

**CENTRAL DISTRICT • KISSIMMEE RIVER BASIN •
UPPER KISSIMMEE PLANNING UNIT**

FINAL TMDL Report

**Nutrient TMDL
for Lake Cypress (WBID 3180A)**

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December 17, 2013

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Acknowledgments

This analysis could not have been accomplished without the funding support of the Florida Legislature. Contractual services were provided by Camp Dresser and McKee (CDM) under Contract WM912. Sincere thanks to CDM for the support from Lena Rivera (Project Manager), Silong Lu (hydrology), and Richard Wagner (water quality). Additionally, significant contributions were made by staff in the Florida Department of Environmental Protection's Watershed Assessment Section, particularly Barbara Donner for Geographic Information System (GIS) support. The Department also recognizes the substantial support and assistance from its Central District Office, the South Florida Water Management District (SFWMD), Polk County Natural Resource Division, and Osceola County and their contributions towards understanding the issues, history, and processes at work in the Lake Cypress watershed.

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

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Websites

Florida Department of Environmental Protection, Bureau of Watershed Restoration

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>

STORET Program

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

2012 Integrated 305(b) Report

http://www.dep.state.fl.us/water/docs/2012_integrated_report.pdf

Criteria for Surface Water Quality Classifications

<http://www.dep.state.fl.us/water/wqssp/classes.htm>

Water Quality Status Report: Kissimmee River/Fisheating Creek

<http://www.dep.state.fl.us/water/basin411/kissimmee/index.htm>

Water Quality Assessment Report: Kissimmee River/Fisheating Creek

<http://www.dep.state.fl.us/water/basin411/kissimmee/index.htm>

U.S. Environmental Protection Agency, National STORET Program

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

Chapter 1: INTRODUCTION

1.1 Purpose of Report

This report presents the Total Maximum Daily Load (TMDL) for nutrients for Lake Cypress, located in the Kissimmee River Basin. This TMDL will constitute the site-specific numeric interpretation of the narrative nutrient criterion pursuant to Paragraph 62-302.531(2)(a), Florida Administrative Code (F.A.C.). Lake Cypress was initially verified as impaired during the Cycle 1 assessment (verified period January 1, 1998, to June 30, 2005) due to excessive nutrients using the methodology in the Identification of Impaired Surface Waters Rule (IWR) (Rule 62-303, F.A.C.), and was included on the Cycle 1 Verified List of impaired waters for the Kissimmee River Basin that was adopted by Secretarial Order on May 12, 2006.

Subsequently, during the Cycle 2 assessment (verified period January 1, 2003, to June 30, 2010), the impairment for nutrients was documented as continuing, as the Trophic State Index (TSI) threshold of 60 was exceeded for 5 years of the Cycle 2 assessment period. The TMDL establishes the allowable loadings to the lake that would restore the waterbody so that it meets its applicable water quality narrative criterion for nutrients.

1.2 Identification of Waterbody

Lake Cypress is located in Osceola County, Florida. However, the northeastern tip of Polk County is adjacent to a portion of the western edge of the lake. The estimated average surface area of the lake is 4,100 acres, with a normal pool volume between 14,400 and 29,027 acre-feet (ac-ft), and an average depth ranging from 3.5 to 7.1 feet. Lake Cypress receives drainage from 352,430 acres through tributary inflow and has a directly connected subbasin surface water drainage area of approximately 16,175 acres, for a total watershed area of 368,605 acres (**Figure 1.1**).

The upstream drainage area land uses comprise wetlands (29%), cropland/improved pasture/tree crops (20%), rangeland/upland forest (19%), commercial/industrial (11%), pasture (9%), medium-density residential (5%), low-density residential (5%), and high-density residential (3%). The Lake Cypress subbasin watershed's land use designations are primarily agriculture (61%), wetlands (21%), rangeland/upland forest (11%), and pastureland (6%).

Significant waterbodies upstream of Lake Cypress include Shingle Creek, East and West Boggy Creek, Reedy Creek Canal, City Ditch Canal, and the following lakes: Big Sand, Tohopekaliga, East

Tohopekaliga, Myrtle, Preston, Hart, Mary Jane, Alligator, Brick, and Gentry. Lake Cypress receives the outflows from Lake Tohopekaliga and Lake Gentry and discharges to Lake Hatchineha, which discharges to Lake Kissimmee. Lake Kissimmee discharges to the Kissimmee River.

For assessment purposes, the Department has divided the Kissimmee River Basin into water assessment polygons with a unique **waterbody identification (WBID)** number for each watershed or stream reach. Lake Cypress is WBID 3180A.

The Lake Cypress WBID and its sampling/monitoring stations are illustrated in **Figure 1.2**.

1.3 Background Information

As depicted in **Figure 1.1**, the Lake Cypress subbasin has a total surface water drainage area of approximately 368,605 acres (352,430 upstream and 16,175 directly tributary to the lake). The Lake Cypress watershed includes upstream connections to Lakes Tohopekaliga and Gentry. Lakes Cypress and Hatchineha are interconnected with Lake Kissimmee, and the three lakes are managed to maintain the same pool level. The water in Lake Cypress discharges to Lake Hatchineha, which flows into Lake Kissimmee. Thus, water quality and quantity in Lake Cypress directly influence the water quality and quantity of these downstream receiving waterbodies and, ultimately, the Kissimmee River.

The TMDL report for Lake Cypress is part of the implementation of the Department's watershed management approach for restoring and protecting water resources 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 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 the waterbody's designated uses. A waterbody that does not meet its designated uses is defined as impaired. TMDLs must be developed and implemented for each of the state's impaired waters, unless the impairment is documented to be a naturally occurring condition that cannot be abated by a TMDL or unless a management plan already in place is expected to correct the problem.

