDL

5.3.1 Meteorological Data

Hourly meteorological data for the Sikes Creek modeling were obtained from the Marianna station of the Florida Automatic Weather Network (FAWN), an observation platform owned by the University of Florida. This weather station is located at Marianna, in Jackson County, where the hourly meteorological data from 2002 to 2009 were recorded. **Table 5.3** summarizes information on the weather station, including periods of data availability and data collection frequency.

Table 5.3. General information on the Marianna weather station

This is a six-column table. Column 1 lists the location name (and identification), Column 2 lists the start date, Column 3 lists the end date, Column 4 lists the frequency, Column 5 lists the facility, and Column 6 lists the county.

Location Name (ID)	Start Date	End Date	Frequency	Facility	County
Marianna (130)	09/24/2002	Present	Hourly/daily	FAWN	Jackson
Marianna (MMA)	07/01/1946	Present	Daily	National Climatic Data Center (NCDC)	Jackson

The hourly meteorological data obtained from this station were included as follows: rainfall, solar radiation, wind speed, dewpoint temperature, and air temperature. Evaporation data and evapotranspiration (ET) rates are also an important factor in hydrologic balances and modeling, since they provide estimates of hydrologic losses from land surfaces and waterbodies within the watershed. Daily potential ET was also obtained from this weather station and computed later for hourly input data. Daily cloud cover was collected from an NCDC weather station at Marianna Municipal Airport, Jackson County.

Several gaps in the meteorological data were identified within the available period of record. If the period of record at a given station was missing data for a month or longer, the data from the closest station were used to complete the dataset. However, if data were missing for only a short period (i.e., days), the average, of the values from the day before and the day after were used to represent the data for the missing days.

Hourly meteorological data as inputs for HSPF were created using the weather data management (WMD) utility program that provides operational capabilities for the input time-series data necessary for HSPF. **Figure 5.1** shows selected time-series input data for hourly air temperature and wind speed. Observed time-series hourly annual rainfall for model input was also created, as shown in **Figure 5.2**. Total annual rainfall varied from 38.9 to 62.6 inches during the period from 2003 to 2008, with average annual rainfall of 51.15 ± 10.50 inches (**Figure 5.2**). The 6-year average rainfall at the Marianna station during this period is slightly lower than the state average (54.3 inches) in the same period and the 100-year state average rainfall (54.2 inches) (Southeast Regional Climate Center [SERCC], 2010). The deficiency in annual rainfall from the long-term average was significant in 2006 and 2007, when the annual rainfall recorded was 39.0 and 38.9 inches, respectively. As a result, the lowest flows in 2006 and 2007 were simulated, as shown in later sections.

5.3.2 Soil Data

Digital coverages and data of the soil characteristics identified in Jackson County, Florida, were obtained from the Soil Survey Geographic (SSURGO) database published by the Natural Resources Conservation Service (NRCS) and developed by the National Cooperative Soil Survey. Each soil type has been assigned to one of the four hydrologic soil groups (A, B, C, or D) established by NRCS and defined in the Soil Survey publication of Jackson County. Hydrologic Soil Group A comprises soils with a high infiltration potential in the range of 0.4 to 1.0 inch/hour and a low runoff potential (EPA, 2000). Hydrologic Soil Group D is made up of soils with a low infiltration potential in the range of 0.01 to 0.05 inches/hour and a high runoff potential. The other two categories fall between the A and D soil groups (EPA, 2000). Dual class soils (e.g., B/D) indicate that a hardpan or impermeable layer limits vertical infiltration. Soil type in the project area was estimated as Soil Group B, with a scatter distribution of Groups C and D.

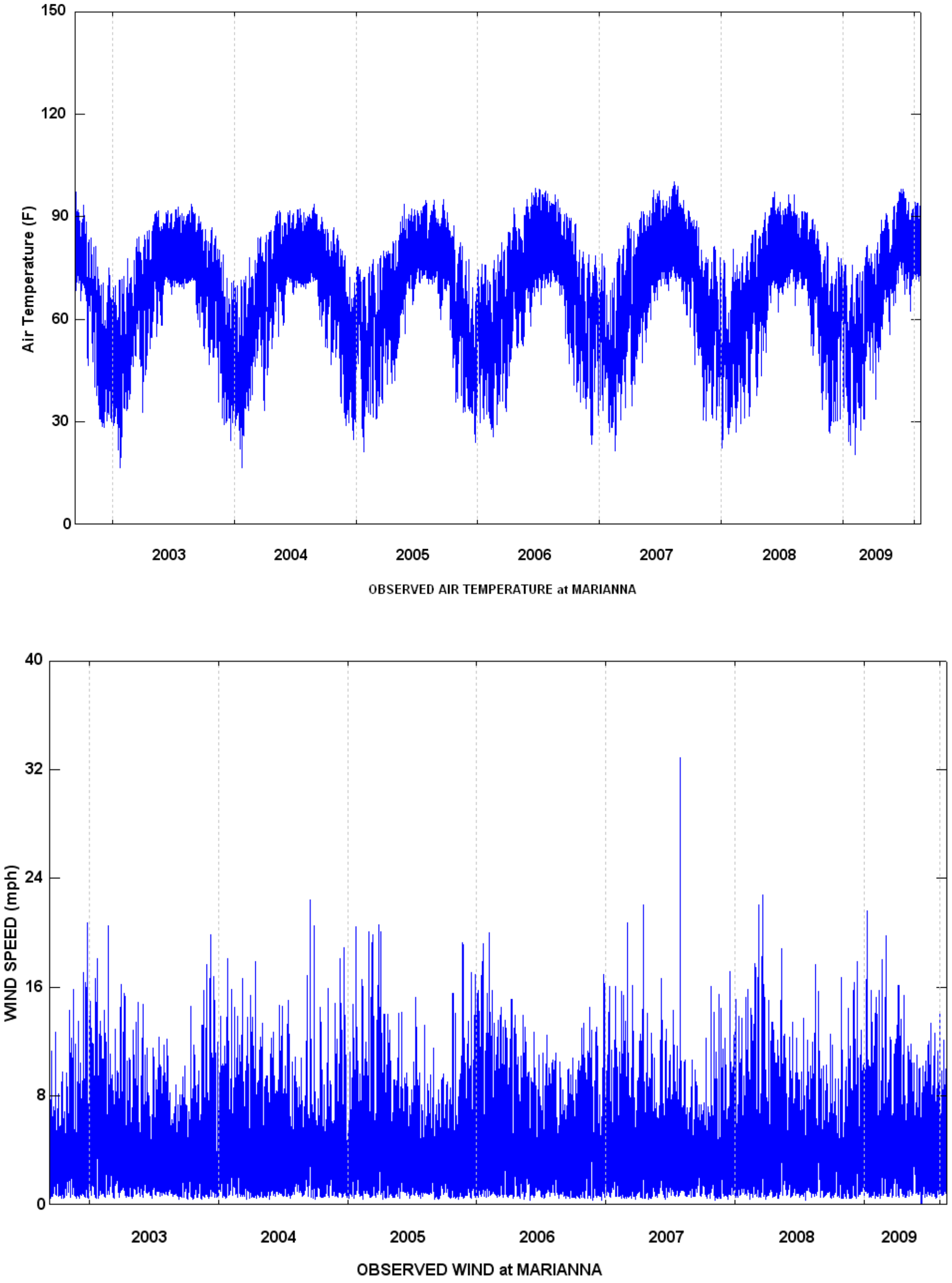
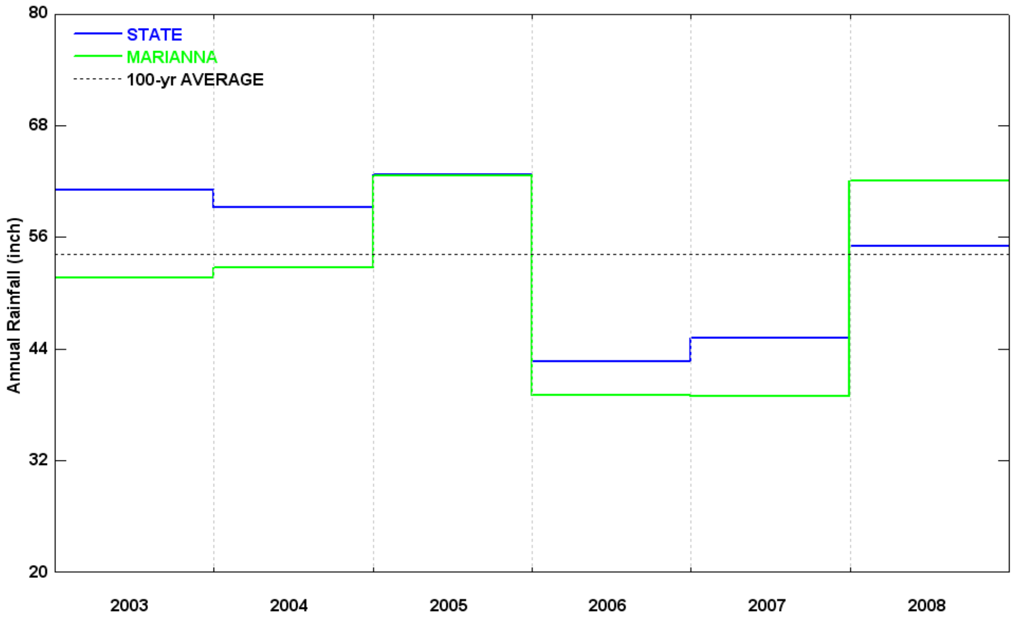


Figure 5.1. Hourly air temperature (top graph) and wind speed (bottom graph) observed from the Marianna weather station, 2002–09.



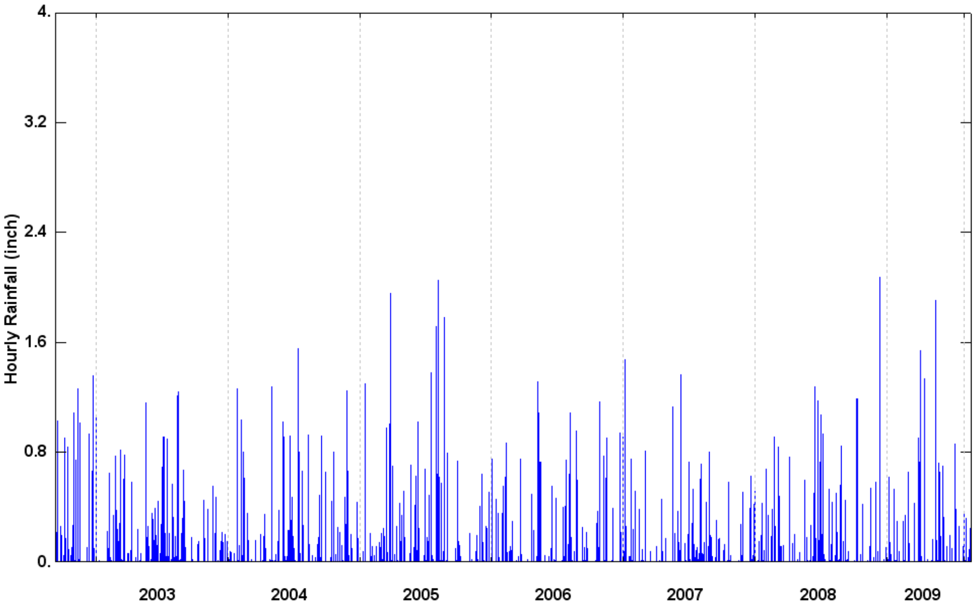


Figure 5.2. Annual rainfall (top graph) and hourly rainfall (bottom graph) observed from the Marianna station versus state average rainfall (top graph), 2003–08. The line with dots in the top graph represents 100-year annual average rainfall in Florida.

5.3.3 Cross-sectional Data

The FTABLE in HSPF was created using a depth-volume-area relation for Sikes Creek. The Department conducted field surveys for Sikes Creek on April 6, 2010, to measure cross-section and flow for each sub-basin (**Appendix B**). The obtained field data were incorporated into WinHSPF (EPA, 2007) to create FTABLEs for each reach using the automated standard method. The longitudinal slope of each reach was obtained from the BASINS stream GIS layer and the roughness coefficient, Manning's n, is set to a default value of 0.05. Surface area and volume in FTABLE are calculated based on the estimated stream geometry, and the outflow from each reach is calculated using Manning's equation.

As cross-sections were only measured at the ends of each model reach and the FTABLE for a reach must represent the average cross-section for the entire length of the reach, small adjustments were made during hydraulic calibration to the relationship between depth and flow to better represent the average cross-section. These adjustments were based on reviewing GIS data for changes in elevation and stream width within each reach. The adjustments improved model hydraulic stability at very low and high flows.

5.3.4 Water Quality Data

The Department provided the water quality data used for this TMDL report. **Figure 2.1** shows the locations of the water quality sites where data were collected. The photographs in **Figures 2.2** through **2.9** illustrate the characteristics of the individual locations where the water quality data were collected. **Table 5.6** contains the paired monthly mean data used to investigate the various relationships in the data, correlating BOD_5, TN, and TP to DO, and to develop Equation 1, which was used to establish the nutrient target concentration by relating TN to DO.

Numerous regressions were conducted on the data to examine the correlations between DO and TN, TP, and BOD_5. Prior to conducting the regression analysis, the data were screened for outliers using the JMP Version 8.0 statistical software programs—in particular, the Outlier portion of the Data Distribution Platform. **Figure 5.3** and **Table 5.4** depict the results for TN. The maximum TN value of 2.7 mg/L (measured at Station PN0114) was identified as an outlier using the JMP software. Given that this value is an outlier, it was not considered during either the regression analysis used to identify the nitrogen concentration that corresponds to a DO of 5.0 mg/L (nutrient target) or during the calibration of the HSPF Model used to establish the relationship between nutrient load reductions and resulting DO concentrations (allowable loads).

Figure 5.4 and **Table 5.5** depict the results for cchl*a*. The maximum cchl*a* value of 9.3 µg/L (measured at Station PN0114) was identified as an outlier using the JMP software. Given that this value is an outlier, it was not considered during either the regression analysis used to relate cchl*a* to DO or during the calibration of the HSPF Model used to establish the relationship between nutrient load reductions and resulting DO concentrations (allowable loads). In both cases, these values were in excess of three standard deviations above the mean.

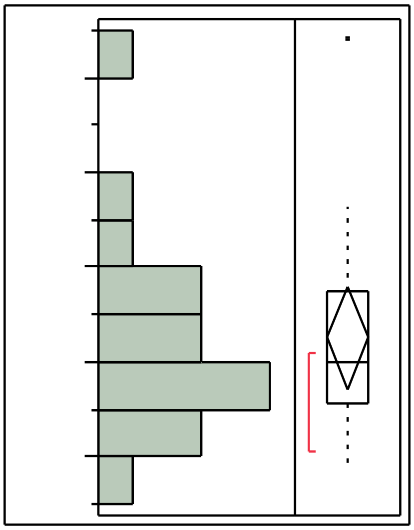


Figure 5.3. Outlier test for TN

Table 5.4. Outlier test for TN

- = Empty cell/no data

Percentile	Frequency Distribution	Value
100.0%	Maximum	2.70
99.5%	-	2.70
97.5%	-	2.70
90.0%	-	1.90
75.0%	Quartile	1.37
50.0%	Median	0.99
25.0%	Quartile	0.78
10.0%	-	0.52
2.5%	-	0.46
0.5%	-	0.46
0.0%	Minimum	0.46

Mean	1.12
Standard Deviation (Std Dev)	0.54
Standard Error of the Mean (Std Err Mean)	0.12
Upper 95% Mean	1.39
Lower 95% Mean	0.85
N	18

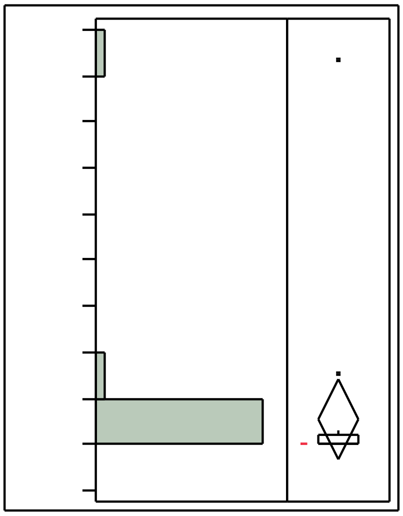


Figure 5.4. Outlier test for cchl*a*

Table 5.5. Outlier test for cchl*a*

Percentile	Frequency Distribution	Value
100.0%	Maximum	9.30
99.5%	-	9.30
97.5%	-	9.30
90.0%	-	2.39
75.0%	Quartile	1.20
50.0%	Median	1.00
25.0%	Quartile	1.00
10.0%	-	1.00
2.5%	-	1.00
0.5%	-	1.00
0.0%	Minimum	1.00

Mean	1.54
Std Dev	1.85
Std Err Mean	0.41
Upper 95% Mean	2.41
Lower 95% Mean	0.67
N	20

5.4 Regression Analysis and Establishment of the Nutrient TMDL Target

5.4.1 Results of Regression Analysis

As a result of using regression analysis on the data, it was determined that the majority of the impacts from BOD_5 on DO are a result of natural conditions and not linked solely to anthropogenic sources. **Tables 5.5** and **5.6** contain all the data used in the regressions (monthly averages) and summary statistics, respectively. As has been the case for over 20 years, the Department uses the 70th percentile concentrations of BOD_5 from STORET data collected from 1970 to 1987 as the target level where BOD_5 values below these concentrations will not cause or contribute to low DO conditions in the water. The documentation for this analysis is contained in the document *Typical Water Quality Values for Florida's Lakes, Streams and Estuaries* (Friedemann and Hand, 1989). The 70th percentile level for BOD in streams (including slough systems) is 2.0 mg/L.

In the case of Sikes Creek, both the mean (1.58 mg/L) and median (1.60 mg/L) BOD_5 are less than 2.00 mg/L and therefore are not expected to cause or contribute to the low DO measured in the creek. As can be seen in **Figure 5.5,** which relates changes in BOD to DO, the R^2 is only 0.13, indicating only a weak relationship between DO and BOD. Taken together with the low BODs measured in the system, BOD is not expected to be a significant contributor to the low DO measured. As shown in **Figure 5.6,** which relates changes in TP to DO, the R^2 is only 0.10 and indicates a weak relationship between DO and TP. Taken together with the low TPs measured in the system (mostly less than the detection limit of 0.02 mg/L), TP is not expected to be a significant contributor to the low DO measured. As shown in **Figure 5.7,** which relates changes in TN to DO, the R^2 is 0.42, indicating that TN accounts for 42 percent of the variance in DO. Taken together with the elevated TN concentrations measured in the system (uncorrected mean of 1.13 mg/L [includes all data]), TN is expected to be a contributor to the low DO measured and is the focus of the TMDL development.

Table 5.5. Regression data (DO, TN, BOD, and TP)

This is a five-column table. Column 1 lists the sampling date, Column 2 lists the regression data for DO, Column 3 lists the regression data for TN, Column 4 lists the regression data for BOD, and Column 5 lists the regression data for TP.

