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 TMDLs for Minnow Creek (WBID 130)

Woo-Jun Kang, Ph.D.

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) Watershed Monitoring Section and its Watershed Evaluation and TMDL Section. Map production assistance was provided by Janis Paulsen with the Department's Division of Environmental Assessment and Restoration.

Editorial assistance provided by: Jan Mandrup-Poulsen and Linda Lord.

For additional information on the watershed management approach and impaired waters in the Choctawhatchee–St. Andrew Bay Basins, contact:

Bonita Gorham
Florida Department of Environmental Protection
Bureau of Watershed Restoration
Watershed Planning and Coordination Section
2600 Blair Stone Road, Mail Station 3565
Tallahassee, FL 32399-2400
Email: bonita.gorham@dep.state.fl.us
Phone: (850) 245–8513
Fax: (850) 245–8434

Access to all data used in the development of this report can be obtained by contacting:

Douglas Gilbert
Florida Department of Environmental Protection
Bureau of Watershed Restoration
Watershed Evaluation and TMDL Section
2600 Blair Stone Road, Mail Station 3555
Tallahassee, FL 32399-2400
Email: douglas.gilbert@dep.state.fl.us
Phone: (850) 245–8450
Fax: (850) 245–8536

Woo-Jun Kang
Florida Department of Environmental Protection
Bureau of Watershed Restoration
Watershed Evaluation and TMDL Section
2600 Blair Stone Road, Mail Station 3555
Tallahassee, FL 32399-2400
Email: woojun.kang@dep.state.fl.us
Phone: (850) 245–8437
Fax: (850) 245–8444

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 Loads (TMDLs) for dissolved oxygen (DO) and nutrients for Minnow 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. These TMDLs establish the allowable nutrient loadings to Minnow Creek that would restore the waterbody so that it meets the applicable water quality criterion for DO.

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. These TMDLs address WBID 130, Minnow Creek.

Minnow Creek is 1 of the 172 waterbody segments in the Choctawhatchee Basin and 1 of 8 waterbody segments in the basin included on the 1998 303(d) list for Florida. The watershed is located in northwest Jackson County, south of the city of Graceville (**Figure 1.1**). The headwaters of Minnow Creek are in the northwestern portion of Jackson County. The creek flows southwest for approximately 7.7 miles to Alligator Creek, eventually flowing into Holmes Creek, a principal tributary of the Choctawhatchee River. The creek receives flow from a number of smaller branches (**Figure 1.2**).

The drainage area within the Minnow Creek WBID boundary is approximately 7,603 acres and is predominantly made up of agricultural and forested land. Additional information about this area is available in the Basin Status Report for Choctawhatchee–St. Andrew Bay (Department, 2003).

Minnow Creek is located in the Dougherty Karst Plain ecoregion, which occupies a portion of the central Florida Panhandle. This ecoregion comprises flat to gently rolling, southwestward-sloping plains generally characterized by karst terrain. The Floridan aquifer is at or near the surface in much of the region. In this area the aquifer is unconfined, allowing water to enter, move through, and discharge from the Floridan aquifer system more readily and rapidly than in other parts of the state (Miller, 1990). In these unconfined areas, the aquifer is either exposed or is covered by a thin layer of sand or by clayey, residual soil (Miller, 1990).

The karst features in the region offer direct access to the aquifers for natural and anthropogenic pollutants (Scott, 1992). The transport of pollutants in karst terrains is quick, and attenuation is limited (Younos et al., 2001). The main sources and causes of ground water pollution in karst areas fall into one of four groups: municipal, industrial, agricultural, and miscellaneous (Younos et al., 2001). Potential sources in predominantly agricultural areas located within karst terrain include organic compounds from the excessive and improper use of fertilizer and pesticides, and nitrate and bacteria from excessive livestock waste. In karst terrains within more urbanized areas, contaminants associated with urban stormwater runoff (lead, chromium, oil, and grease), bacteria from pet wastes, leaky underground storage tanks, and septic tanks are potential problems. Other sources of potential ground water contamination include unauthorized hazardous waste disposal sites, old landfills, unauthorized dumps, and abandoned wells.

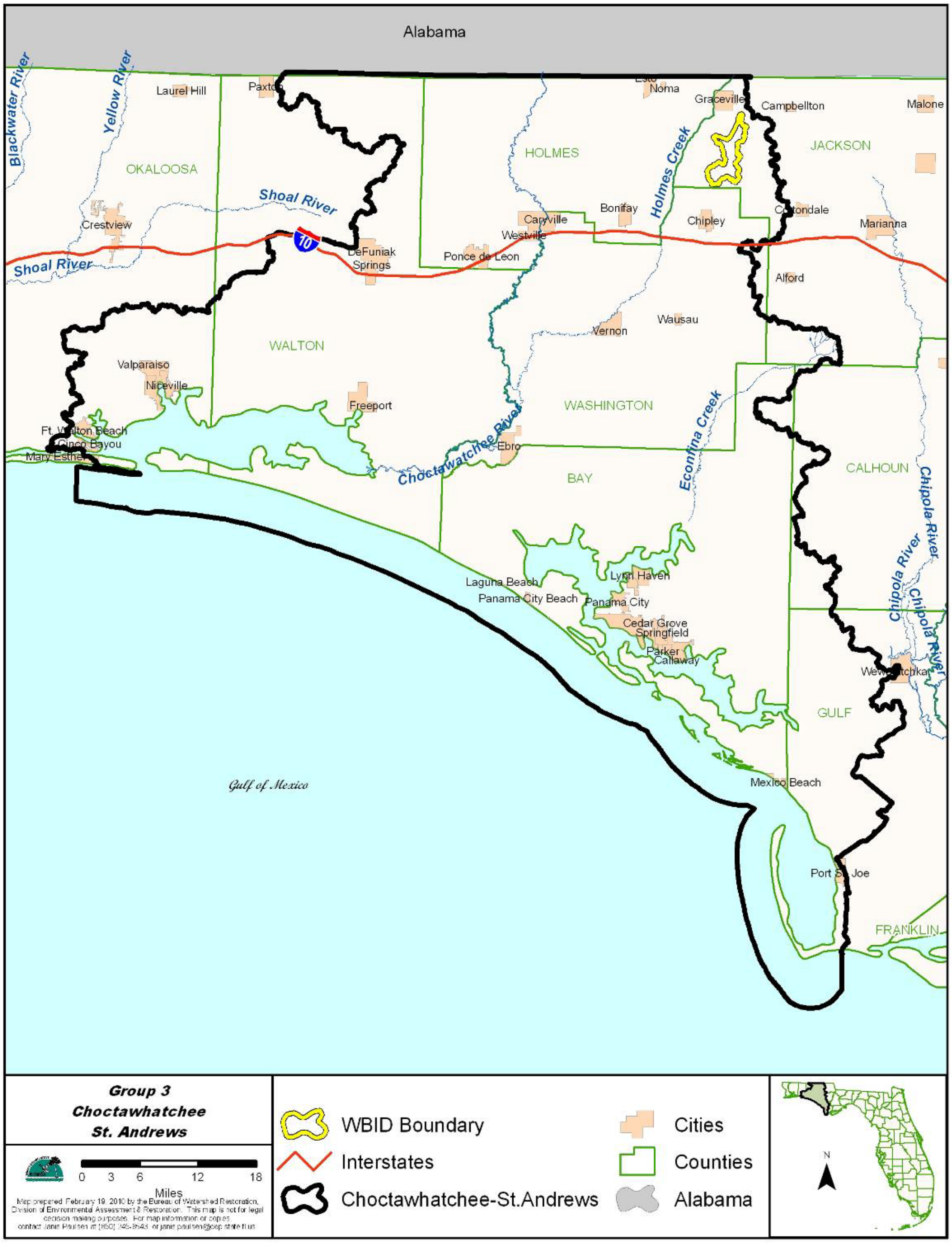


Figure 1.1. Location of Minnow Creek in the Choctawhatchee–St. Andrew Bay Basins and major hydrologic and geopolitical features in the area

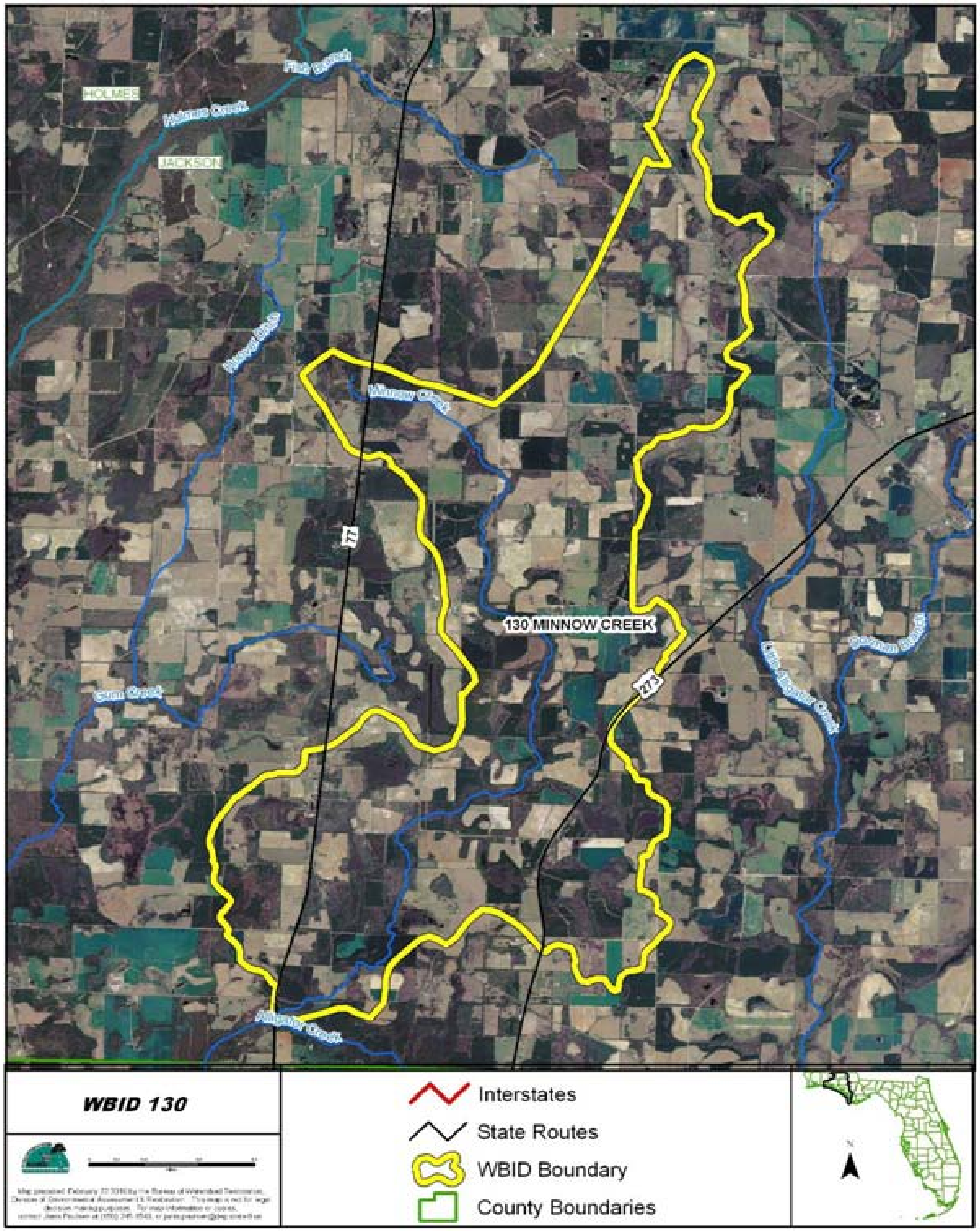


Figure 1.2. Location of Minnow Creek (WBID 130) in Jackson County and major hydrologic features in the area

1.3 Background

This report was developed as part of FDEP'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.

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), Jackson County, local governments, businesses, and other stakeholders. FDEP 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 8 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 the Minnow Creek watershed and verified the impairments for DO during Cycle 2 of the TMDL Program (**Table 2.1**). The projected year for the 1998 303(d)-listed DO TMDL for the creek was 2009, but the Settlement Agreement between 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, these TMDLs must be adopted and submitted to the EPA by September 30, 2010.

Water quality data used in this report are based on the IWR Run38 database. **Figure 2.1** shows the sampling stations for Minnow Creek. **Table 2.2** provides summary statistics for DO collected during Cycle 2 of the verified period (January 1, 2002, through June 30, 2009). During the verified period, water quality data were collected during 7 daily sampling events. Minnow Creek was verified as impaired for low DO because more than 10 percent of the values were below the Class III freshwater DO criterion of 5.0 milligrams per liter (mg/L) during the verified period, with exceedances of 27.8 percent (**Table 2.2**). When the total number of samples is less than 20, the IWR requires a waterbody to be included on the Verified List if 5 or more samples do not meet the DO criterion based on temporally independent sampling events. Total nitrogen (TN) was identified as the causative pollutant due to an elevated median TN value of 0.932 mg/L for the verified period. The water quality data for Minnow Creek shown in **Table 2.3** were collected on March 16, 2010. The data collected on this date for TN, 5-day biochemical oxygen demand (BOD_5), total phosphorus (TP), and corrected chlorophyll *a* (cchl*a*) are similar to the data collected during 2008 and 2009.

Figure 2.2 shows that for the samples collected in 2002, 2008, and 2009, DO concentrations of less than 5.0 mg/L were observed at 3 of the 4 stations. The lowest and highest concentrations (3.64 and 10.1 mg/L, respectively) were recorded at the upstream sampling station.

The verified impairments were based on water quality data collected in 2002, 2008, and 2009 at four STORET stations: 21FLGW 13696, 21FLPNS 305301908530266, 21FLPNS 305125408530557, and 21FLPNS 305012408531460 (**Table 2.4** and **Figure 2.1**). The water quality stations referred to in all subsequent tables and graphs in this report are as follows:

- *Station 21FLGW 13696, the most upstream station, is listed as GW3696;*
- *Station 21FLPNS 21FLPNS 305301908530266, located upstream, is listed as PN0266;*
- *Station 21FLPNS 21FLPNS 305125408530557, located midstream, is listed as PN0557; and*
- *Station 21FLPNS 305012408531460, the most downstream station, is listed as PN1460.*

Figures 2.3 through **2.7** present temporal trends for other water quality parameters. The majority of the data in the IWR database were collected in 2009, while 1 data point was available in both 2002 and 2008. Concentrations of TN ranged from 0.645 to 2.92 mg/L, with an average of 1.11 mg/L (**Figure 2.3**). The highest TN value of 2.92 mg/L was recorded at Station GW3696 in 2002. TP concentrations ranged between 0.026 and 0.16 mg/L, with the highest concentration recorded at Station GW3696 in 2002 (**Figure 2.4**). **Figures 2.5** through **2.6** present temporal data analyses for cchl*a*. Although cchl*a* in Minnow Creek was often below 12 micrograms per liter (µg/L), the highest value, a concentration of 26 µg/L, was recorded at Station GW3696 in 2002. However, there are insufficient cchl*a* data available to determine impairment for nutrients for Minnow Creek. The IWR methodology requires a stream to be included on the Verified List for nutrients if annual average concentrations of cchl*a* based on 4 quarters per year are greater than 20 µg/L (Section 62-303.351, F.A.C.). **Figure 2.7** shows that BOD_5 is less than 2.0 mg/L in the majority of the samples (53 percent). The median BOD_5 was 1.8 mg/L. The highest BOD_5 recorded at Minnow Creek was 2.8 mg/L at Station PN0557, one of the midstream stations.

Table 2.1. Verified impaired listings for Minnow Creek

This is a four-column table. Column 1 lists the waterbody and WBID number, Column 2 lists the waterbody class, Column 3 lists the 1998 303(d) parameters of concern, and Column 4 lists the parameters causing impairment.

[1] IIIF = Class III fresh water

Waterbody Name (WBID)	Waterbody Class[1]	1998 303(d) Parameters of Concern	Parameter Causing Impairment
Minnow Creek (WBID 130)	IIIF	DO	Nitrogen (N) Phosphorus (P)

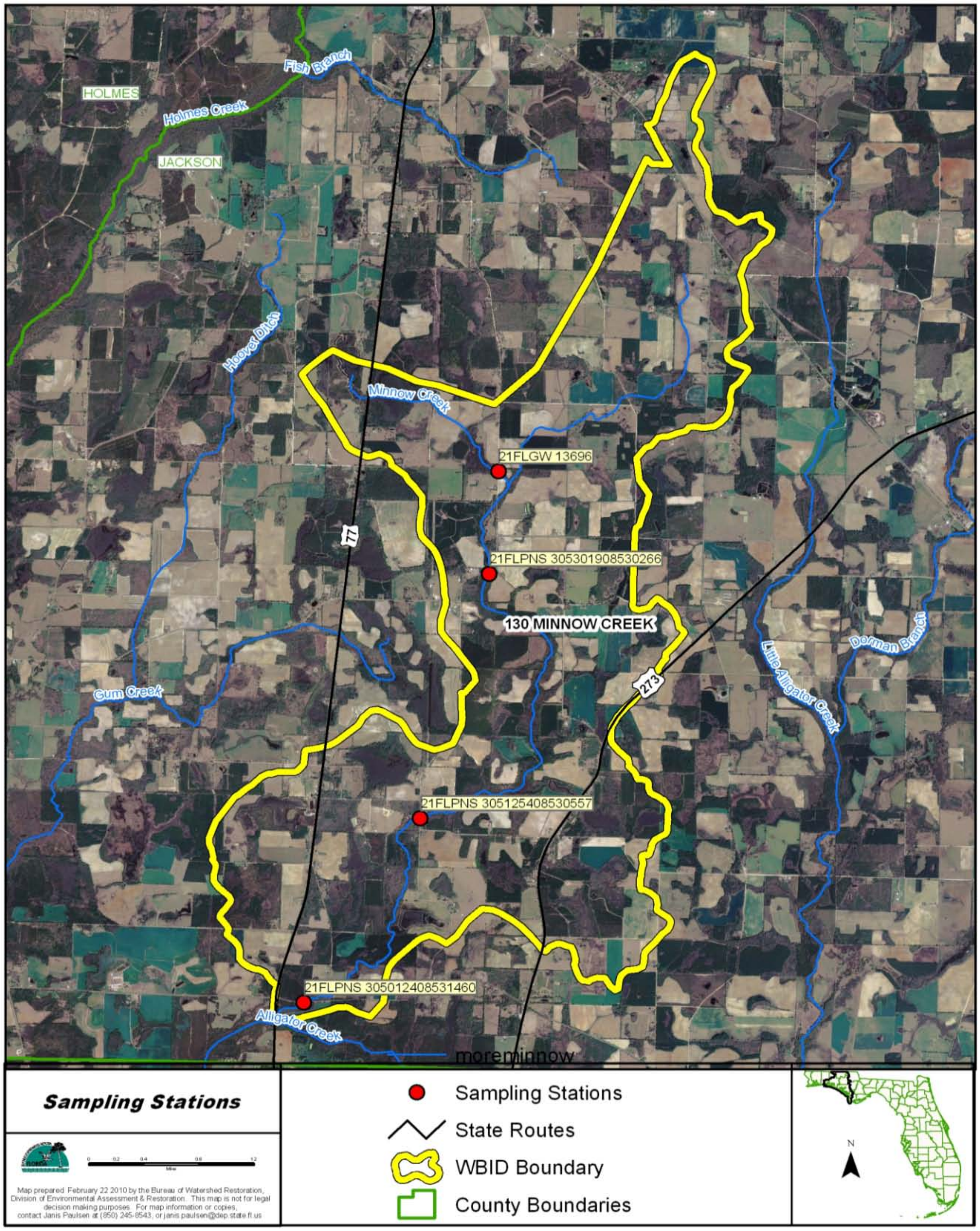


Figure 2.1. Location of water quality monitoring stations in Minnow Creek

Table 2.2. DO summary statistics for Minnow Creek

This is an eight-column table. Column 1 lists the parameter, Column 2 lists the number of samples, Column 3 lists the mean concentration (mg/L), Column 4 lists the median concentration (mg/L), Column 5 lists the minimum concentration (mg/L), Column 6 lists the maximum concentration (mg/L), Column 7 lists the number of exceedances, and Column 8 lists the percent exceedances.