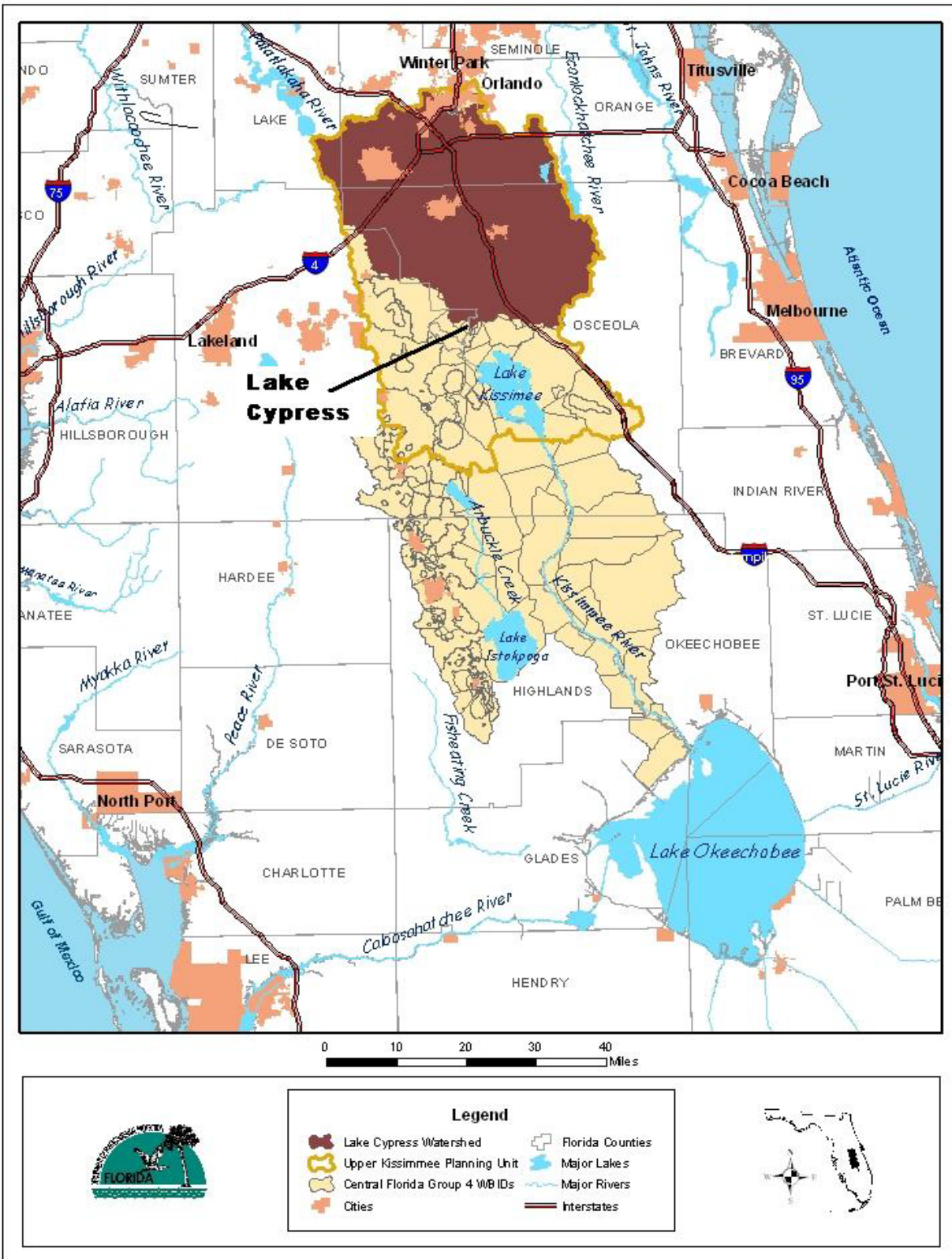


Figure 1.1. Upper Kissimmee Planning Unit and Lake Cypress Watershed

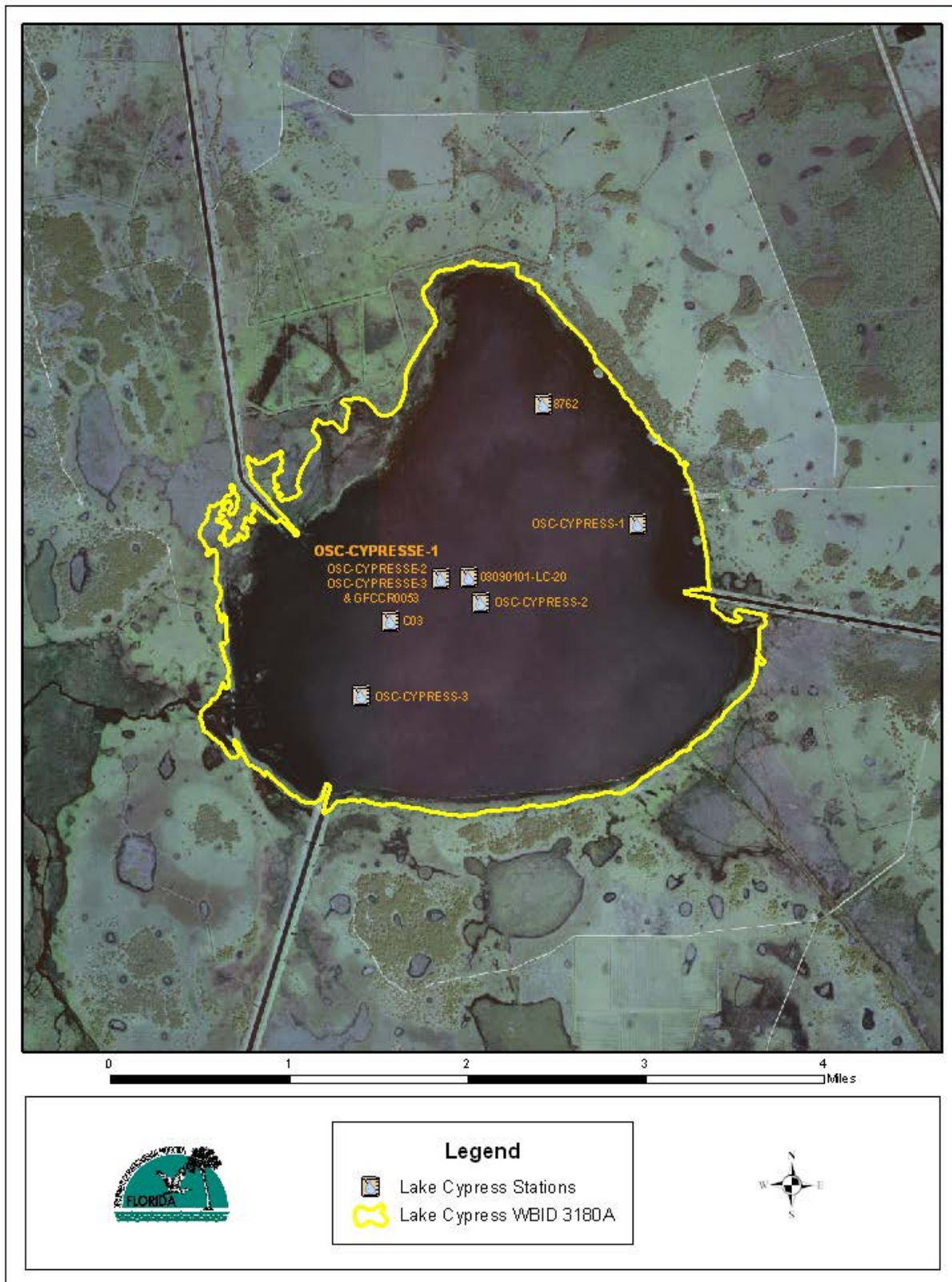


Figure 1.2. Lake Cypress (WBID 3180A) and Monitoring Stations

This TMDL Report will be followed by the development and implementation of a restoration plan to reduce the amount of pollutants that caused the verified impairment. These activities will depend heavily on the active participation of Osceola County, Polk County, the SFWMD, local governments, local businesses, and other stakeholders. The Department will work with these organizations and individuals to undertake or continue reductions in the discharge of pollutants and achieve the established TMDL for the impaired lake.

Chapter 2: STATEMENT OF WATER QUALITY PROBLEM

2.1 Legislative and Rulemaking History

Section 303(d) of the federal Clean Water Act requires states to submit to the U.S. Environmental Protection Agency (EPA) a list of surface waters that do not meet applicable water quality standards (impaired waters) and establish a TMDL for each pollutant causing the impairment of the 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.]), and the state's 303(d) list is amended annually to include basin updates.

Lake Cypress was included on Florida's 1998 303(d) list. 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. The Environmental Regulation Commission adopted the new methodology as Rule 62-303, F.A.C. (IWR), in April 2001; the rule was amended in 2006 and January 2007.

2.2 Information on Verified Impairment

The Department used the IWR to assess water quality impairments in Lake Cypress. All data presented in this report are from IWR Run 42. Data reductions followed the procedures in Rule 62-303, F.A.C., and were then further reduced by calculating daily averages. These are the data from which graphs and summary statistics were prepared. The annual averages were calculated from these data by averaging for each calendar quarter and then averaging the four quarters to determine the annual average.

The lake was verified as impaired for nutrients based on an elevated annual average TSI value over the Cycle 1 verified period for the Group 4 basins (January 1, 1998, to June 30, 2005). The impairment for nutrients was documented as still present during the Cycle 2 verified period (January 1, 2003, to June 30, 2010). The IWR methodology uses the water quality variables total nitrogen (TN), total phosphorus (TP), and corrected chlorophyll *a* (cchl_a) (a measure of algal mass) in calculating annual TSI values and in interpreting Florida's narrative nutrient threshold.

For Lake Cypress, data were available for the three water quality variables for all four seasons in 1998, 1999, 2000, and 2002 through 2009 of the combined Cycle 1 and Cycle 2 verified periods. The resulting annual average TSI values for these years were 65, 62, 64, 61, 65, 61, 63, 66, 63, 67, and 67,

respectively. Per the IWR methodology, exceeding a TSI of 60 in any one year of the verified period is sufficient in determining nutrient impairment for a lake with color greater than 40 platinum cobalt units (PCU). Annual average color values for the verified period for the lake were 95.8 (1998), 81.3 (1999), 79.2 (2000), 69.5 (2001), 84.4 (2002), 93.2 (2003), 124.4 (2004), 115.8 (2005), 100.6 (2006), 37.4 (2007), 59.9 (2008), and 78.6 (2009). The annual average color value over both verified periods was 87.4. Based on the period of record data (1954 to 2009) in **Figures 2.1** and **2.2** and **Tables 2.1a** and **2.1b**, it appears that while color in Lake Cypress ranged from just above 20 to nearly 300 PCU, there is no long-term trend. The mean of 84 PCU for the period from 1954 to 1995 is essentially the same as the mean for the period from 1996 to 2009 (85 PCU).

The data for alkalinity (1954 to 2009) depicted in **Figure 2.3** and **Tables 2.1a** and **2.1b** show a slight but insignificant increase over time, as both the mean and median values increased between 1954 and 1995 from 20.0 and 18.2 mg/L to 30.1 and 26.0 mg/L, respectively, from 1996 to 2009. The data for pH (1954 to 2009) depicted in **Figure 2.4** and **Tables 2.1a** and **2.1b** show a slight but insignificant increase over time, as both the mean and median values increased between 1954 and 1995 from 7.5 and 7.4 standard units (SU) to 7.7 and 7.7 SU, respectively, from 1996 to 2009. The data for Secchi disk depth (1976 to 2009) depicted in **Figure 2.5** and **Tables 2.1a** and **2.1b** show no change over time, as both the mean and median values of 0.6 and 0.6 meters, respectively, were the same as the period from 1976 to 1995, and 1996 to 2009.

The TSI is calculated based on concentrations of TP, TN, and chl_a, as follows:

$CHLA_{TSI} = 16.8 + 14.4 * LN(Chla)$	Chlorophyll <i>a</i> (chl _a) in micrograms per liter (µg/L)
$TN_{TSI} = 56 + 19.8 * LN(N)$	Nitrogen in milligrams per liter (mg/L)
$TN2_{TSI} = 10 * [5.96 + 2.15 * LN(N + 0.0001)]$	Phosphorus in mg/L
$TP_{TSI} = 18.6 * LN(P * 1000) - 18.4$	
$TP2_{TSI} = 10 * [2.36 * LN(P * 1000) - 2.38]$	

If $N/P > 30$, then $NUTR_{TSI} = TP2_{TSI}$

If $N/P < 10$, then $NUTR_{TSI} = TN2_{TSI}$

if $10 < N/P < 30$, then $NUTR_{TSI} = (TP_{TSI} + TN_{TSI})/2$

$TSI = (CHLA_{TSI} + NUTR_{TSI})/2$

Note: TSI has no units

The Hydrologic Simulation Program Fortran (HSPF) model was run for 1996 to 2006. However, 1996 was used to allow the model to establish antecedent conditions and model comparisons with measured data were only conducted for 1997 to 2006. For modeling purposes, the analysis of the eutrophication-

related data presented in this report for Lake Cypress used all the available data from 1997 to 2006 for which records of TP, TN, and cchla were sufficient to calculate seasonal and annual average conditions. However, the comparisons in the Camp Dresser and McKee (CDM) report (2008) do not contain any LakeWatch data. Additionally, to calculate the TSI for a given year under the IWR, there must be at least one sample of TN, TP, and cchla taken within the same quarter (each season) of the year. As data were absent for at least one of the four seasons, the year 2001 was eliminated from the TSI analysis for Lake Cypress.

Key to Figure Legends in Chapter 2

- C = Results for calibrated/validated model
- M< = Results for measured data; annual average missing data from at least one quarter
- M4 = Results for measured data; at least one set of data from all four quarters

Annual average results for data from outside the combined verified periods (1998 to 2009) are displayed but were not used in the assessment of impairment. Similarly, any results flagged as M< are displayed but were not used in the assessment of impairment, regardless of the year.