***** The TN monthly average for March, shown in boldface type and highlighted in yellow, was affected by the removal of the 2.7 mg/L outlier. Without the outlier removed, the average TN would be 1.13 mg/L.
- = Empty cell/no data

Date	DO	TN	BOD	TP
12/9/1992	8.4	0.4	-	0.03
3/10/1993	8.9	0.442	-	0.02
8/12/1993	3.3	0.809	-	0.055
2/16/1994	6.4	0.96	-	0.02
5/18/1994	3.1	0.72	-	0.022
8/23/1994	5.7	0.922	-	0.024
7/28/1998	2.96	0.527	1.7	0.021
2/12/2008	6.20	0.61	0.81	0.02
3/31/2008	5.29	**0.55 ***	0.89	0.03
4/23/2008	4.43	1.02	1.10	0.03
6/2/2008	2.79	-	0.72	0.03
7/21/2008	2.00	1.47	2.00	0.04
8/26/2008	4.51	1.35	1.66	0.03
10/6/2008	2.02	0.93	2.00	0.02
10/27/2008	4.26	-	-	-
11/18/2008	3.66	1.13	2.87	0.02
12/1/2008	4.80	0.88	2.30	0.02

Table 5.6 Summary statistics (DO, TN, BOD, and TP)

This is a four-column table. Column 1 lists the type of statistic, Column 2 lists the values for DO, Column 3 lists the values for TN, Column 4 lists the values for BOD, and Column 5 lists the values for TP.

- = Empty cell/no data

Statistic/ Parameter	DO	TN	BOD	TP
Monthly Target	**-**	**0.87**	**N/A**	**N/A**
Average	-	0.991	1.593	0.027
Std Dev	-	0.324	0.757	0.006
Coefficient of Variance (CV)	-	0.327	0.475	0.243

N/A is not applicable

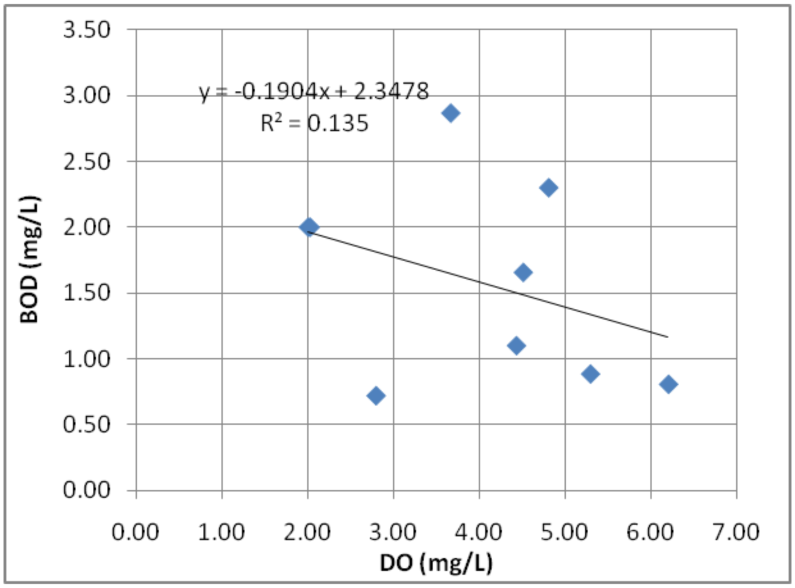


Figure 5.5. Regression of DO and BOD

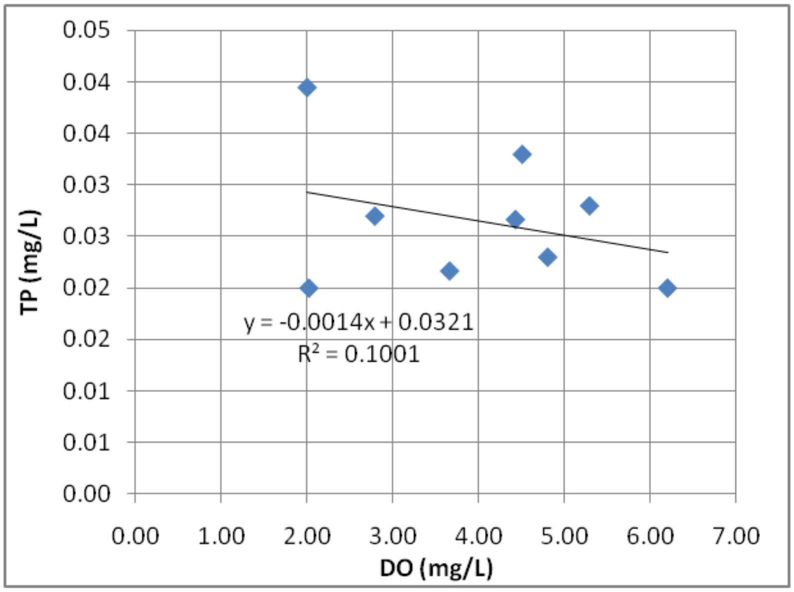


Figure 5.6. Regression of DO and TP

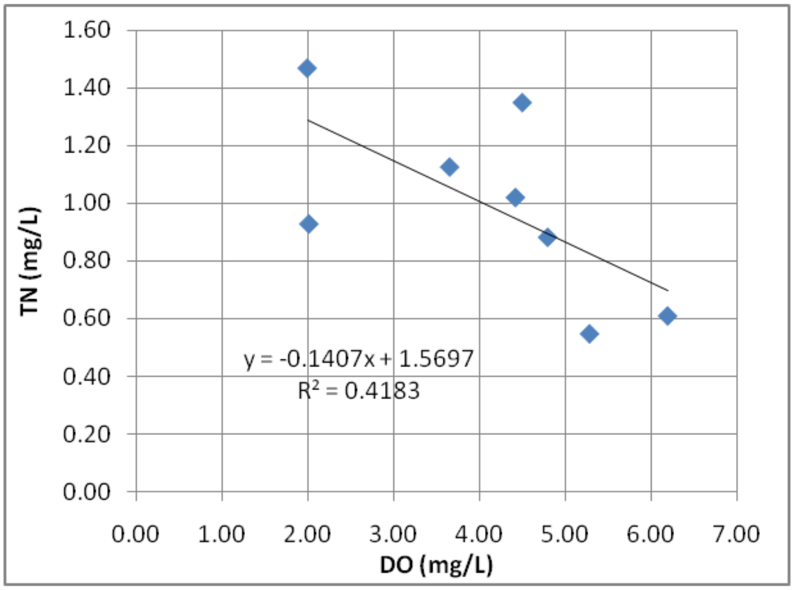


Figure 5.7. Regression of DO and TN

5.4.2 *Use of Regression Model To Develop TN TMDL Target*

The regression relating TN to DO was used to establish the TN target for TMDL development. Based on Equation 1, a TN of 0.87 mg/L as a monthly average should result in the creek meeting the DO criterion of 5.00 mg/L.

Equation 1: TN = (-0.1407*DO of 5.00) + 1.5697

or TN = 0.869 (0.87 mg/L)

As a part of developing the TMDL, a daily maximum TN concentration was developed to use as a reference for reducing TN during the use of the HSPF Model. To calculate the daily maximum TN that would result in compliance with a long-term TN concentration of 0.87 mg/L, the Department followed the guidelines and recommendations established by the EPA (EPA, 2006; 2007) to establish daily maximum concentrations from long-term averages.

Daily maximum concentration targets for TN were established using the following equation (EPA, 2006; 2007), which assumes that the data distributions are lognormal:

$\mathrm{MDL} = \mathrm{LTA} * \exp(Z_p \sigma_y - 0.5\sigma y^2)$

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

Where:

LTA = long-term average (0.87 mg/L);
Z_p = pth percentage point of the standard normal distribution, at 95% (Z_p = 1.645);
σ = standard deviation; and
CV = coefficient of variance.

Given the CV of 0.327 in **Table 5.6b**, the above equation resolves to a daily maximum TN of 1.39 mg/L.

The two nutrient targets for TN are a monthly average TN of 0.87 mg/L and a daily value not to be exceeded of 1.39 mg/L. The calibrated HSPF Model was used to establish the load reductions necessary to ensure that the TN did not exceed 0.87 mg/L as an average for any month or 1.39 mg/L as a daily value. The development of the TMDL to achieve the 0.87 mg/L for each month in the year instead of an overall monthly average is part of the margin of safety (MOS) for this TMDL.

5.5 HSPF Model Setup

The sub-basin delineation was conducted based on the location of water quality monitoring stations in the watershed, and the National Hydrography Dataset (NHD) reach information (EPA, 2007). Several studies indicated that an increase in the number of HSPF sub-basins may increase the accuracy of prediction of hydrologic routing and pollution loading by reducing standard errors and, at the same time, can benefit nonpoint source reduction programs by targeting key sub-basins for pollutant reduction (Jeffrey et al., 2009; Chang, 2009). Considering stream length and velocity, sub-basin size, modeling time steps, stream geometry measurements, and the ultimate goal of this report, the Sikes Creek watershed was subdivided into four hydrologically connected subbasins (connected to stream reaches) to provide a more realistic representation of the creek as it changes from headwaters to outlet. The physical dimensions of each reach were based on measurements made in the field in April 2010 (**Appendix B**).

During the field surveys, it was discovered that Sikes Creek below Station R1 (County Road 179) did not follow the path detailed on the NHD, and so the area between County Road 179 and the confluence of Sikes Creek with the Choctawhatchee River was not included in the model, as the hydrology of this area is in question. **Figure 5.8** depicts the Sikes Creek watershed, the four HSPF sub-basins and reaches included in the model, and the portions of the watershed downstream of Reach 1 not included in the model. The most upstream reach is identified as Reach 7 (R7), and the next downstream reach is Reach 3 (R3). Just below R3, a tributary to Sikes Creek enters as Reach 4 (R4), and the most downstream reach, or the outlet, at County Road 179, is referred to as Reach 1 (R1).

5.5.1 HSPF Model Calibration

While the model was set up using four reaches to improve the overall representation of the watershed, calibration was focused on the outlet (R1), as it had the most data and this downstream location is representative of all upstream loadings and in-stream processes. The model was set up to begin simulation in January 2003, and was run for several years to establish reliable antecedent conditions for surface runoff, interflow, and baseflow that would be used for calibration with the data collected in 2008. The water quality data collected in 2008 were used for calibration at the outlet of the model (R1).

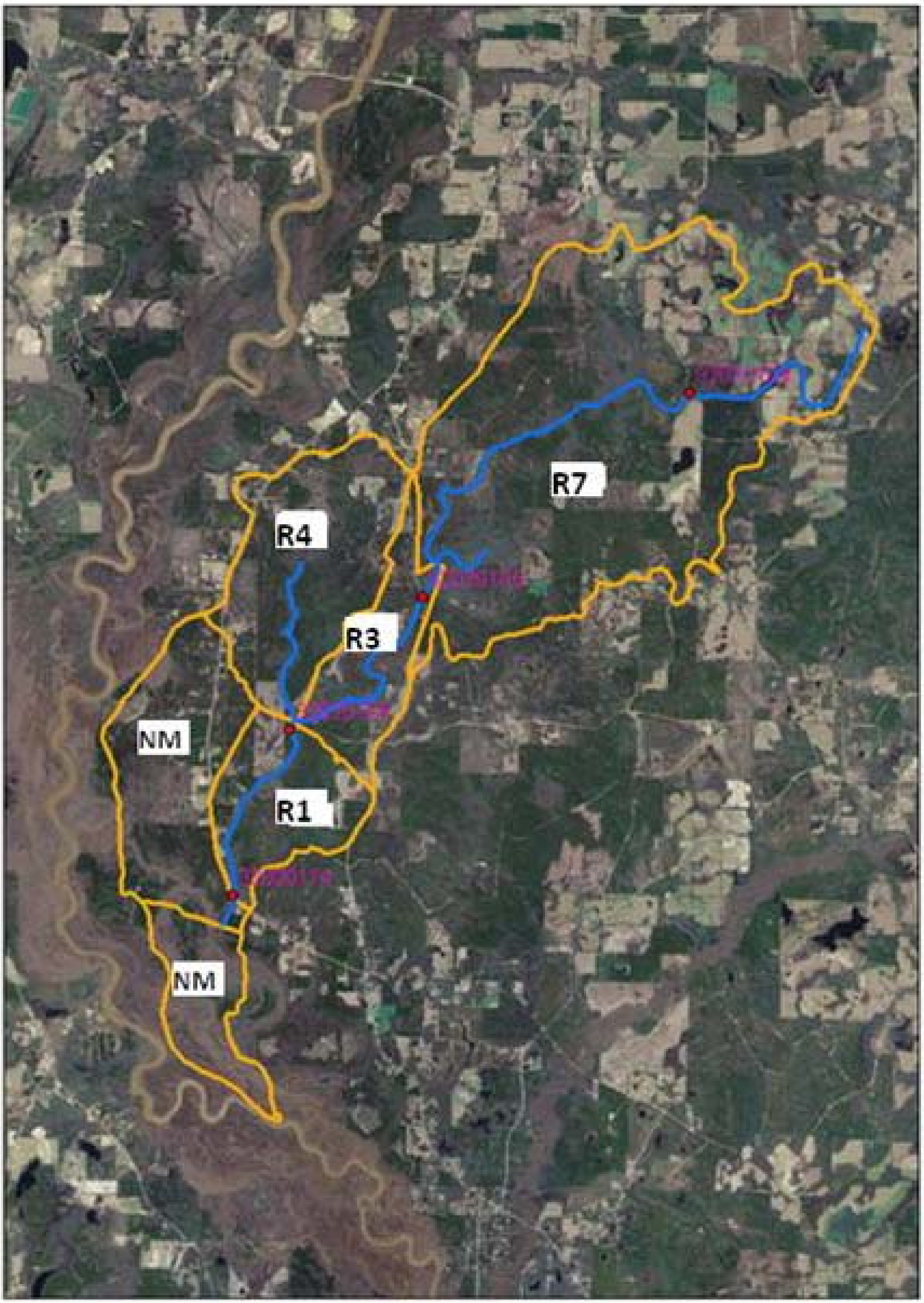


Figure 5.8. HSPF Model sub-basins and reaches

NM = Not modeled

5.5.2 HSPF Hydraulic Calibration

No flow data were available for Sikes Creek in 2008 (or before) for calibrating flow. The USGS maintains a flow station (USGS 02365470) in Wrights Creek (**Figure 5.9**), located about 7 kilometers to the east of Sikes Creek. Wright Creek's geology, land use, and topographic relief are similar to those of Sikes Creek, and thus it was determined to be suitable for use in calibrating the flow pattern for Sikes Creek. It should be noted that the area above the USGS gauge in Wrights Creek is substantially larger than the total area of Sikes Creek.

Calibration was achieved by iteratively adjusting the model parameters related to flow until the ***pattern*** in Sikes Creek matched that of Wrights Creek. **Figure 5.10** depicts the relationship between the measured flow at the USGS gauge in Wrights Creek and the local rainfall data used to drive the Sikes Creek model for the full model period (2003–09). **Figure 5.11** depicts the same information for 2008. **Figure 5.12** depicts the final calibration effort for the full model period, and **Figure 5.13** depicts the same information for 2008. Based on the comparative similarity in the flow patterns between the measured flow in Wrights Creek and the predicted flow for Sikes Creek, the model was considered satisfactorily calibrated for flow.

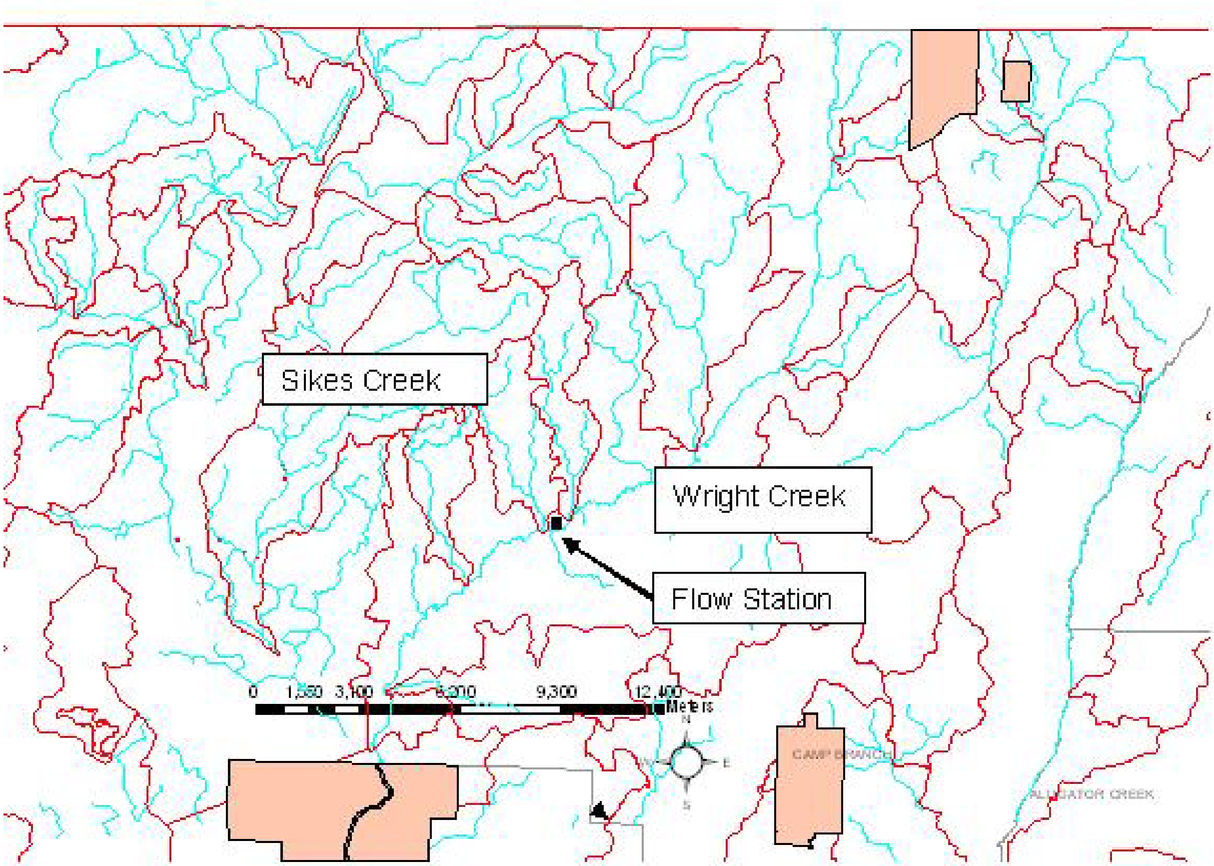


Figure 5.9. Wrights Creek and USGS Flow Station 02365470

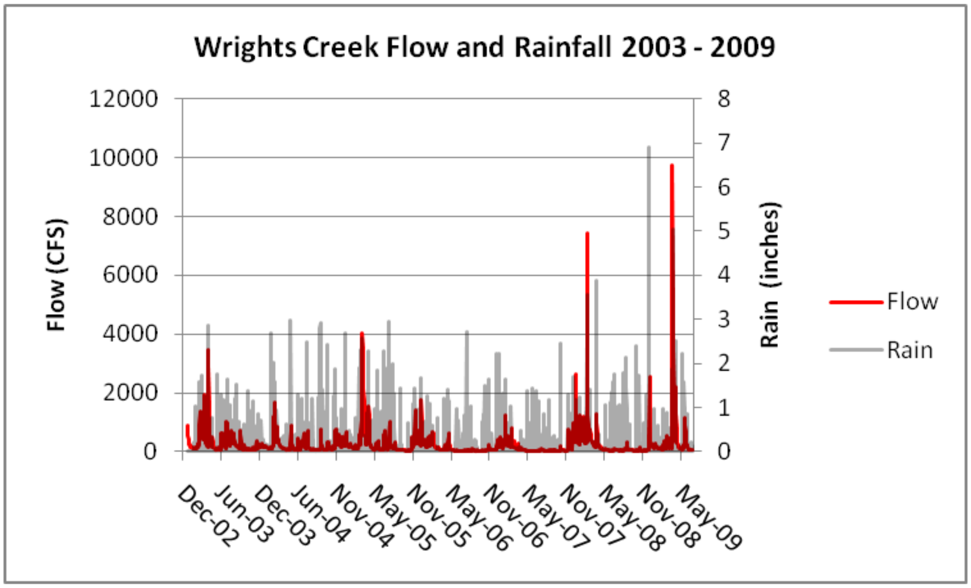


Figure 5.10. Wrights Creek flow and local rain, 2003–09

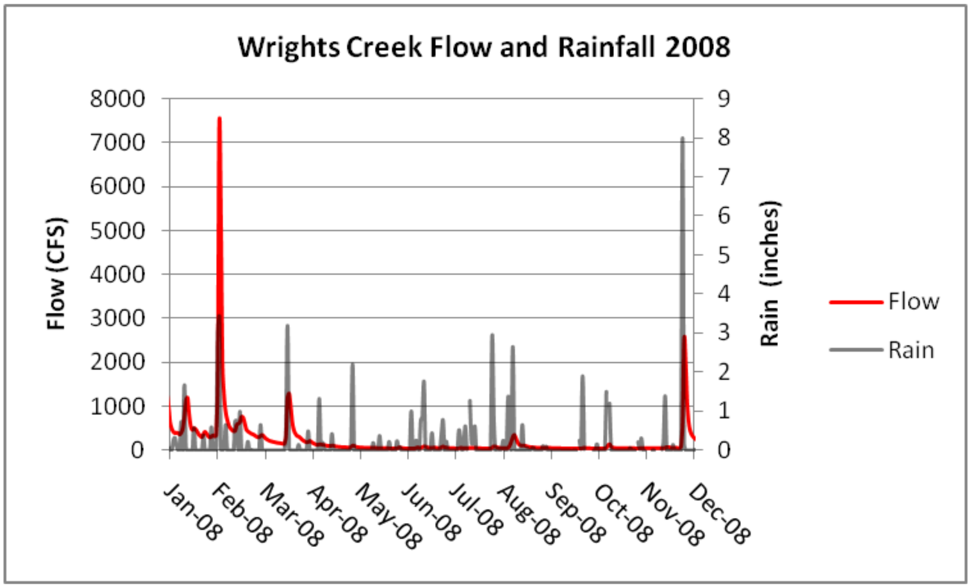


Figure 5.11. Wrights Creek flow and rainfall, 2008 (calibration year)