Parameter	Number of Samples	Mean (mg/L)	Median (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	% Exceedances
DO	18	6.72	6.95	3.64	10.10	5	27.8%

Table 2.3. Water quality data collected during the 2010 survey

This is an eight-column table. Column 1 lists the station number, Column 2 lists the sample date, Column 3 lists the water temperature (°C.), Column 4 lists the DO concentration (mg/L), Column 5 lists the TN concentration (mg/L), Column 6 lists the TP concentration (mg/L), Column 7 lists the cchla concentration (µg/L), and Column 8 lists the BOD_5 concentration (mg/L).

Station	Sample Date	Water Temperature (°C.)	DO (mg/L)	TN (mg/L)	TP (mg/L)	Cchla (µg/L)	BOD_5 (mg/L)
PN1460	3/16/2010	11.4	9.22	0.562	0.034	4.0	1.1

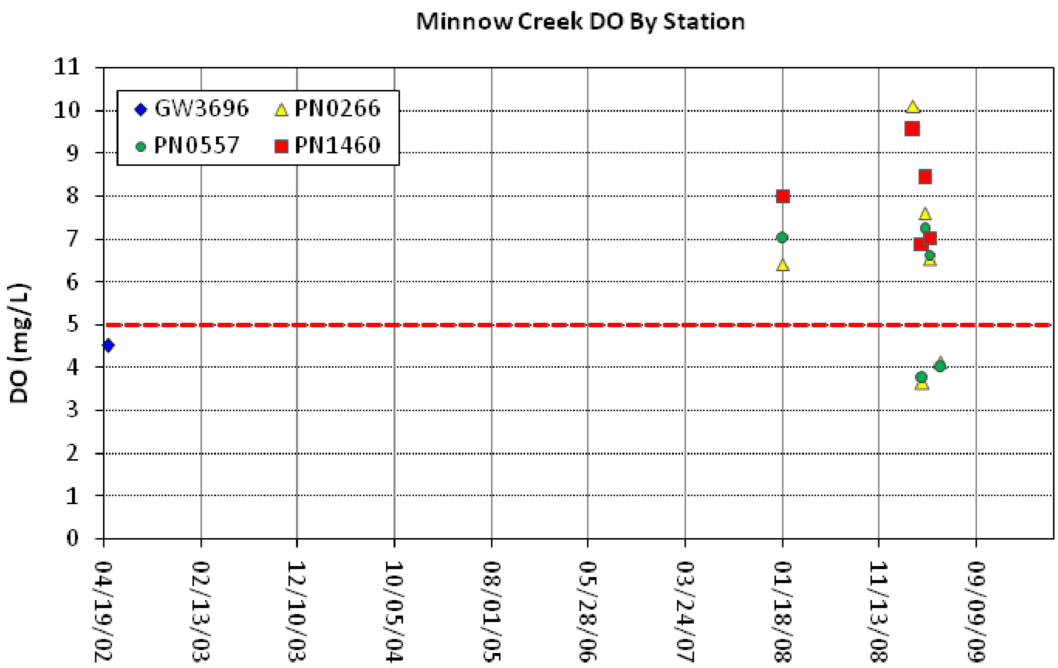


Figure 2.2. Concentrations of DO measured in Minnow Creek during the verified period. Red dots indicate the DO criterion of 5 mg/L.

Table 2.4. Water quality stations and location description

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

Station	Description
21FLGW 13696	NWC-SS-1033 Minnow Creek
21FLPNS 305301908530266	Minnow Creek @ Galilee Road
21FLPNS 305125408530557	Minnow Creek South @ Gailee Road
21FLPNS 305012408531460	Minnow Creek @ Lovewood Road

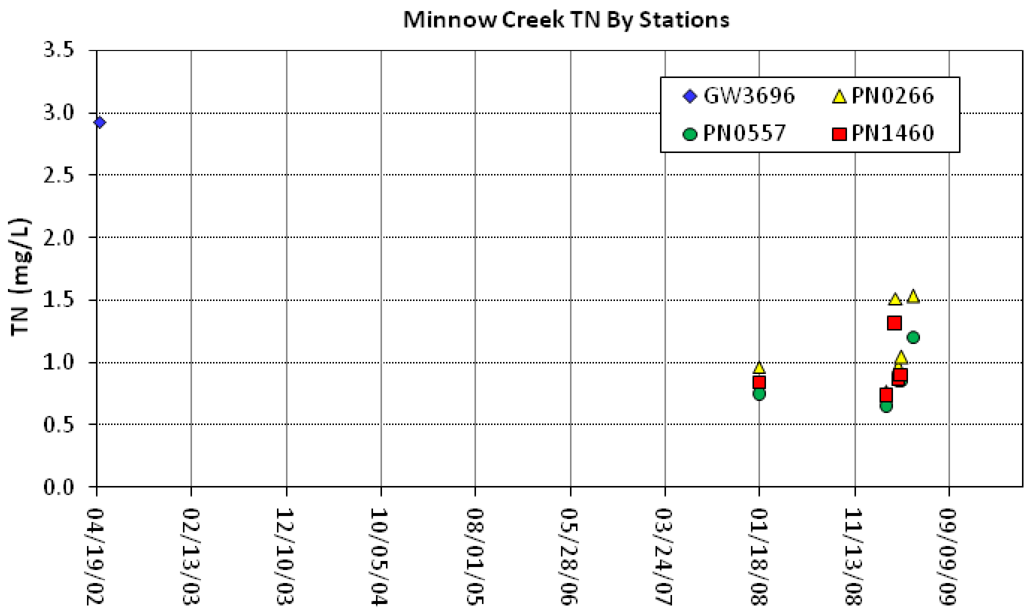


Figure 2.3. Concentrations of TN measured in Minnow Creek during the verified period

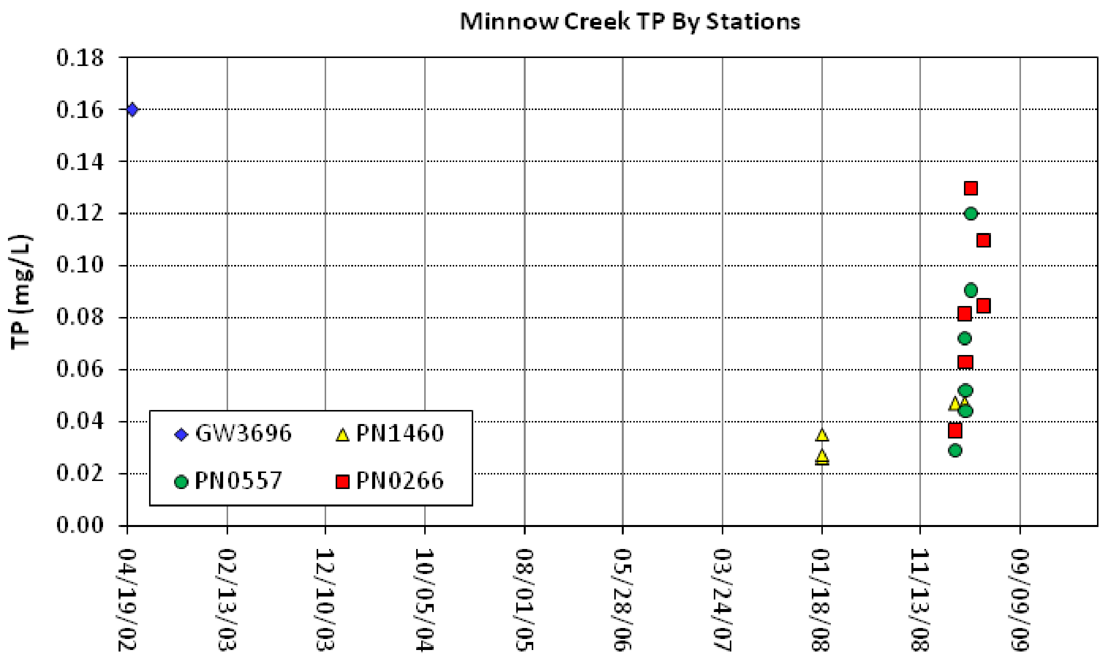


Figure 2.4. Concentrations of TP measured in Minnow Creek during the verified period

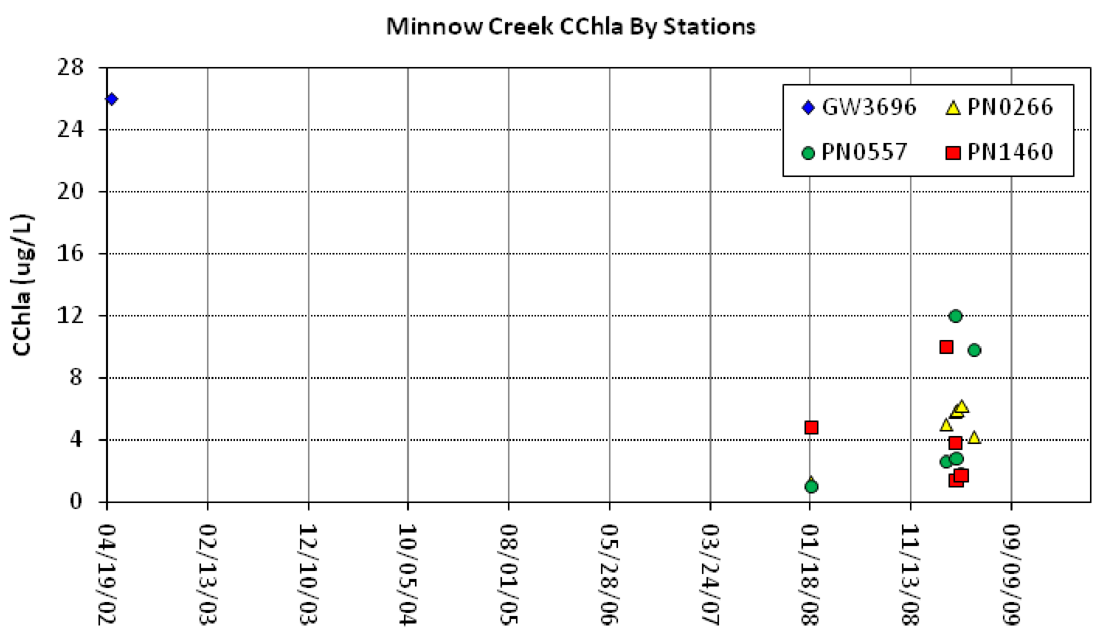


Figure 2.5. Concentrations of cchl*a* measured in Minnow Creek during the verified period

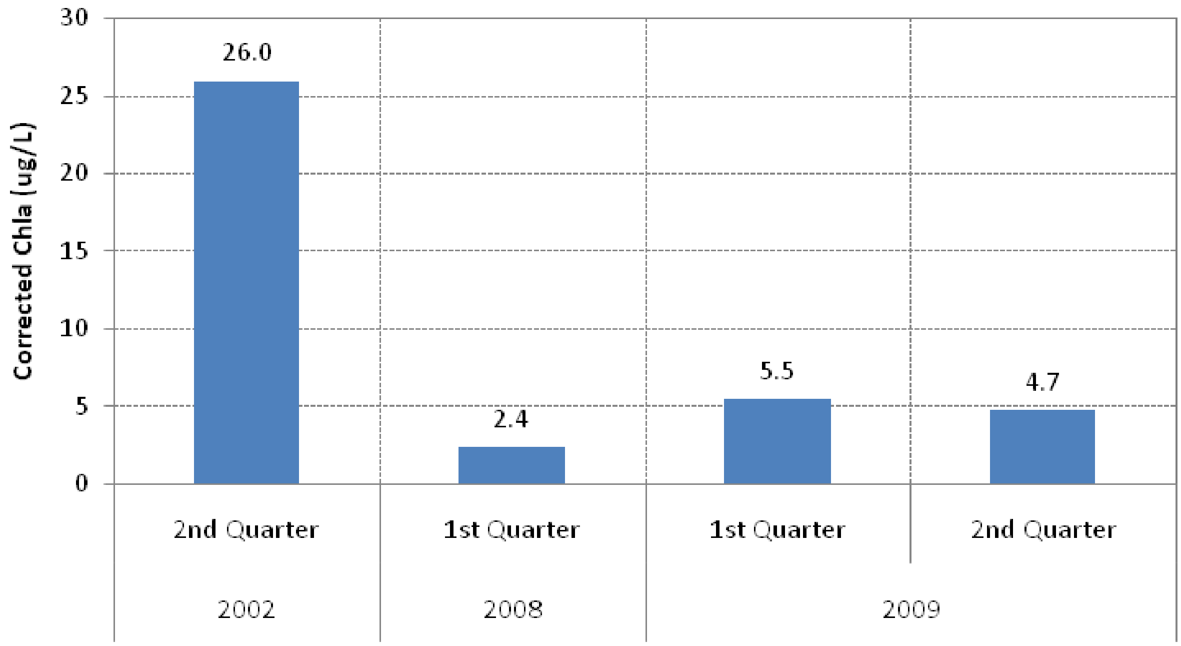


Figure 2.6. Seasonal and annual average concentrations of cchl*a* measured in Minnow Creek during the verified period

Figure 2.7. Concentrations of BOD_5 measured in Minnow Creek during the verified period

Chapter 3. DESCRIPTION OF APPLICABLE WATER QUALITY STANDARDS AND TARGETS

3.1 Classification of the Waterbody and Criterion Applicable to the TMDLs

Florida's surface waters are protected for 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)**

Minnow Creek (WBID 130) 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 these TMDLs is the Class III criterion for DO.

3.2 Narrative Nutrient Criteria Definitions

3.2.1 Chlorophyll a

Chlorophyll, 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 chlorophyll 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, chlorophyll 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 chlorophyll *a* (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 estuarine 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 exist 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 a state 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 lowered DO concentrations as a result of algal decomposition.

3.2.3 Total Phosphorus as P

Phosphorus is one of the primary nutrients that regulates 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 process of eutrophication. 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 Interpretation of the DO Criterion

Florida's DO criterion for Class III fresh waterbodies states that DO shall not be less than 5.0 mg/L, and normal daily and seasonal fluctuations above this level shall be maintained. DO concentrations in ambient waters can be controlled by many factors, including DO solubility, which is controlled by temperature; 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 and the oxidation of some reductants such as ammonia and metals; and respiration by aquatic organisms.

One of the major sources of DO consumption may originate from organic sediments accumulated in a stream 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 the 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.

One method of identifying causative pollutants for the DO impairment is to use statewide screening level concentrations set at the 70^{th} percentile of all STORET data across the state from 1970 to 1987 (Friedemann and Hand, 1989). This approach is useful if there are no significant regional differences in what is defined as a waterbody meeting its intended designated uses. The Department's statewide screening level for streams is 2.0 mg/L for BOD_5, 1.6 mg/L for TN, and 0.22 mg/L for TP. However, the Department has noted that there are significantly lower values than the nutrient screening levels leading to DO impairment in many areas with a greater portion of anthropogenic land uses. Therefore, this report focuses on TN, TP, and BOD concentrations, as discussed in later sections.

3.3.2 Interpretation of the Narrative Nutrient Criterion

Florida's nutrient criterion is narrative only. Nutrient concentrations of a waterbody 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 there are annual cchl*a* averages more than 50 percent greater than the historical value for at least 2 consecutive years.

While the IWR provides a threshold 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 Department used the IWR threshold concentration of 20 µg/L cchl*a* for assessing Minnow Creek for nutrient impairment and determined there was no impairment based on this metric.

3.3.3 Numerical Water Quality Target Development

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. The results for TN are presented here in **Figure 3.1** and **Table 3.1,** as shown in the outlier portion of the Data Distribution Platform of JMP. The maximum TN value of 2.92 mg/L measured at Station 21FLGW 13696 was identified as indicated by the outlier box in **Figure 3.1**. 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 Hydrological Simulation Program–Fortran (HSPF) Model (Bicknell et al., 2001) used to establish the relationship between nutrient load reductions and the resulting DO concentration (allowable load).

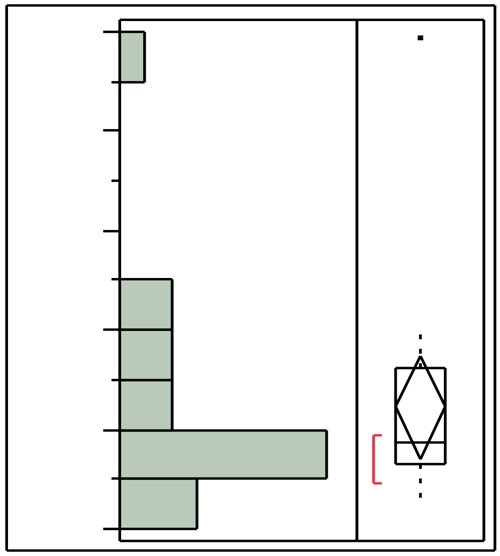


Figure 3.1. TN concentration distributions in Minnow Creek during the verified period

Table 3.1. Summary statistics for TN observed in Minnow Creek during the verified period

This is a two-column table. Column 1 lists the statistic, and Column 2 lists the value.

Statistic	Value
100.0% (maximum)	2.9600
99.5%	2.9600
97.5%	2.9600
90.0%	1.6730
75.0% (quartile)	1.3048
50.0% (median)	0.9320
25.0% (quartile)	0.8225
10.0%	0.7224
2.5%	0.6450
0.5%	0.6450
0.0% (minimum)	0.6450
Mean	1.1107778
Standard deviation (std dev)	0.5317189
Standard error (std err) mean	0.1253274
Upper 95% mean	1.3751954
Lower 95% mean	0.8463602
Number	18

A multivariable analysis was conducted for Minnow Creek to screen point-to-point (daily) relationships in the data, correlating TN, TP, BOD_5, cchl*a*, NH_4, and alkalinity (Alk) to DO (**Table 3.2**). The results indicated that DO is strongly related to TN (r = -0.855), BOD (r = -0.642), TP (r = -0.528), NH_4 (r = -0.588), and Alk (r = -0.659), as commonly expected in DO-impaired waterbodies. In particular, a strong relationship (r = 0.970) between Alk and NH_4 in a stream can be evidence of increased DO consumption by reducing bacteria in the system (**Figure 3.2**). Moreover, a strong negative relationship between TN and DO, and between TP and DO, indicates that elevated TN and TP in the stream can result in reducing conditions (**Figures 3.3** and **3.4**). Therefore, load reductions of TN and TP (and thus BOD_5) most likely help the stream by preventing any increase in reducing conditions.

After the initial data investigation, empirical equations were developed using the stream daily data to establish the nutrient targets that directly respond to the DO impairment for Minnow Creek. Daily TN and DO measurements showed that there is an excellent relationship between TN and DO. Based on the best-fit equation for TN (r^2 = 0.731, n = 17), a daily maximum TN concentration of 1.21 mg/L should result in the creek meeting the DO criterion of 5.0 mg/L. Similarly, the TP daily maximum target was set at 0.089 mg/L using a daily relationship between TP and DO (r^2 = 0.326, n = 18). The calibrated HSPF Model was then used to establish the load reductions of TN and TP necessary to ensure that they did not exceed the daily maximum of 1.21 mg/L for TN and 0.089 mg/L for TP. It should be noted that watershed load reductions in TN and TP are expected to eventually reduce BOD_5 in the stream, as organic portions of TN and TP compounds are part of BOD_5.