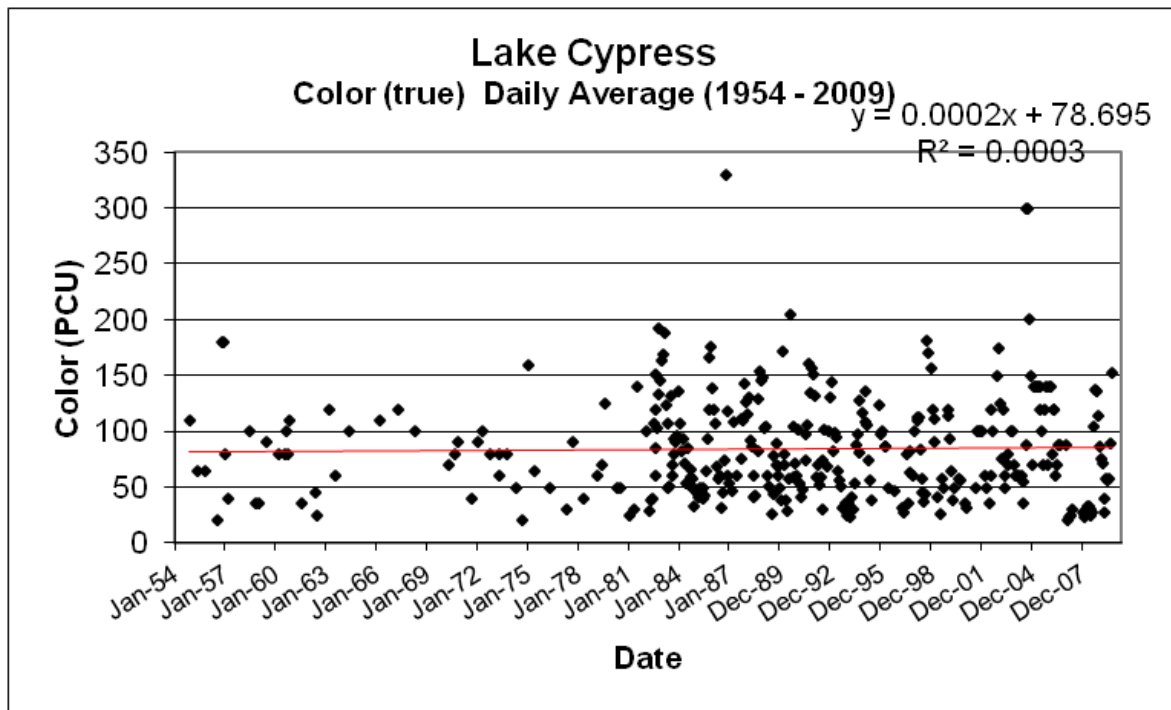


Figure 2.1. Daily Average True Color (PCU) for Lake Cypress, 1954–2009

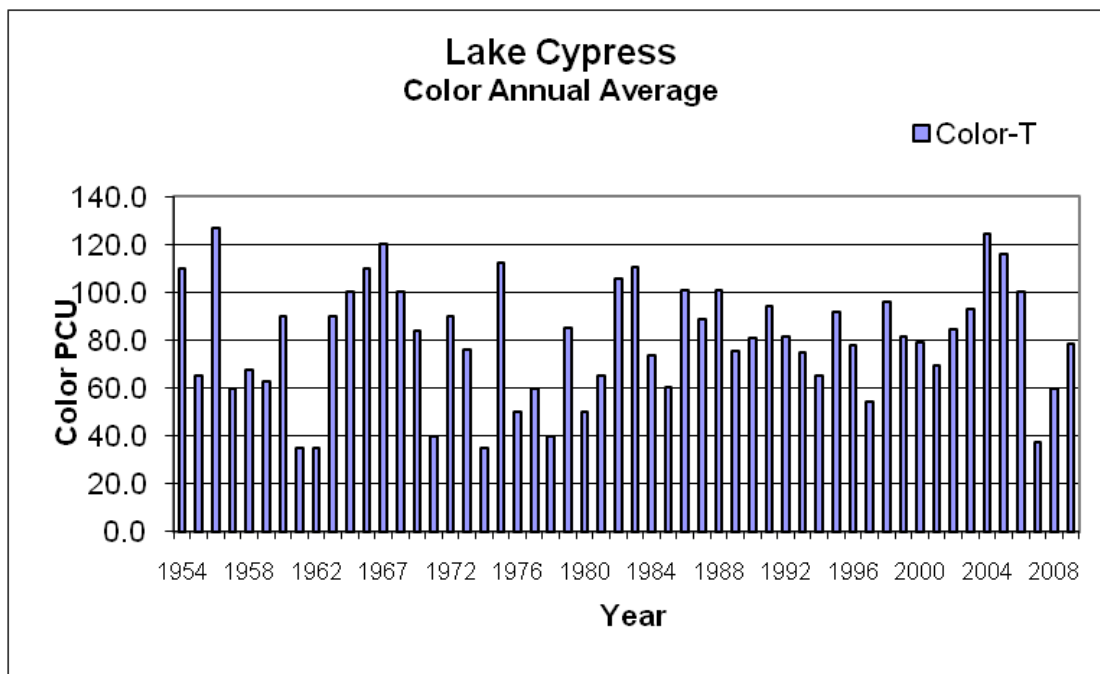


Figure 2.2. Annual Average True Color (PCU) for Lake Cypress, 1954–2009

Table 2.1a. Water Quality Summary Statistics for TN, NH₃, TP, PO₄, Chl_a, Color, Alkalinity, pH, and Secchi Depth (through 1995)

Statistic	TN (mg/L)	NH ₃ -N (mg/L)	TP (mg/L)	PO ₄ -P (mg/L)	Chl _a (µg/L)	Color True (PCU)	Alkalinity (mg/L)	pH (SU)	Secchi Depth (meters)
Period of Record	1970–1995	1970–1995	1968–1995	1971–1995	1979–1995	1954–1995	1954–1995	1954–1995	1976–1995
Count	273	258	301	138	222	213	276	305	261
Minimum	0.43	0.01	0.006	0.002	0.55	20.0	1.0	4.0	0.2
Mean	1.71	0.06	0.118	0.033	44.35	83.9	20.9	7.5	0.6
Median	1.52	0.02	0.091	0.020	33.32	76.0	18.2	7.4	0.6
Maximum	9.03	0.70	0.590	0.525	194.00	330.0	300.0	10.7	6.5

Table 2.1b. Water Quality Summary Statistics for TN, NH₃, TP, PO₄, Chl_a, Color, Alkalinity, pH, and Secchi Depth (after 1995)

Statistic	TN (mg/L)	NH ₃ -N (mg/L)	TP (mg/L)	PO ₄ -P (mg/L)	Chl _a (µg/L)	Color True (PCU)	Alkalinity (mg/L)	pH (SU)	Secchi Depth (meters)
Period of Record	1996–2009	1996–2009	1996–2009	1996–2009	1996–2009	1996–2009	1996–2009	1996–2009	1996–2009
Count	185	162	191	125	167	124	167	155	184
Minimum	0.36	0.00	0.005	0.001	1.00	20.1	4.0	5.4	0.2
Mean	1.48	0.04	0.080	0.009	34.15	84.8	30.1	7.7	0.6
Median	1.43	0.02	0.072	0.005	30.55	75.0	26.0	7.7	0.6
Maximum	4.42	0.30	0.248	0.084	151.40	300.0	290.0	9.9	5.0