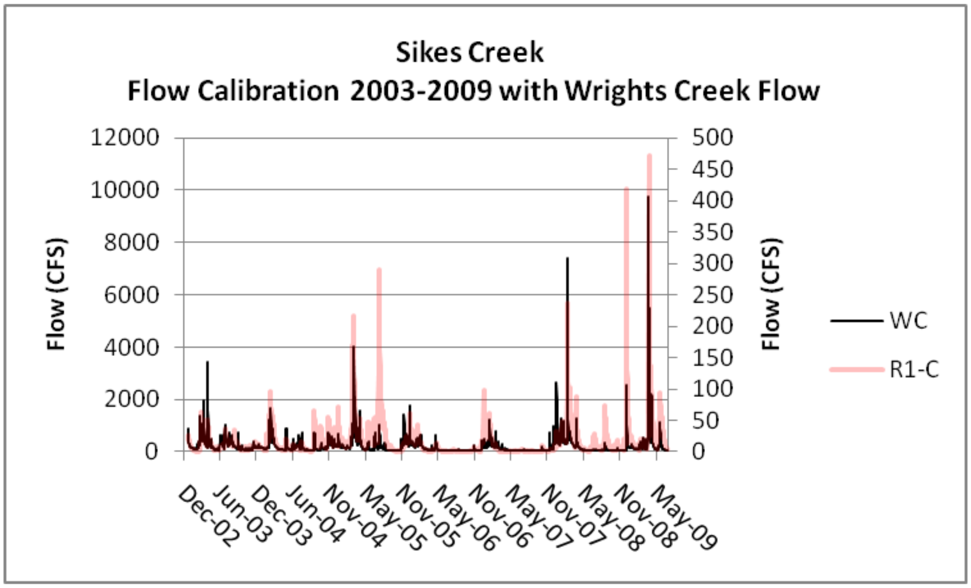


Figure 5.12. Flow calibration for Reach 1, 2003–09

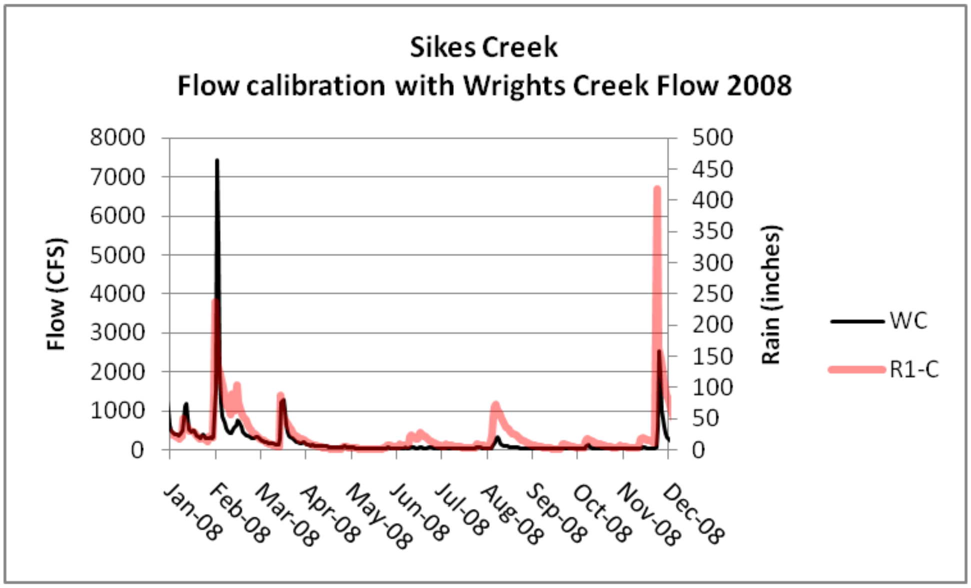


Figure 5.13. Flow calibration year, 2008

5.5.3 HSPF Water Quality Calibration

Water quality calibration consisted of adjusting model coefficients (**Table D.1** in **Appendix D**) until a visual “best-fit” was achieved between model predictions for the outlet (R1) of Sikes Creek and the measured data from the same location. After calibrations for nutrients, cchl*a*, and BOD were achieved, calibration for sediment oxygen demand (SOD) was refined by adjusting the initial SOD of 62.4 milligrams per square meter per hour ($mg/m^2/hr$) in the model until the difference between the measured DO and predicted DO for R1 was minimized. This resulted in an SOD of 54.1 $mg/m^2/hour$, which in combination with the calibrated results for nutrients best represented the DO measured in Sikes Creek.

Calibration for BOD is complicated, as the model predictions are for ultimate carbonaceous BOD (uCBOD), and the measured data are for BOD after only 5 days (BOD_5). Five-day BOD results are generally considered to only represent the carbonaceous portion of total BOD (nitrogenous and carbonaceous). Due to these differences between model predictions and measured data, the BOD_5 measured data must be converted to BOD ultimate (BOD_u) for comparison. The observed BOD_5 concentrations were converted to BOD_u by multiplying by 1.40 (Chapra, 1997). This value is based on a first-order decay rate of 0.25/day, which is considered typical for natural stream conditions.

TP Results

The results for the TP calibration are shown in **Figure 5.14** for 2003 to 2009, and in **Figure 5.15** for 2008. **Figure 5.14** illustrates that the model predictions for TP are stable throughout the model run time, and the recurring seasonal pattern is reflective of the measured data, as seen in **Figure 5.15**. In **Figure 5.15**, each measured data point is plotted against the model prediction for 2008. There were 9 data points available for calibration, of which 4 were reported as less than detection (0.02 mg/L). The model predictions follow the pattern and magnitude of the measured data, and if the predicted results that were less than the detection limit (0.02 mg/L) were plotted at the detection limit, these points would also be consistent with the measured data. Based on these results, the model was considered calibrated for TP.

As previously discussed for the measured TP data and for the regression analysis results, phosphorus is not significantly related to DO and is not present in concentrations that should cause or contribute to any lowering of DO, and Sikes Creek will not require a TP nutrient TMDL.

TN Results

The results for the TN calibration are shown in **Figure 5.16** for 2003 to 2009 and **Figure 5.17** for 2008. **Figure 5.16** illustrates that the model predictions for TN are stable throughout the model run time, and the recurring seasonal pattern is reflective of the measured data, as seen in **Figure 5.17**. In **Figure 5.17**, each measured data point is plotted against the model prediction for 2008. There were 7 data points available for calibration (recall that the 2.7 mg/L outlier was not considered a calibration point). The model predictions generally match the pattern of the measured data, except for the outlier value previously discussed. Based on these results, the model was considered calibrated for TN. As reported previously for the measured TN data and while discussing the results of the regression analysis, nitrogen is related to DO and is present in concentrations that could cause or contribute to a lowering of DO, and thus the creek will require a TN nutrient TMDL.

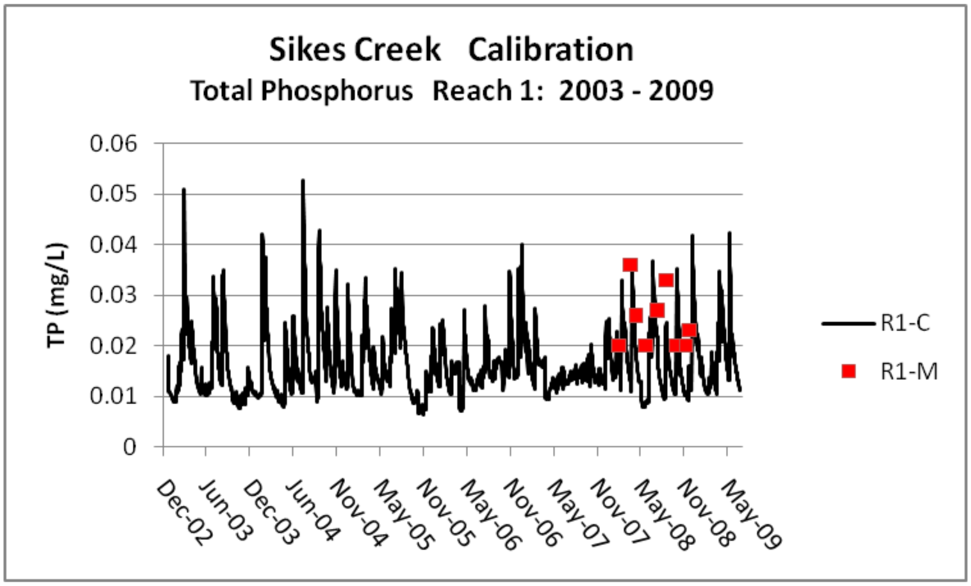


Figure 5.14. TP model results, 2003–09, with 2008 calibration data

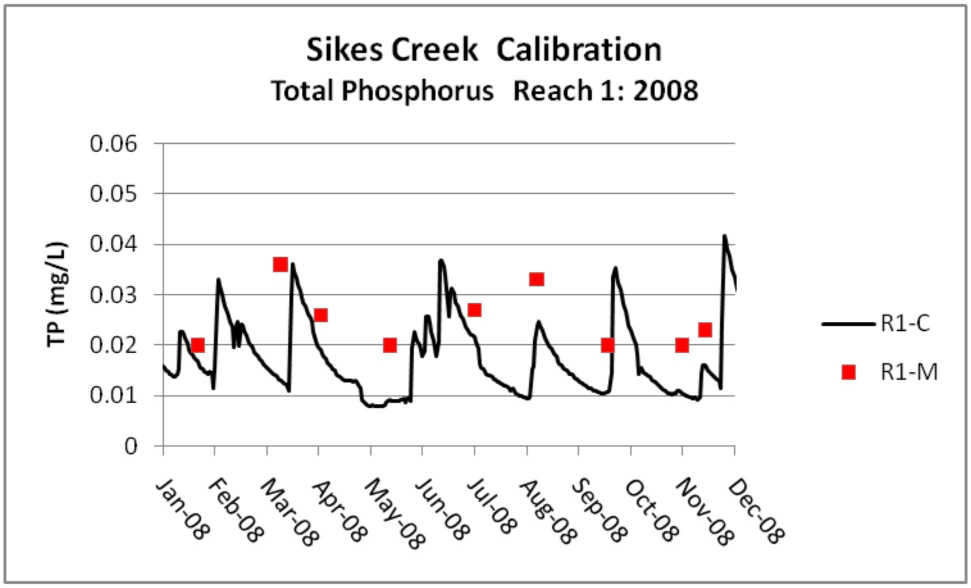


Figure 5.15. TP calibration for Reach 1, 2008

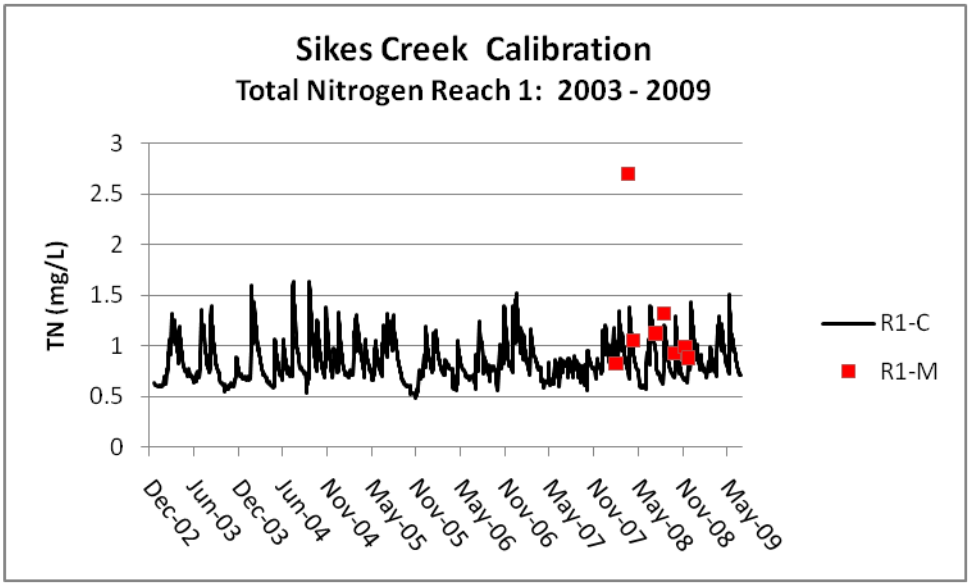


Figure 5.16. TN model results, 2003–09, with calibration data (includes 2.7 mg/L outlier)

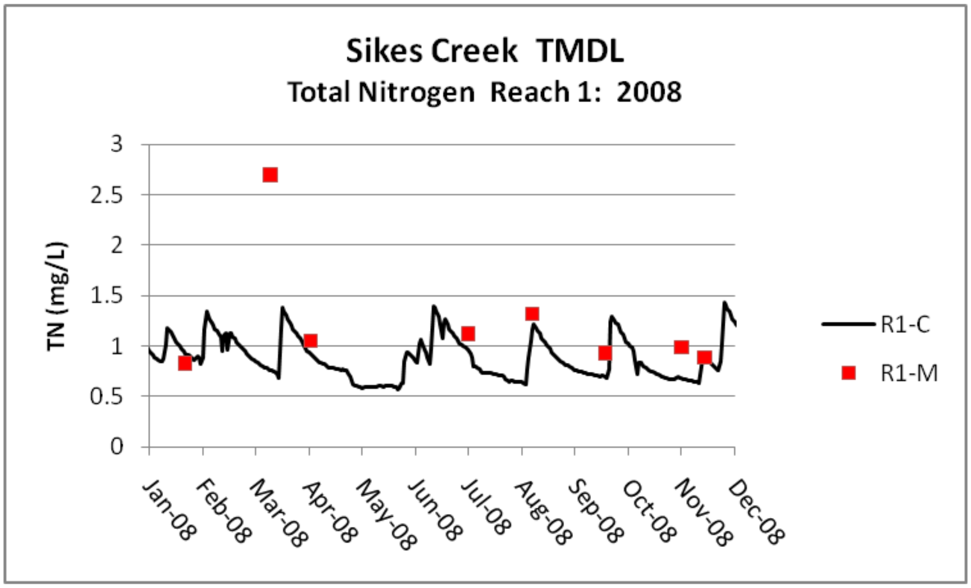


Figure 5.17. TN calibration for Reach 1, 2008 (includes 2.7 mg/L outlier)

Cchl*a* Results

The results for the cchl*a* calibration are shown on **Figure 5.18** for 2003 to 2009 and **Figure 5.19** for 2008. **Figure 5.18** illustrates that the model predictions for cchl*a* are stable throughout the model run (except for the first modeled month in 2003). Subsequent to an initial startup period, the recurring seasonal pattern reflects a summer growing season, as seen in **Figure 5.18. Figure 5.19** shows each measured data point plotted against the model prediction for 2008. There were 8 data points available for calibration (recall that the 9.3 µg/L value was identified as an outlier). Of these, 7 were at the limits of detection (1.0 µg/L). The model predictions for each of these points are also less than the method detection limit and this indicates that the model predictions for cchl*a* are reasonable. If the model predictions that are less than detection are plotted as the detection limit (1.0 µg/L) these points would also be consistent with the measured data. Based on these results, the model was considered calibrated for cchl*a* . As previously discussed for the measured cchl*a* data and for the regression analysis results, cchl*a* is not significantly related to DO and is not present in concentrations that should cause or contribute to any lowering of DO, and thus the creek will not require a separate cchl*a* TMDL.

BOD_5 Results

The results for the BOD_u calibration are shown in **Figure 5.20** for 2003 to 2009 and **Figure 5.21** for 2008. **Figure 5.20** illustrates that the model predictions for BOD_u are stable throughout the model run (except for the first few months in 2003). There were nine data points available for calibration, and **Figure 5.21** shows each measured data point plotted against the model prediction. As shown, the model appears to very accurately reproduce the measured data. Based on these results, the model was considered calibrated for BOD_u. As previously discussed for the measured BOD_5 data and for the regression analysis results, BOD_5 is not significantly related to DO and is not present in concentrations that should cause or contribute to any lowering of DO, and thus the creek will not require a separate BOD_5 TMDL.

DO Results

The results for the DO calibration shown in **Figure 5.22** for 2003 to 2009 and **Figure 5.23** for 2008. **Figure 5.22** illustrates that the model predictions for DO are stable throughout the model run. The model predictions of a recurring seasonal pattern reflective of a summer growing season, with annual summer DOs predicted as less than the 5.0 mg/L criterion, are consistent with the measured data**. Figure 5.23** shows each measured data point plotted against the model prediction for 2008. There were 10 data points available for calibration. As seen in **Figure 5.23**, the model was generally able to reproduce both the pattern and magnitude of the measured data with two exceptions: it was not able to match the 2 lowest DOs measured. Attempts to force the model to match these two low DO values during calibration resulted in an overall worse calibration.

In this case, in order to get the model to match these 2 low values, it grossly under predicted DO for the rest of the year. In general, if a model is correctly matching the majority (8 of 10 data points), forcing it to fit the lowest or highest data points is not recommended. Based on these results, the model was considered calibrated for DO. As stated previously, Sikes Creek is impaired for DO, and the creek requires the development of a TMDL for the causative pollutant (TN).