Table 3.2. Multivariable analysis of the water quality parameters observed in Minnow Creek during the verified period

This is a nine-column table. Column 1 lists the parameter, Column 2 lists the DO values, Column 3 lists the TN values, Column 4 lists the TP values, Column 5 lists the TN/TP values, Column 6 lists the BOD values, Column 7 lists the cchla values, Column 8 lists the alk values, and Column 9 lists the NH_4 values.

- = Empty cell/no data

Parameter	DO	TN	TP	TN/TP	BOD	Cchl*a*	Alk	NH_4
DO	1.000	-	-	-	-	-	-	-
TN	-0.855	1.000	-	-	-	-	-	-
TP	-0.528	0.494	1.000	-	-	-	-	-
TN/TP	0.162	-0.114	-0.828	1.000	-	-	-	-
BOD	-0.642	0.448	0.546	-0.242	1.000	-	-	-
Cchl*a*	-0.319	0.352	0.200	-0.270	0.314	1.000	-	-
Alk	-0.659	0.754	0.446	-0.221	0.132	0.335	1.000	-
NH_4	-0.588	0.720	0.409	-0.183	0.046	0.175	0.970	1.000

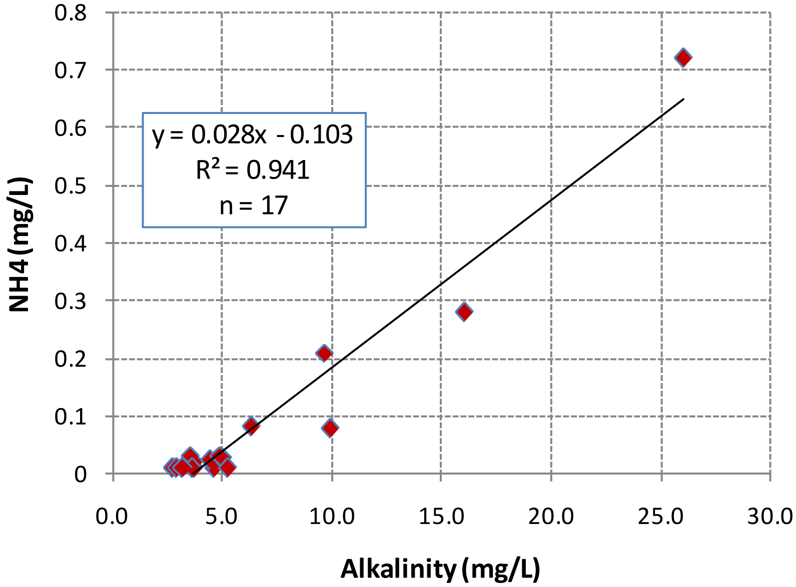


Figure 3.2. Daily relationship between Alk and NH_4 in Minnow Creek during the verified period

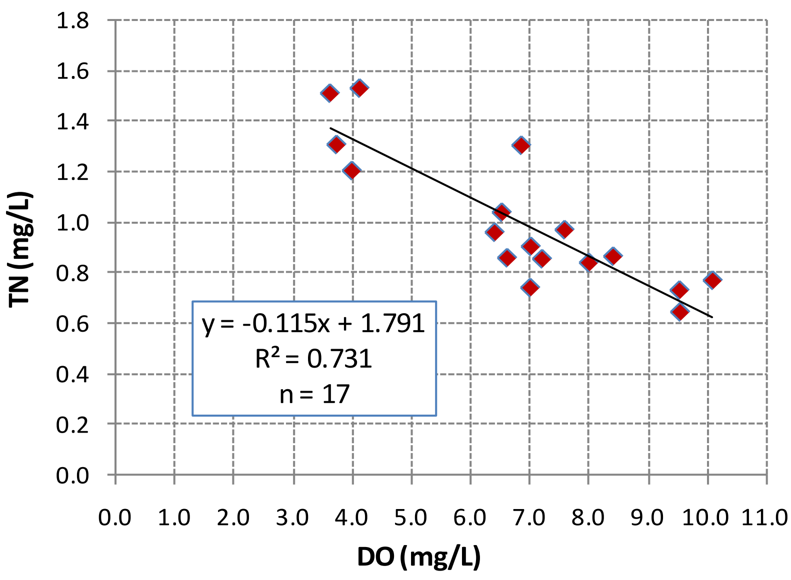


Figure 3.3. Daily relationship between DO and TN in Minnow Creek during the verified period

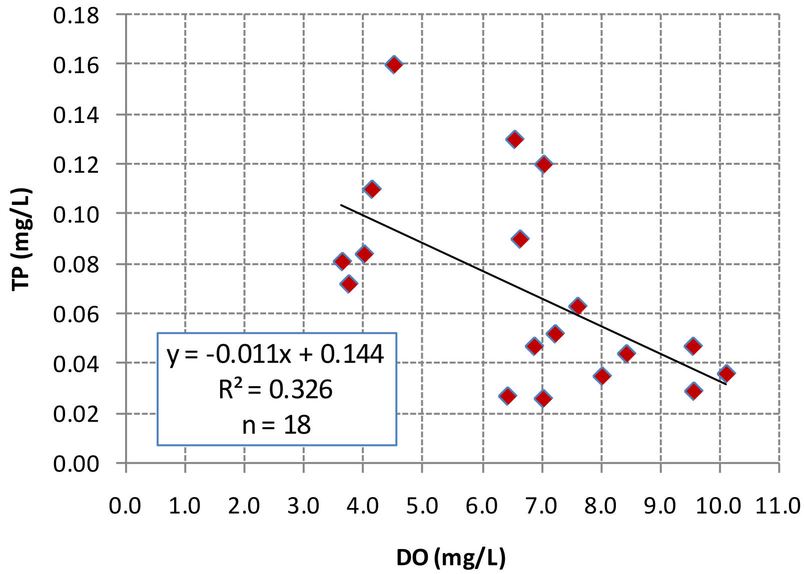


Figure 3.4. Daily relationship between DO and TP in Minnow Creek during the verified period

Chapter 4: ASSESSMENT OF SOURCES

4.1 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 have often been used to assess watershed impacts on the water quality of a receiving waterbody. A detailed watershed model would be beneficial in estimating time-series DO and nutrient loads from potential sources in the watershed, in order to predict biological and chemical 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 were evaluated using the Windows version of HSPF (WinHSPF Version 2.3). Assessing the external load entailed assessing land use patterns, soils, topography, hydrography, point sources, service area coverage, 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).

The PERLND (Pervious Land) Module in HSPF 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, 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, 2001) is available at www.epa.gov/waterscience/basins/.

4.2 Types of Potential Sources

An important part of the TMDL analysis is the identification of pollutant source categories, source subcategories, or individual sources of the pollutant of concern in the watershed and the amount of pollutant loading contributed by each of these sources. Sources are broadly classified as either “point sources” or “nonpoint sources.” Historically, the term point sources have 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). These nonpoint sources included certain urban stormwater discharges, such as those from local government master drainage systems, construction sites over five acres, and a wide variety of industries (see **Appendix 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. 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.

4.2.1 Point Sources

No NPDES-permitted wastewater treatment facilities or industrial wastewater facilities discharge directly into Minnow 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 Minnow Creek watershed.

4.2.2 Nonpoint Sources and Land Uses

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 use coverages for the watershed were aggregated using the Florida Land Use, Cover and Forms Classification System (FLUCCS) (Florida Department of Transportation [FDOT], 1999) into nine different land use categories: cropland/ improved pasture/tree crops (agriculture), unimproved pasture/woodland pasture (pasture), rangeland/upland forests, commercial/industrial, high-density residential, low-density residential, medium-density residential, water, and wetlands. The spatial distribution and acreage of different land use categories for HSPF were identified using 2004 land use coverage (scale 1:40,000) provided by the NWFWMD and contained in the Department’s GIS library. Land use categories within the

Minnow Creek WBID boundary were aggregated using the simplified Level 1 codes and tabulated in **Table 4.1**. **Figure 4.1** shows the spatial distribution of the principal land uses within the WBID boundary.

As shown in **Table 4.1,** the Minnow Creek watershed was estimated to cover a total area of about 7,603 acres, as implemented in the Schematic blocks of the HSPF Model. The predominant land uses are improved pasture and cropland (3,278 acres), followed by upland forests and rangeland (2,554 acres), and wetlands (1,130 acres). As shown in **Figure 4.2**, percent land use in the watershed indicated that human land uses (including residential areas, agriculture, and pasturelands) covered about 51 percent of the total watershed area, while natural land uses, including wetlands, upland forests/rangeland, and water, accounted for the remaining 49 percent.

Onsite sewage treatment and disposal systems (OSTDS), including septic tanks, are commonly used where providing central sewer is not cost-effective or practical. When properly sited, designed, constructed, maintained, and operated, OSTDS are a safe means of disposing of domestic waste. The effluent from a well-functioning OSTDS is comparable to secondarily treated wastewater from a sewage treatment plant. When not functioning properly, however, OSTDS can be a source of nutrients (nitrogen and phosphorus), pathogens, and other pollutants to both ground water and surface water. 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 surface water through stormwater runoff. In these circumstances, a high water table can result in nutrient pollution reaching the receiving waters through baseflow.

Based on data obtained from the Florida Department of Health (FDOH), which is currently undertaking a project to inventory the use of OSTDS (i.e., septic tanks) by determining the methods of wastewater disposal for developed property sites statewide, an estimated 159 housing units within the Minnow 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, the Department's 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.

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 highly productive aquifers (U.S. Geological Survey [USGS], 2010). Compared with nonkarst areas, springs, caves, sinkholes, and other karst features act as direct pathways for pollutants to enter waterbodies.

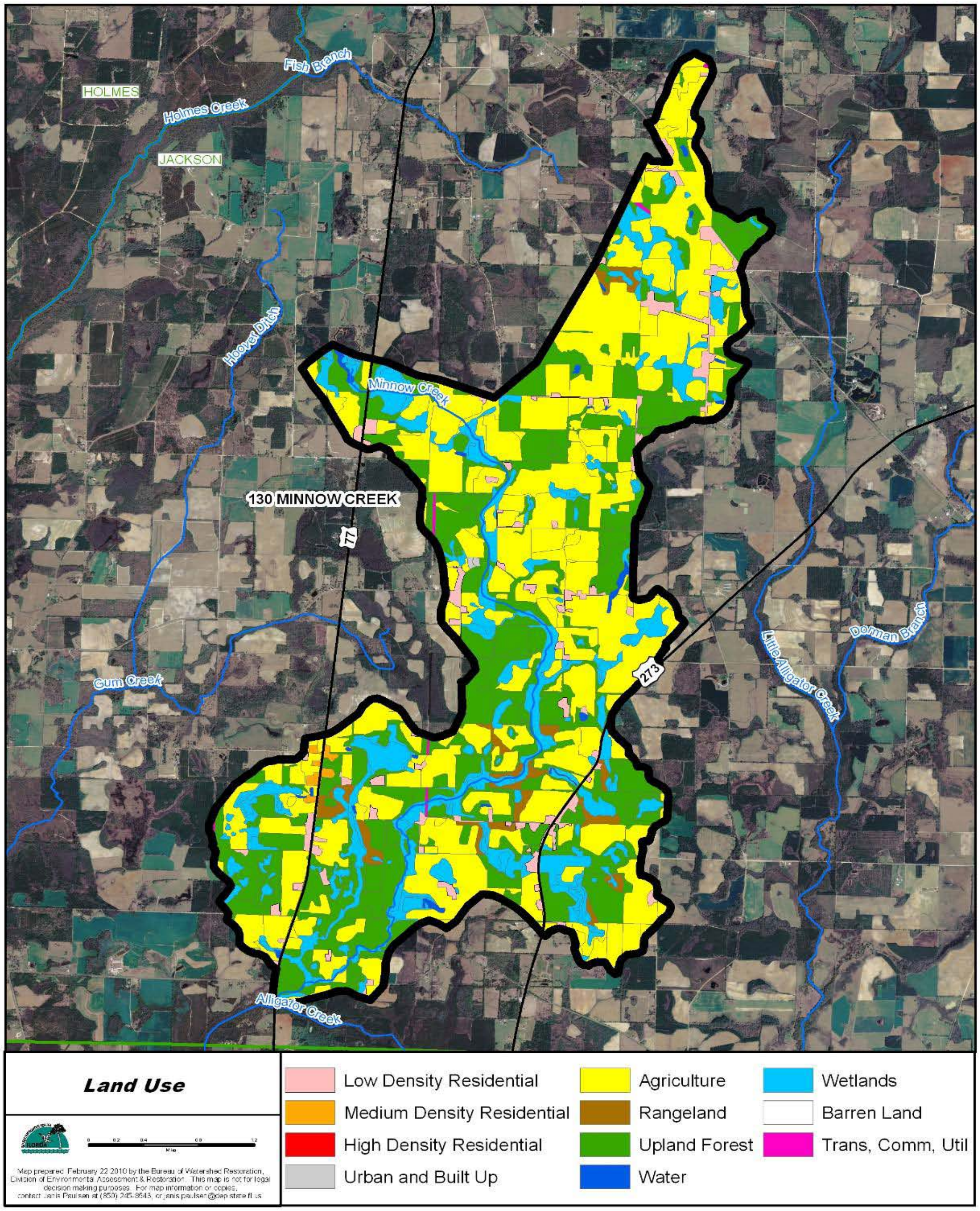


Figure 4.1. Principal land uses in the Minnow Creek watershed in 2004

Table 4.1. Total and percent acreage of the various land use categories in the Minnow Creek watershed in 2004

This is a four-column table. Column 1 lists the FLUCCS code, Column 2 lists the land use category, Column 3 lists the acres, and Column 4 lists the percent acreage.

- = Empty cell/no data

FLUCCS Code	Land Use Category	Acres	Acreage (%)
1100	Low-density residential	305	4.0%
1200	Medium-density residential	25	0.3%
2110/50	Improved pastures/crops	3,278	43.1%
2120/30	Unimproved pastures/woodland pastures	250	3.3%
3000/4000	Rangeland/upland forests	2,554	33.6%
5000	Water	45	0.6%
6000	Wetlands	1,130	14.9%
8000	Transportation/communication/utilities	16	0.2%
-	**Total**	**7,603**	**100.0%**

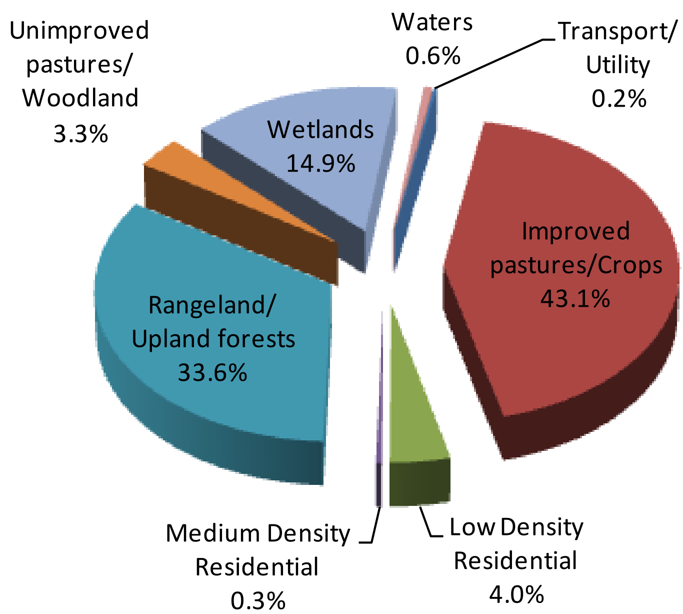


Figure 4.2. Percent acreage of the various land use categories in the Minnow Creek watershed in 2004

Sanitary Sewer Overflows

Sanitary sewer overflows (SSOs) can also be a potential source of fecal bacteria 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 bacteria loads in most watersheds. There is no evidence of sanitary sewers within the Minnow Creek watershed.

Livestock

Livestock and other agricultural animals are potentially an important nonpoint source of nutrients. 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 Minnow Creek WBID boundary, nutrient contributions from residential areas could not be excluded based on the current data, especially for the residential areas located immediately adjacent to Minnow 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 surface waters.

4.3 Estimating Point and Nonpoint Source Loadings

4.3.1 Model Approach

The HSPF Model was used to estimate the nutrient loads discharged from the Minnow 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 six-year model simulation period from 2003 to 2009 to represent existing conditions.

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 4.2,** based on published values (CDM, 2002). Four of the nine land uses contain fractions of impervious lands.

Table 4.2. Percentage of impervious area in the Minnow Creek watershed

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 and balances this with outflows from evaporation and outflows based on a rating curve. This project consists of four sets of PERLND and IMPLND land uses representing the watershed, draining to four RCHRES, representing Minnow Creek. The RCHRES element defines the depth-area-volume relationship for the modeled waterbody. **Appendix B** contains more detailed information on the HSPF Model approach and the HSPF input parameters and values used for model calibration.

Chapter 5: DETERMINATION OF ASSIMILATIVE CAPACITY

5.1 Determination of Loading Capacity

Nutrient enrichment and the resulting problems related to eutrophication tend to be widespread and are frequently manifested far (in both time and space) from their source. Addressing eutrophication involves relating water quality and biological effects (such as photosynthesis, decomposition and nutrient recycling), as acted upon by hydrodynamic factors (including flow, wind, tide, and salinity), to the timing and magnitude of constituent loads supplied from various categories of pollution sources. The assimilative capacity should be related to some specific hydrometeorological condition such as an "average" during a selected period or to cover some range of expected variation in these conditions.

The goal of this TMDL development is to identify the maximum allowable TN and TP loadings from the watershed, so that Minnow Creek will meet the DO criterion and thus maintain its function and designated use as a Class III water. 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.

5.1.1 Meteorological Data

Hourly meteorological data for Minnow Creek were obtained from the Marianna station of the Florida Automatic Weather Network (FAWN), an observation platform owned by the University of Florida. The selected weather station is located at Marianna, in Jackson County, Florida, where the hourly meteorological data from September 2002 to June 2009 were recorded. **Table 5.1** provides information on weather station name, periods of data availability, and data collection frequency.

Table 5.1. General information on the Marianna weather station

This is a six-column table. Column 1 lists the location name and identification number, 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 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 a NCDC weather station at Marianna Municipal Airport, Jackson County.

Several data gaps were identified within the available period of record for the meteorological data. 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 was 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**.