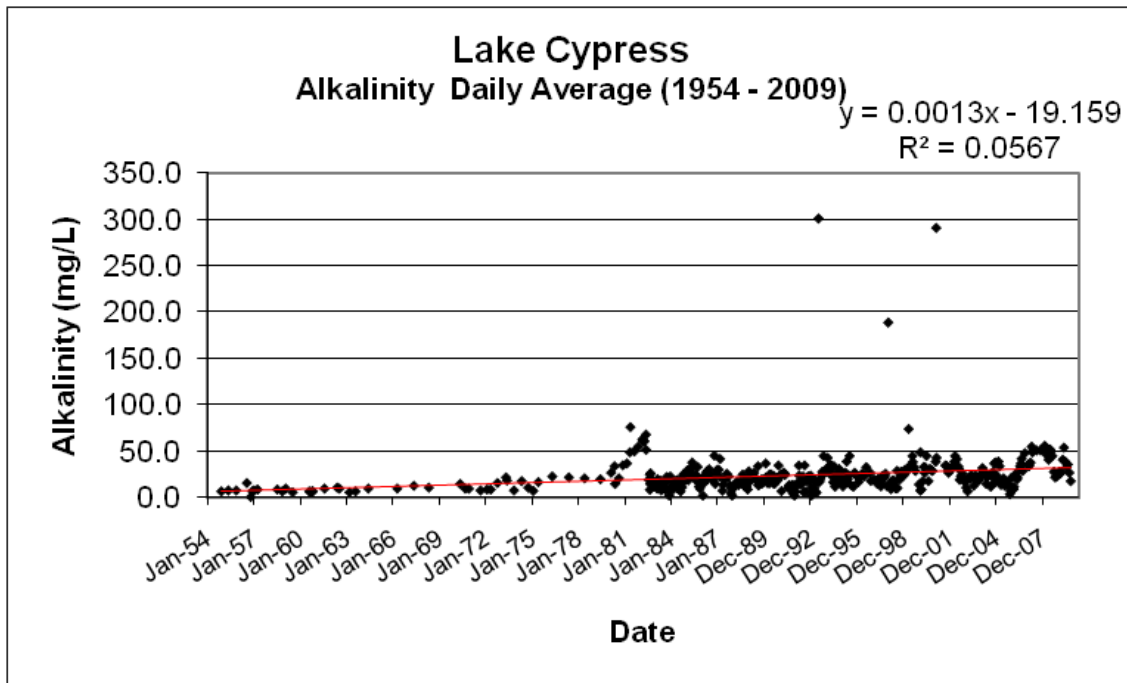


Figure 2.3. Daily Average Alkalinity (mg/L) for Lake Cypress, 1954–2009

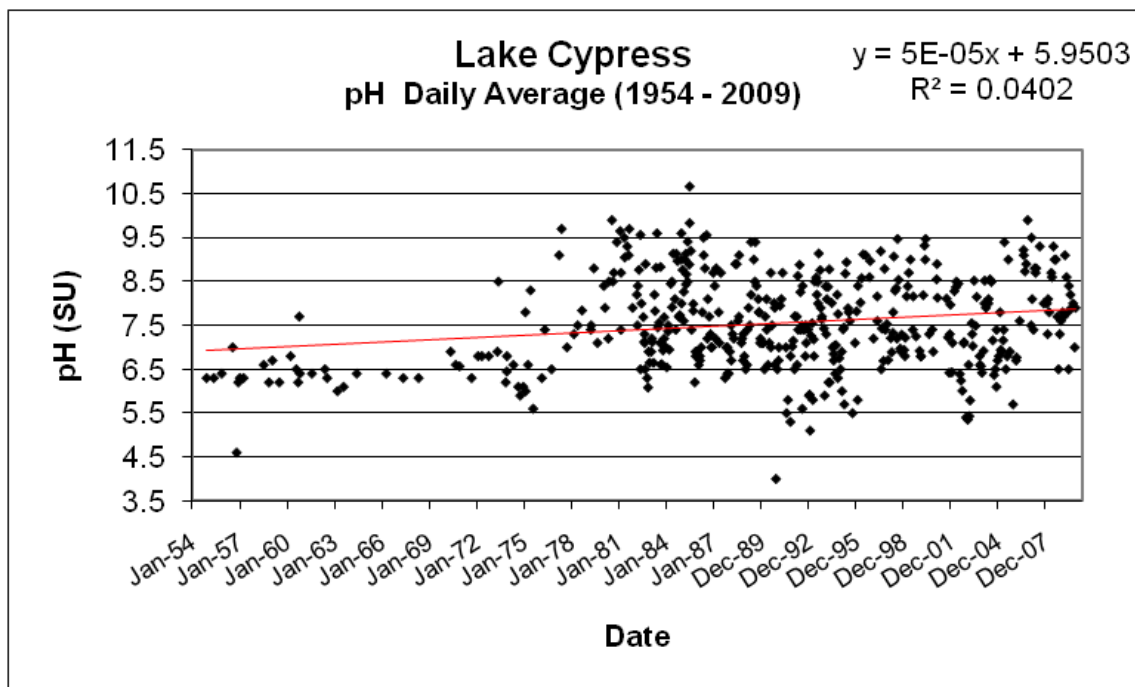


Figure 2.4. Daily Average pH (SU) for Lake Cypress, 1954–2009

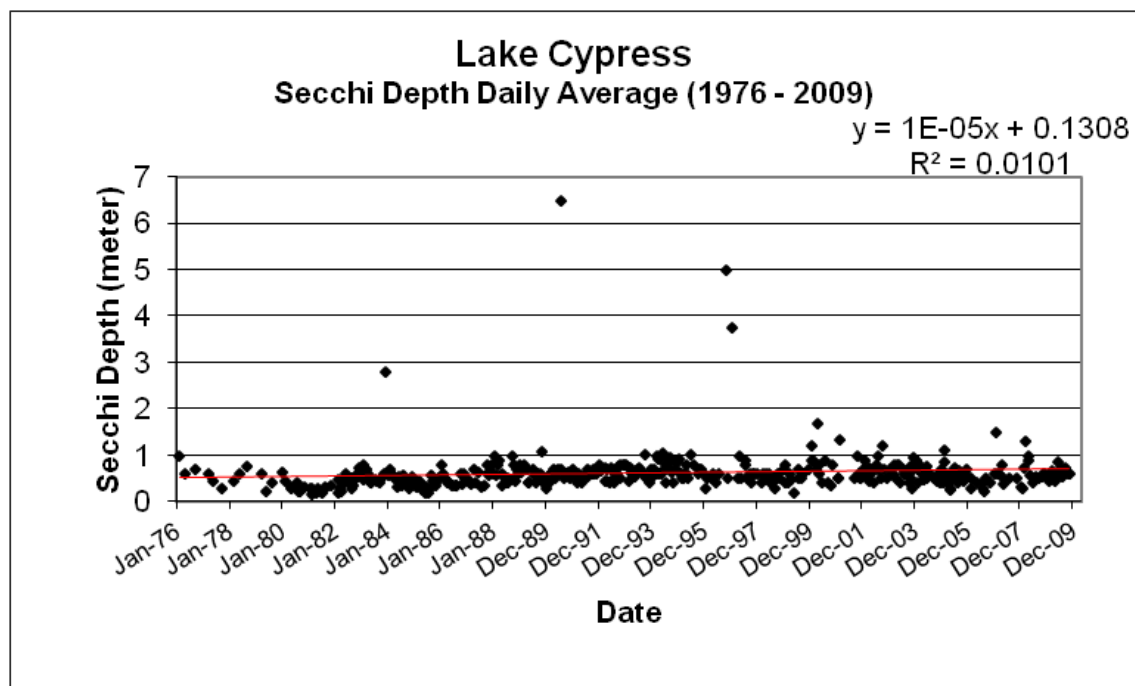


Figure 2.5. Daily Average Secchi Depth (meters) for Lake Cypress, 1976–2009

Figure 2.6 displays the annual average TSI values for all data from 1979 to 2009 (including LakeWatch data). During the combined verified periods (January 1998 to June 2009), annual average TSI values exceeded the IWR threshold level of 60 in 1998, 1999, 2000, and from 2002 to 2009, with a mean TSI result of 65.7. While the annual average TSI has declined from the values over 70 reported during 1980 to 1987, it remains above the IWR threshold value of 60, indicating a need for additional nutrient reductions.

The daily, annual, and monthly average TN results for Lake Cypress (1970 to 2009) are displayed in **Figures 2.7** through **2.9** and summarized in **Tables 2.1a** and **2.1b**. These data indicate that while the daily and annual average TN results have improved since 1988 (no more annual averages over 2.0 mg/L), the mean of 1.48 mg/L for the period from 1996 to 2009 remains at a level that is contributing to the elevated TSI results. The monthly average TN results appear highest in early spring (1.8 mg/L) and lowest during December (1.36 mg/L)

The daily average total ammonia (NH₃-N) results (1970 to 2009) are displayed in **Figure 2.10** and summarized in **Tables 2.1a** and **2.1b**. These data indicate that while the mean (0.06 mg/L) and maximum (0.70 mg/L) NH₃-N concentration from 1970 to 1995 improved between 1996 and 2009 to 0.04 and 0.30 mg/L, respectively, the median concentration of 0.02 mg/L remains unchanged.

The daily, annual, and monthly average TP results for Lake Cypress from 1968 to 2009 are displayed in **Figures 2.11** through **2.13** and summarized in **Tables 2.1a** and **2.1b**. These data indicate that while the daily and annual average TP results have improved since 1988 (no more annual averages over 0.10 to 0.20 mg/L), the mean of 0.08 mg/L from 1996 to 2009 remains at a level that is contributing to the elevated TSI. The monthly average TP results are highest in late spring and summer (May through August), averaging 0.124 mg/L, and lowest during December and January, averaging 0.086 mg/L.

The daily average orthophosphate (PO₄) results (1971 to 2009) are displayed in **Figure 2.14** and summarized in **Tables 2.1a** and **2.1b**. These data indicate a large reduction in PO₄ concentrations over the period of record. The mean and median concentration for 1971 to 1995 of 0.033 and 0.02 mg/L decreased to 0.009 and 0.005 mg/L, respectively, from 1996 to 2009. However, it is important to note that values over 0.04 mg/L still occur periodically.

The daily, annual, and monthly average cchl_a results for Lake Cypress from 1979 to 2009 are displayed in **Figures 2.15** through **2.17** and summarized in **Tables 2.1a** and **2.1b**. These data indicate that while the daily and annual average cchl_a results have improved since data collection began (no more annual

averages over 50 µg/L), the mean of 45 µg/L for 2008 and 41 µg/L for 2009—together with daily average concentrations over 100 µg/L that occurred during the combined verified periods—is indicative of nutrient enrichment. The monthly average *cchl_a* results build over the spring months from a seasonal winter low (December through February) of 30.8 µg/L to a summer high in June of 63.6 µg/L, and then decline each month towards the winter lows. **Tables 2.1a** and **2.1b** provide summary statistics for the lake for TN, TP, and *cchl_a* from 1993 to 2009.