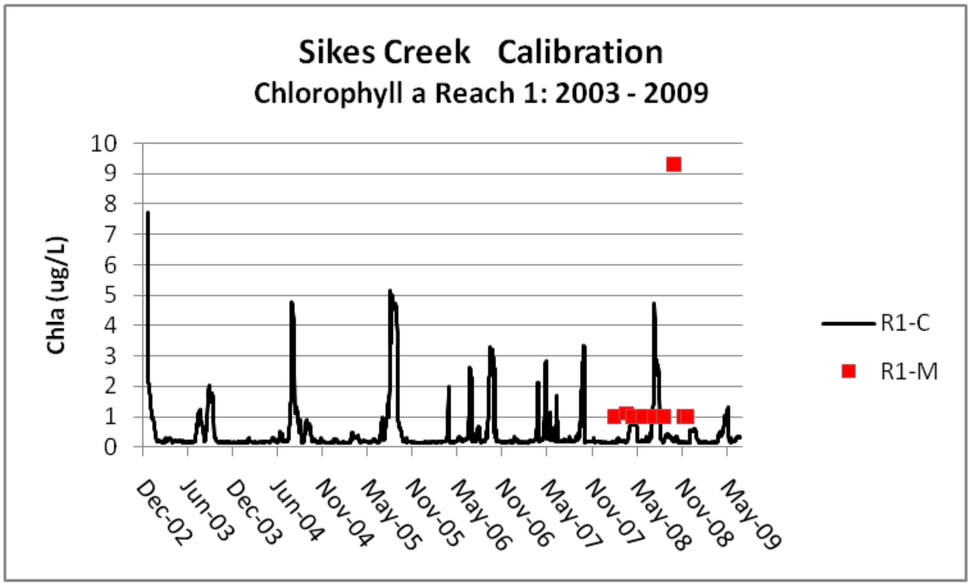


Figure 5.18. Cchl*a* model results, 2003–09 with calibration data (includes 9.3 µg/L outlier)

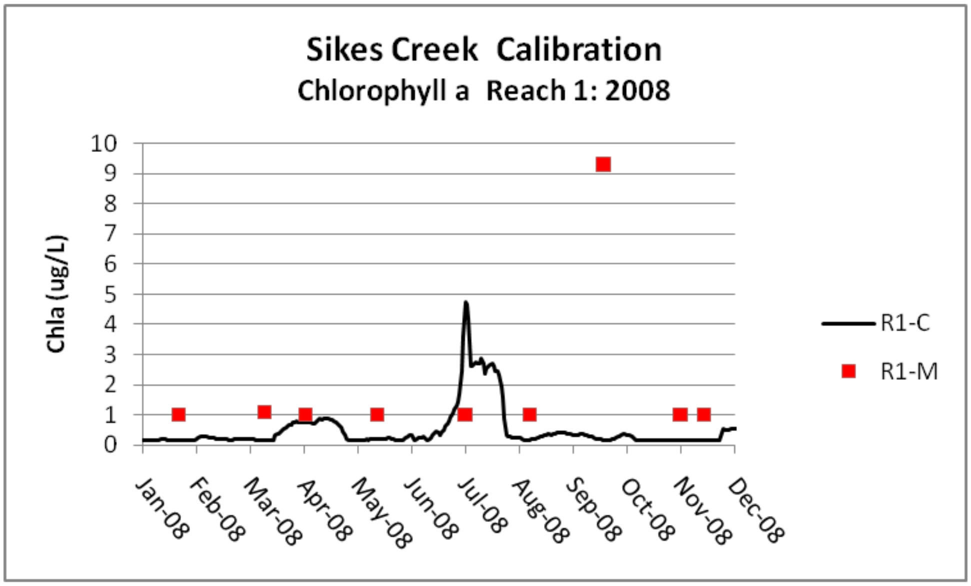


Figure 5.19. Cchl*a* calibration for Reach 1, 2008 (includes 9.3 µg/L outlier)

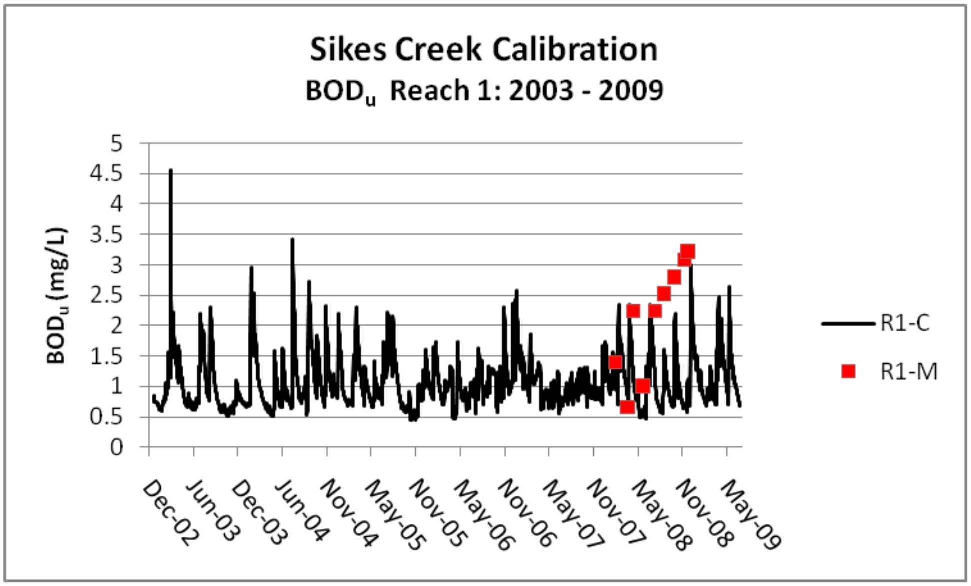


Figure 5.20. BOD_u model results, 2003–09, with calibration data

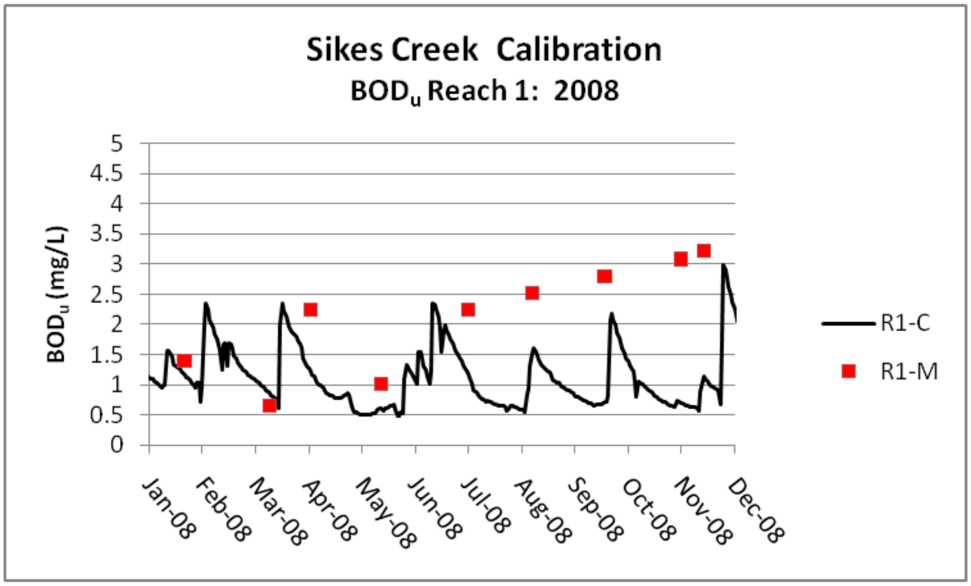


Figure 5.21. BOD_u calibration for Reach 1, 2008

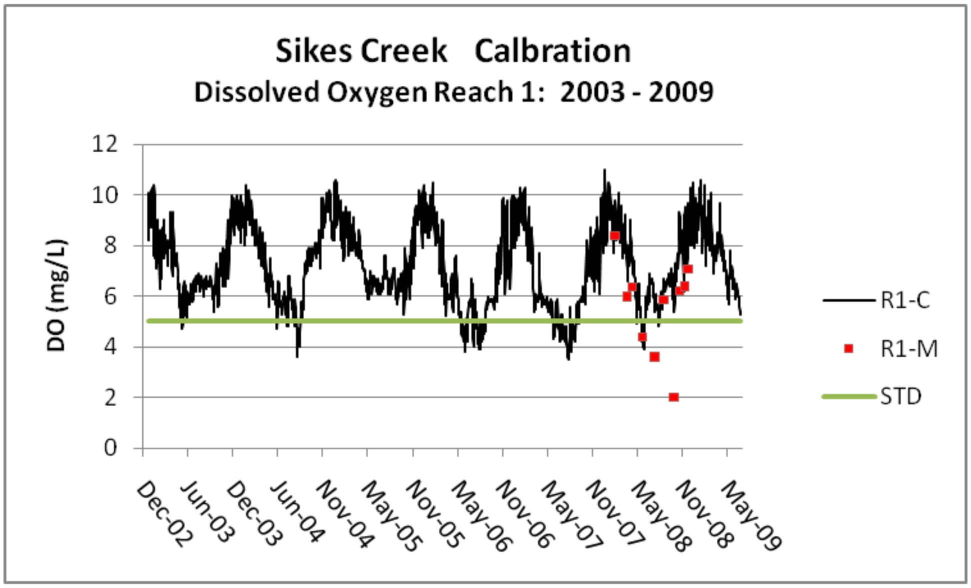


Figure 5.22.DO model results, 2003–09, with calibration data

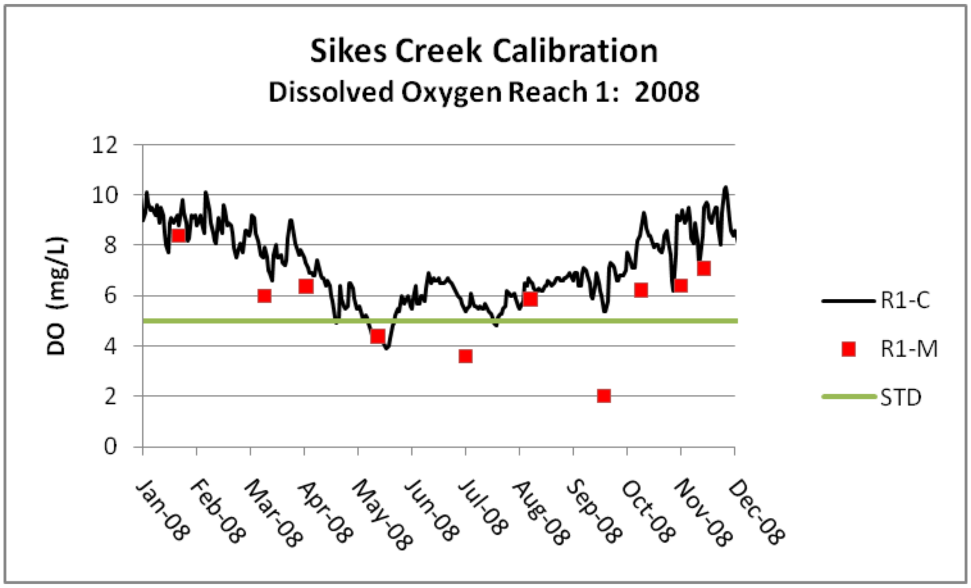


Figure 5.23.DO calibration for Reach 1, 2008

5.6 HSPF TMDL Development

As discussed above, the three targets for development of the TMDL were to achieve TN concentrations below 1.39 mg/L for each day, TN concentrations less than 0.87 mg/L for each month, and DO concentrations above 5.0 mg/L. The changes made to the calibrated model in order to achieve these endpoints were to iteratively reduce the loading of TN from the total watershed (for the TMDL, no load reductions were made for water or wetland land uses). This was accomplished by reducing the values for sediment composition in HSPF (PWATER ISED 1, 2, 3) and values for organic nitrogen, ammonia nitrogen, and nitrate nitrogen (PQUAL 2, 3, and 5 respectively). In addition, a 40 percent reduction in SOD was implemented in the model, based on a recommendation from EPA Region 4 modeling staff (T. Wool, personal communication, 2010). The EPA recommendation is based on its experience using a sediment diagenesis model to calculate the relationship between reductions in nutrients (and corresponding changes in carbon flow through the watershed) and ultimate changes in SOD.

5.6.1 HSPF TMDL Results

After the TMDL was developed from the calibrated model, the existing (calibrated) loads of TN delivered from each of the model sub-basins to the creek were tabulated. As applied in HSPF, a final 16 percent reduction in ***total*** watershed loading was required to achieve water quality standards (recall that the watershed only has 2 percent nonforested/wetland land uses). Because no reductions were made for wetlands or water, the reduction from land uses with potential anthropogenic loading was set at 24 percent in order to achieve an overall reduction from the entire watershed of 16 percent. **Figures 5.24** through **5.39** present the results for each parameter**.**

The TP results at R1 (model outlet) for both the calibrated model and the TMDL condition are presented in **Figure 5.24** (2003–09) and in **Figure 5.25** for 2008. As expected, these graphs illustrate that the reductions in TN did not produce any change in TP concentrations.

The BOD results at R1 for both the calibrated model and the TMDL condition are presented in **Figure 5.26** (2003–09) and **Figure 5.27** for 2008. Similarly, these graphs illustrate that the reductions in TN did not produce any change in BOD concentrations.

The cchl*a* results at R1 for both the calibrated model and the TMDL condition are presented in **Figure 5.28** (2003–09) and **Figure 5.29** for 2008. These graphs illustrate that the reductions in TN resulted in some reduction in cchl*a*, particularly during the growing season, when peak concentrations were reduced from about 5.0 to about 2.0 µg/L. These predicted reductions in cchl*a* during the growing season may result in minor improvements to the DO regime. **Figure 5.30** depicts the results for the average from all four model reaches and illustrates that as the model average is lower than the concentrations at the outlet, upstream cchl*a* concentrations are lower (on average) than the concentrations at the outlet.

The TN results at R1 for both the calibrated model and the TMDL condition are presented in **Figure 5.31** (2003–09) and **Figure 5.32** for 2008. These graphs illustrate that the reductions in TN resulted in compliance with both TN targets. **Figure 5.31** shows that the 1.39 mg/L TN daily maximum is not exceeded on any day (2003–09). **Figure 5.32** illustrates that the daily maximum is not exceed during the year of data collection (2008). **Figure 5.33** compares the daily maximum TN at the outlet (R1) to the model average. This figure illustrates that both the model average and the concentration at the outlet meet the daily maximum target. **Figure 5.34** depicts the results for the long-term (2003–09) monthly averages for both R1 and the model average. These results indicate that the monthly average of 0.87 mg/L is not exceeded. **Figure 5.35** depicts the same data for 2008 and also illustrates that both the model average and R1 meet the monthly average TN of 0.87 mg/L.

Figure 5.36 presents the DO results (2003–09) at R1 for both the calibrated model and the TMDL condition. This graph illustrates that during each growing season, the calibrated model predicts recurring episodes of DO less than the criterion (5.0 mg/L) and that the TN TMDL results in compliance with the 5.0 mg/L DO criterion. **Figure 5.37** shows the same information for the model averages with the same result, with all DO concentrations above 5.0 mg/L. **Figure 5.38** presents the DO results at R1 for both the calibrated model and the TMDL condition for 2008. The graphic illustrates that the calibrated model predicted DO exceedances for the current condition and no exceedances after the TMDL was implemented. **Figure 5.39** depicts the same data for 2008 and also illustrates that for the model average, the DO criterion is achieved.