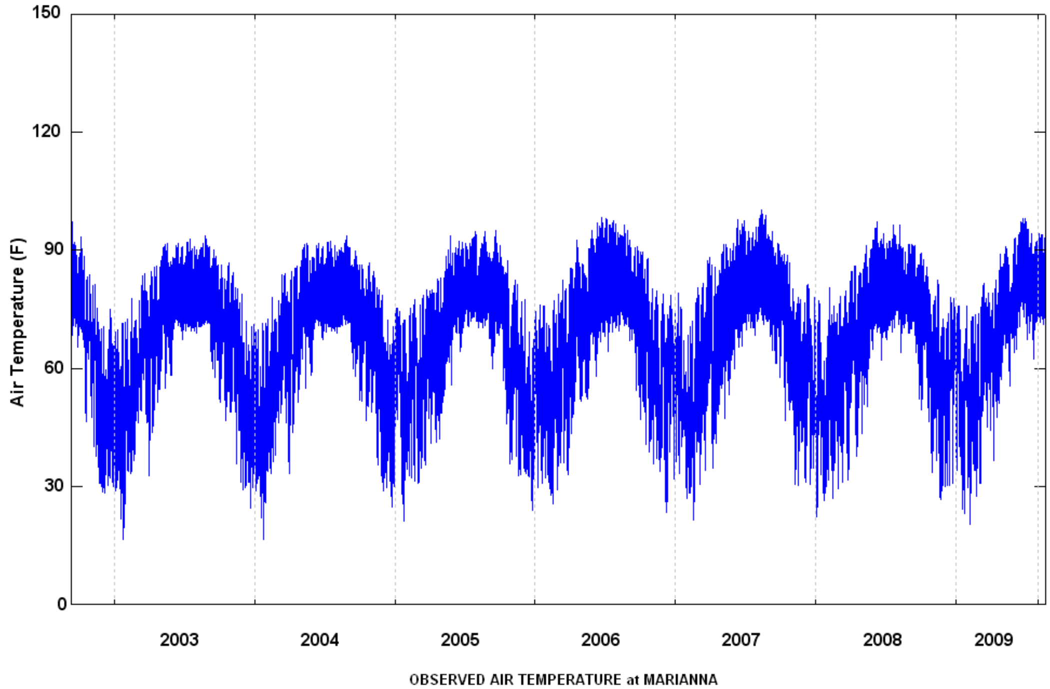
Total annual rainfall varied from 38.9 to 62.6 inches between 2003 and 2008, with an average annual rainfall of 51.15 ± 10.50 inches (**Figure 5.2**). The 6-year average rainfall at the Marianna station during this period is slightly lower than the state average (54.3 inches) in the same period and the 100-year state average rainfall (54.2 inches) (Southeast Regional Climate Center [SERCC], 2010). The deficiency in annual rainfall from the long-term (100-year) average was identified 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. Overall, a comparison between the local 6-year rainfall data obtained from 2003 to 2008 and the state's long-term average rainfall data indicated that the local rainfall data are a good representation of the dry and wet years covered by the simulation period.

5.1.2 Soil Data

Digital coverages and data on 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 is assigned to one of four hydrologic soil groups (A, B, C, or D) established by the NRCS and defined in the Soil Survey publication for Jackson County. Hydrologic Soil Group A comprises soils with a high infiltration potential in the range of 0.4 to 1.0 inches/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. The soil type in the watershed was estimated as Soil Group B, with a scatter distribution of Groups C and D.

5.1.3 Cross-Sectional Data

The FTABLE in HSPF was also created using a depth-volume-area relation for Minnow Creek. Recent field surveys for Minnow Creek were conducted by the Department's Watershed Evaluation and TMDL (WET) Section on April 6, 2010, to measure cross-section and flow for each sub-basin. The obtained field data were incorporated into WinHSPF (EPA, 2007) to create the FTABLE 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 the FTABLE are calculated based on the estimated stream geometry. The outflow from each reach is calculated using Manning's equation.



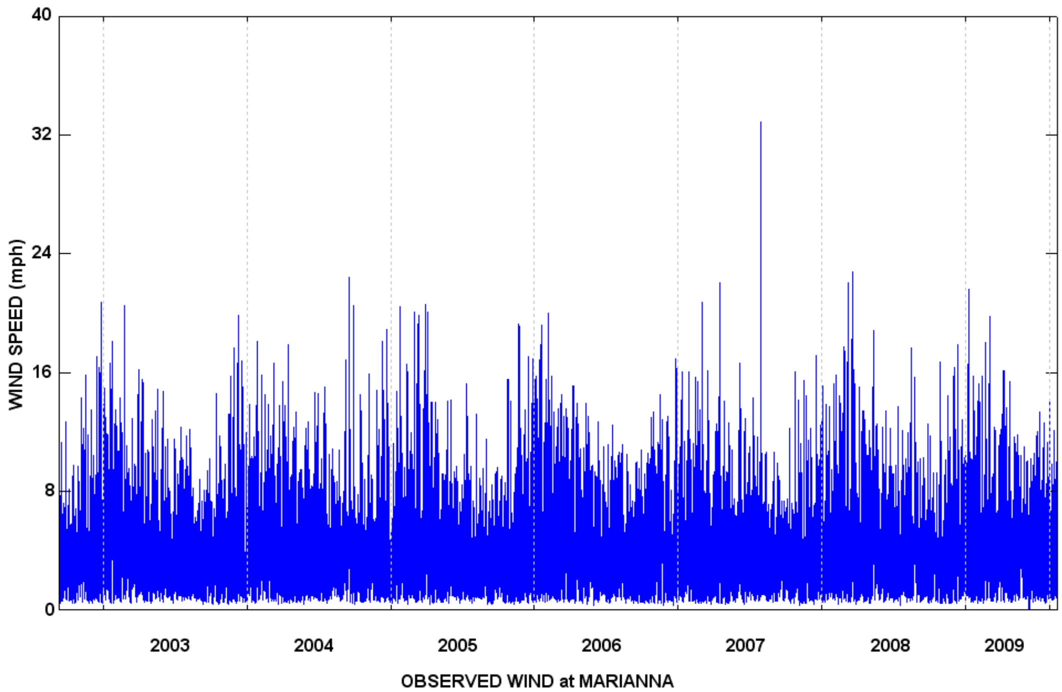


Figure 5.1. Hourly air temperature (top graph) and wind speed (bottom graph) observed at the Marianna weather station, 2002–09

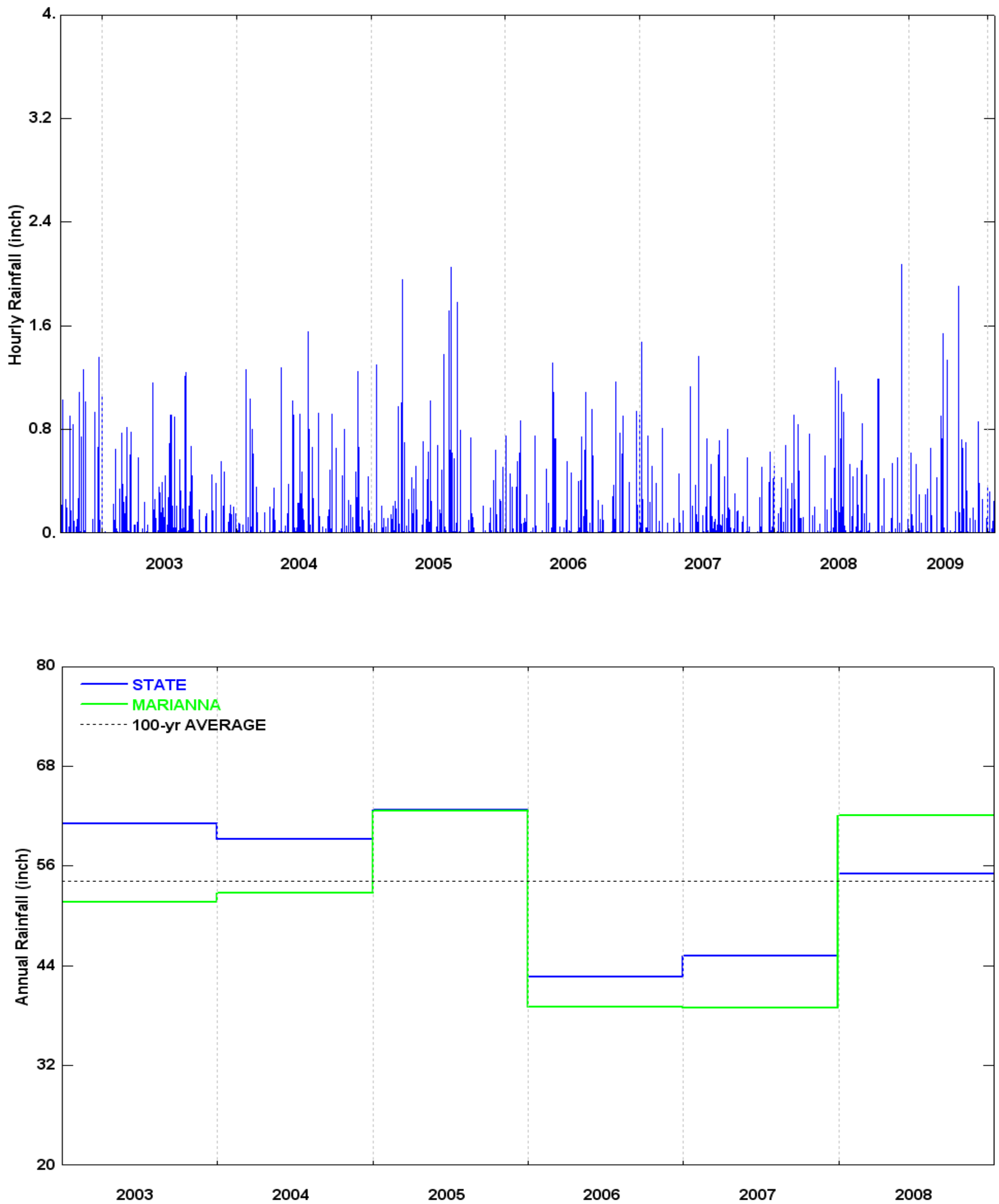


Figure 5.2. Hourly rainfall (top graph) and annual rainfall (bottom graph) observed at the Marianna station versus state average rainfall (bottom graph), 2003–08. The line with dots represents 100-year annual average rainfall in Florida.

5.1.4 HSPF Modeling Sub-basins

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, 1994). Several studies indicated that the increased number of watersheds may increase the accuracy of predicting hydrologic routing and pollution loading by reducing standard errors and, at the same time, can benefit nonpoint source reduction programs in targeting key watersheds for pollutant reduction (Maxted et al., 2009; Chang, 2009). Considering stream length and velocity, watershed size, modeling time, stream geometry measurements, and the TMDL development (the ultimate goal of this report), the Minnow Creek watershed was initially subdivided into four hydrologically connected subwatersheds to see if there were any significant differences in water quality, in order to focus on a target subwatershed. **Figure 5.3** shows reach routing and sub-basins.

Reach 820, the most upstream segment, connects to Reach 830, where water quality Station PN0226 is located in the upper portion of the reach. Hydrologic and water quality outputs simulated for Reach 820 can be then calibrated with the data observed from Station PN 0226. Similarly, simulated results obtained from Reach 830 and Reach 840 were used for calibration with the data observed at water quality Stations PN0557 and PN1460, respectively. Reach 850 is the outflow from Minnow Creek to Alligator Creek. There are no water quality data with Reach 850 to include in the calibration.

5.2 Model Calibration for Minnow Creek

5.2.1 Hydrology Calibration

The HSPF Model, based on the aggregated land use categories, simulated the watershed hydraulics and hydrology. The predicted flow was a result of the balance between water input from the watershed to a reach and losses from the reach. Modeled flows for segmented sub-basins for Minnow Creek were shown for the period from January 1, 2003, to June 30, 2009 (**Figures 5.4** through **5.8)**. There are no flow gauging stations located in the Minnow Creek watershed for model calibration. The only gauging station adjacent to the watershed is the USGS flow gauging station (USGS 02365470) for Wrights Creek near Bonifay in Holmes County, Florida. The observed flow data obtained from Wrights Creek were used for model calibration and validation purposes in simulating Minnow Creek hydrology (**Figure 5.6**).

Overall, the simulated flow for Minnow Creek showed similar patterns compared with the observed flow for Wrights Creek, representing dry and wet seasons of each year. The simulated flow for Minnow Creek at the outlet to Alligator Creek was also plotted, along with a time-series of daily, monthly, and annual rainfall (**Figures 5.7** through **5.9**). As generally expected, time-series of the simulated flows are similar to the overall patterns of observed rainfall throughout the modeling period. Simulated monthly flow is a good representation of a seasonal pattern associated with rainfall (**Figure 5.8**). In particular, a good relationship between annual rainfall and annual flow at the outlet of Minnow Creek indicates that the model simulation accurately represents the long-term flow for Minnow Creek (**Figure 5.9**).

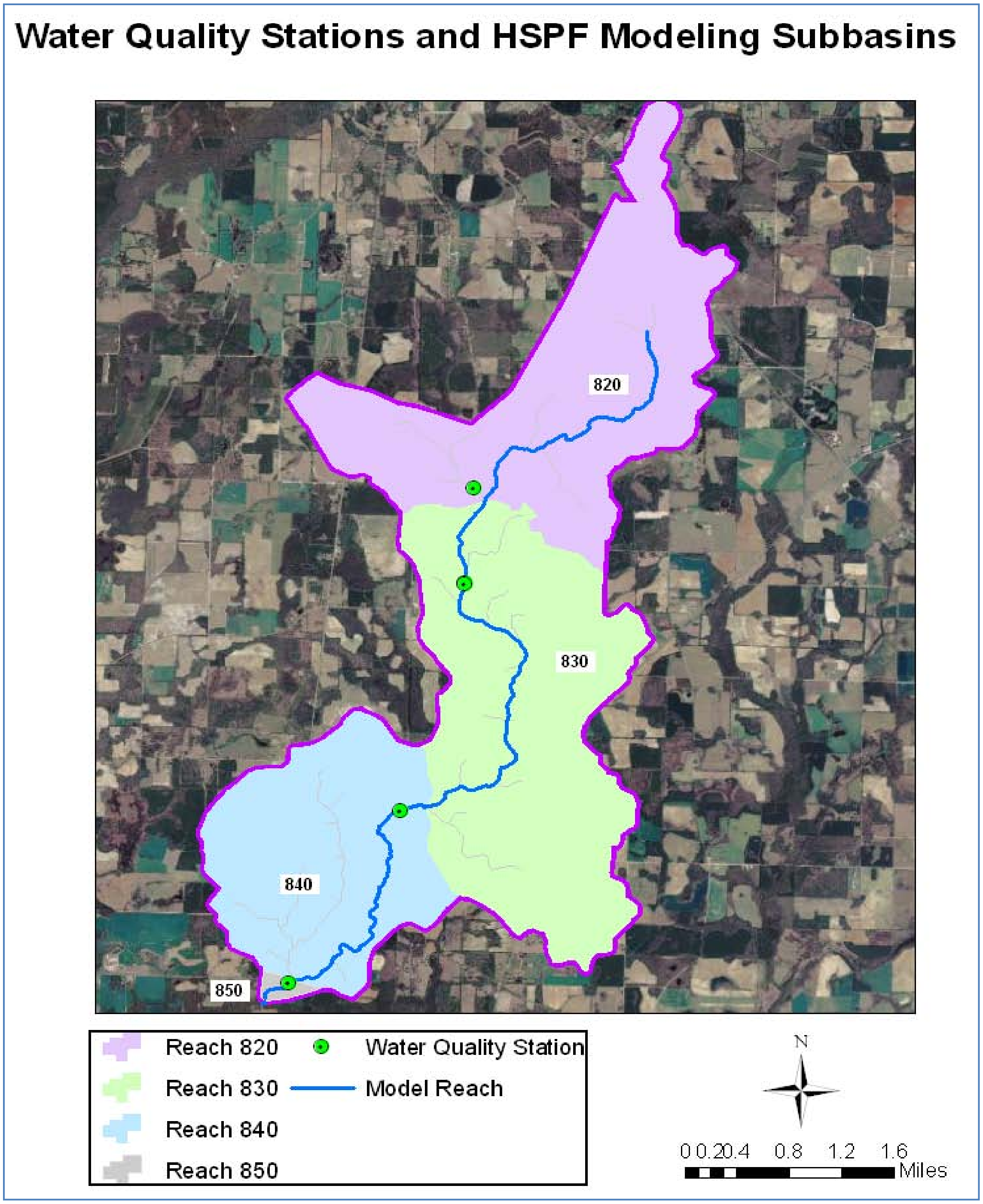


Figure 5.3. Modeling sub-basins and water quality stations in the Minnow Creek watershed

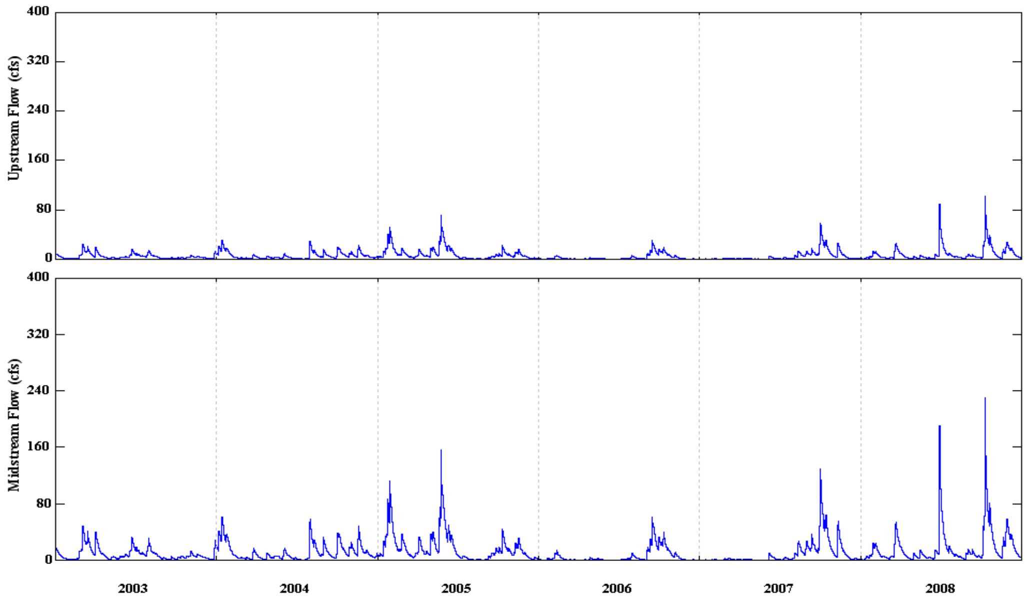


Figure 5.4. Simulated flows for upstream (top graph) and midstream (bottom graph) in Minnow Creek, 2003–09

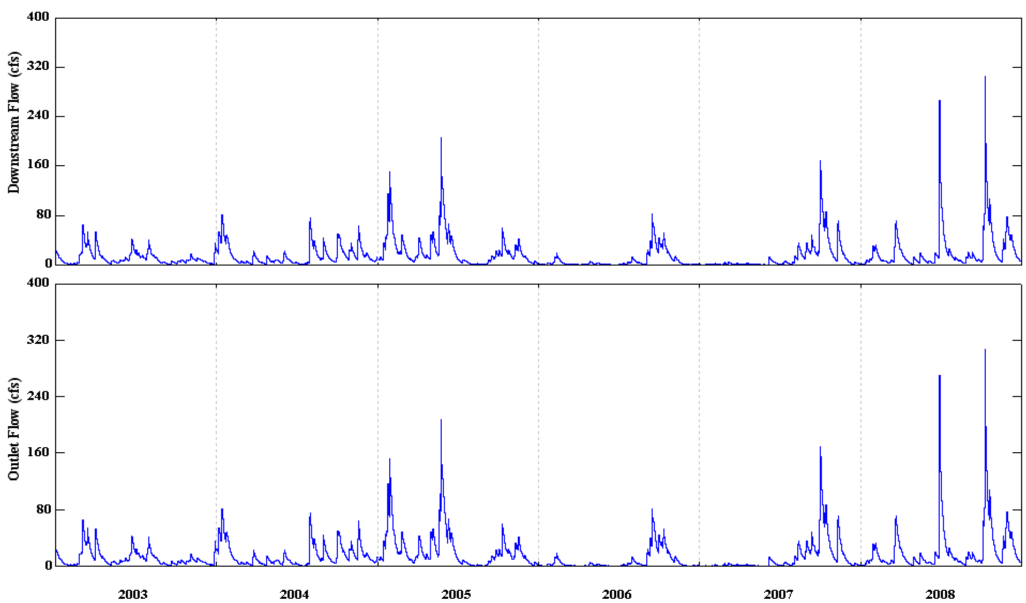


Figure 5.5. Simulated flows for downstream (top graph) and outlet (bottom graph) in Minnow Creek, 2003–09