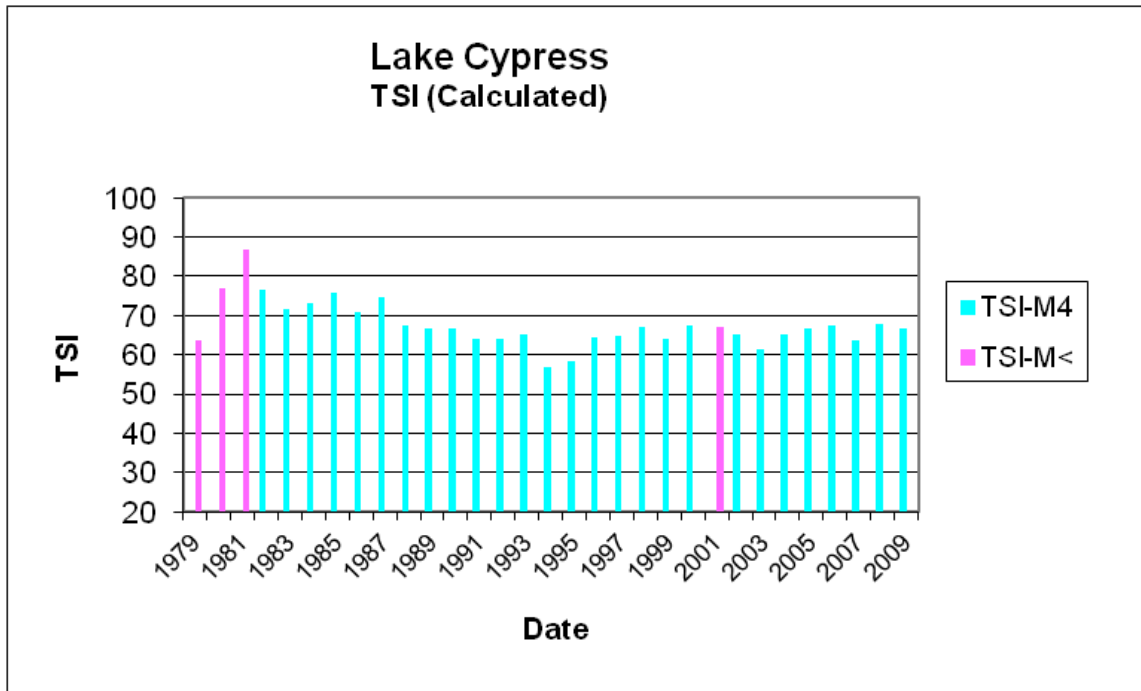


Figure 2.6. TSI Annual Average for Lake Cypress, 1979–2009

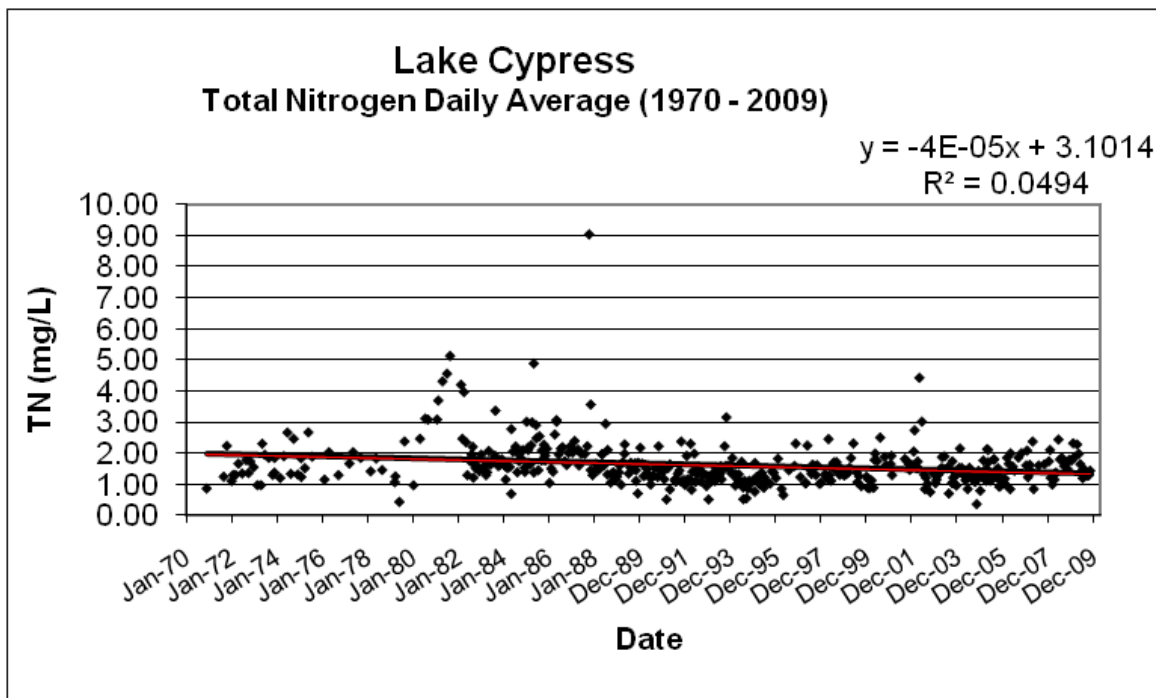


Figure 2.7. TN Daily Average Results for Lake Cypress, 1970–2009

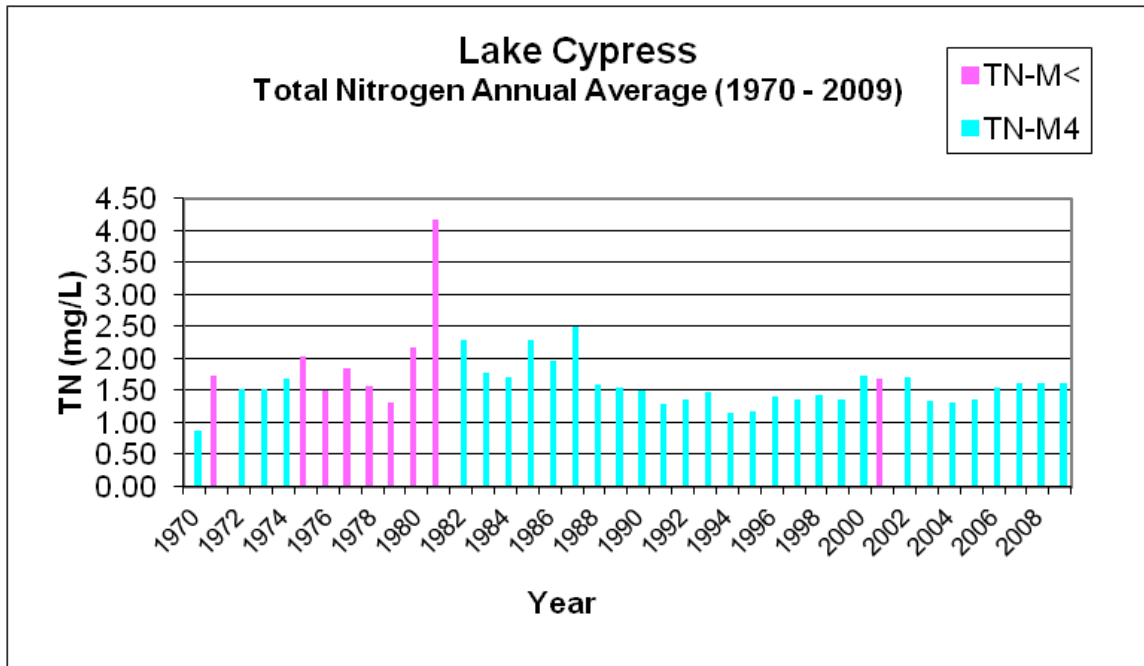


Figure 2.8. TN Annual Average Results for Lake Cypress, 1970–2009

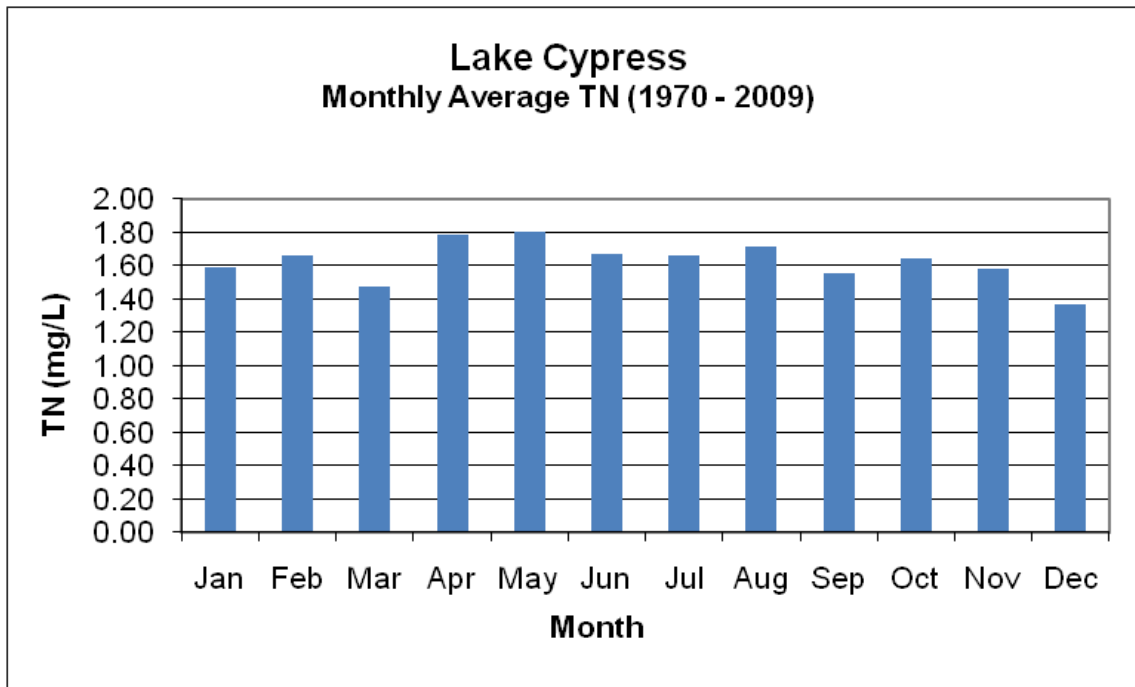


Figure 2.9. TN Monthly Average Results for Lake Cypress, 1970–2009

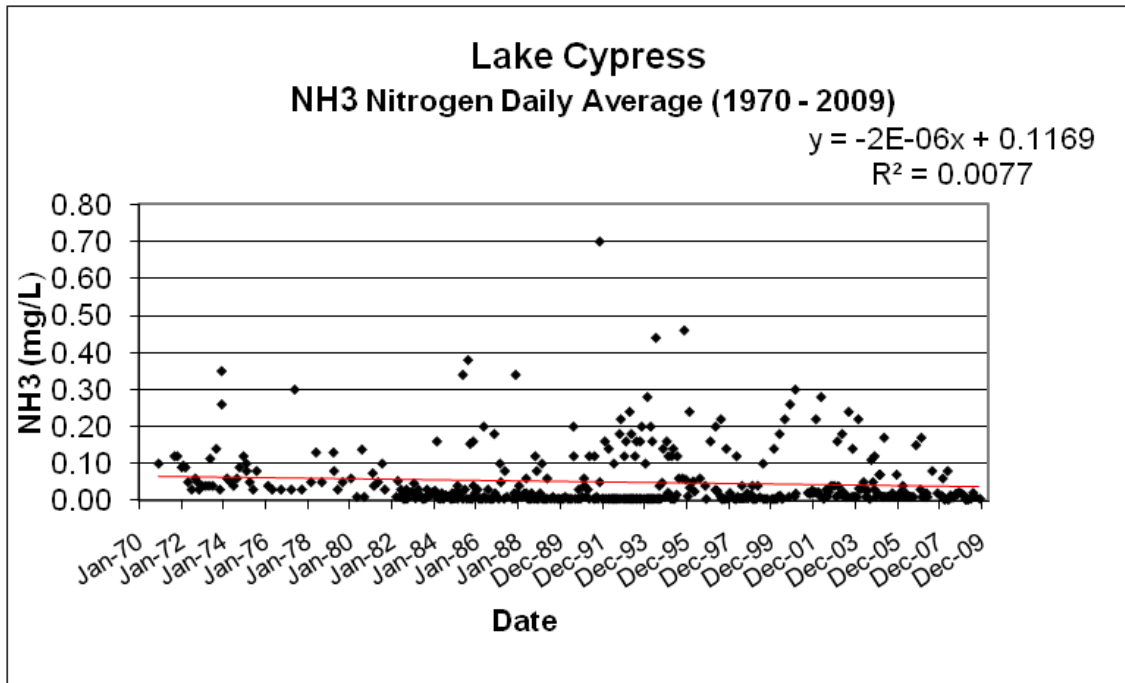


Figure 2.10. Total Ammonia Nitrogen Daily Average Results for Lake Cypress, 1970–2009