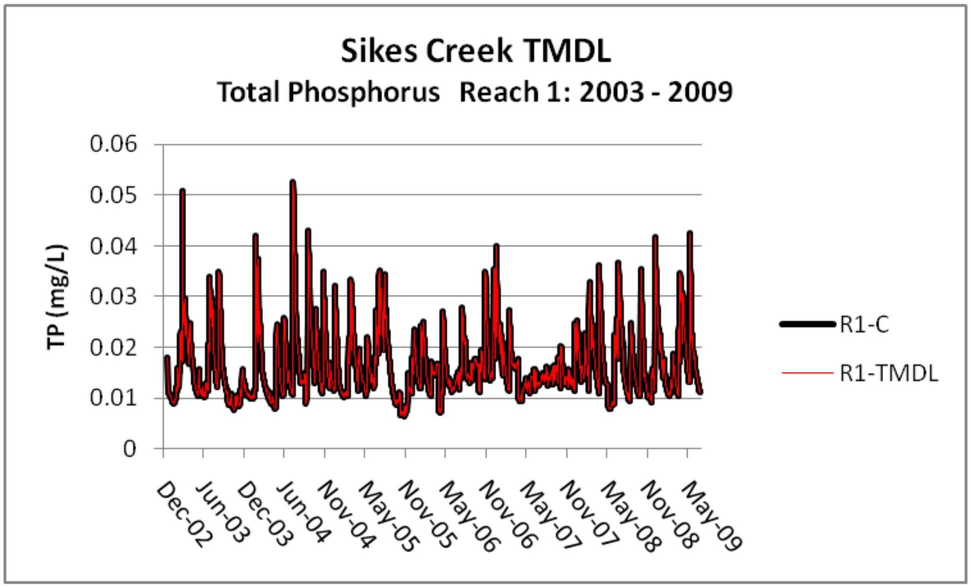


Figure 5.24. TP TMDL for Reach 1, 2003–09

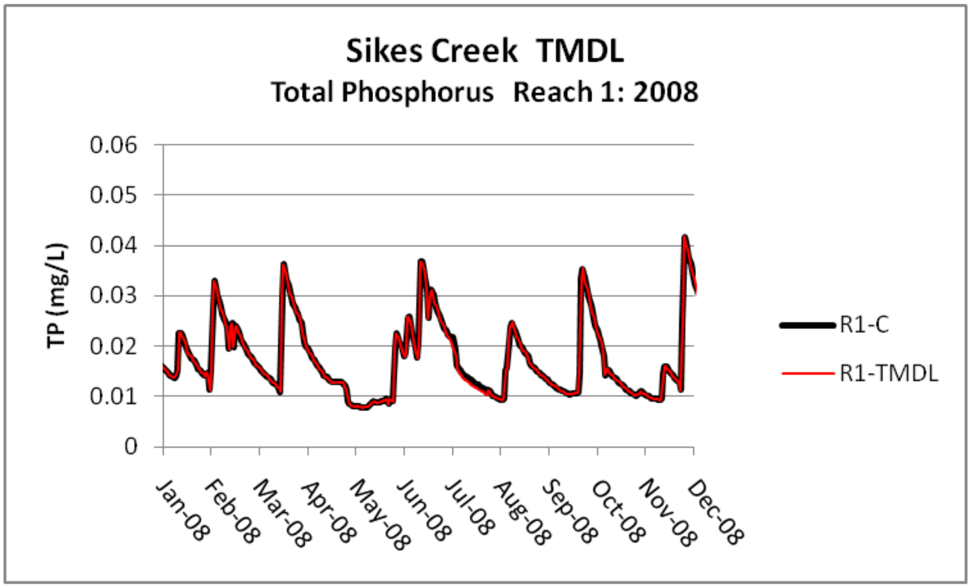


Figure 5.25. TP TMDL for Reach 1, 2008

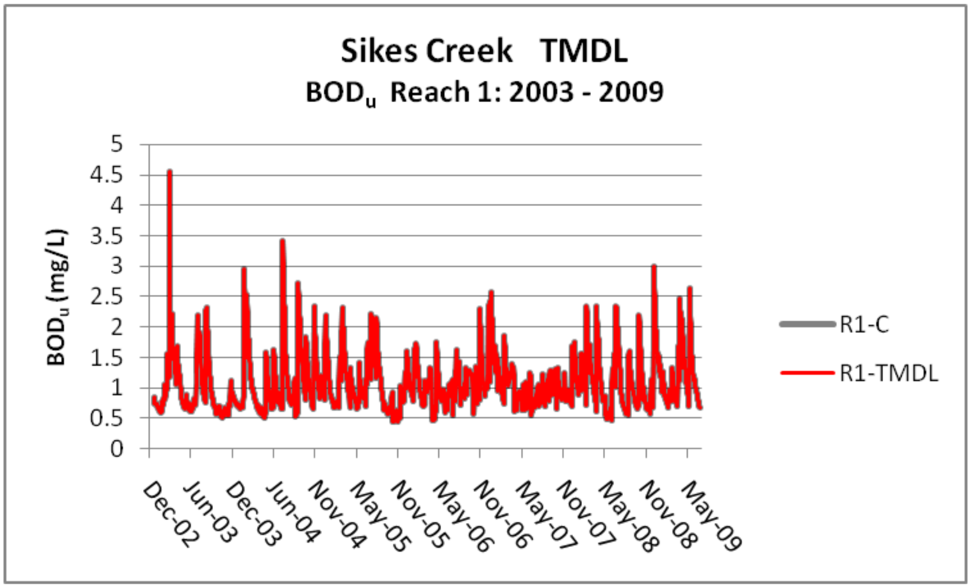


Figure 5.26. BOD$_5$ TMDL for Reach 1, 2003–09

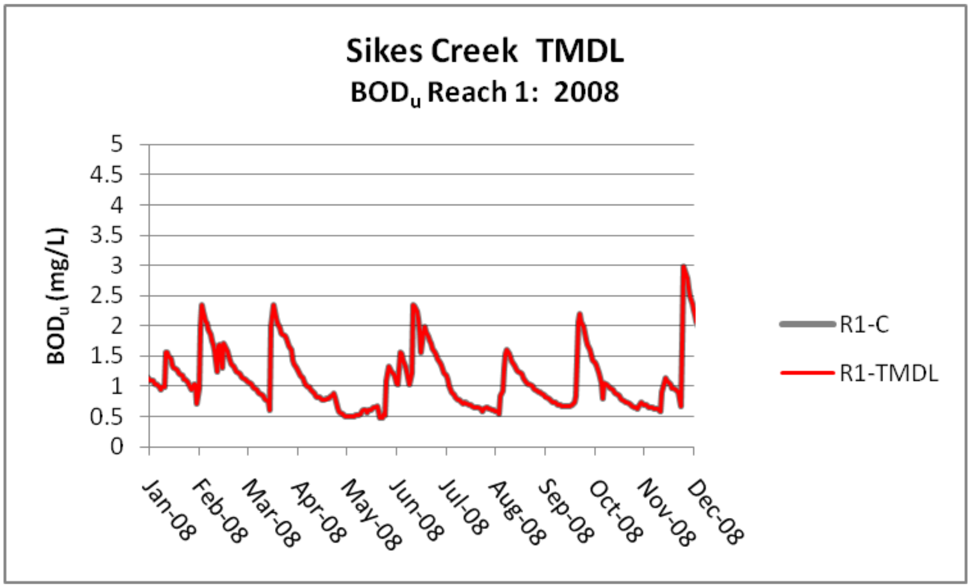


Figure 5.27. BOD$_5$ TMDL for Reach 1, 2008

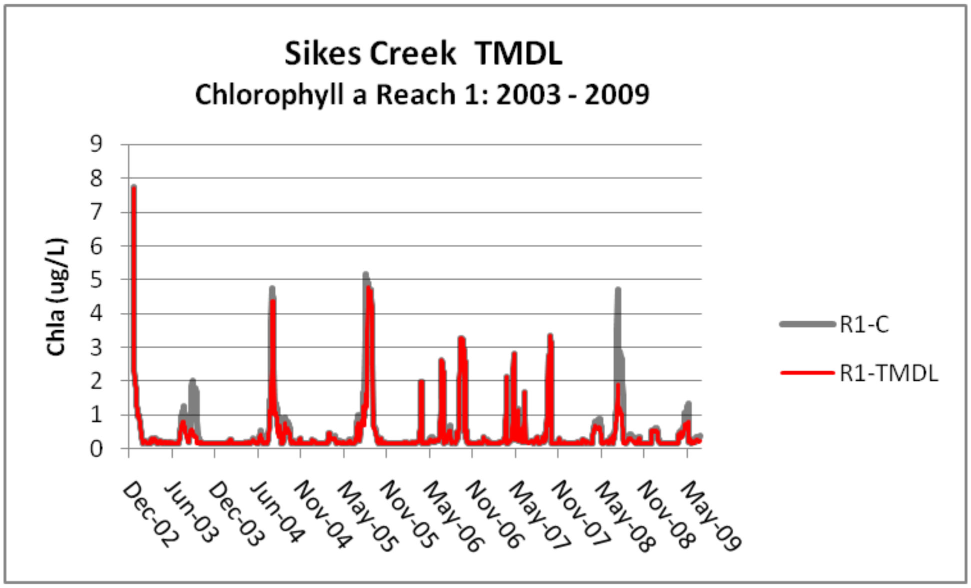


Figure 5.28. Chl*a* TMDL for Reach 1, 2003–09

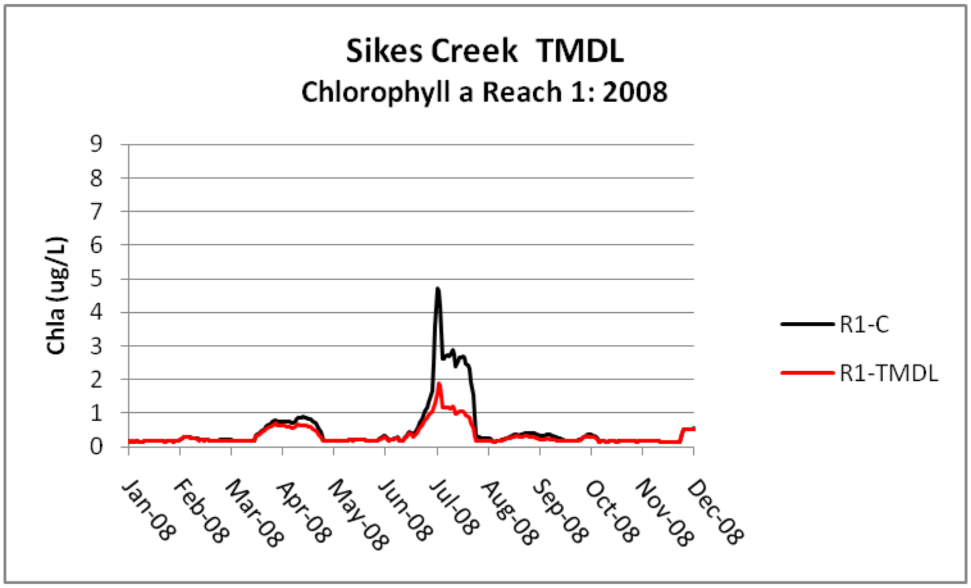


Figure 5.29. Chl*a* TMDL for Reach 1, 2008

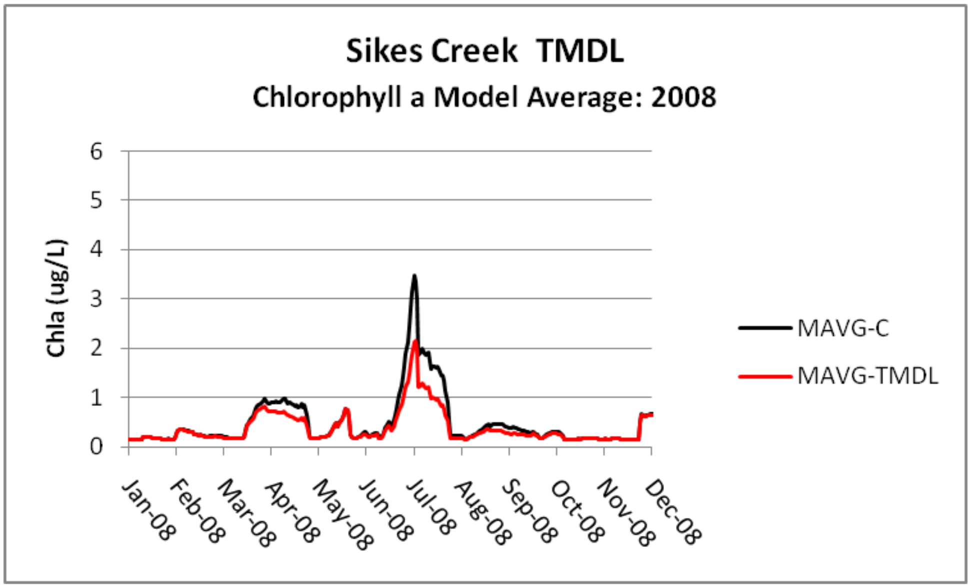


Figure 5.30. Chl*a* TMDL model average for all reaches, 2008

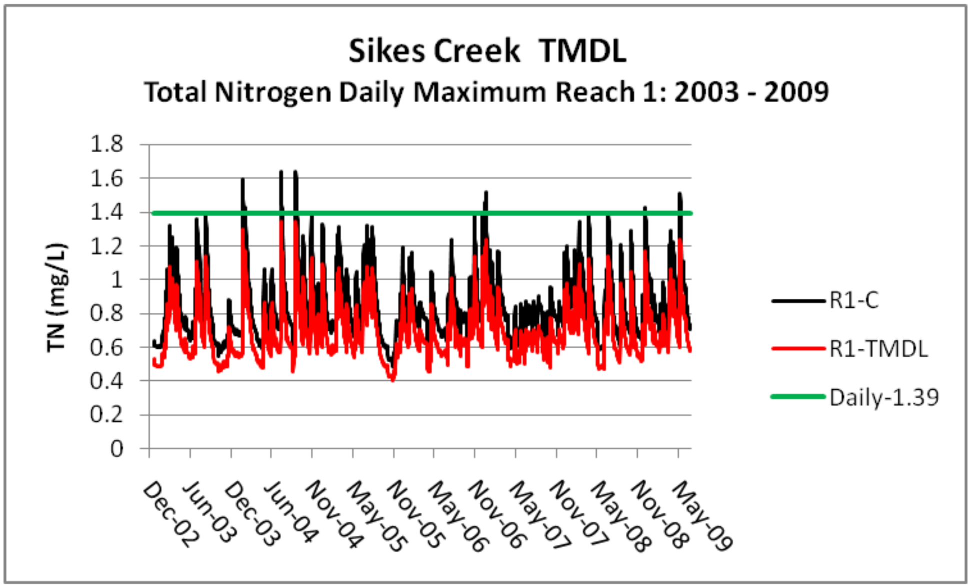


Figure 5.31. TN TMDL daily maximum for Reach 1, 2003–09

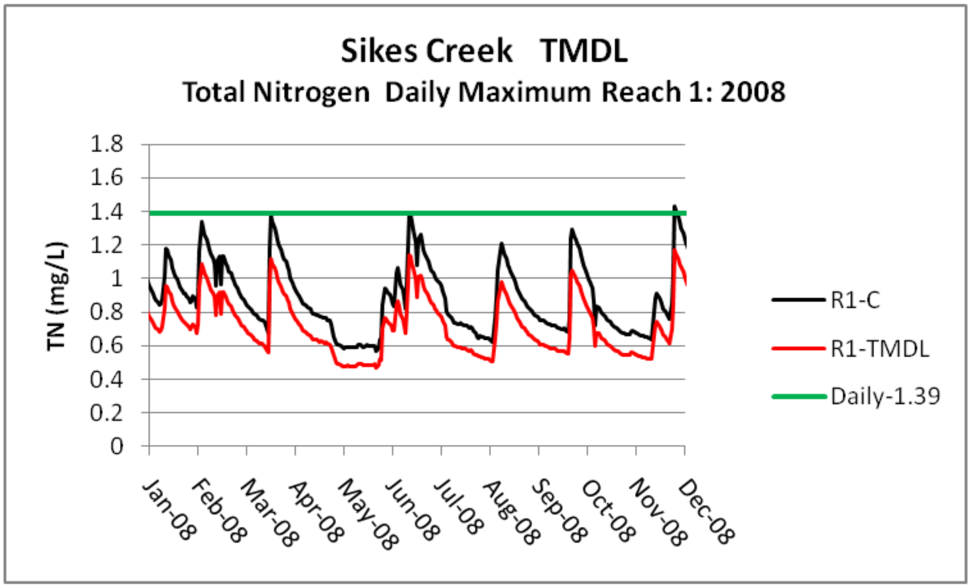


Figure 5.32. TN TMDL daily maximum for Reach 1, 2008

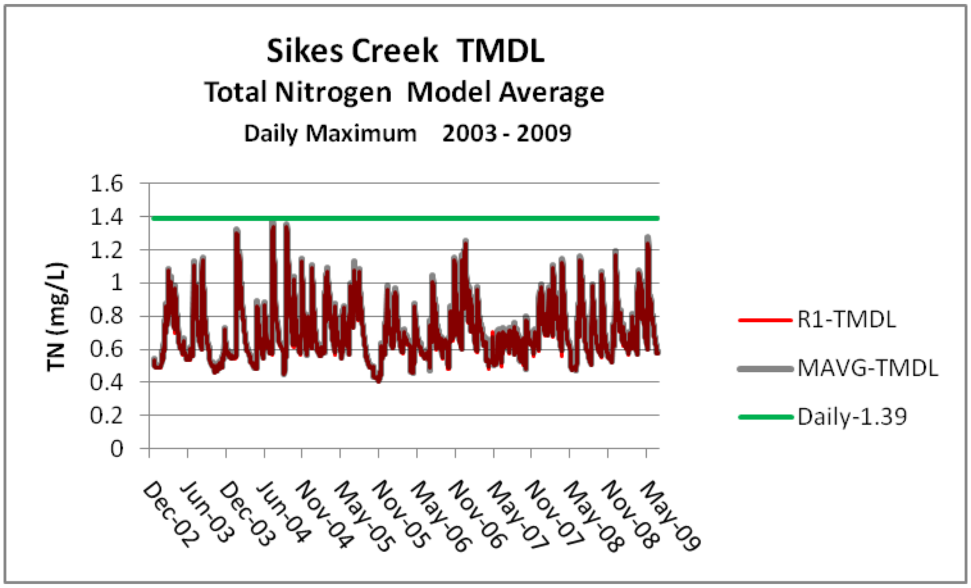


Figure 5.33. TN TMDL daily maximum model average, 2003–09

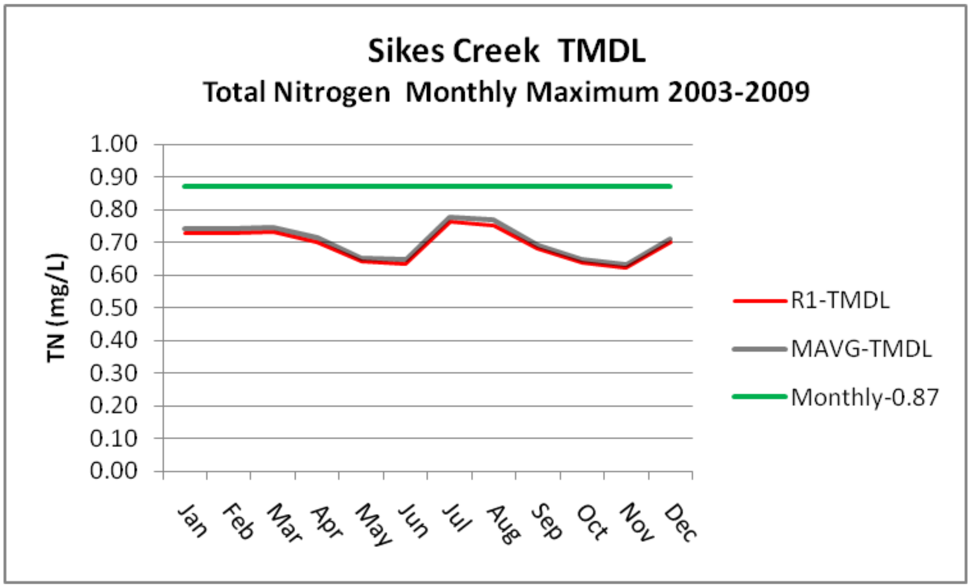


Figure 5.34. TN TMDL monthly maximum for Reach 1 and model average, 2003–09

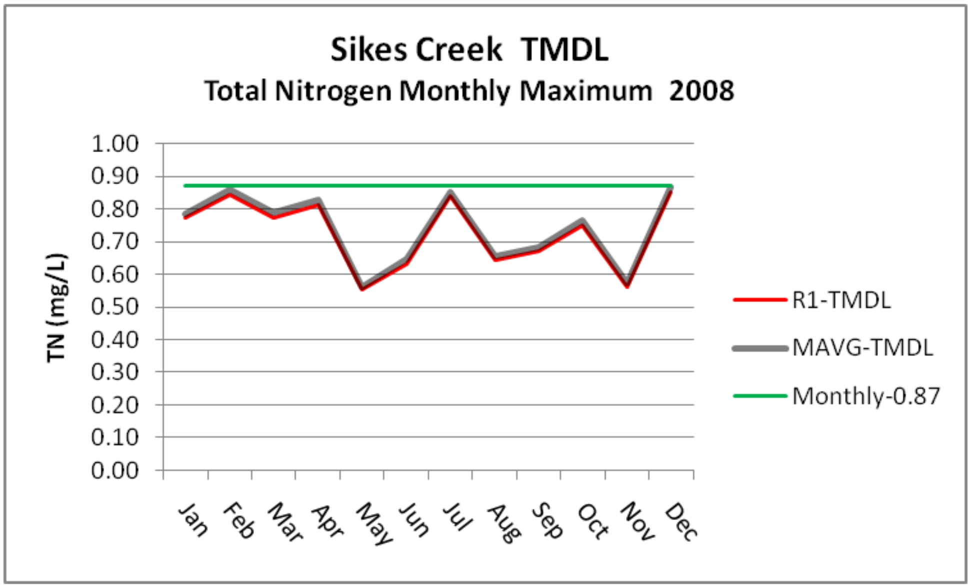


Figure 5.35. TN TMDL monthly maximum for Reach 1 and model average, 2008

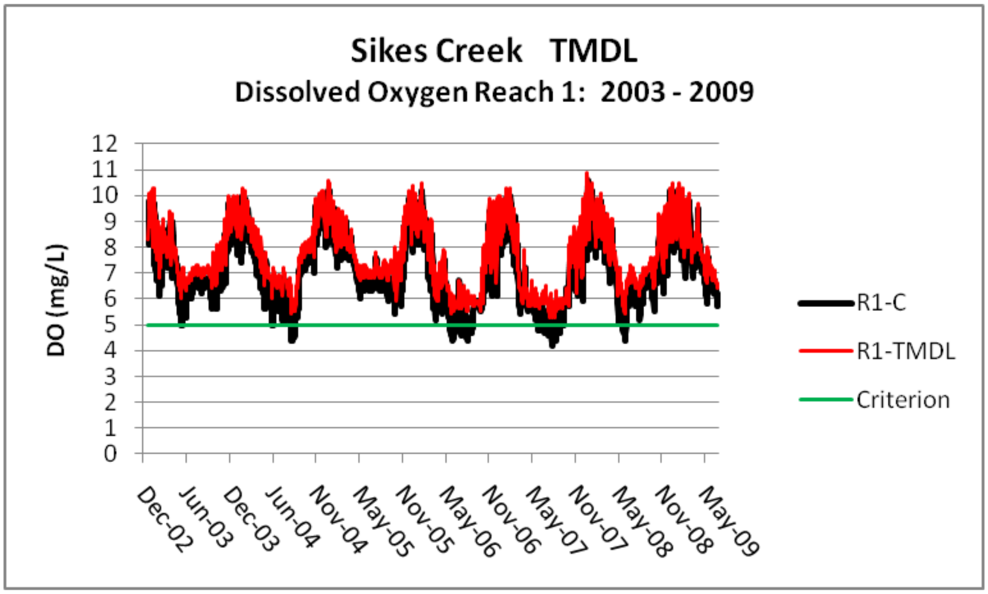


Figure 5.36. DO TMDL for Reach 1, 2003–09

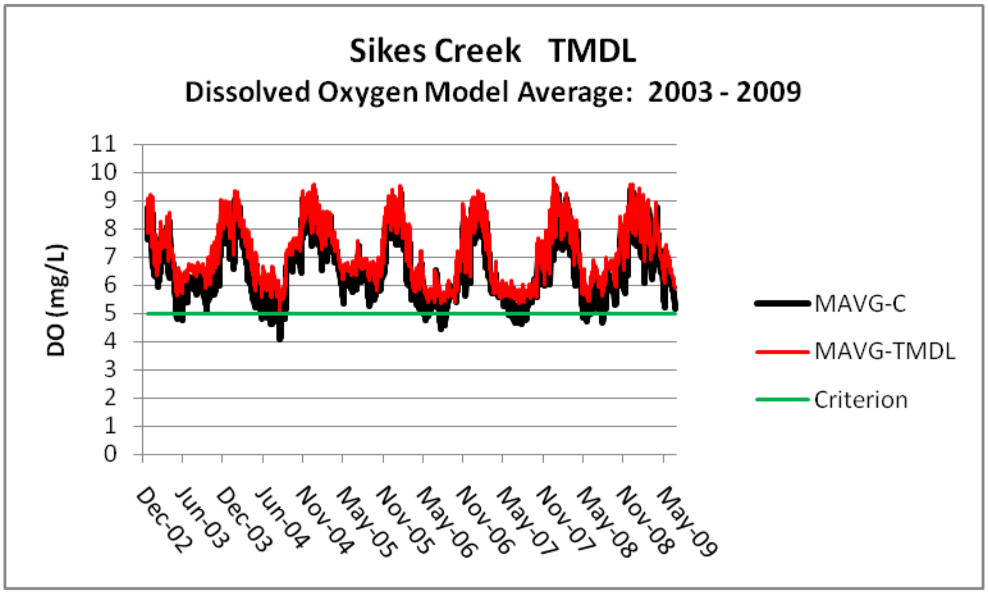


Figure 5.37. DO TMDL model average, 2003–09

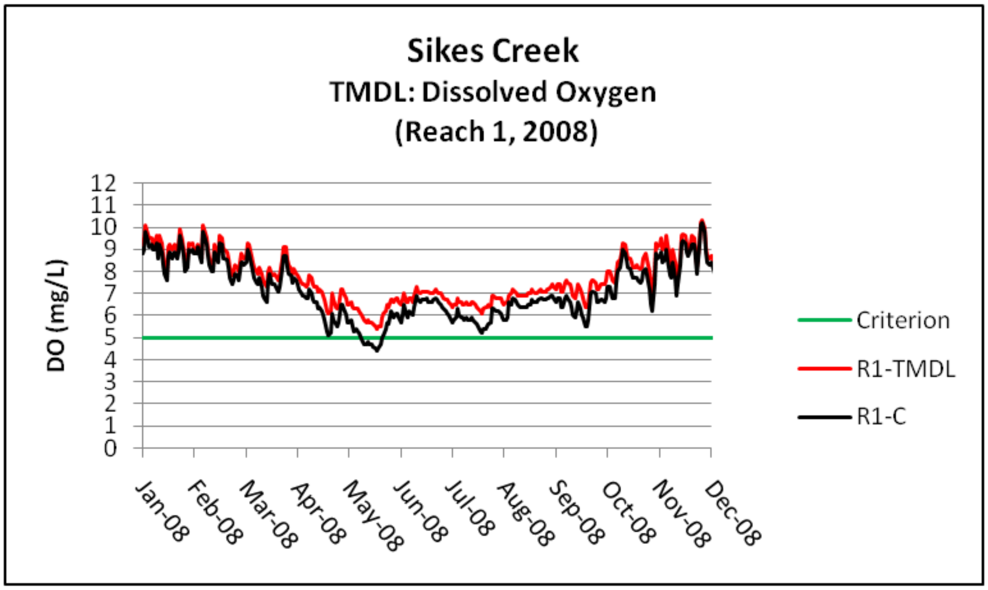


Figure 5.38. DO TMDL for Reach 1, 2008

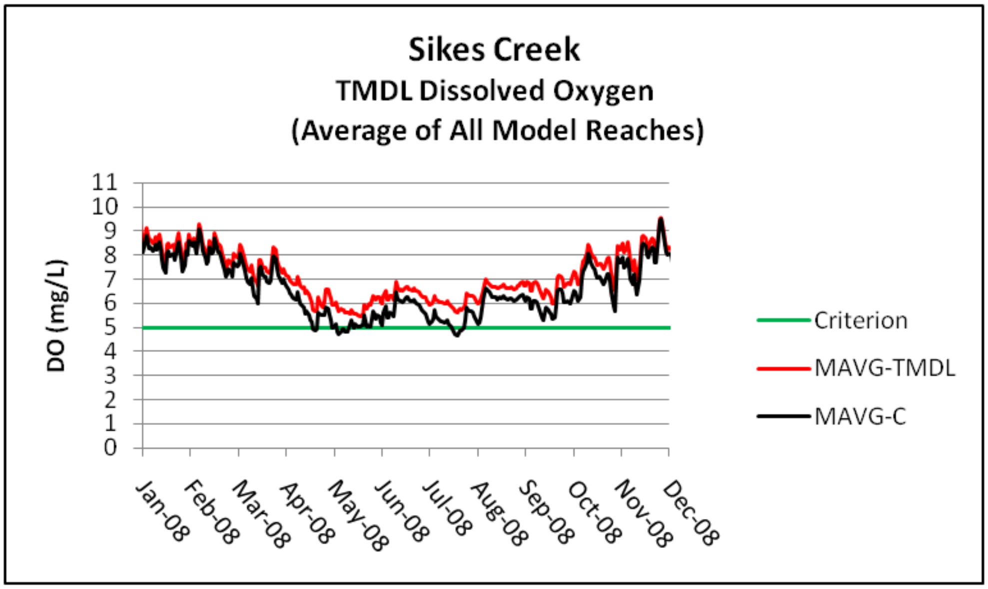


Figure 5.39.DO TMDL model average, 2008

Table 5.7 shows the TN loading results for the current condition (calibrated model) of 25,977 pounds per year (lbs/yr) of TN and for the TMDL condition of 21,819 lbs/yr of TN. The TMDL allowable loading of 21,819 lbs/yr is based on the average model results for 2004 to 2008 (2003 was for spin-up and 2009 was only the first 6 months), as this period contains both low- and high rainfall years. This reduction of 4,158 lbs/yr of TN (16 percent of the ***total*** watershed load or 24 percent of the ***anthropogenic*** load) is required for the stream to attain water quality standards for DO.

It should be noted that **Table 5.7** is not intended to provide a detailed land use–specific allocation of loadings, but rather a breakout of land use loadings between those with the potential to contribute anthropogenic loads and those that are considered natural (wetlands and water). These predictions of anthropogenic loadings should be used as a starting point for BMAP discussions with stakeholders. Since reductions are only anticipated in land uses associated with human activity, no reductions were assigned to acreage classified as water or wetlands.

In this context, to achieve an overall 16 percent reduction in total loading from the entire watershed, reductions from the land uses with potential anthropogenic loading were calculated as 24 (23.9) percent. The TMDL is based on the total watershed load reductions of 4,158 lbs/yr of TN applied to anthropogenic land uses, for a 24 percent reduction from the current average loading from these land uses, which will result in an overall 16 percent reduction in total watershed loading.

Table 5.7. Existing and TMDL TN loads

This is a nine-column table. Column 1 lists the land use, Columns 2 through 6 list the TN load (lbs) for each year from 2004 to 2008, respectively, Column 7 lists the existing average (lbs), Column 8 lists the TMDL average (lbs), and Column 9 lists the TMDL percent reduction.

Land Use	2004 (lbs)	2005 (lbs)	2006 (lbs)	2007 (lbs)	2008 (lbs)	Existing Average (lbs)	TMDL Average (lbs)	TMDL % Reduction
Transportation/utilities	0	0	0	0	0	0	0	0%
Improved pasture/crops/ groves/poultry	8,023	11,320	17,719	4,427	5,417	9,381	7,139	23.9%
High-density residential	0	0	0	0	0	0	0	0%
Medium-density residential	54	70	110	35	38	61	46	23.9%
Low-density residential	756	996	1,591	458	503	861	655	23.9%
Rangeland/upland forest	4,512	5,752	12,246	2,653	2,506	5,534	4,211	23.9%
Unimproved and woodland pasture	1,142	1,737	3,440	655	817	1,558	1,186	23.9%
Wetland	6,469	9,687	17,129	4,010	5,088	8,477	8,477	0%
Water	87	122	197	54	66	105	105	0%
Total	**21,043**	**29,684**	**52,432**	**12,292**	**14,435**	**25,977**	**21,819**	**16%**

5.7 Critical Conditions/Seasonality

The critical conditions for nutrient loadings in a given watershed depend on the existence of point sources, land use patterns, and rainfall in the watershed. Typically, the critical condition for nonpoint sources is an extended dry period, followed by a rainfall runoff event. During wet weather periods, pollutants that have built up on the land surface under dry weather conditions are washed off by rainfall, resulting in wet weather loadings. However, significant nonpoint source contributions could also occur under dry weather conditions without any major surface runoff event. This usually happens when nonpoint sources contaminate the surficial aquifer, and pollutants are brought into the receiving waters through baseflow. Animals with direct access to the receiving water could also contribute to the exceedances during dry weather conditions. The critical condition for point source loading typically occurs during periods of low stream flow, when dilution is minimized. As previously noted, there are no point source discharges within the watershed. The data did not indicate a seasonal pattern, with DO exceedances occurring throughout the year.

5.8 Spatial Patterns

Data are very limited, and no conclusions can be reached regarding spatial patterns in the watershed.

Chapter 6: DETERMINATION OF THE TMDL

6.1 Expression and Allocation of the TMDL

The percent reduction and annual allowable load listed on **Table 6.1** was established to achieve both nutrient and DO water quality standards. While this load and the percent reductions are the expression of the TMDL that will be implemented, the EPA 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 TN were established, as detailed in Chapter 5. For the daily maximum TN concentration, it was assumed that the average monthly concentration is the long-term component. Also, assuming the target dataset will have the same CV as the existing measured dataset and allowing a 10 percent exceedance, the daily maximum TN concentration for Sikes Creek is 1.39 mg/L.

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:

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

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

$$\textbf{TMDL} \cong \sum \textbf{WLAs}_{\textbf{wastewater}} + \sum \textbf{WLAs}_{\textbf{NPDES Stormwater}} + \sum \textbf{LAs} + \textbf{MOS}$$

It should be noted that the various components of the revised TMDL equation may not sum up to the value of the TMDL because (a) 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 (b) TMDL components can be expressed in different terms (for example, the WLA for stormwater is typically expressed as a percent reduction, and the WLA for wastewater is typically expressed as mass per day).

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

This approach is consistent with federal regulations (40 CFR § 130.2[I]), which state that TMDLs can be expressed in terms of mass per time (e.g., pounds per day), toxicity, or **other**

appropriate measure. The TMDL for Sikes Creek is expressed in terms of an allowable load and percent reduction; it represents the maximum TN loads the stream can assimilate and maintain DO and nutrient criteria (**Table 6.1**).

Table 6.1. TMDL components for nutrients in Sikes Creek (WBID 142)

This is a seven-column table. Column 1 lists the WBID number, Column 2 lists the parameter, Column 3 lists the TMDL (lbs/yr), Column 4 lists the WLA for wastewater, Column 5 lists the WLA for NPDES stormwater (percent reduction), Column 6 lists the LA (percent reduction), and Column 7 lists the MOS.