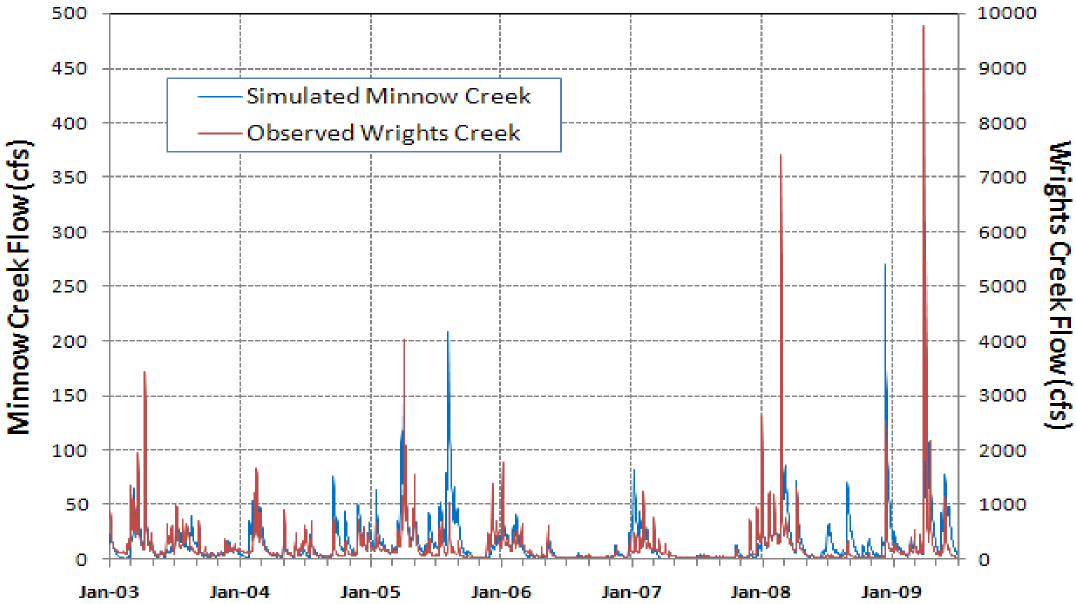


Figure 5.6. Simulated flow at the outlet of Minnow Creek and observed flow at the USGS station on Wrights Creek, 2003–09

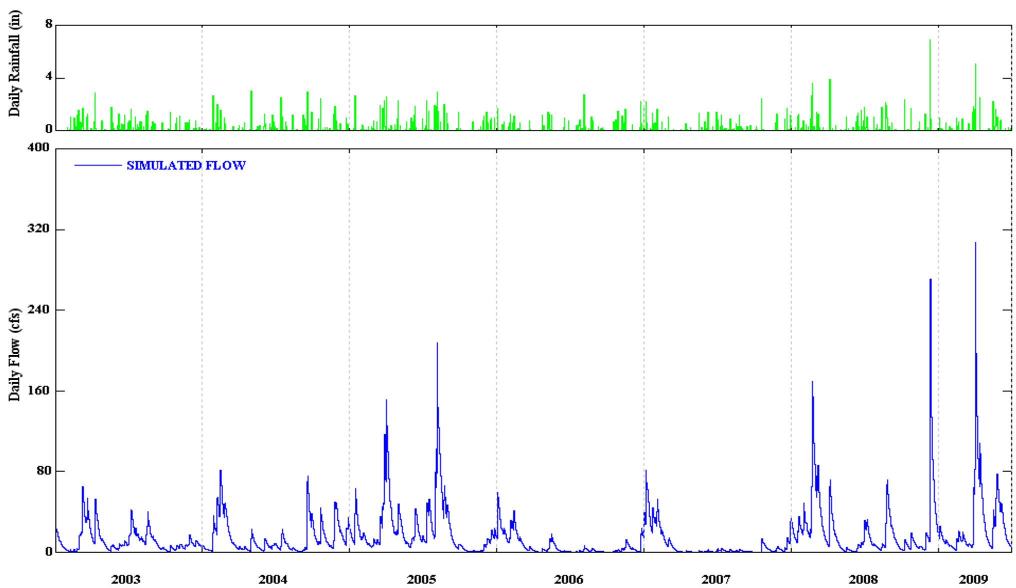


Figure 5.7. Daily rainfall and simulated flow at the outlet of Minnow Creek, 2003–09

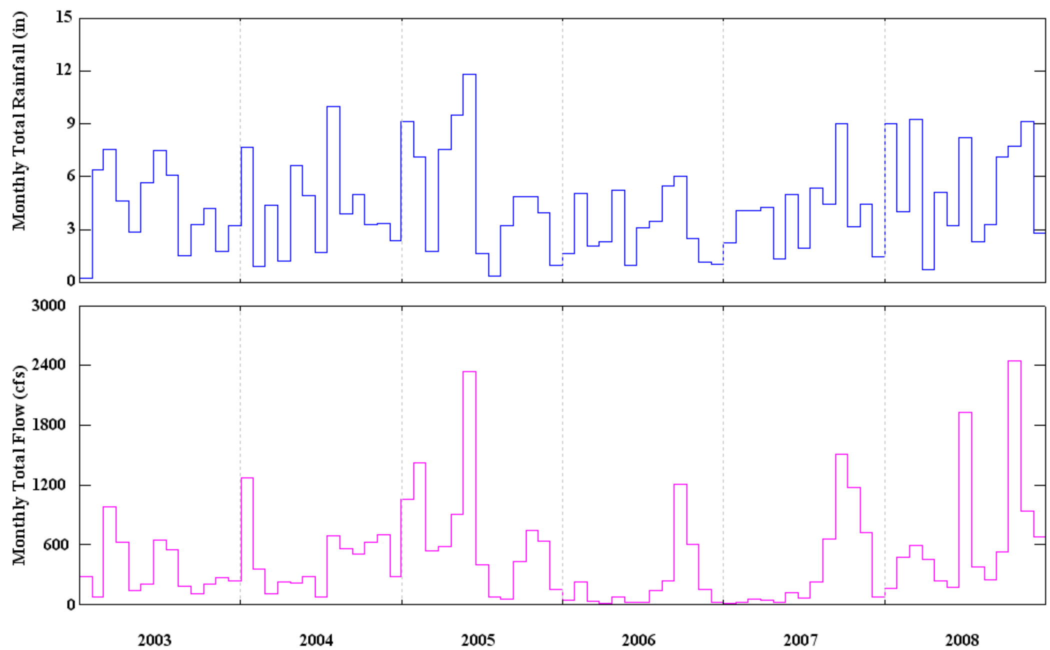


Figure 5.8. Monthly rainfall (top graph) and simulated monthly flow (bottom graph), 2003–09

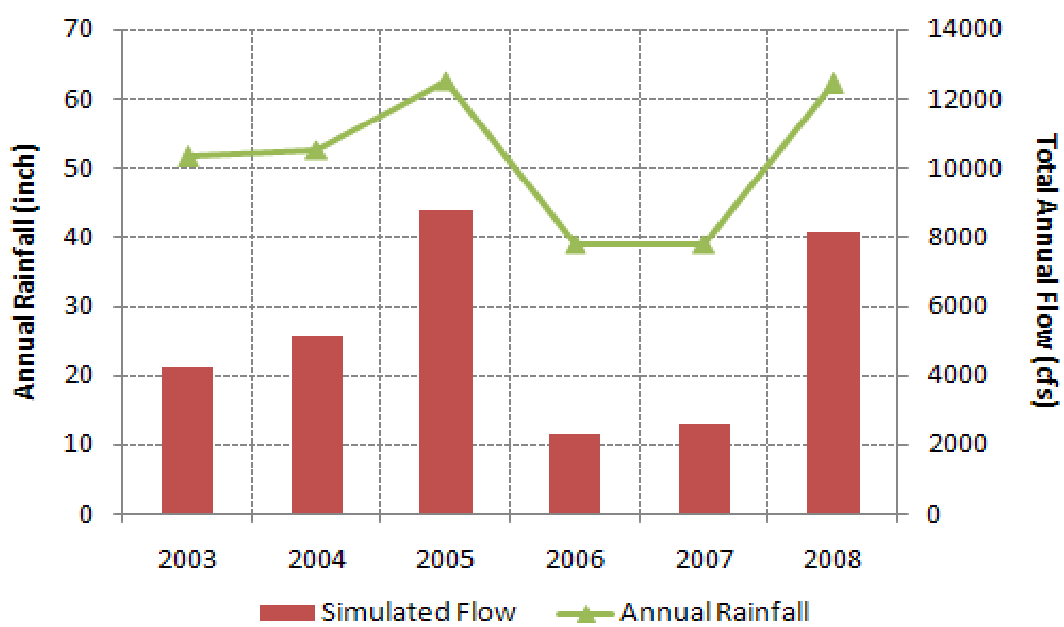


Figure 5.9. Annual rainfall and simulated total annual flow, 2003–08

5.2.2 Incoming Flows Based on Land Use Types

HSPF simulations were conducted for the watershed considering both pervious and impervious surfaces. The modeled watershed has separate parameter values to assess runoff hydrographs and includes adjustments for infiltrations, baseflow, ground water storage, seasonal variations, hydrograph shape factors, wetland and water table interactions, and other parameters. Water inflows (i.e., surface runoff, interflow, and baseflow) through each land use that carry nutrients from all sources were identified in HSPF. Then, nutrient loads from different types of land use were quantified. For this estimate, new Schematic and Mass-Link blocks in HSPF were created to separate monthly flow components (i.e., surface runoff, interflow, baseflow) based on land use types.

Table 5.2 lists simulated annual total inflows to the creek from different land use types. The simulated inflow (about 4,594 acre-feet) was estimated to be lowest in 2006, when annual rainfall was lowest. In contrast, when annual rainfall was highest (62.6 inches), the simulated total annual inflows (17,308 acre-feet) in 2005 were estimated to be about 4 times higher than those of 2006, which was the dry year. A 6-year annual average of the total inflow to Minnow Creek was also estimated to be about 10,268 acre-feet. In addition, simulated annual inflows to the creek varied depending on land use types.

Figure 5.10 shows the associated percent contributions of inflows generated by anthropogenic and natural land uses. The largest inflows each year were from anthropogenic land uses, including improved pasturelands and crops, during the simulation period. In contrast, natural land use types such as upland forests and wetlands were the second largest contributors of water to the creek. Anthropogenic land uses (i.e., improved pasturelands/crops, unimproved pastureland, and low- and medium-density residential) accounted for about 58 percent of the total incoming flows, while natural land uses (i.e., upland forests and wetlands) comprised about 41 percent (**Figure 5.10**).

Table 5.2. Annual total inflows (acre-feet) to Minnow Creek based on different land use types in the watershed

This is a nine-column table. Column 1 lists the land use type; Columns 2 through 8 list the total inflows (in acre-feet) annually from 2004 to 2009, respectively; and Column 9 lists the average value (in acre-feet) from 2003 to 2008.

Land Use Type	2003	2004	2005	2006	2007	2008	2009	Average (2003–08)
Transportation/utilities	44	47	60	31	31	61	33	46
Improved pasture/crops	4,332	5,110	7,883	2,242	2,564	7,914	4,747	5,007
Low-density residential	463	548	802	286	304	795	462	533
Medium-density residential	47	54	74	32	32	74	42	52
Upland forests	2,295	2,771	5,492	1,293	1,238	4,450	3,214	2,923
Unimproved pastureland	266	326	567	141	156	517	337	329
Wetland	927	1,283	2,336	547	675	2,170	1,419	1,323
Water	39	53	94	23	29	89	57	54
Total	**8,414**	**10,191**	**17,308**	**4,594**	**5,029**	**16,071**	**10,311**	**10,268**

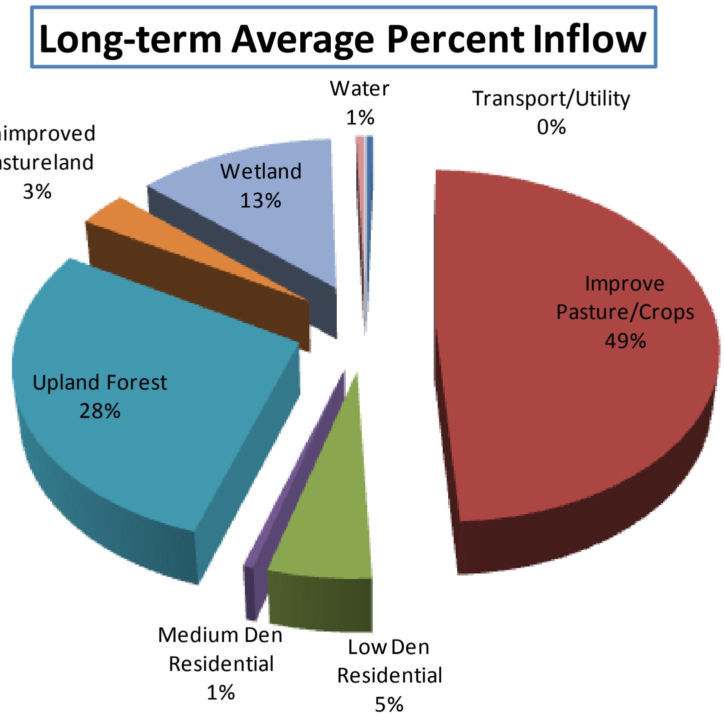


Figure 5.10. Long-term (6-year) average percent inflows to Minnow Creek during the simulation period, 2003–08

5.2.3 Temperature Calibration

Water temperature itself is considered a conservative parameter that does not undergo chemical reactions in a system. It is a critical habitat characteristic for fish and other organisms, and affects rates of biogeochemical processes of functional importance to an environment. For example, the saturation level of DO varies inversely with temperature. The decay of reduced organic matter, and hence oxygen demand caused by the decay, increases with increasing temperature. Some form of temperature dependence is present in nearly all processes. The prevalence of individual phytoplankton and zooplankton species is often temperature dependent. It should be also noted that water temperature in a stream is a result of heat balance along with water movement in the air-land-stream system. Key parameters controlling the energy balance for water temperature are short- and long-wave radiation, conduction, convection, evaporation, and ground conduction (HSPF Manual, 2001).

For Minnow Creek, Parameters PSTEMP, IWTGAS, and RCHRES (KATRAD, KCOND, KEVAP) were adjusted as shown in **Table B-1** (in **Appendix B**) for calibration. The observed and model-predicted time-series of daily average water temperature were calibrated for each subbasin. Daily average temperature observed from 3 different monitoring stations in Minnow Creek was compared with the simulated temperature for the creek over the simulation period (2003–09) and from 2008 to 2009 (**Figures 5.11** and **5.12,** respectively). **Table 5.3** summarizes the statistics on the temperature calibration for 2008–09, indicating that mean absolute error (MSE) is only 0.8 ^{o}C. on daily calibration. Therefore, the Department decided that the model performed well enough to simulate temperature-associated parameters such as DO.

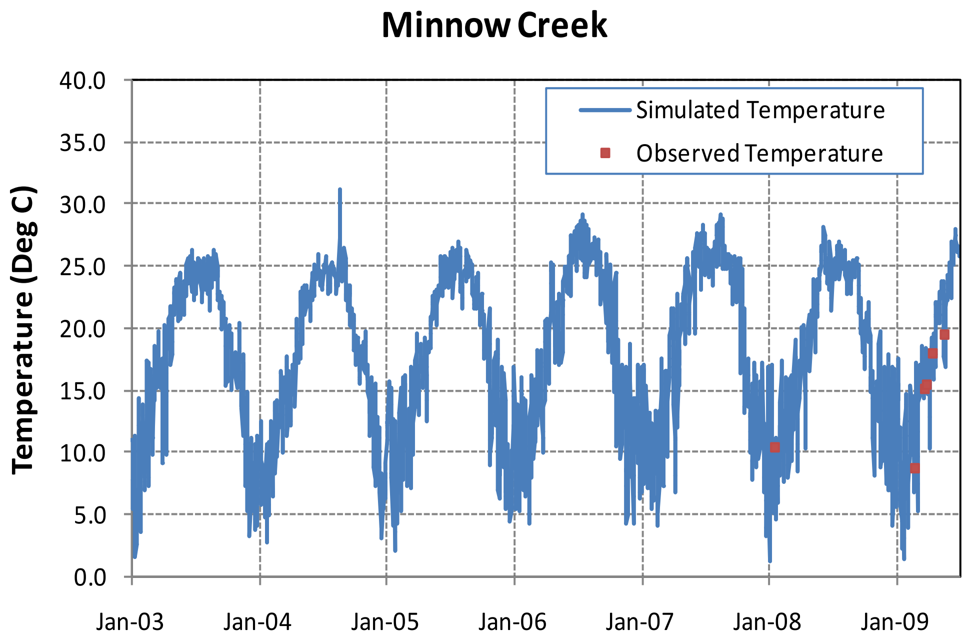


Figure 5.11. Observed versus simulated daily temperature (°C.) during the simulation period, 2003–09

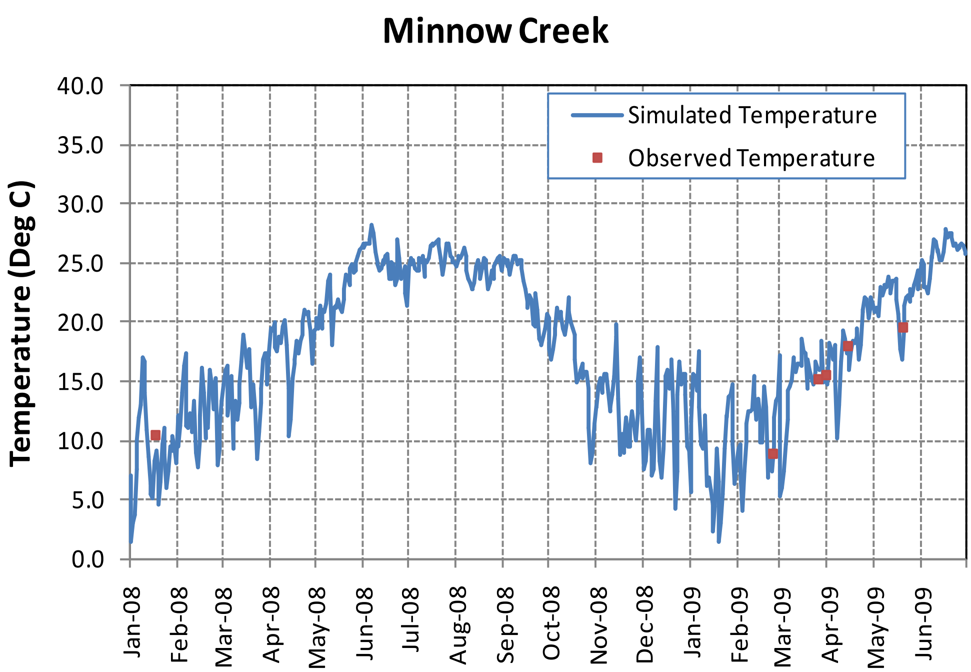


Figure 5.12. Observed versus simulated daily temperature (°C.), 2008–09

Table 5.3. Summary of statistics for daily water temperature calibration in Minnow Creek

This is a four-column table. Column 1 lists the date, Column 2 lists the observed daily water temperature (^{o}C.), Column 3 lists the simulated water temperature (^{o}C.), and Column 4 lists the absolute error (^{o}C.).