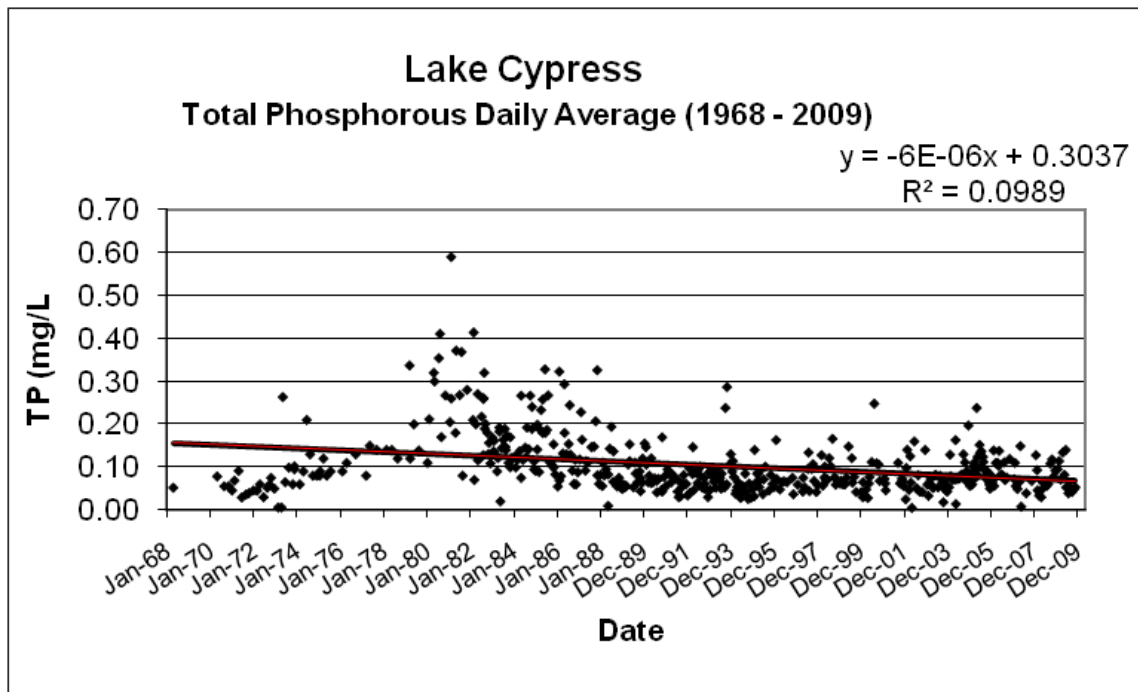


Figure 2.11. TP Daily Average Results for Lake Cypress, 1968–2009

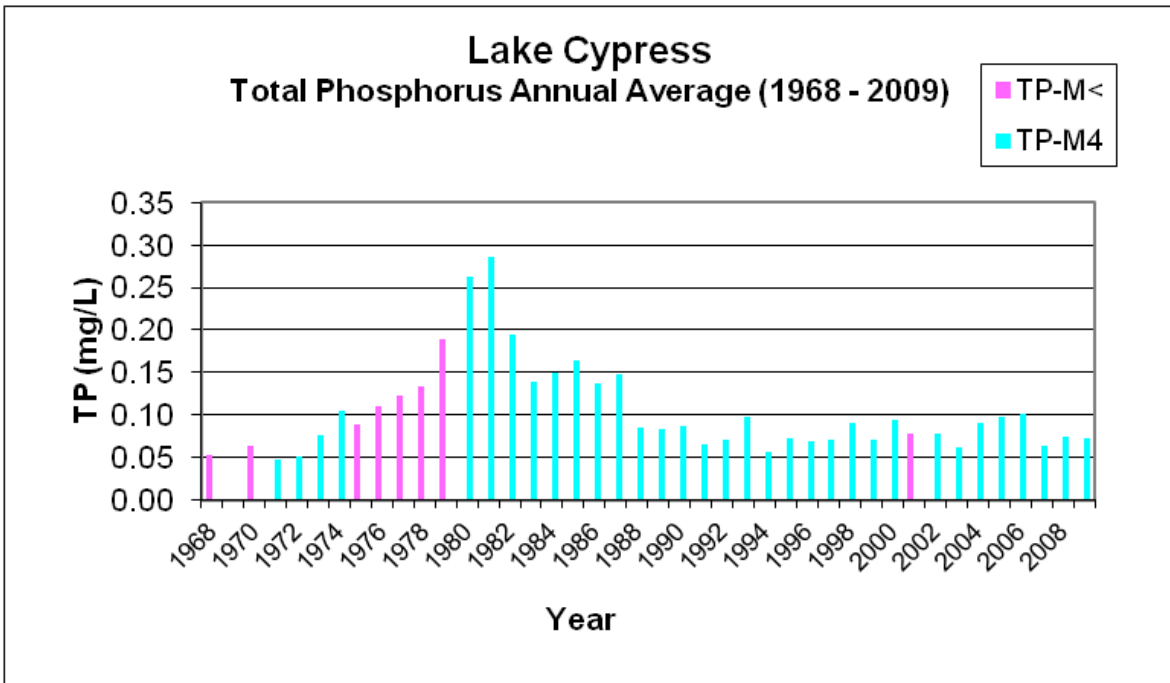


Figure 2.12. TP Annual Average Results for Lake Cypress, 1968–2009

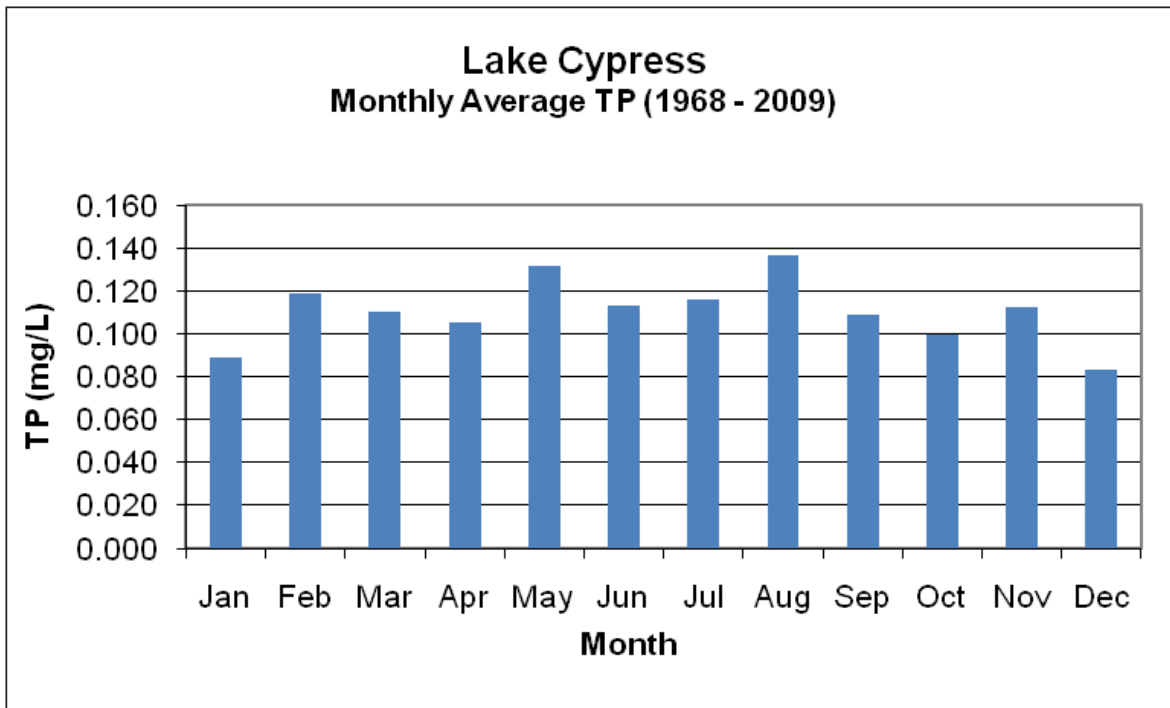


Figure 2.13. TP Monthly Average Results for Lake Cypress, 1968–2009

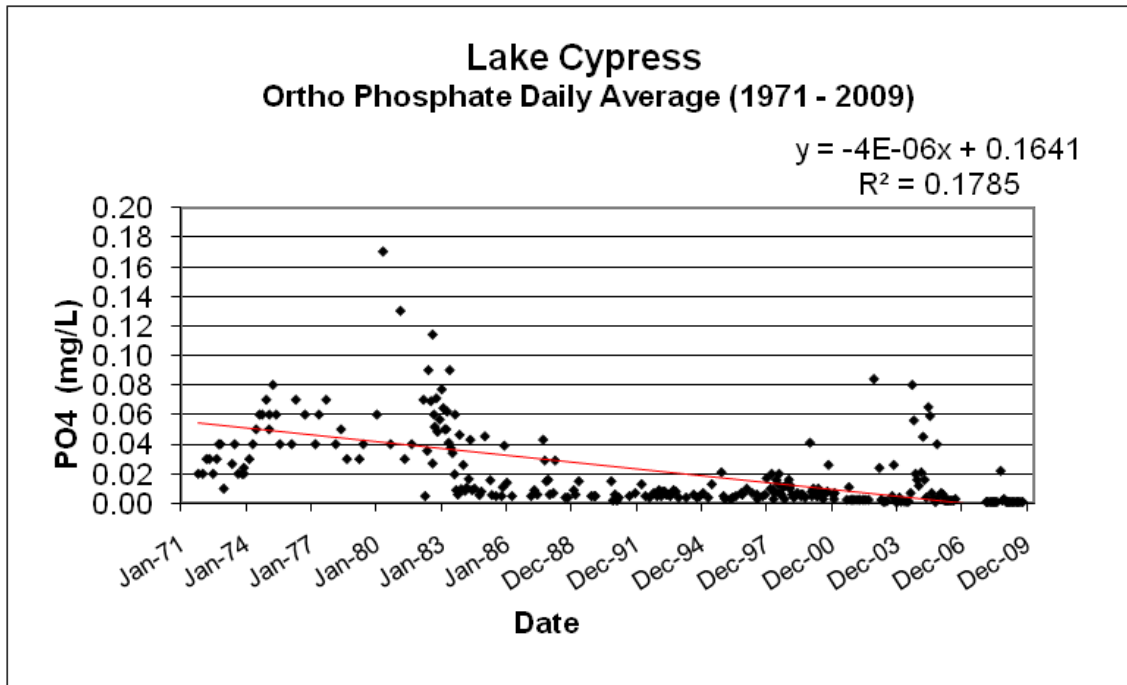


Figure 2.14. Orthophosphate-Phosphorus Daily Average Results for Lake Cypress, 1971–2009