***** 21,819 lbs/yr of TN would average 59.7 lbs/day.
****** A 24 percent reduction is required for land uses with potential anthropogenic loading in order to achieve an overall 16 percent reduction for the entire watershed.
N/A = Not applicable

WBID	Parameter	TMDL (lbs/yr)*	WLA for Wastewater	WLA for NPDES Stormwater (% reduction)	LA (% reduction)	MOS
142	TN	21,819	N/A	N/A	24%**	Implicit

6.2 Load Allocation

TN reductions of 24 percent for Sikes Creek are needed from nonpoint sources (anthropogenic). It should be noted that the LA includes loading from stormwater discharges regulated by the Department and the water management districts that are not part of the NPDES Stormwater Program (see **Appendix A**).

6.3 Wasteload Allocation

6.3.1 NPDES Wastewater Discharges

No NPDES-permitted wastewater facilities were identified in the Sikes Creek watershed.

6.3.2 NPDES Stormwater Discharges

No NPDES-permitted stormwater facilities were identified in the Sikes Creek watershed.

6.4 Margin of Safety

Consistent with the recommendations of the Allocation Technical Advisory Committee (Department, 2001), an implicit MOS was used in the development of this TMDL by establishing the reductions based on meeting both a monthly average TN of 0.87 mg/L in each month and a daily maximum TN of 1.38 mg/L for each day and month of the model run (2003–09).

6.5 Evaluating Effects of the TMDL on DO

Sikes Creek is expected to attain water quality standards for DO and nutrients following the implementation of the TMDL, because the TMDL will require a reduction of 24 percent in anthropogenic sources of TN loadings. The nutrient reductions are also expected to result in a reduction in cchla and an associated reduction in respiration and the algal component of BOD_5. These reductions will improve overall water quality in the watershed, including DO levels. They will have a positive effect on reducing diurnal fluctuations in DO and will improve DO levels in the creek by removing anthropogenic sources of nutrients. The expected reductions in algal biomass will reduce the DO fluctuations and the BOD that results from the breakdown of the algal cells in the watershed by a relative amount. As the total BOD is composed of both a carbonaceous fraction and a nitrogenous fraction, additional reductions in BOD will occur as a result of reducing the mass of TN entering the system from anthropogenic land uses by an average of 24 percent.

Chapter 7: TMDL IMPLEMENTATION PLAN

7.1 Basin Management Action Plan

Following the adoption of this TMDL by rule, the Department will determine the best course of action regarding its implementation. Depending upon the pollutant(s) causing the waterbody impairment and the significance of the waterbody, the Department will select the best course of action leading to the development of a plan to restore the waterbody. Often this will be accomplished cooperatively with stakeholders by creating a Basin Management Action Plan, referred to as the BMAP. Basin Management Action Plans are the primary mechanism through which TMDLs are implemented in Florida (see Subsection 403.067[7], F.S.). A single BMAP may provide the conceptual plan for the restoration of one or many impaired waterbodies.

If the Department determines that a BMAP is needed to support the implementation of this TMDL, a BMAP will be developed through a transparent stakeholder-driven process intended to result in a plan that is cost-effective, technically feasible, and meets the restoration needs of the applicable waterbodies.

Once adopted by order of the Department Secretary, BMAPs are enforceable through wastewater and municipal stormwater permits for point sources and through BMP implementation for nonpoint sources. Among other components, BMAPs typically include the following:

- *Water quality goals (based directly on the TMDL);*
- *Refined source identification;*
- *Load reduction requirements for stakeholders (quantitative detailed allocations, if technically feasible);*
- *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;*
- *Implementation funding mechanisms;*
- *An evaluation of future increases in pollutant loading due to population growth;*
- *Implementation milestones, project tracking, water quality monitoring, and adaptive management procedures; and*
- *Stakeholder statements of commitment (typically a local government resolution).*

BMAPs are updated through annual meetings and may be officially revised every five years. Completed BMAPs in the state have improved communication and cooperation among local stakeholders and state agencies, improved internal communication within local governments, applied high-quality science and local information in managing water resources, clarified the obligations of wastewater point source, MS4 and non-MS4 stakeholders in TMDL implementation, enhanced transparency in the Department's decision making, and built strong relationships between the Department and local stakeholders that have benefited other program areas.

7.2 Other TMDL Implementation Tools

However, in some basins, and for some parameters, particularly those with fecal coliform impairments, the development of a BMAP using the process described above will not be the most efficient way to restore a waterbody, such that it meets its designated uses. This is because fecal coliform impairments result from the cumulative effects of a multitude of potential sources, both natural and anthropogenic. Addressing these problems requires good old-fashioned detective work that is best done by those in the area.

A multitude of assessment tools is available to assist local governments and interested stakeholders in this detective work. The tools range from the simple (such as Walk the WBIDs and GIS mapping) to the complex (such as bacteria source tracking). Department staff will provide technical assistance, guidance, and oversight of local efforts to identify and minimize fecal coliform sources of pollution. Based on work in the Lower St Johns River tributaries and the Hillsborough Basin, the Department and local stakeholders have developed a logical process and tools to serve as a foundation for this detective work. In the near future, the Department will be releasing these tools to assist local stakeholders with the development of local implementation plans to address fecal coliform impairments. In such cases, the Department will rely on these local initiatives as a more cost-effective and simplified approach to identify the actions needed to put in place a road map for restoration activities, while still meeting the requirements of Subsection 403.067(7), F.S.

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Appendices

Appendix A: Background Information on Federal and State Stormwater Programs

In 1982, Florida became the first state in the country to implement statewide regulations to address the issue of nonpoint source pollution by requiring new development and redevelopment to treat stormwater before it is discharged. The Stormwater Rule, as authorized in Chapter 403, F.S., was established as a technology-based program that relies on the implementation of BMPs that are designed to achieve a specific level of treatment (i.e., performance standards) as set forth in Rule 62-40, F.A.C.

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

In 1987, the 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 implementation of 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 the master drainage systems of local governments with a population above 100,000, which are better known as 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 NPDES and other state stormwater permitting programs is that the NPDES Program covers both new and existing discharges, while the other state programs focus on new discharges. 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 reopener clause that allows permit revisions to implement TMDLs when the implementation plan is formally adopted.