Date	Observed Daily Water Temperature (^{o}C.)	Simulated Water Temperature (^{o}C.)	Absolute Error (^{o}C.)
1/17/2008	10.4	8.2	2.13
2/24/2009	10.8	9.4	1.37
3/25/2009	16.5	16.1	0.36
3/31/2009	15.2	14.8	0.42
4/14/2009	17.8	18.1	0.24
5/20/2009	18.9	19.4	0.49
Mean std	**14.9 3.6**	**14.3 4.6**	**0.83**

5.2.4 Water Quality Calibration

Water quality monitoring stations in Minnow Creek were used for calibration purposes. A total of 4 water quality stations are listed in Florida STORET with a period of record from 2002 to 2009 (**Table 5.4**). As discussed in the previous section, the TN concentration from Station 21FLGW 13696 was considered as an outlier and not used.

Spatial and temporal patterns of TN, TP, and DO measured from the three remaining water quality stations were analyzed to screen each subwatershed (**Figures 5.13** through **5.15**). It should be noted that no DO, TN, and TP data were available on May 20, 2009, for Station PN1460. Overall, differences in spatial patterns of DO, TN, and TP over the sampling locations in the watershed seemed minor, and the distribution of low or high concentrations appeared similar across the locations on the same sampling date. In addition, spatial variations in simulated parameters were also insignificant over the segmented reaches. Therefore, it was decided to conduct a watershedwide calibration for TMDL development purposes by comparing the averaged values of water quality parameters simulated from four segmented sub-basins to those observed values measured at the water quality stations.

As the waterbody was impaired for DO due to nutrients, the model calibration for water quality focused on DO, BOD_5, and nutrients. Water quality calibration consisted of adjusting model coefficients until a “best-fit” was achieved between model predictions and the measured data averaged from the entire watershed. After calibration for nutrients, cchl*a*, and BOD_5 was achieved, calibration for SOD was refined by adjusting the SOD in the model until the difference between the measured DO and predicted DO was minimized. A SOD of 51.2 milligrams per square meter per hour (mg/m^2/hr), in combination with the calibrated results for nutrients, best represented the DO measured in Minnow Creek.

Table 5.4 General information on water quality stations during the calibration and validation period, 2002–09

This is a six-column table. Column 1 lists the station, Column 2 lists the latitude, Column 3 lists the longitude, Column 4 lists the number of observations, Column 5 lists the start date, and Column 6 lists the end date.

Station	Latitude	Longitude	Number of Observations	Start Date	End Date
21FLGW 13696	30.8951	-85.5064	29	2002	2002
21FLPNS 305012408531460	30.8368	-85.5294	153	2008	2009
21FLPNS 305125408530557	30.8571	-85.5155	185	2008	2009
21FLPNS 305301908530266	30.8839	-85.5074	183	2008	2009

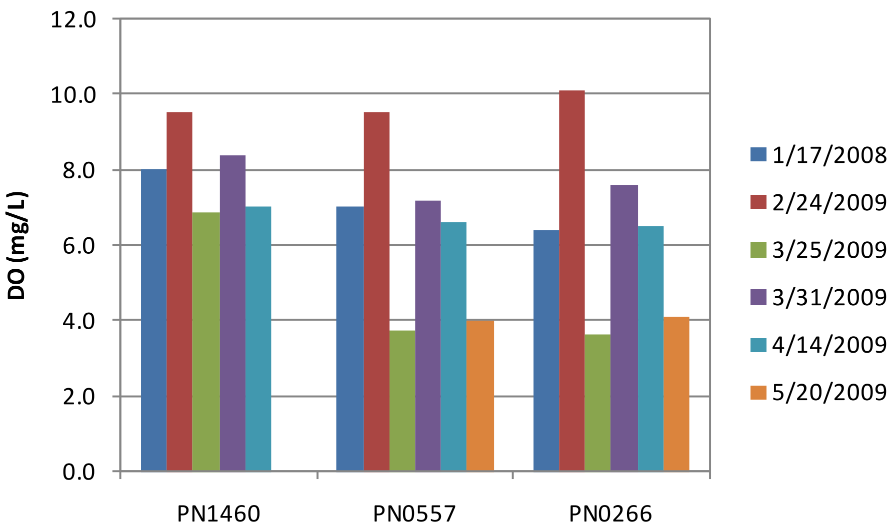


Figure 5.13. Spatial and temporal patterns of DO collected from the three water quality stations, 2008–09

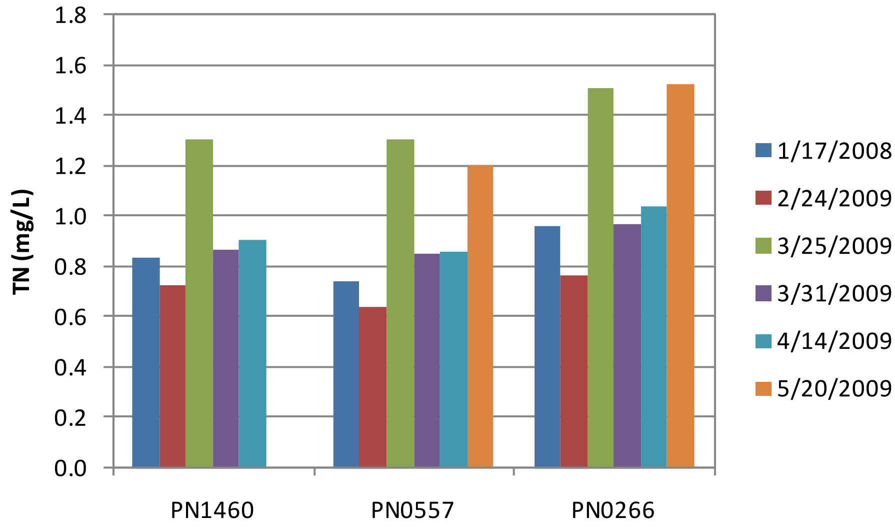


Figure 5.14. Spatial and temporal patterns of TN collected from the three water quality stations, 2008–09

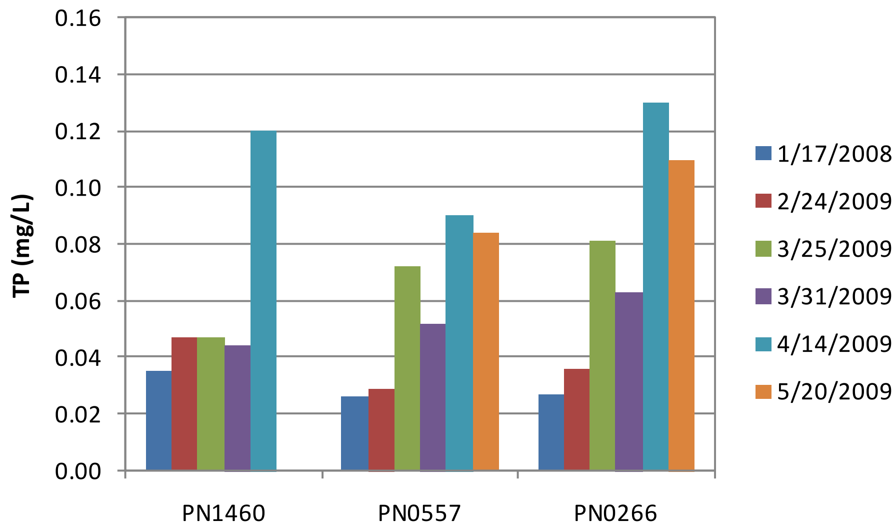


Figure 5.15. Spatial and temporal patterns of TP collected from the three water quality stations, 2008–09

All simulated times series of TN, TP, BOD_5, and DO for the observed data indicated that the model reasonably predicts the observed concentrations for Minnow Creek, showing that there is an acceptable agreement between the observed and the simulated data, as shown in **Figures 5.16** through **5.23**. Mean and standard deviation and coefficient of variance were presented for calibration purposes. Due to the limited availability of observed data, distribution percentiles of observed data over the simulated data were not analyzed.

Although only limited observed water quality data were available in 2008 and 2009 during the period of simulation, point-to-point (daily) calibration for TN was conducted for Minnow Creek. The results indicated that the model reasonably predicted peak and base concentrations of the observed TN concentrations (**Figures 5.16** and **17**). The mean (± standard deviation) and the coefficient of variance (percent) of the simulated TN were 1.02 ± 0.28 mg/L (n = 6) and 27 percent, which are similar to the observed TN mean and standard deviation and coefficient of variance of 1.02 ± 0.26 mg/L (n = 6) and 25 percent. Overall, each measured daily data point for TN during the period was accurately predicted by the corresponding TN simulation.

Following the same procedures, the time-series of simulated TP was calibrated against the observed TP (**Figures 5.18** and **19**). Each daily data point collected from 2008 to 2009 is plotted against the model prediction. The model predictions generally match the pattern of measured data with peak (0.113 mg/L) and base (0.029 mg/L) concentrations of TP. Based on point-to-point calibration, the mean concentration of the observed TP was 0.066 ± 0.030 mg/L (n = 6) with a coefficient of variance of about 46 percent, in good agreement with the mean (0.058 ± 0.030 mg/L) of the simulated TP with a coefficient of variance of about 50 percent.

The model also indicated that ultimate carbonaceous biochemical oxygen demand (uCBOD) predictions matched the peak and base concentrations of the observed uCBOD (**Figures 5.20** and **21**). The observed carbonaceous 5-day biochemical oxygen demand ($CBOD_5$) concentrations were converted to uCBOD by multiplying 1.40 to calibrate against the simulated uCBOD (Chapra, 1997). This value is based on a first-order decay rate of 0.25/day, which is considered typical for natural stream conditions. Based on point-to-point calibration, the mean concentration of the observed uCBOD was 2.62 ± 0.80 mg/L (n = 6) with a coefficient of variance of about 30 percent, in good agreement with the mean (1.97 ± 1.01 mg/L) of the simulated uCBOD with a coefficient of variance of about 51 percent.

The results for the DO calibration are shown in **Figure 5.22** for 2003 to 2009, and **Figure 5.23** for 2008 and 2009. **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 and 2009. In general, the model was able to reproduce both the pattern and magnitude of the measured data. The mean concentration of observed DO was 6.7 ± 1.9 mg/L, with a coefficient of variance of 28 percent in 2008 and 2009. These results are in good agreement with the mean value (8.0 ± 0.5 mg/L) of simulated DO, with a coefficient of variance of 7 percent. Based on these results, the model was considered calibrated for DO.

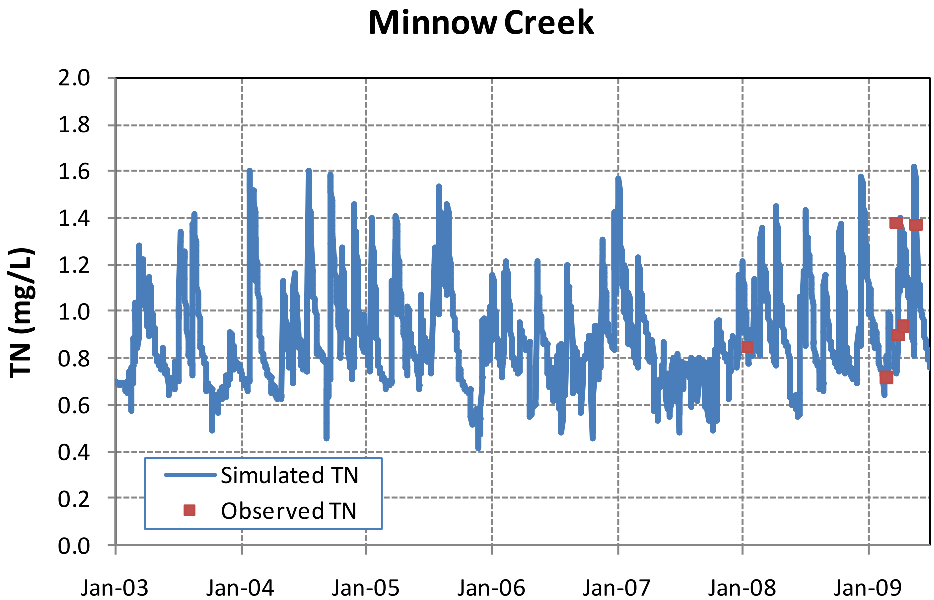


Figure 5.16. Time-series of simulated versus observed TN in Minnow Creek, 2003–09

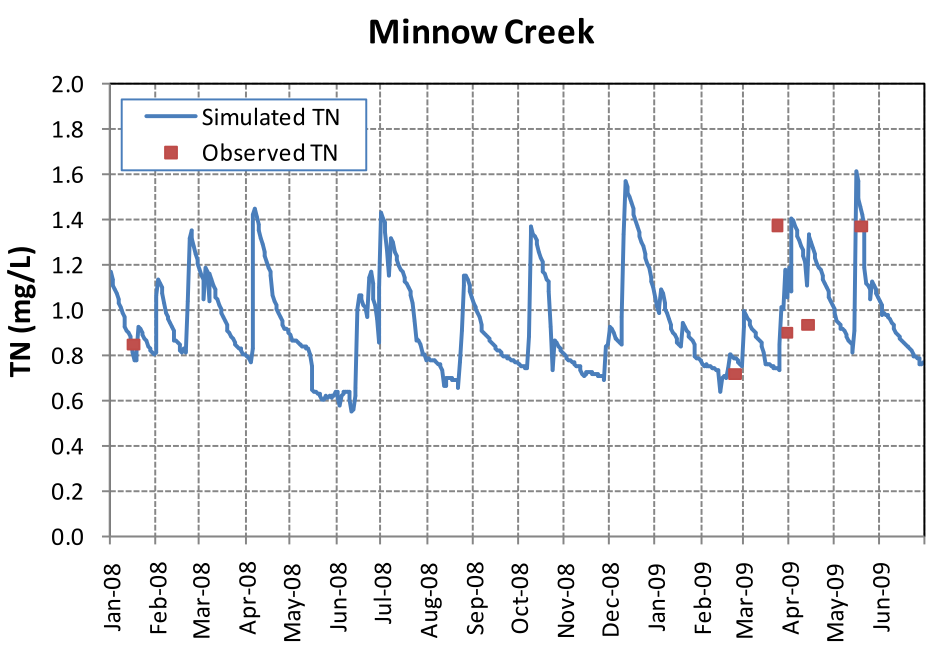


Figure 5.17. Time-series of simulated versus observed TN in Minnow Creek, 2008–09

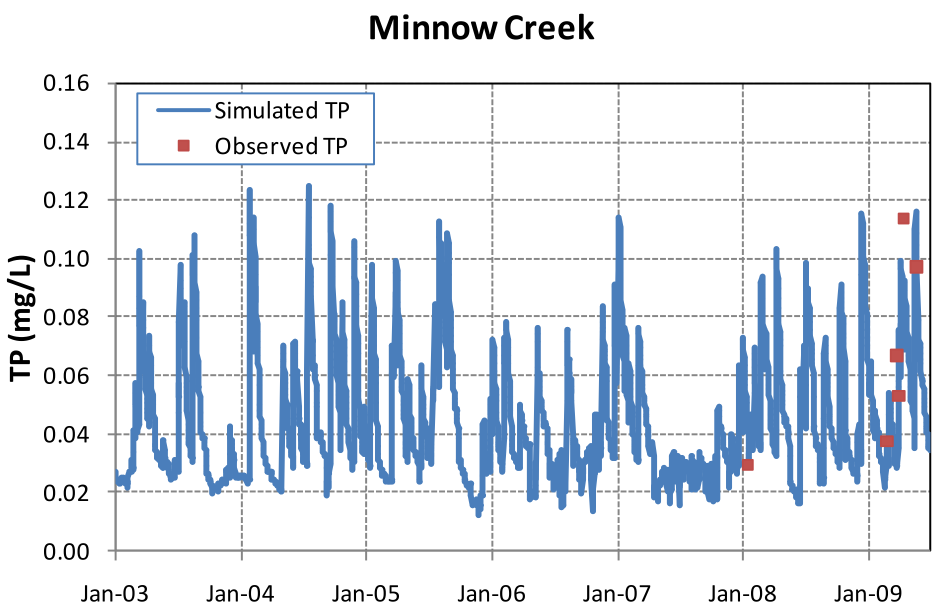


Figure 5.18. Time-series of simulated versus observed TP in Minnow Creek, 2003–09

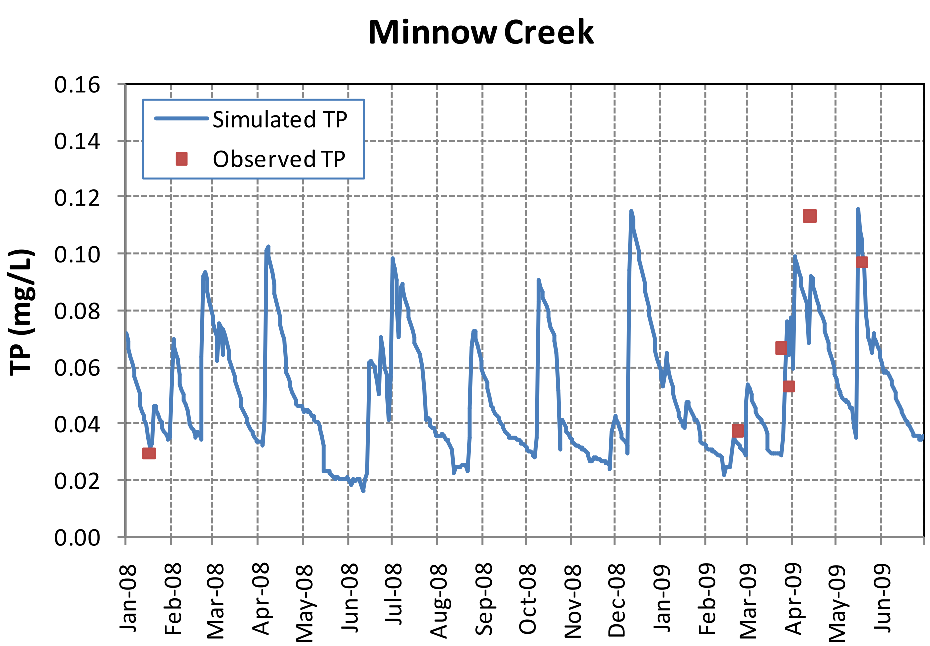


Figure 5.19. Time-series of simulated versus observed TP in Minnow Creek, 2008–09

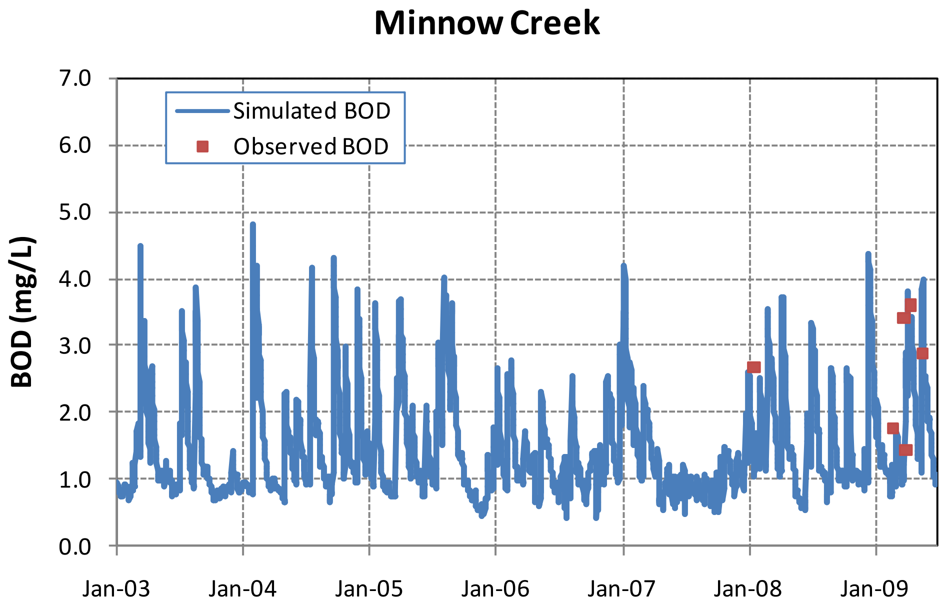


Figure 5.20. Time-series of simulated versus observed BOD in Minnow Creek, 2003–09