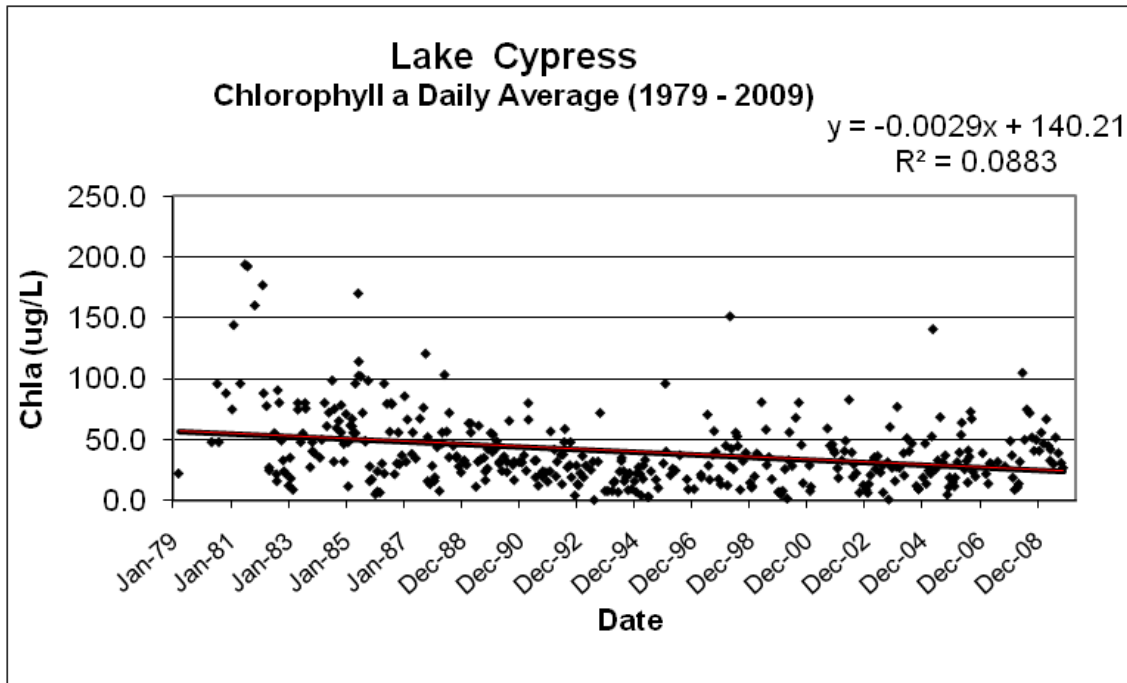


Figure 2.15. CChla Daily Average Results for Lake Cypress, 1979–2009

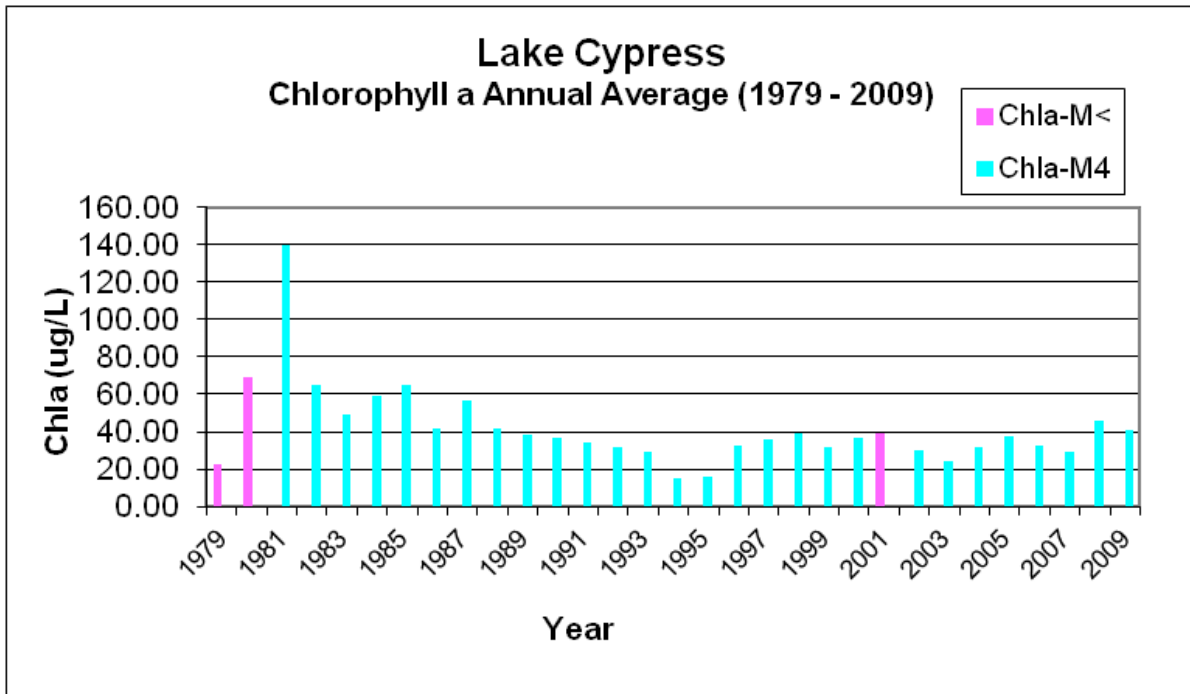


Figure 2.16. CChla Annual Average Results for Lake Cypress, 1979–2009

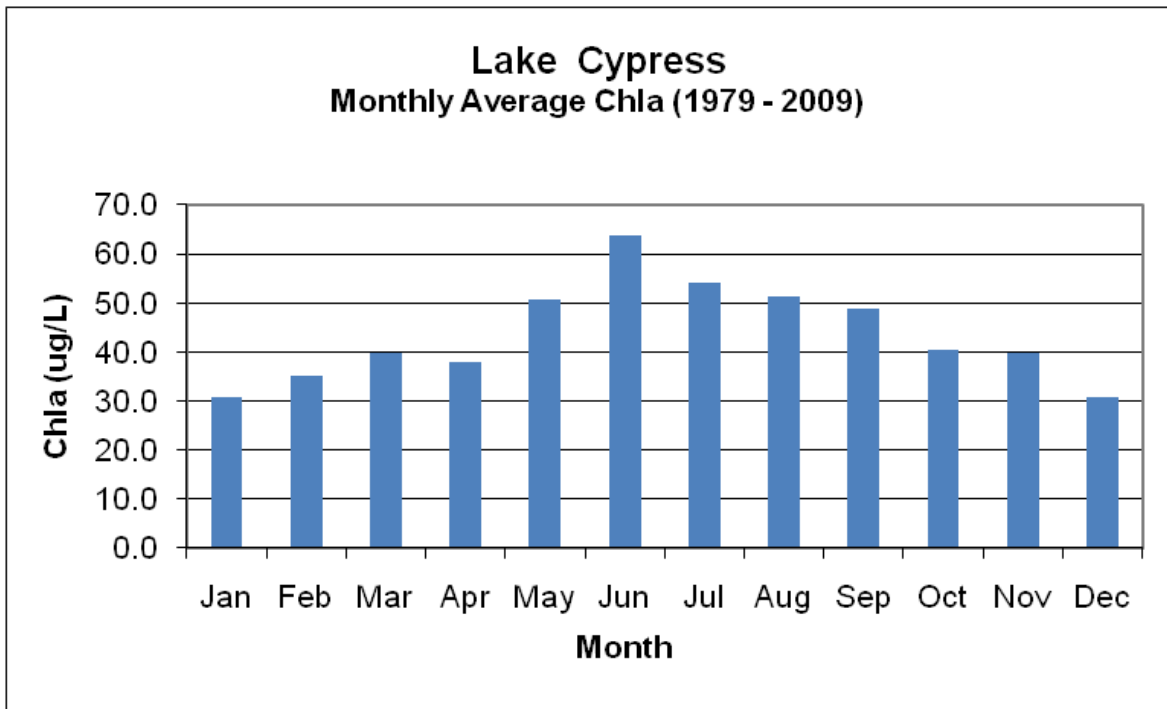


Figure 2.17. CChla Monthly Average Results for Lake Cypress, 1979–2009

Chapter 3. DESCRIPTION OF APPLICABLE WATER QUALITY STANDARDS AND TARGETS

3.1 Classification of the Waterbody and Criterion Applicable to the TMDL

Florida's surface water is 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)

Lake Cypress is classified as a Class III freshwater waterbody, with a designated use of recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife. The Class III water quality criterion applicable to the observed impairment for Lake Cypress is the state of Florida's narrative nutrient criterion (Subsection 62-302.530[30], F.A.C.). This TMDL constitutes the site-specific numeric interpretation of the narrative nutrient criterion pursuant to Paragraph 62-302.531(2)(a), F.A.C., which states:

(2) The narrative water quality criterion for nutrients in paragraph 62-302.530(47)(b), F.A.C., shall be numerically interpreted for both nutrients and nutrient response variables in a hierarchical manner as follows:

(a) Where a site specific numeric interpretation of the criterion in paragraph 62-302.530(47)(b), F.A.C., has been established by the Department, this numeric interpretation shall be the primary interpretation. If there are multiple interpretations of the narrative criterion for a waterbody, the most recent interpretation established by the Department shall apply. A list of the site specific numeric interpretations of paragraph 62-302.530(47)(b), F.A.C., may be obtained from the Department's internet site at <http://www.dep.state.fl.us/water/wqssp/swq-docs.htm> or by writing to the Florida Department of Environmental Protection, Standards and Assessment Section, 2600 Blair Stone Road, MS 6511, Tallahassee, FL 32399-2400.