Appendix B: Sikes Creek Cross-section and Flow Data, April 6, 2010

End of Reach 1:

Station name: Reach 1 (R1)
Sampling date: April 6, 2010
Sampling time: 15:30
Location: About 500 ft downstream of County Road 179 Bridge
Method: SonTec
Latitude: 30° 50' 49"
Longitude: 85° 51' 35.4"

Table B.1. Sikes Creek, lower portion of Reach 1, flow and stream cross-section data

- = Empty cell/no data

Station?	Distant from Initial Point	Set to 0 (ft)	Depth (ft)	Area (ft^2)	Velocity (ft/s)	Q (cfs)
LEW	1.50	0.00	0	0.0000	0	0.00000
LEW	2.20	0.70	0.5	0.3500	0	0.00000
LEW	2.90	1.40	0.8	0.5600	0.1	0.05600
LEW	3.60	2.10	1	0.7000	0.17	0.11900
LEW	4.30	2.80	1.1	0.7700	0.08	0.06160
LEW	5.00	3.50	1.25	0.8750	0.19	0.16625
LEW	5.70	4.20	1.5	1.0500	0.09	0.09450
LEW	6.40	4.90	1.6	1.1200	0.22	0.24640
LEW	7.10	5.60	1.75	1.2250	0.3	0.36750
LEW	7.80	6.30	1.75	1.2250	0.37	0.45325
LEW	8.50	7.00	1.72	1.2040	0.4	0.48160
LEW	9.20	7.70	1.6	1.1200	0.42	0.47040
LEW	9.90	8.40	1.45	1.0150	0.41	0.41615
LEW	10.60	9.10	1.3	0.9100	0.39	0.35490
LEW	11.30	9.80	1.22	0.8540	0.35	0.29890
LEW	12.00	10.50	1.1	0.7700	0.3	0.23100
LEW	12.70	11.20	0.85	0.5950	0.18	0.10710
LEW	13.40	11.90	0.52	0.3640	0.13	0.04732
LEW	14.10	12.60	0.35	0.2450	0.04	0.00980
LEW	14.80	13.30	0.22	0.1540	0.03	0.00462
REW	15.50	14.00	0	0.0000	0	0.00000
-	-	-	-	-	**Flow**	**3.98629**

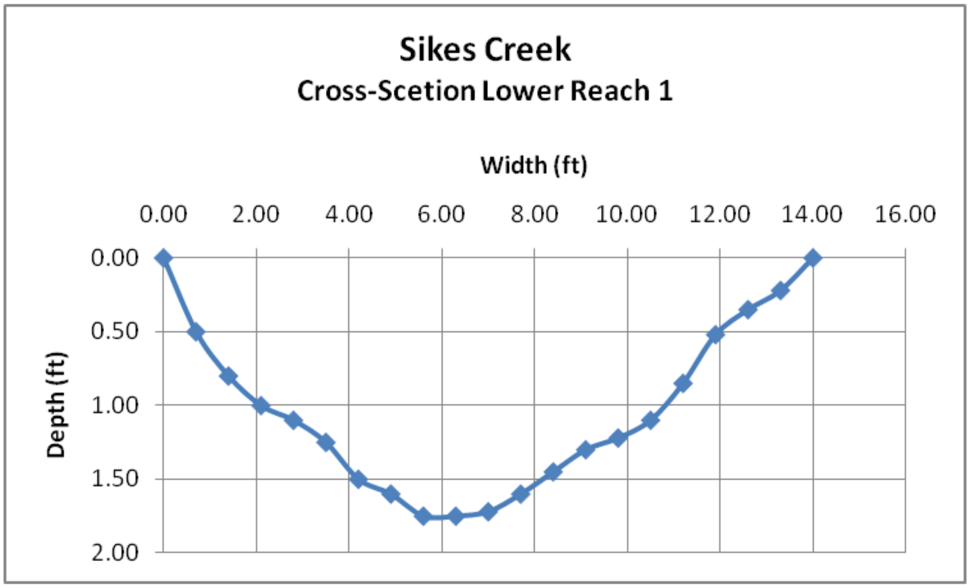

Figure B.1. Sikes Creek, lower portion of Reach 1, stream cross-section

Table B.2. Sikes Creek, lower portion of Reach 1, floodplain data

This is a four-column table. Column 1 lists the station; Column 2 lists the location, Column 3 lists the depth (feet), and Column 4 lists the width (ft).

- = Empty cell/no data

Sampled 4/6/2010, 16:00 hrs., by Greg White

Station?	Location	Depth (ft)	Width (ft)
WR	R-edge FP to R-edge channel	-	167
WR	-	2.51	0
WR	-	4.09	62.4
WR	-	2.94	108.1
WR	-	2.12	145
WR	R-edge of channel	2.83	167.4
WR	R-edge of water	1.3	165.7
WM	Channel width	-	14
YM	Current maximum depth	1.75	-
YM	Center of channel	-	172.7
YM	L-edge of water	3.83	147.1
YM	L-edge of channel	3.54	144.8
WL	L-edge FP to L-edge channel	2.18	136.2

End of Reach 3 (beginning of Reach 1)

Station name: Reach 3 (R3)
Sampling date: April 6, 2010
Sampling time: -
Location: 200 ft downstream of Harris Stevenson Road
Method: SonTec
Latitude: 30^{o} 52’ 8.04”
Longitude: 85^{o} 51’ 5.75”

Table B.3. Sikes Creek, lower portion of Reach 3, flow and cross-section data

- = Empty cell/no data

Station?	Distant from Initial Point	Set to 0 (ft)	Depth (ft)	Area (ft^2)	Velocity (ft/s)	Q (cfs)
LEW	2.50	0.00	0	0.0000	0	0.00000
LEW	3.10	0.60	0.35	0.2100	0.08	0.01680
LEW	3.70	1.20	0.48	0.2880	0.26	0.07488
LEW	4.30	1.80	0.6	0.3600	0.44	0.15840
LEW	4.90	2.40	0.65	0.3900	0.42	0.16380
LEW	5.50	3.00	0.75	0.4500	0.46	0.20700
LEW	6.10	3.60	0.79	0.4740	0.49	0.23226
LEW	6.70	4.20	0.8	0.4800	0.48	0.23040
LEW	7.30	4.80	0.8	0.4800	0.4	0.19200
LEW	7.90	5.40	0.74	0.4440	0.42	0.18648
LEW	8.50	6.00	0.72	0.4320	0.44	0.19008
LEW	9.10	6.60	0.68	0.4080	0.36	0.14688
LEW	9.70	7.20	0.6	0.3600	0.36	0.12960
LEW	10.30	7.80	0.55	0.3300	0.39	0.12870
LEW	10.90	8.40	0.53	0.3180	0.34	0.10812
LEW	11.50	9.00	0.5	0.3000	0.28	0.08400
LEW	12.10	9.60	0.5	0.3000	0.03	0.00900
LEW	12.70	10.20	0.35	0.2100	0.03	0.00630
LEW	13.30	10.80	0.2	0.1200	0	0.00000
LEW	13.90	11.40	0	0.0000	0	0.00000
REW	-	-	-	-	-	-
-	-	-	-	-	**Flow**	**2.26470**

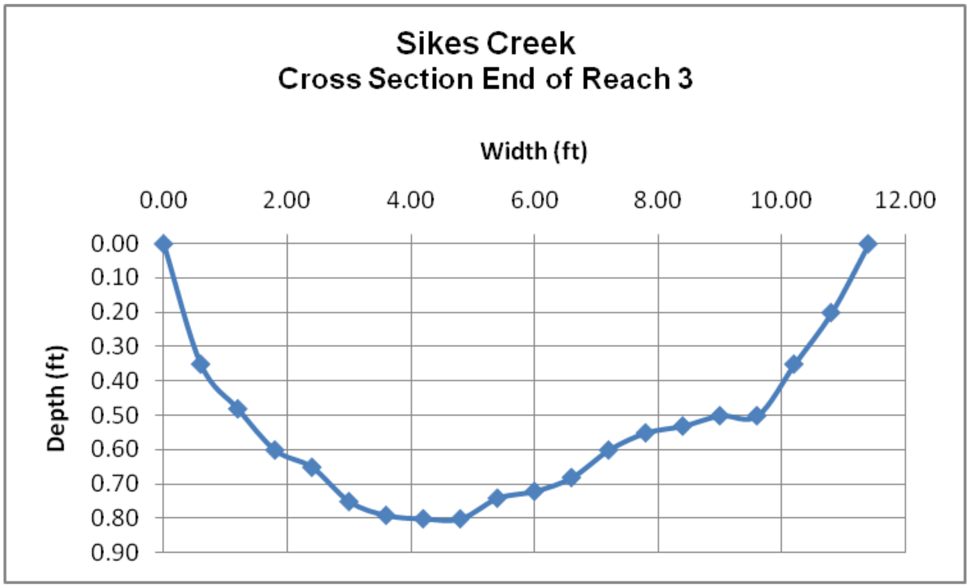

Figure B.2. Sikes Creek, lower portion of Reach 3, stream cross-section

Table B.4. Sikes Creek, end of Reach 3, floodplain data

This is a four-column table. Column 1 lists the station; Column 2 lists the location, Column 3 lists the depth (feet), and Column 4 lists the width (ft).

- = Empty cell/no data

Sampled 4/6/2010, 12:15 hrs, by Greg White

Station?	Location	Depth (ft)	Width (ft)
W_R	R edge to edge of channel	-	96
W_R	Right Edge FP	2.75	96
W_R	R-edge of channel	3.56	80.8
W_R	Mid-creek	5.2	73.3
W_L	L-edge of channel	4.71	65.5
W_L	L-edge of FP	5.2	4.4

End of Reach 4

Station name: Reach 4 (R4)
Sampling date: April 6, 2010
Sampling time: 18:10
Location: 200 ft upstream of culvert, dirt road on Plum property
Method: SonTec
Latitude: 30° 50’ 49”
Longitude: 85° 51’ 35.4”

Table B.5. Sikes Creek, end of Reach 4, flow and cross-section data

This is a seven-column table. Column 1 lists the station ??, Column 2 lists the distance from initial point, Column 3 lists set to 0 (ft), Column 4 lists the depth (ft), Column 5 lists the area (ft^2), Column 6 lists the velocity (ft/s), and Column 7 lists the Q value (cfs).

- = Empty cell/no data

Station?	Distant from Initial Point	Set to 0 (ft)	Depth (ft)	Area (ft^2)	Velocity (ft/s)	Q (cfs)
LEW	0.70	0.00	0	0.0000	0	0.00000
LEW	1.10	0.40	0.2	0.0800	0	0.00000
LEW	1.50	0.80	0.2	0.0800	0.01	0.00080
LEW	1.90	1.20	0.21	0.0840	0.25	0.02100
LEW	2.30	1.60	0.21	0.0840	0.29	0.02436
LEW	2.70	2.00	0.25	0.1000	0.41	0.04100
LEW	3.10	2.40	0.25	0.1000	0.23	0.02300
LEW	3.50	2.80	0.27	0.1080	0.26	0.02808
LEW	3.90	3.20	0.3	0.1200	0.37	0.04440
LEW	4.30	3.60	0.3	0.1200	0.28	0.03360
LEW	4.70	4.00	0.35	0.1400	0.36	0.05040
LEW	5.10	4.40	0.35	0.1400	0.28	0.03920
LEW	5.50	4.80	0.35	0.1400	0.32	0.04480
LEW	5.90	5.20	0.3	0.1200	0.27	0.03240
LEW	6.30	5.60	0.25	0.1000	0.26	0.02600
LEW	6.70	6.00	0.24	0.0960	0.23	0.02208
LEW	7.10	6.40	0.2	0.0800	0.06	0.00480
REW	7.50	6.80	0	0.0000	0	0.00000
-	**-**	**-**	**-**	**-**	**Flow**	**0.43592**

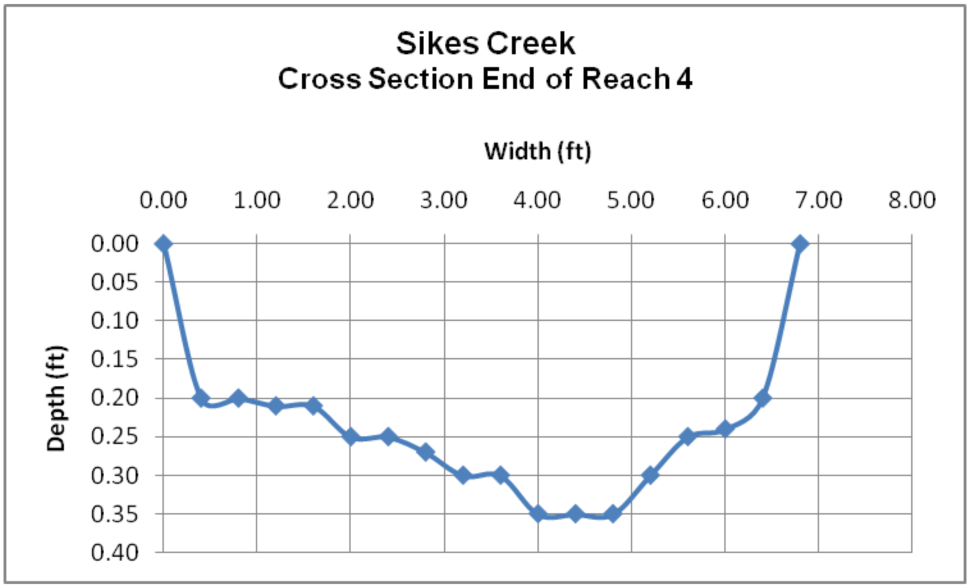

Figure B.3. Sikes Creek, end of Reach 4, cross-section

Table B.6. Sikes Creek, end of Reach 4, floodplain data

- = Empty cell/no data

Sampled 4/6/2010, 16:00 hrs., by Greg White

Station?	Location	Depth (ft)	Width (ft)
W_R	R edge to edge of channel	-	126
W_R	-	0	-
W_R	Right edge FP	1.91	126
W_R	-	2.38	114
W_R	Right edge of channel	2.92	91.6
W_R	-	1.13	87.7
W_R	Mid-stream depth = 0.48 +	0.48	84.5
W_R	Left edge of channel	2.9	77
W_R	-	2.11	46
W_L	-	2.23	26.51

End of Reach 7

Station name: Reach 7 (R7)
Sampling date: April 6, 2010
Sampling time: 8:46
Location: Upstream of Clemmons Road Bridge ¼ mile, just past first confluence
Method: SonTec
Latitude: 30^{o} 53’ 14.9”
Longitude: 85^{o} 49’ 53.1”

Table B.7. Sikes Creek, end of Reach 7, flow and stream cross-section data

Station?	**Distant from initial point**	**Set to 0 (ft)**	**Depth (ft)**	**Area (ft^2)**	**Velocity (ft/s)**	**Q (cfs)**
LEW	3.00	0.00	0	0.0000	0	0.00000
LEW	3.40	0.40	0.25	0.1000	0	0.00000
LEW	3.80	0.80	0.4	0.1600	0	0.00000
LEW	4.20	1.20	0.45	0.1800	0	0.00000
LEW	4.60	1.60	0.54	0.2160	0.04	0.00864
LEW	5.00	2.00	0.56	0.2240	0.13	0.02912
LEW	5.40	2.40	0.53	0.2120	0.15	0.03180
LEW	5.80	2.80	0.54	0.2160	0.3	0.06480
LEW	6.20	3.20	0.54	0.2160	0.4	0.08640
LEW	6.60	3.60	0.57	0.2280	0.2	0.04560
LEW	7.00	4.00	0.62	0.2480	0.4	0.09920
LEW	7.40	4.40	0.6	0.2400	0.54	0.12960
LEW	7.80	4.80	0.6	0.2400	0.52	0.12480
LEW	8.20	5.20	0.57	0.2280	0.29	0.06612
LEW	8.60	5.60	0.55	0.2200	0.33	0.07260
LEW	9.00	6.00	0.51	0.2040	0.18	0.03672
LEW	9.40	6.40	0.45	0.1800	0.04	0.00720
LEW	9.80	6.80	0.4	0.1600	0.03	0.00480
LEW	10.20	7.20	0.27	0.1080	0.15	0.01620
LEW	10.60	7.60	0.15	0.0600	0.15	0.00900
REW	11.00	8.00	0	0.0000	0	0.00000
-	-	-	-	-	**Flow**	**0.83260**

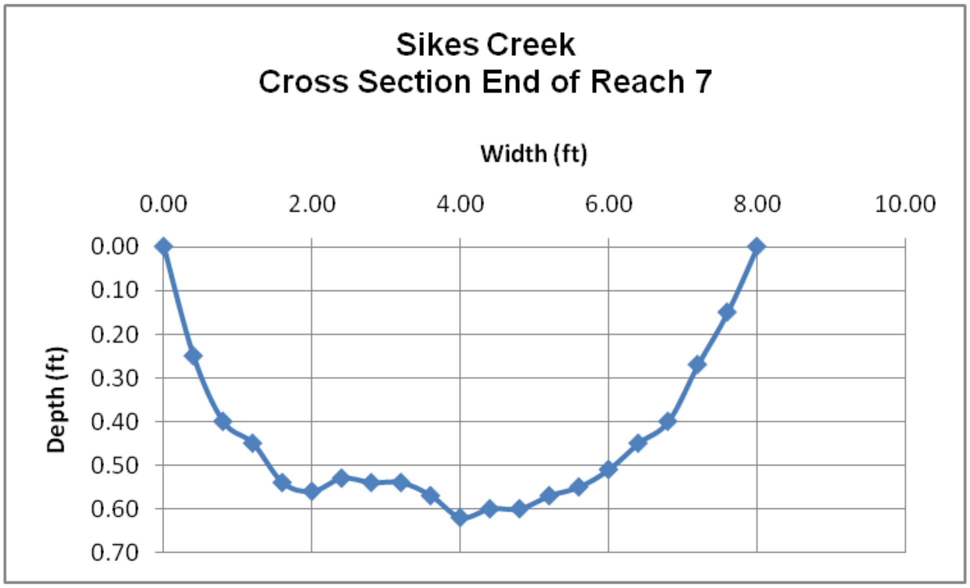

Figure B.4. Sikes Creek, end of Reach 7, stream cross-section

Table B.8. Sikes Creek, end of Reach 7, floodplain data

- = Empty cell/no data

Sampled 4/6/2010, 08:30 hrs, by Greg White

Station?	Location	Depth (ft)	Width (ft)
W_R	R-edge FP to R-edge channel	4.6	66
W_R	R-edge of channel	5.32	32.5
W_R	R-edge of water	5.59	30.5
W_M	Channel width	-	8
Y_M	Current maximum depth	0.62	-
Y_M	Center of channel	6.19	27
Y_M	L-edge of water	5.56	23.1
Y_M	L-edge of channel	5.34	22.03
W_L	L-edge FP to L-edge channel	4.58	21.8

Appendix C: Sikes Creek Raw Data

- = Empty cell/no data
N/A = Not available
R codes are as follows: A = average of one or more values; I = values between the method detection limit and practical quantitation limit; & = cchla data reported as less than 1.0 ug/L; U = result reported as less than method detection limit; + = result calculated from component parts

Table C.1. BOD_5 raw data

Constituent	Station	Date	Time	Result	Units	Rcode[1]	MDL
BOD_5	21FLA 32020114	7/28/1998	10:10	1.7	mg/L	-	-
BOD_5	21FLPNS 32020114	2/12/2008	10:45	1	mg/L	I	0.2
BOD_5	21FLPNS 32020114	3/31/2008	11:00	0.47	mg/L	I	0.2
BOD_5	21FLPNS 32020114	4/23/2008	13:20	1.6	mg/L	I	0.2
BOD_5	21FLPNS 32020114	6/2/2008	11:45	0.72	mg/L	I	0.2
BOD_5	21FLPNS 32020114	7/21/2008	11:30	1.6	mg/L	I	0.2
BOD_5	21FLPNS 32020114	8/26/2008	10:10	1.8	mg/L	I	0.2
BOD_5	21FLPNS 32020114	10/6/2008	10:30	2	mg/L	A	0.2
BOD_5	21FLPNS 32020114	11/18/2008	10:25	2.2	mg/L	-	0.2
BOD_5	21FLPNS 32020114	12/1/2008	12:00	2.3	mg/L	-	0.2
BOD_5	21FLPNS 32020156	2/12/2008	11:30	0.73	mg/L	I	0.2
BOD_5	21FLPNS 32020156	4/23/2008	13:00	0.3	mg/L	I	0.2
BOD_5	21FLPNS 32020156	8/26/2008	11:25	0.47	mg/L	I	0.2
BOD_5	21FLPNS 32020156	11/18/2008	10:45	2.4	mg/L	-	0.2
BOD_5	21FLPNS 32020155	4/23/2008	12:20	1.4	mg/L	I	0.2
BOD_5	21FLPNS 32020155	7/21/2008	10:30	2.4	mg/L	-	0.2
BOD_5	21FLPNS 32020155	8/26/2008	10:45	2.7	mg/L	-	0.2
BOD_5	21FLPNS 32020155	11/18/2008	11:45	4	mg/L	-	0.2
BOD_5	21FLPNS 32020154	2/12/2008	11:40	0.69	mg/L	I	0.2
BOD_5	21FLPNS 32020154	3/31/2008	11:30	1.3	mg/L	I	0.2