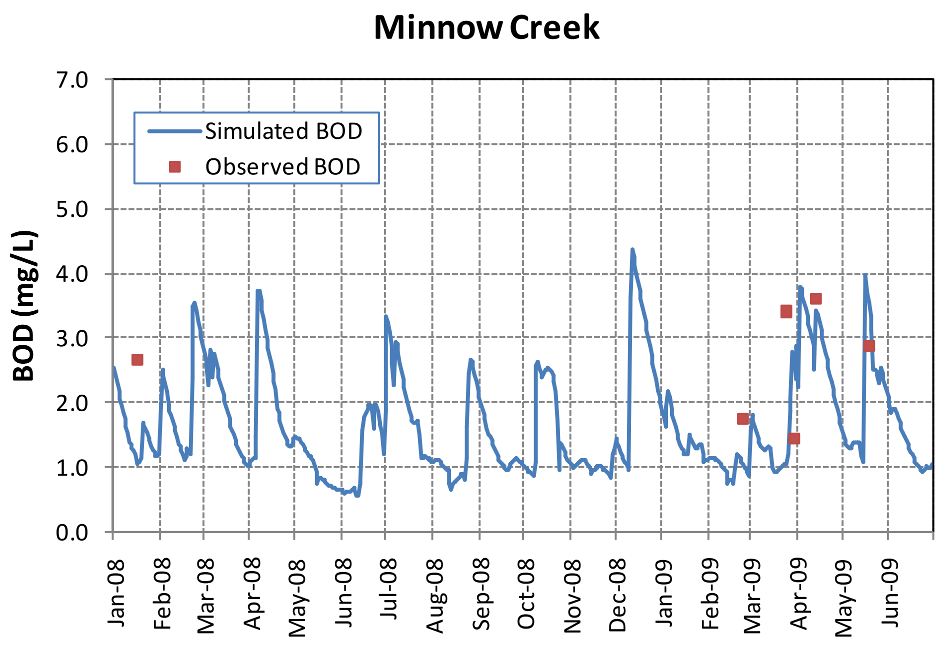


Figure 5.21. Time-series of simulated versus observed BOD in Minnow Creek, 2008–09

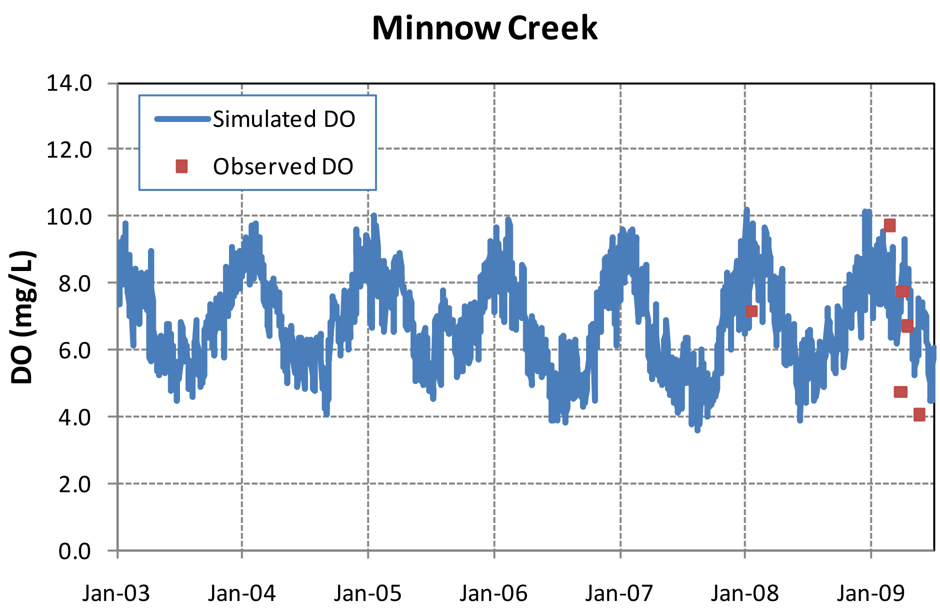


Figure 5.22. Time-series of simulated versus observed DO in Minnow Creek, 2003–09

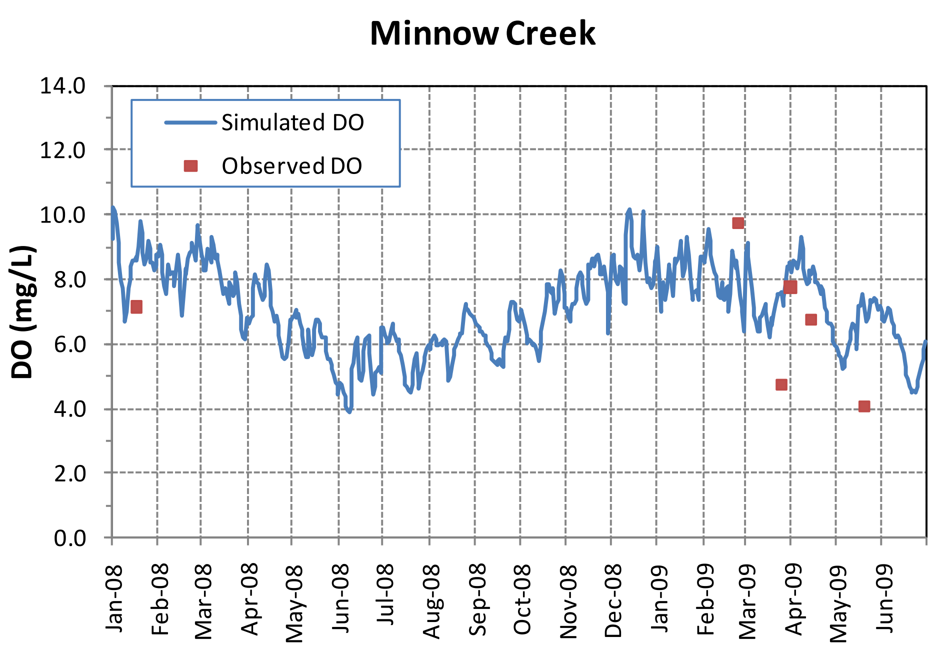


Figure 5.23. Time-series of simulated versus observed DO in Minnow Creek, 2008–09

Minnow Creek Existing Land Use Loadings

Outputs of monthly watershed loads of flow, TN, and TP to Minnow Creek were generated using the report function of the HSPF Model. The HSPF simulation of pervious lands (PERLNDs) and impervious lands (IMPLNDs) calculates hourly values of runoff from pervious and impervious lands, interflow and baseflow from pervious lands, and surface flow from impervious lands, plus the loads of water quality constituents associated with these flows. For PERLNDs, the loads of TN and TP in PERLND and IMPLND runoff were calculated in the General Quality Constituent (GQUAL) component of HSPF.

Nonpoint source loads of TN and TP were simulated for the existing conditions of the Minnow Creek watershed, as shown in **Tables 5.5** through **5.6,** and in **Figures 5.24** and **5.25**. **Figures 5.24** and **5.25** show the annual average TN and TP loads from existing land uses to Minnow Creek, indicating that anthropogenic land uses of improved pasturelands and crops are the major contributors, supplying annual TN loads of 29,597 pounds per year (lbs/yr) and annual TP loads of 4,437 lbs/yr. These TN and TP loads account for about 70 percent of the total TN loads and about 59 percent of the total TP loads to the stream during the 6-year period. Under the existing conditions, simulated long-term daily loads of TN and TP were estimated to be 81.09 and 12.16 lbs/day, respectively. Overall, higher nutrient loads were found during wet years, especially in 2005 and 2008, while lower nutrient loads were simulated for the dry years in 2006 and 2007. The peak nutrient loads of TN and TP (49,648 lbs/yr for TN and 7,383 lbs/yr for TP) were found in 2005, when annual rainfall was the highest during the 6-year period. Based on the model results, existing TN and TP loads are strongly associated with rainfall.

Table 5.5. Annual TN loads (lbs/yr) to Minnow Creek simulated from 2003 to 2009 based on land use types in the watershed

This is a nine-column table. Column 1 lists the land use type; Columns 2 through 8 list the annual TN load (lbs/yr) for each land use type from 2003 to 2009, respectively; and Column 9 lists the average load from 2003 to 2009.

Land Use Type	2003	2004	2005	2006	2007	2008	2009	Average (2003–08)
Transportation/utilities	47	55	70	36	37	74	40	53
Improved pasture/crops	15,732	21,930	33,811	8,515	10,372	34,246	20,955	20,768
Low-density residential	1,032	1,438	2,189	649	722	2,235	1328	1,378
Medium-density residential	81	115	163	56	60	171	99	108
Upland forest	2,821	3,658	7,736	1,655	1,601	6,402	4,687	3,979
Unimproved pastureland	729	1,053	2,006	410	497	1,862	1,259	1,093
Wetland	1,657	2,259	3,533	985	1,184	3,183	2,047	2,134
Water	66	90	139	41	48	128	81	85
Total TN Load (lbs/yr)	**22,166**	**30,598**	**49,648**	**12,347**	**14,521**	**48,302**	**30,497**	**29,597**

Table 5.6. Annual TP loads (lbs/yr) to Minnow Creek simulated from 2003 to 2009 based on land use types in the watershed

This is a nine-column table. Column 1 lists the land use type; Columns 2 through 8 list the annual TP load (lbs/yr) for each land use type from 2003 to 2009, respectively; and Column 9 lists the average load from 2003 to 2009.

Land Use Type	2003	2004	2005	2006	2007	2008	2009	Average (2003–08)
Transportation/utility	11	12	16	8	8	16	9	12
Improved pasture/crops	2,194	2,712	4,140	1,150	1,338	4,173	2,511	2,618
Low-density residential	213	260	386	131	142	383	226	253
Medium-density residential	3	5	7	2	2	8	5	4
Upland forest	735	881	1,756	412	398	1,423	1,029	934
Unimproved pastureland	155	194	341	82	92	311	204	196
Wetland	286	385	696	164	203	643	422	396
Water	17	23	41	10	13	39	25	24
Total TP Load (lbs/yr)	**3,614**	**4,472**	**7,383**	**1,960**	**2,196**	**6,997**	**4,430**	**4,437**

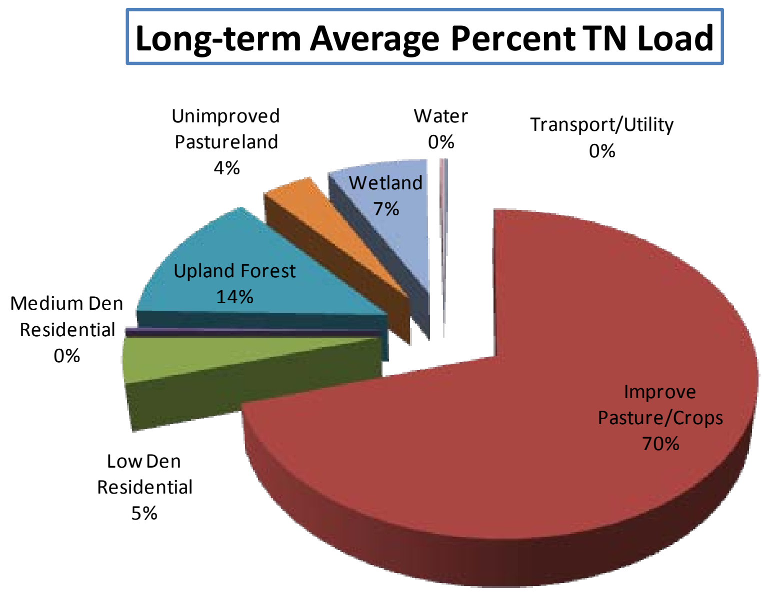


Figure 5.24. Annual TN loads (percent) to Minnow Creek from different land use types in the watershed, 2003–08

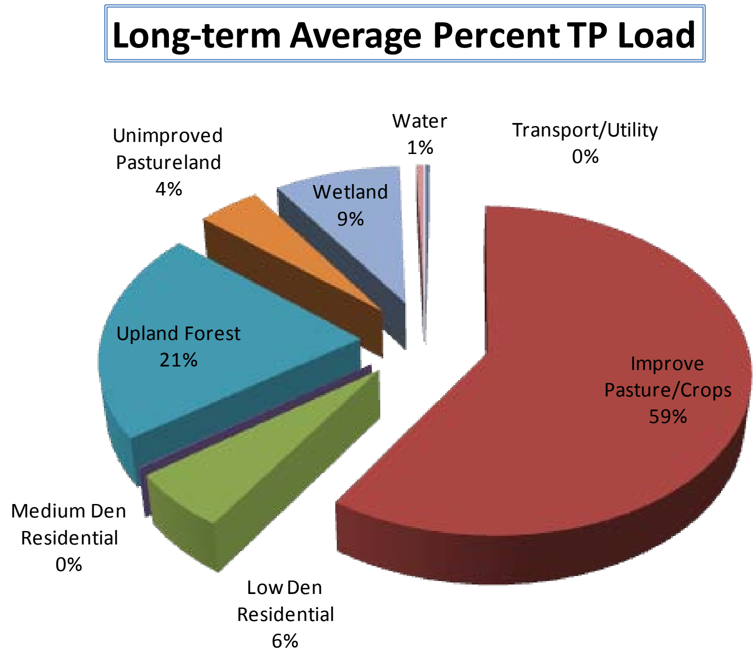


Figure 5.25. Annual TP loads (percent) to Minnow Creek from different land use types in the watershed, 2003–08

5.3 TMDL Load Reductions

As discussed in the previous section, the TN and TP targets for the development of the TMDLs were set up to meet the DO criterion of 5.0 mg/L. The targets in compliance were expected to achieve daily concentrations below 1.21 mg/L for TN and below 0.89 mg/L for TP. Under the existing conditions, however, daily TN and TP concentrations often exceeded the target TN and TP concentrations, especially during the wet season, as shown in **Figures 5.26** through **5.28**. Based on the simulation of existing conditions, percent exceedances of TN and TP were estimated to be about 9 percent and 5 percent, respectively. Similarly, the percent DO exceedance based on the model simulation for the existing conditions was estimated to be more than 10 percent over the simulation period.

For TMDL conditions, the changes made to the calibrated model in order to achieve these endpoints each day were to iteratively reduce the loadings of TN and TP from the watershed. This was accomplished by reducing the values for sediment composition in SEDMNT and for state variables (PQUAL). 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 the agency's 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. For Minnow Creek, SOD is an important factor affecting DO concentrations in the stream, and a 40 percent reduction appeared reasonable for the TMDL condition. Along with the SOD reduction, a 28 percent reduction for both TN and TP for the TMDL condition is required to meet the TN and TP targets and thus the DO criterion over the simulation period (**Figures 5.29** through **5.31**).

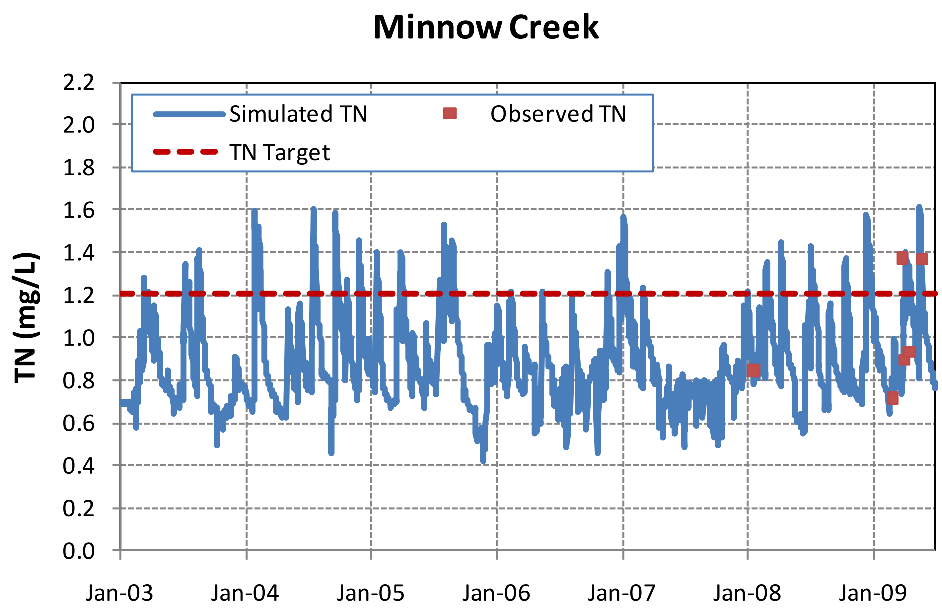


Figure 5.26. Simulated and observed TN for existing conditions versus the target concentration of TN during the simulation period

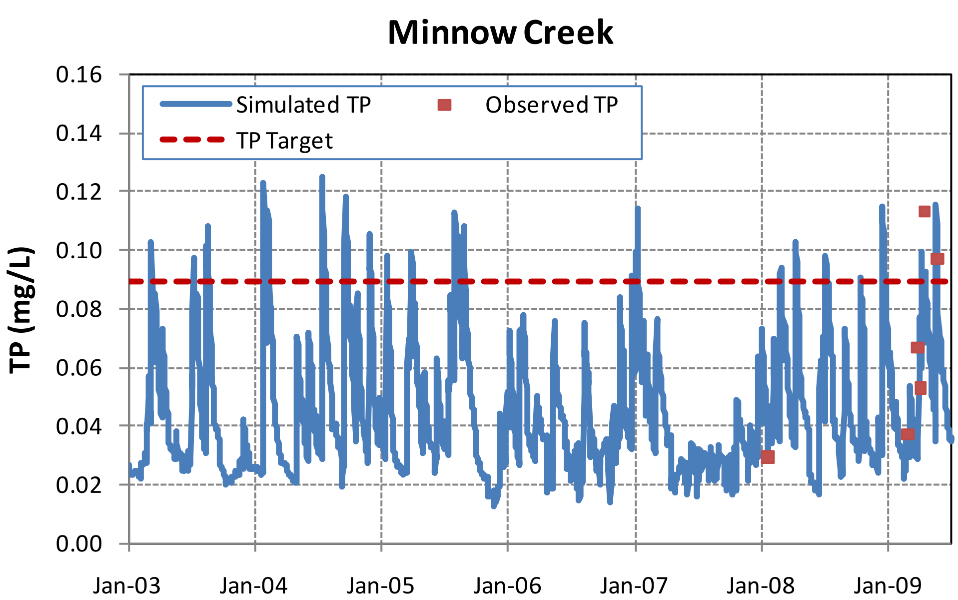


Figure 5.27. Simulated and observed TP for existing conditions versus the target concentration of TP during the simulation period