Table C.2. Cchl*a* raw data

** Outlier (see the discussion in **Section 5.3.4**)

Constituent	Station	Date	Time	Result	Units	Rcode*	MDL
Cchl*a*	21FLA 32020114	7/28/1998	10:10	5.3	µg/L	-	-
Cchl*a*	21FLPNS 32020114	2/12/2008	10:45	1	µg/L	&	1
Cchl*a*	21FLPNS 32020114	3/31/2008	11:00	1.1	µg/L	U	1.1
Cchl*a*	21FLPNS 32020114	4/23/2008	13:20	1	µg/L	&	1
Cchl*a*	21FLPNS 32020114	6/2/2008	11:45	1	µg/L	&	1
Cchl*a*	21FLPNS 32020114	7/21/2008	11:30	1	µg/L	&	1
Cchl*a*	21FLPNS 32020114	8/26/2008	10:10	1	µg/L	&	1
Cchl*a*	21FLPNS 32020114	10/6/2008	10:30	**9.3****	µg/L	-	0.61
Cchl*a*	21FLPNS 32020114	11/18/2008	10:25	1	µg/L	&	1
Cchl*a*	21FLPNS 32020114	12/1/2008	12:00	1	µg/L	&	1
Cchl*a*	21FLPNS 32020156	2/12/2008	11:30	1	µg/L	&	1
Cchl*a*	21FLPNS 32020156	4/23/2008	13:00	1	µg/L	&	0.55
Cchl*a*	21FLPNS 32020156	8/26/2008	11:25	1.4	µg/L	U	1.4
Cchl*a*	21FLPNS 32020156	11/18/2008	10:45	1	µg/L	&	1
Cchl*a*	21FLPNS 32020155	4/23/2008	12:20	1	µg/L	&	1
Cchl*a*	21FLPNS 32020155	6/2/2008	11:15	1.2	µg/L	I	0.79
Cchl*a*	21FLPNS 32020155	7/21/2008	10:30	2.5	µg/L	-	0.79
Cchl*a*	21FLPNS 32020155	8/26/2008	10:45	1.2	µg/L	I	0.98
Cchl*a*	21FLPNS 32020155	11/18/2008	11:45	1.2	µg/L	I	0.79
Cchl*a*	21FLPNS 32020154	2/12/2008	11:40	1	µg/L	&	1
Cchl*a*	21FLPNS 32020154	3/31/2008	11:30	1	µg/L	&	1

Table C.3. DO raw data

Constituent	Station	Date	Time	Result	Units	Rcode	MDL
DO	21FLA 32020114	7/28/1998	10:10	2.96	mg/L	-	N/A
DO	21FLPNS 32020114	2/12/2008	9:45	8.38	mg/L	-	N/A
DO	21FLPNS 32020114	3/31/2008	10:00	5.98	mg/L	-	N/A
DO	21FLPNS 32020114	4/23/2008	12:20	6.37	mg/L	-	N/A
DO	21FLPNS 32020114	6/2/2008	10:45	4.38	mg/L	-	N/A
DO	21FLPNS 32020114	7/21/2008	10:30	3.6	mg/L	-	N/A
DO	21FLPNS 32020114	8/26/2008	9:10	5.86	mg/L	-	N/A
DO	21FLPNS 32020114	10/6/2008	9:30	2.02	mg/L	-	N/A
DO	21FLPNS 32020114	10/27/2008	14:15	6.21	mg/L	-	N/A
DO	21FLPNS 32020114	11/18/2008	9:25	6.39	mg/L	-	N/A
DO	21FLPNS 32020114	12/1/2008	11:00	7.08	mg/L	-	N/A
DO	21FLPNS 32020156	2/12/2008	10:30	2.38	mg/L	-	N/A
DO	21FLPNS 32020156	4/23/2008	12:00	1.8	mg/L	-	N/A
DO	21FLPNS 32020156	8/26/2008	10:25	2.4	mg/L	-	N/A
DO	21FLPNS 32020156	11/18/2008	9:45	1.53	mg/L	-	N/A
DO	21FLPNS 32020156	12/1/2008	11:50	2.5	mg/L	-	N/A
DO	21FLPNS 32020155	4/23/2008	11:20	5.11	mg/L	-	N/A
DO	21FLPNS 32020155	6/2/2008	10:15	1.2	mg/L	-	N/A
DO	21FLPNS 32020155	7/21/2008	9:30	0.4	mg/L	-	N/A
DO	21FLPNS 32020155	8/26/2008	9:45	5.26	mg/L	-	N/A
DO	21FLPNS 32020155	10/27/2008	14:40	2.31	mg/L	-	N/A
DO	21FLPNS 32020155	11/18/2008	10:45	3.06	mg/L	-	N/A
DO	21FLPNS 32020155	12/1/2008	11:30	3.62	mg/L	-	N/A
DO	21FLPNS 32020154	2/12/2008	10:40	7.84	mg/L	-	N/A
DO	21FLPNS 32020154	3/31/2008	10:30	4.6	mg/L	-	N/A
DO	21FLPNS 32020154	12/1/2008	12:05	6.01	mg/L	-	N/A

Table C.4. TN raw data

** Outlier (see the discussion in **Section 5.3.4**)

Constituent	Station	Date	Time	Result	Units	Rcode*	MDL
TN	21FLA 32020114	7/28/1998	10:10	0.527	mg/L	+	N/A
TN	21FLPNS 32020114	2/12/2008	10:45	0.827	mg/L	+	N/A
TN	21FLPNS 32020114	3/31/2008	11:00	**2.7****	mg/L	+	N/A
TN	21FLPNS 32020114	4/23/2008	13:20	1.051	mg/L	+	N/A
TN	21FLPNS 32020114	7/21/2008	11:30	1.121	mg/L	+	N/A
TN	21FLPNS 32020114	8/26/2008	10:10	1.318	mg/L	+	N/A
TN	21FLPNS 32020114	10/6/2008	10:30	0.928	mg/L	+	N/A
TN	21FLPNS 32020114	11/18/2008	10:25	0.988	mg/L	+	N/A
TN	21FLPNS 32020114	12/1/2008	12:00	0.882	mg/L	+	N/A
TN	21FLPNS 32020156	2/12/2008	11:30	0.532	mg/L	+	N/A
TN	21FLPNS 32020156	4/23/2008	13:00	0.642	mg/L	+	N/A
TN	21FLPNS 32020156	8/26/2008	11:25	1.01	mg/L	+	N/A
TN	21FLPNS 32020156	11/18/2008	10:45	0.984	mg/L	+	N/A
TN	21FLPNS 32020155	4/23/2008	12:20	1.367	mg/L	+	N/A
TN	21FLPNS 32020155	7/21/2008	10:30	1.816	mg/L	+	N/A
TN	21FLPNS 32020155	8/26/2008	10:45	1.719	mg/L	+	N/A
TN	21FLPNS 32020155	11/18/2008	11:45	1.405	mg/L	+	N/A
TN	21FLPNS 32020154	2/12/2008	11:40	0.468	mg/L	+	N/A
TN	21FLPNS 32020154	3/31/2008	11:30	0.547	mg/L	+	N/A

Table C.5. TP raw data

- = Empty cell/no data
[1] R code: I = ??; U = ??

Constituent	Station	Date	Time	Result	Units	Rcode[1]	MDL
TP	21FLA 32020114	7/28/1998	10:10	0.021	mg/L	I	-
TP	21FLPNS 32020114	2/12/2008	10:45	0.02	mg/L	U	0.02
TP	21FLPNS 32020114	3/31/2008	11:00	0.036	mg/L	I	0.02
TP	21FLPNS 32020114	4/23/2008	13:20	0.026	mg/L	I	0.02
TP	21FLPNS 32020114	6/2/2008	11:45	0.02	mg/L	U	0.02
TP	21FLPNS 32020114	7/21/2008	11:30	0.027	mg/L	I	0.02
TP	21FLPNS 32020114	8/26/2008	10:10	0.033	mg/L	I	0.02
TP	21FLPNS 32020114	10/6/2008	10:30	0.02	mg/L	U	0.02
TP	21FLPNS 32020114	11/18/2008	10:25	0.02	mg/L	U	0.02
TP	21FLPNS 32020114	12/1/2008	12:00	0.023	mg/L	I	0.02
TP	21FLPNS 32020156	2/12/2008	11:30	0.02	mg/L	U	0.02
TP	21FLPNS 32020156	4/23/2008	13:00	0.02	mg/L	U	0.02
TP	21FLPNS 32020156	8/26/2008	11:25	0.02	mg/L	U	0.02
TP	21FLPNS 32020156	11/18/2008	10:45	0.02	mg/L	U	0.02
TP	21FLPNS 32020155	4/23/2008	12:20	0.034	mg/L	I	0.02
TP	21FLPNS 32020155	6/2/2008	11:15	0.034	mg/L	I	0.02
TP	21FLPNS 32020155	7/21/2008	10:30	0.052	mg/L	I	0.02
TP	21FLPNS 32020155	8/26/2008	10:45	0.046	mg/L	I	0.02
TP	21FLPNS 32020155	11/18/2008	11:45	0.025	mg/L	I	0.02
TP	21FLPNS 32020154	2/12/2008	11:40	0.02	mg/L	U	0.02
TP	21FLPNS 32020154	3/31/2008	11:30	0.02	mg/L	U	0.02

Appendix D: HSPF Model Information

The Hydrological Simulation Program–Fortran (HSPF) Model (Bicknell et al., 2001) was developed under the joint sponsorship of the EPA and USGS. This dynamic model is capable of simulating both hydrologic and water quality processes in the watershed and receiving waterbodies. It allows the input of rainfall, temperature, evaporation, evapotranspiration, point source flows and loads, upstream or tributary inflows and constituent loads, sediment mass and associated constituent loads, and other time-series data. The model also allows the input of parameters related to the physical characteristics of subwatersheds—such as topography and roughness, land uses, soil characteristics, and agricultural practices—to conduct watershed simulations.

Within each subwatershed, HSPF conducts simulations of water quantity and quality in several layers, including the land surface, several soil zones, and the ground water table. The watershed simulations can generate stormwater runoff flows and concentrations or loads of sediments, BOD, nutrients, bacteria, pesticides, metals, toxic chemicals, and other quality constituents. The flows and loadings from the watershed can then be used together with channel and boundary information to conduct in-stream simulations, which then yield results of flow, constituent concentrations, and loads at the user-selected output locations.

HSPF can also simulate the transport of flow and sediment, and their associated water quality constituents, in stream channels and mixed reservoirs. These simulations include hydraulics, constituent advection, the transport of conservative constituents, inorganic sediment, and generalized quality constituents, water temperature, nutrient cycles, DO-related processes, first-order decay, sediment sorption and desorption, and other water quality processes. To conduct hydrology simulations in HSPF, the user must provide a rating relationship that relates flow, water depth, water surface area, and water volume at each model reach. While it is a time variable model, HSPF does not accept a time-varying downstream boundary condition and cannot simulate backwater effects.

Datasets of land use, soils, and rainfall are used to calculate the combined impact of the watershed characteristics for a given modeled area on a waterbody represented in the model as a reach. GIS and model datasets used to derive the inputs for HSPF include land use, soils, topography and depressions, hydrography, USGS gauge and flow data, septic tanks, water use pumpage, point sources, rainfall, ground water, atmospheric deposition, solar radiation, control structures, and stream reaches.

IMPLND Module for Impervious Tributary Area

The IMPLND Module of HSPF accounts for surface runoff from impervious land areas (*e.g.,* parking lots and highways). For the purposes of this model, each land use was assigned a typical percentage of directly connected impervious area (DCIA), as shown in **Table 5.1,** based on published values (CDM, 2002). Four of the nine land uses contain fractions of impervious lands.

PERLND Module for Pervious Tributary Area

The PERLND Module of HSPF accounts for surface runoff, interflow, and ground water flow (baseflow) from pervious land areas. For the purposes of modeling, the total amount of pervious tributary area was estimated as the total tributary area minus the impervious area.

HSPF uses the Stanford Watershed Model methodology as the basis for hydrologic calculations. This methodology calculates soil moisture and water flow between a number of different storage areas, including surface storage, interflow storage, an upper soil storage zone, a lower soil storage zone, an active ground water zone, and deep storage. Rain that is not converted to surface runoff or interflow infiltrates into the soil storage zones. The infiltrated water is lost by evapotranspiration, discharged as baseflow, or lost to deep percolation (e.g., deep aquifer recharge). In the HSPF Model, water and wetland land uses were generally modeled as pervious land (PERLND) elements. Since these land use types are expected to generate more flow as surface runoff than other pervious lands, the PERLND elements representing water and wetlands were assigned lower values for infiltration rate (INFILT), upper zone nominal storage (UZSN), and lower zone nominal storage (LZSN).

The hydrology of large waterbodies *(e.g.,* lakes) and rivers and streams should be modeled in the RCHRES Module of HSPF (described below), rather than the PERLND Module. For each sub-basin containing a main stem reach, a number of acres should be removed from the water land use in PERLND, which are then modeled explicitly in RCHRES. The acres removed from these sub-basins correspond to the areas of the lakes and the streams. In the reaches representing these waterbodies, HSPF accounts for direct rainfall on the water surface and direct evaporation from the water surface.

Several of the key parameters adjusted in the analysis include the following:

- *LZSN (lower zone nominal storage)–LZSN is the key parameter in establishing an annual water balance. Increasing the value of LZSN increases the amount of infiltrated water that is lost by evapotranspiration, and therefore decreases the annual streamflow volume.*
- *LZETP (lower zone evapotranspiration parameter)–LZETP affects the amount of potential evapotranspiration that can be satisfied by lower zone storage and is another key factor in the annual water balance.*
- *INFILT (infiltration)–INFILT can also affect the annual water balance. Increasing the value of INFILT decreases surface runoff and interflow, increases the flow of water to lower soil storage and ground water, and results in greater evapotranspiration.*
- *UZSN (upper zone nominal storage)–Reducing the value of UZSN increases the percentage of flow that is associated with surface runoff as opposed to ground water flow. This is appropriate for areas where receiving water inflows are highly responsive to rainfall events. Increasing UZSN can also affect the annual water balance by resulting in greater overall evapotranspiration.*

RCHRES Module for Stream/Lake Routing

The RCHRES Module of HSPF conveys flows input from the PERLND and IMPLND Modules, together with rainfall directly on the water surface, and balances this with outflows from evaporation and outflows based on a rating curve supplied by the modeler. This project consists of four sets of PERLND and IMPLND land uses representing the watershed, draining to four RCHRES representing Sikes Creek. The RCHRES element defines the depth-area-volume relationship for the modeled waterbody. **Table 5.2** and **Figure 5.8** depict the land uses and acreage of each land use incorporated in the HSPF Model. Within the table, Reach 7 is the most upstream reach, and Reach 3 is the middle part of Sikes Creek, Reach 4 is a major tributary to Sikes Creek that enters the creek at the junction of Reach 3 and Reach 1. Reach 1 is the most downstream reach and terminates at County Road 179.

The domain does not include about 1,355 acres in the watershed located below County Road 179, as the hydrology below this point is unknown for several reasons. Field surveys during January, March, and April 2010 have documented that the creek below this point does not follow the path indicated by the GIS data used to set up the model domain and receives significant flow from an unnamed tributary just below the bridge. Also, this unnamed tributary may convey overflow from the Choctawhatchee River floodplain when that river is out of its banks.

Table D.1. HSPF input parameters and values for model calibration

This is a five-column table. Column 1 lists the HSPF variable for each module, Column 2 describes the variable, Column 3 lists the units, Column 4 lists the value, and Column 5 lists the source.

- = Empty cell/no data

Module/ HSPF Variable	Description	Units	Value	Source
HTRCH Module	-	-	-	-
CFSAEX	Correction factor for solar radiation	none	0.40	Calibration
KATRAD	Longwave radiation coefficient	none	9.3	Calibration
KCOND	Conductive-convection heat transport coefficient	none	6.12	Calibration
KEVAP	Evaporation coefficient	none	2.24	Default
SEDTRN Module	-	-	-	-
KSAND	Coefficient in sandload formula	complex	1.1	Calibration
EXPSND	Exponent in sandload formula	complex	2.2	Calibration
W	Fall velocity in still water–silt	in/s	.0003	Calibration
TAUCD	Critical shear stress for deposition–silt	lb/ft^2	0.08	Calibration
TAUCS	Critical shear stress for scour–silt	lb/ft^2	0.21	Calibration
M	Erodibility coefficient of sediment–silt	$lb/ft^2/day$	0.02	Calibration
W	Fall velocity in still water–clay	in/s	1.0E-05	Calibration
TAUCD	Critical shear stress for deposition–clay	lb/ft^2	0.09	Previous studies
TAUCS	Critical shear stress for scour–clay	lb/ft^2	0.22	Calibration
M	Erodibility coefficient of sediment–clay	$lb/ft^2/day$	0.02	Calibration
OXRX Module	-	-	-	-
KBOD20	Unit BOD decay rate at 20 ^oC.	hr^{-1}	0.0104	Calibration
TCBOD	Temperature correction coefficient for BOD decay	none	1.037	Calibration
KODSET	Rate of BOD settling	ft/hr	0.010	Calibration
BENOD	Benthal oxygen demand at 20 ^oC. (assuming sufficient water column DO)	$mg/m^2/hr$	54.1	Calibration
TCBEN	Temperature correction coefficient for benthal oxygen demand	none	1.040	Calibration
NUTRX Module	-	-	-	-
KTAM20	Nitrification rate of ammonia at 20 ^oC.	hr^{-1}	0.004	Calibration
TCNIT	Temperature correction coefficient for nitrification	None	1.07	Default

Module/ HSPF Variable	Description	Units	Value	Source
PLANK Module	-	-	-	-
RATCLP	Ratio of chl*a* content of biomass to phosphorus content	none	2.0	Calibration
NONREF	Nonrefractory fraction of algae and zooplankton biomass	none	1.00	Calibration
ALNPR	Fraction of nitrogen requirements for phytoplankton growth that is satisfied by nitrate	none	0.25	Calibration
EXTB	Base extinction coefficient for light	ft^{-1}	0.20	Calibration
MALGR	Maximum unit algal growth rate	hr^{-1}	0.110	Calibration
CMMLT	Michaelis-Menton constant for light-limited growth	ly/min	0.033	Default
CMMN	Nitrate Michaelis-Menton constant for nitrogen-limited growth	mg/L	0.025	Calibration
CMMNP	Nitrate Michaelis-Menton constant for phosphorus-limited growth	mg/L	0.028	Default
CMMP	Phosphate Michaelis-Menton constant for phosphorus-limited growth	mg/L	0.015	Default
TALGRH	Temperature above which algal growth ceases	deg F.	95.0	Calibration
TALGRL	Temperature below which algal growth ceases	deg F.	45.0	Calibration
TALGRM	Temperature below which algal growth is retarded	deg F.	86.0	Calibration
ALR20	Algal unit respiration rate at 20 ^{o}C.	hr^{-1}	0.003	Calibration
ALDH	High algal unit death rate	hr^{-1}	0.003	Calibration
ALDL	Low algal unit death rate	hr^{-1}	0.001	Calibration
CLALDH	Chl*a* concentration above which high algal death rate occurs	µg/L	70	Calibration
PHYSET	Rate of phytoplankton settling	ft/hr	0.0025	Calibration
REFSET	Rate of settling for dead refractory organics	ft/hr	0.000	Calibration
CVBO	Conversion from milligrams of biomass to milligrams of oxygen	mg/mg	1.31	Previous studies
CVBPC	Conversion from biomass expressed as phosphorus to carbon	mol/mol	106	Previous studies
CVBPN	Conversion from biomass expressed as phosphorus to nitrogen	mol/mol	10	Previous studies
BPCNTC	Percentage of biomass that is carbon (by weight)	none	49	Previous studies

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