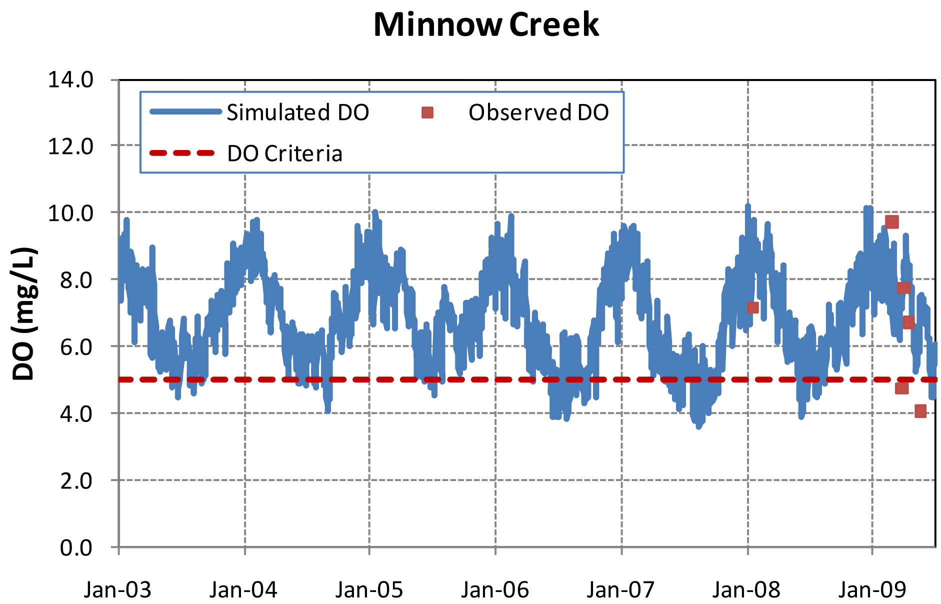


Figure 5.28. Simulated and observed DO for existing conditions versus the DO criterion during the simulation period

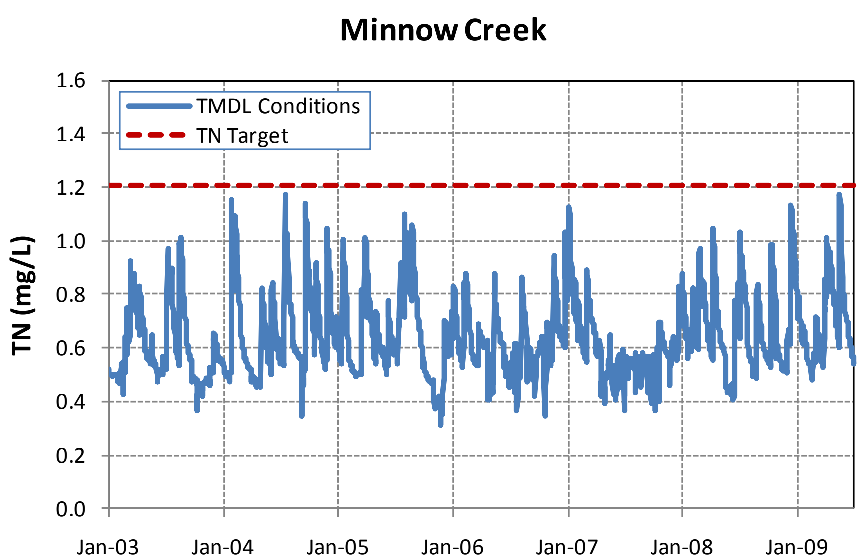


Figure 5.29. Simulated TN concentrations for TMDL conditions versus the TN target concentration during the simulation period

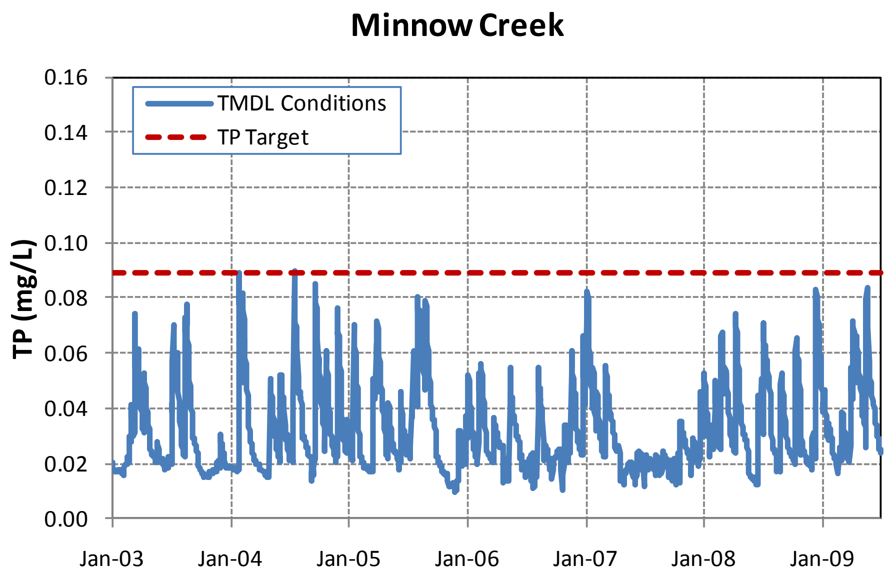


Figure 5.30. Simulated TP concentrations for TMDL conditions versus the TP target concentration during the simulation period

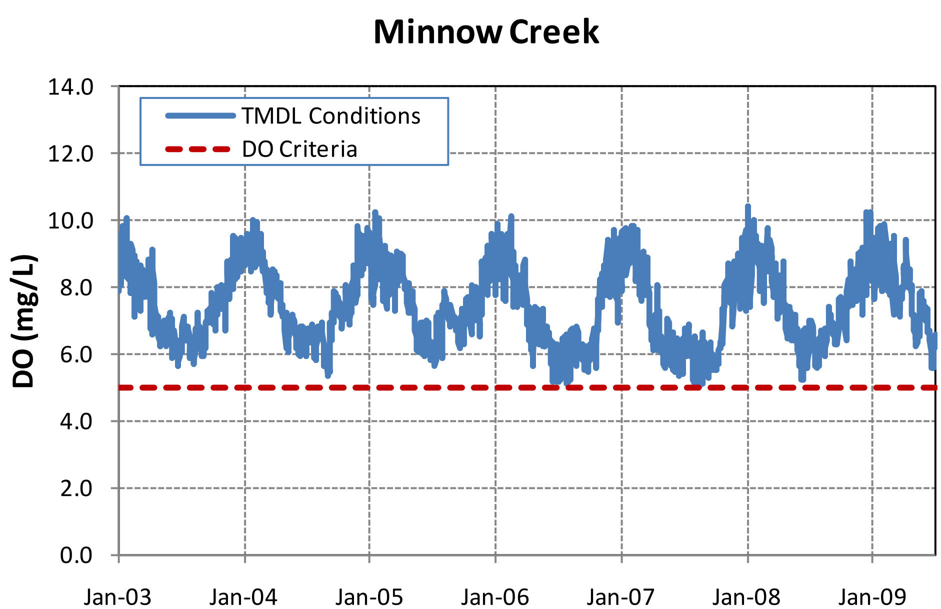


Figure 5.31. Simulated DO concentrations for TMDL conditions versus the DO criterion during the simulation period

5.3.1 Calculation of Allowable TMDL Loads

The model predictions for the current condition loads are 29,597 lbs/yr of TN and 4,437 lbs/yr of TP. A 28 percent reduction in watershed TN and TP loads results in allowable loadings of 21,310 lbs/yr for TN and 3,195 Ibs/yr for TP entering Minnow Creek. 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 28 percent reduction in total loading from the entire watershed, reductions from land uses that have anthropogenic components were calculated as 30 percent for TN and 31 percent for TP. **Table 5.7** shows existing average TN and TP loads, load allocations by land uses, and percent reductions applied to anthropogenic land uses.

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. To calculate a daily allowable loading, each annual average load was divided by 365. This results in a daily allowable load of 58.38 lbs/day for TN and 8.75 lbs/day for TP.

5.4 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 a receiving water could also contribute to 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.

Table 5.7. Existing and allowable TN and TP loads for Minnow Creek for each land use type

This is a seven-column table. Column 1 lists the land use type, Column 2 lists the existing average TN load (lbs/yr), Column 3 lists the TN TMDL (lbs/yr), Column 4 lists the TN TMDL percent reduction, Column 5 lists the existing average TP load (lbs/yr), Column 6 lists the TP TMDL (lbs/yr), and Column 7 lists the TP TMDL percent reduction.

Land Use Type	TN Existing Average Load (lbs/yr)	TN TMDL (lbs/yr)	TN TMDL % Reduction	TP Existing Average Load (lbs/yr)	TP TMDL (lbs/yr)	TP TMDL % Reduction
Transportation/utilities	53	37	30%	12	8	31%
Improved pasture/crops	20,768	14,481	30%	2,618	1,808	31%
Low-density residential	1,378	961	30%	253	175	31%
Medium-density residential	108	75	30%	4	3	31%
Upland forest	3,979	2,774	30%	934	645	31%
Unimproved pastureland	1,093	762	30%	196	135	31%
Wetland	2,134	2,134	0%	396	396	0%
Water	85	85	0%	24	24	0%
Total Load (lbs/yr)	**29,597**	**21,310**	**28%**	**4,437**	**3,195**	**28%**

Chapter 6: DETERMINATION OF THE TMDLs

6.1 Expression and Allocation of the TMDLs

A TMDL can be 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) that takes into account any uncertainty about the relationship between effluent limitations and water quality:

As mentioned previously, 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 TMDL equation may not sum up to the value of the TMDLs because (a) the WLA for NPDES stormwater is typically based on the percent reduction needed for nonpoint sources and is accounted for within the LA, and (b) TMDL components can be expressed in different terms (for example, the WLA for stormwater is typically expressed as a percent reduction and the WLA for wastewater is typically expressed as mass per day).

WLAs for stormwater discharges are typically expressed as a "percent reduction" because it is very difficult to quantify the loads from MS4s (given the numerous discharge points) and to distinguish loads from MS4s from other nonpoint sources (given the nature of stormwater transport). The permitting of stormwater discharges is also different than the permitting of most wastewater point sources. Because stormwater discharges cannot be centrally collected, monitored and treated, they are not subject to the same types of effluent limitations as wastewater facilities, and instead are required to meet a performance standard of providing treatment to the "maximum extent practical" through the implementation of best management practices (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 TMDLs for Minnow Creek are expressed in terms of percent reductions and allowable loads. These TMDLs represent the maximum TN and TP loads that the waterbody can assimilate and maintain the Class III narrative nutrient and DO criteria.

6.2 Load Allocation

Table 6.1 presents the allowable LAs for Minnow Creek. It should be noted that the LAs may include loading from stormwater discharges regulated by the Department and the water management district that are not part of the NPDES Stormwater Program (see **Appendix A**).

Table 6.1. Minnow Creek TMDL load allocations

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

Note: The allowable loads as lbs/day are 58.34 lbs/day for TN and 8.75 lbs/day for TP.
N/A = Not applicable

WBID	Parameter	WLA for Wastewater (lbs/yr)	WLA for Stormwater (% reduction)	LA (% reduction)	TMDL (lbs/yr)	MOS
130	TN	N/A	N/A	30%	21,310	Implicit
130	TP	N/A	N/A	31%	3,195	Implicit

6.3 Wasteload Allocation

6.3.1 NPDES Wastewater Discharges

No NPDES-permitted wastewater treatment facilities or industrial wastewater facilities discharge directly into Minnow Creek.

6.3.2 NPDES Stormwater Discharges

Currently, there are no NPDES-permitted MS4 stormwater facilities within the Minnow Creek watershed.

6.4 Margin of Safety

Consistent with the recommendations of the Allocation Technical Advisory Committee (Department, February 2001), an implicit MOS was used in the development of these TMDLs by establishing the reductions based on meeting both TN and TP targets as a daily maximum for each day of the model run (2003–09).

6.5 Evaluating the Effects of the TMDLs on DO

Minnow Creek is expected to attain water quality standards for DO and nutrients following the implementation of the TMDLs because the TMDLs will require reductions of 30 percent for TN and 31 percent for TP from anthropogenic sources. The nutrient reductions are also expected to result in a reduction in cchl*a* and a corresponding 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 reduce diurnal fluctuations in DO and improve DO levels in the creek by removing anthropogenic sources of nutrients. These expected reductions in algal biomass will reduce DO fluctuations and the BOD that results from the breakdown of algal cells in the waterbody by a relative amount. As 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 and TP entering the system from anthropogenic land uses.

Chapter 7: TMDL IMPLEMENTATION

7.1 Basin Management Action Plan

Following the adoption of these TMDLs by rule, the Department will determine the best course of action regarding their implementation. Depending on 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. BMAPs 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 these TMDLs, 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 TMDLs);*
- *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 TMDLs;*
- *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.

References

Bicknell, B.R., J.C. Imhoff, J.L. Kittle, A.S. Donigian, Jr. and R.C. Johanson. 2001. *Hydrological Simulation Program–Fortran: User's manual for Release 12.* EPA/600/R-97/080. Athens, GA: U.S. Environmental Protection Agency, Environmental Research Laboratory. Available: http://www.epa.gov/waterscience/BASINS/b3docs/HSPF.pdf.

CDM. 2002. *Northern Coastal Basin watersheds hydrology model development: Pellicer Creek Planning Unit 9B.* Prepared for the St. Johns River Water Management District, Palatka, FL.

Chang, C.L. 2009. The impact of watershed delineation on hydrology and water quality simulation. *Environ. Monit. Assess. 148:159–165.*

Chapra, S.C. 1997. *Surface water-quality modeling.* McGraw-Hill Companies, Inc.

Duda, P., J. Kittle, M. Gray Jr., P. Hummel, and R. Dusenbury. 2001. *WinHSPF Version 2.0: An interactive Windows interface to HSPF (WinHSPF), User's manual.* Washington, DC: U.S. Environmental Protection Agency.

Florida Department of Environmental Protection. February 2001. *A report to the Governor and the Legislature on the allocation of Total Maximum Daily Loads in Florida.* Tallahassee, FL: Florida Department of Environmental Protection, Allocation Technical Advisory Committee, Division of Water Resource Management, Bureau of Watershed Management.

———. April 2001a. *Chapter 62-302, Florida Administrative Code (F.A.C.). Surface water quality standards.* Tallahassee, FL: Florida Department of Environmental Protection, Division of Water Resource Management, Bureau of Watershed Management.

———. April 2001b. *Chapter 62-303, Florida Administrative Code*. *Identification of impaired surface waters rule (IWR).* Tallahassee, FL: Florida Department of Environmental Protection, Division of Water Resource Management, Bureau of Watershed Management.

———. 2003. *Basin status report: Choctawhatchee–St. Andrew Bay Basins.* Tallahassee, FL: Bureau of Watershed Management. Available: http://tlhdwf2.dep.state.fl.us/basin411/csa/status/ChoctawhatcheeWEB.pdf.

———. 2006. *Water quality assessment report: Choctawhatchee–St. Andrew Bay Basins.* Tallahassee, FL: Bureau of Watershed Management. Available: http://tlhdwf2.dep.state.fl.us/basin411/csa/assessment/G3AS-Chocta-LR-Merge.pdf.

———. June 2004. *Geographic Information Systems website.* Tallahassee, FL: Division of Water Resource Management, Bureau of Information Systems, Geographic Information Systems Section. Available: http://www.dep.state.fl.us/gis/contact.htm.

Florida Department of Health website. 2010. *Onsite sewage programs statistical data.* Available: http://www.doh.state.fl.us/environment/OSTDS/statistics/ostdsstatistics.htm.

Florida Department of Transportation. 1999. *Florida Land Use, Cover and Forms Classification System (FLUCCS)*. Thematic Mapping Section.

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

Friedemann, M., and J. Hand. July 1989. *Typical water quality values for Florida's lakes, streams and estuaries.* Tallahassee, FL: Florida Department of Environmental Protection.

Gardiner, R.D., M.T. Auer, and R.P. Canale. 1984. Sediment oxygen demand in Green Bay (Lake Michigan). *Proc. 1984 Specialty Conf., ASCE, 514–519.*

Maxted, J.M., M.W. Diebel, and M.J. Zanden. 2009. Landscape planning for agricultural non-point source pollution reduction. II. Balancing watershed size, number of watersheds, and implementation effort. *Environ. Manage. 43:60–68.*

Miller, J.A. 1990. *Ground water atlas of the United States: Alabama, Florida, Georgia, and South Carolina (HA 730-G).* U.S. Geological Survey. Available: http://pubs.usgs.gov/ha/ha730/ch_g/G-text6.html.

Scott, T.M. 1992. *A geological overview of Florida*. Tallahassee, FL: Florida Geological Survey.

Southeast Regional Climatic Center. 2010. *Florida state averaged precipitation data.* Available: http://www.acis.sercc.com/climateinfo_files/monthly/Florida_prcp.html.

U. S. Environmental Protection Agency. 1994. *Nonpoint source pollution: The nation's largest water quality problem.* Pointer No. 1. EPA-841-F-94-005. Available: http://www.epa.gov/owow/nps/facts/point1.htm.

———. 1997. *Compendium of tools for watershed assessment and TMDL development.* EPA841-B-97-006. Washington, DC: Office of Water.

———. 2000. *BASINS technical note 6: Estimating hydrology and hydraulic parameters for HSPF.* EPA 823-R00-012. Washington, DC: Office of Water.

———. 2001. *Better assessment science integrating point and non-point sources (BASINS) Version 3.0 user manual*. Available: http://www.epa.gov/waterscience/basins/bsnsdocs.html.

———. 2007. *BASINS technical note 1: Creating hydraulic function tables (FTABLES) for reservoirs in BASINS.* EPA 823-R99-006. Washington, DC: Office of Water. Available: http://water.epa.gov/scitech/datait/models/basins/upload/2009_04_13_BASINSs_tecnote1.pdf.

U.S. Geological Survey. 2010. *Karst and the USGS: What is karst?* Available: http://water.usgs.gov/ogw/karst/index.

Younos, T., F.W. Kaurish, T. Brown, and R. de Leon. 2001. Determining the source of stream contamination in a karst-water system, southwest Virginia, USA. *J. Am. Water Resour. As. 37(2): 327–334.*

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: HSPF Model Calibration and Input Parameters and Values

The Hydrological Simulation Program–Fortran (HSPF) Model (Bicknell et al., 2001) was developed under the joint sponsorship of the EPA and USGS. This 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 model, HSPF does not accept a 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.

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.*

Table B-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	0.40-0.50	Calibration
KATRAD	Longwave radiation coefficient	none	9.5	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	2.0	Calibration
W	Fall velocity in still water–silt	in/s	1.00E-05	Previous studies
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	1.60E-06	Previous studies
TAUCD	Critical shear stress for deposition–clay	lb/ft^2	0.09	Calibration
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)	$mg/m^2/hr$	51.2	Calibration
TCBEN	Temperature correction coefficient for benthal oxygen demand	none	1.050	Calibration
NUTRX Module	-	-	-	-
KTAM20	Nitrification rate of ammonia at 20 ^oC.	hr^{-1}	0.004	Previous studies
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	1.0	Calibration
NONREF	Nonrefractory fraction of algae and zooplankton biomass	none	1.0	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}	0.30	Calibration
MALGR	Maximum unit algal growth rate	hr^{-1}	0.110	Calibration
CMMLT	Michaelis-Menton constant for light-limited growth	ly/min	0.025	Default
CMMN	Nitrate Michaelis-Menton constant for nitrogen-limited growth	mg/l	0.045	Default
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}	0.0010	Calibration
CLALDH	Chl*a* concentration above which high algal death rate occurs	µg/l	50	Calibration
PHYSET	Rate of phytoplankton settling	ft/hr	0.008	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

Florida Department of Environmental Protection
Division of Environmental Assessment and Restoration
Bureau of Watershed Restoration
2600 Blair Stone Road, Mail Station 3565
Tallahassee, FL 32399-2400