1. The primary site specific interpretations are as follows:

a. Total Maximum Daily Loads (TMDLs) adopted under Chapter 62-304, F.A.C., that interpret the narrative water quality criterion for nutrients in paragraph 62-302.530(47)(b), F.A.C., for one or more nutrients or nutrient response variables;

b. *Site specific alternative criteria (SSAC) for one or more nutrients or nutrient response variables as established under Rule 62-302.800, F.A.C.;*

c. *Estuary-specific numeric interpretations of the narrative nutrient criterion established in Rule 62-302.532, F.A.C.; or*

d. *Other site specific interpretations for one or more nutrients or nutrient response variables that are formally established by rule or final order by the Department, such as a Reasonable Assurance Demonstration pursuant to Rule 62-303.600, F.A.C., or Level II Water Quality Based Effluent Limitations (WQBEL) established pursuant to Rule 62-650.500, F.A.C. To be recognized as the applicable site specific numeric interpretation of the narrative nutrient criterion, the interpretation must establish the total allowable load or ambient concentration for at least one nutrient that results in attainment of the applicable nutrient response variable that represents achievement of the narrative nutrient criterion for the waterbody. A site specific interpretation is also allowable where there are documented adverse biological effects using one or more Biological Health Assessments, if information on chlorophyll a levels, algal mats or blooms, nuisance macrophyte growth, and changes in algal species composition indicate there are no imbalances in flora and a stressor identification study demonstrates that the adverse biological effects are not due to nutrients.*

3.2 Interpretation of the Narrative Nutrient Criterion for Lakes

To place a waterbody segment on the Verified List for nutrients, the Department must identify the limiting nutrient or nutrients causing impairment, as required by the IWR. The following method is used to identify the limiting nutrient(s) in streams and lakes:

The individual ratios over the combined verified periods for Cycle 1 (i.e., January 1, 1998, to June 30, 2005) and Cycle 2 (i.e., January 1, 2003, to June 30, 2010) were evaluated to determine the limiting nutrient(s). If all the sampling event ratios were less than 10, nitrogen was identified as the limiting nutrient, and if all the ratios were greater than 30, phosphorus was identified as the limiting nutrient. Both nitrogen and phosphorus were identified as limiting nutrients if the ratios were between 10 and 30. For Lake Cypress, the median TN/TP ratio was 19.5 for the combined period, indicating co-limitation of TP and TN for the lake.

Florida's nutrient criterion is narrative only, *i.e.*, nutrient concentrations of a body of water shall not be altered so as to cause an imbalance in natural populations of aquatic flora or fauna. Accordingly, a nutrient-related target was needed to represent levels at which an imbalance in flora or fauna is expected to occur. While the IWR provides a threshold for nutrient impairment for lakes based on annual average TSI levels, these thresholds are not standards and are not required to be used as the nutrient-related water quality target for TMDLs. 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 TSI originally developed by R.E. Carlson (1977) was calculated based on Secchi depth, chlorophyll concentration, and TP concentration, and was used to describe a lake's trophic state. It assumed that the lakes were all phosphorus limited. In Florida, because the local geology has produced a phosphorus-rich soil, nitrogen can be the sole or co-limiting factor for phytoplankton population in some lakes. In addition, because of the existence of dark-water lakes in the state, using Secchi depth as an index to represent lake trophic state can produce misleading results.

Therefore, the TSI was revised to be based on TN, TP, and *chl_a* concentrations. This revised calculation for TSI now contains options for determining a TN-TSI, TP-TSI, and *chl_a*-TSI. As a result, there are three different ways of calculating a final in-lake TSI. If the TN to TP ratio is equal to or greater than 30, the lake is considered phosphorus limited, and the final TSI is the average of the TP-TSI and the *chl_a*-TSI. If the TN to TP ratio is 10 or less, the lake is considered nitrogen limited, and the final TSI is the average of the TN-TSI and the *chl_a*-TSI. If the TN to TP ratio is between 10 and 30, the lake is considered co-limited, and the final TSI is the result of averaging the *chl_a*-TSI with the average of the TN- and TP-TSIs.

The Florida-specific TSI was determined based on the analysis of data from 313 Florida lakes. The index was adjusted so that a *chl_a* concentration of 20 µg/L was equal to a *chl_a*-TSI value of 60. The final TSI for any lake may be higher or lower than 60, depending on the TN- and TP-TSI values. A TSI of 60 was then set as the threshold for nutrient impairment for most lakes (for those with color higher than 40 PCU) because, generally, phytoplankton communities may become dominated by blue-green algae at *chl_a* levels above 20 µg/L. These blue-green algae are often an undesirable food source for zooplankton and many other aquatic animals. Some blue-green algae may even produce toxins, which could be harmful to fish and other animals. In addition, excessive phytoplankton growth and the subsequent death of these algae may consume large quantities of dissolved oxygen (DO) and result in anaerobic conditions in a lake, making conditions unfavorable for fish and other wildlife. All of these processes may negatively impact the health and balance of native fauna and flora.

Because of the amazing diversity and productivity of Florida lakes, almost all lakes have a natural background TSI that is different from 60. In recognition of this natural variation, the IWR allows for the

use of a lower TSI (40) in very clear lakes, a higher TSI if paleolimnological data indicate the lake was naturally above 60, and the development of site-specific thresholds that better represent the levels at which nutrient impairment occurs.

For the Lake Cypress TMDL, the Department applied the HSPF model to simulate water quality discharges and eutrophication processes to determine the appropriate nutrient target. The HSPF model was used to estimate existing conditions in the Lake Jackson watershed and the background TSI by setting land uses to natural or forested land, and then comparing the resulting TSI with the IWR thresholds. If the background TSI could be reliably determined and represented an appropriate target for TMDL development, then an increase of 5 TSI units above background would be used as the water quality target for the TMDL. Otherwise, the IWR threshold TSI of 60 would be established as the target for TMDL development.

3.3 Nutrient Criterion Definitions

3.3.1 *Chlorophyll a*

Chlorophyll is a green pigment found in plants and is an essential component in the process of converting light energy into chemical energy. Chlorophyll is capable of channeling the energy of 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 *chl a*. The measurement of *chl a* in a water sample is a useful indicator of phytoplankton biomass, especially when used in conjunction with the analysis of algal growth potential and species abundance. Typically, the greater the abundance of *chl a* in a waterbody, 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 lakes and streams. As noted earlier, *chl a* measurements are also used to estimate the trophic conditions of lakes and lentic waters.

3.3.2 *Nitrogen Total as N (TN)*

TN is the combined measurement of nitrate (NO₃), nitrite (NO₂), ammonia, and organic nitrogen found in water. Nitrogen compounds function as important nutrients for many aquatic organisms and are

essential to the chemical processes that take place 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 accelerate the eutrophication rate in an aquatic system. Usually, the eutrophication process is observed as a change in the structure of the algal community and includes severe algal blooms that may cover large areas for extended periods. Large algal blooms are generally followed by depletion in DO concentrations as a result of algal decomposition.

3.3.3 *Phosphorus Total as P (TP)*

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

High phosphorus concentrations are frequently responsible for accelerating the eutrophication process in a waterbody. 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.

Chapter 4: ASSESSMENT OF SOURCES

4.1 Overview of Modeling Process

The Lake Cypress watershed is a part of a larger network of lakes and streams that drain to the Kissimmee River, and ultimately, Lake Okeechobee. As there are several other lakes/streams in the Kissimmee River Basin for which TMDLs are being developed, the Department contracted with CDM to gather all available information and to set up, calibrate, and validate HSPF model projects for these waters. See **Appendix B** for modeling details.

HSPF (EPA 2001; Bicknell *et al.* 2001) is a comprehensive package that can be used to develop a combined watershed and receiving water model. The external load assessment conducted using HSPF was intended to determine the loading characteristics of the various sources of pollutants to Lake Cypress. Assessing the external load entailed assessing land use patterns, soils, topography, hydrography, point sources, service area coverages, climate, and rainfall to determine the volume, concentration, timing, location, and underlying nature of the point, nonpoint, and atmospheric sources of nutrients to the lake.

The model has the capability of modeling various species of nitrogen and phosphorus, chl_a, coliform bacteria, and metals in receiving waters (bacteria and metals can be simulated as a “general” pollutant with potential in-stream processes, including first-order decay and adsorption/desorption with suspended and bed solids). HSPF has been developed and maintained by Aqua Terra and the EPA and is available as part of the EPA-supported software package BASINS (Better Assessment Science Integrating Point and Nonpoint Sources).

The PERLND (pervious land) module performs detailed analyses of surface and subsurface flow for pervious land areas based on the Stanford Watershed Model. Water quality calculations for sediment in pervious land runoff can include sediment detachment during rainfall events and reattachment during dry periods, with potential for wash off during runoff events. For other water quality constituents, runoff water quality can be determined using buildup-wash off algorithms, “potency factors” (*e.g.*, factors relating constituent wash off to sediment wash off), or a combination of both.

The IMPLND (impervious land) module performs analysis of surface processes only and uses buildup-wash off algorithms to determine runoff quality. The RCHRES (free-flowing reach or mixed reservoir) 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 utilize 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 HSPF/BASINS is available at www.epa.gov/waterscience/basins/.

4.2 Potential Sources of Nutrients in the Lake Cypress Watershed

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” has meant discharges to surface waters that typically have a continuous flow via a discernible, confined, and discrete conveyance, such as a pipe. Domestic and industrial wastewater treatment facilities (WWTFs) are examples of traditional point sources. In contrast, the term “nonpoint sources” was used to describe intermittent, rainfall-driven, diffuse sources of pollution associated with everyday human activities, including runoff from urban land uses, agriculture, silviculture, and mining; discharges from failing septic systems; and atmospheric deposition.

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

There are no permitted WWTFs or industrial wastewater facilities that discharge directly to Lake Cypress. The NPDES facilities listed in **Table 4.1** and shown in **Figure 4.1** are within the extended Lake Kissimmee watershed but were not included in the model as they are not surface water dischargers.

Municipal Separate Storm Sewer System Permittees

Municipal separate storm sewer systems (MS4s) may discharge nutrients to waterbodies in response to storm events. To address stormwater discharges, the EPA developed the NPDES stormwater permitting program in two phases. Phase I, promulgated in 1990, addresses large and medium MS4s located in incorporated places and counties with populations of 100,000 or more. Phase II permitting began in 2003. Regulated Phase II MS4s, which are defined in Section 62-624.800, F.A.C., typically cover urbanized areas serving jurisdictions with a population of at least 10,000 or discharge into Class I or Class II waters, or Outstanding Florida Waters (OFWs).

The stormwater collection systems in the Lake Cypress watershed, which are owned and operated by Polk County in conjunction with the Florida Department of Transportation (FDOT) District 1, are covered by NPDES Phase I MS4 Permit Number FLS000015. The collection systems owned and operated by Osceola County and the city of St. Cloud are covered by NPDES Phase II MS4 Permit Number FLR04E012. The collection system for the city of Orlando is covered by NPDES Phase I Permit Number FLS000014. The collection systems for Orange County, FDOT District 5, and the city of Belle Isle are covered by NPDES Phase 1 Permit Number FLS000011. The collection system for the city of Kissimmee is covered by NPDES Phase II Permit Number FLR04E64. The collection system for the Florida Turnpike is covered by NPDES Phase II-C Permit Number FLRO4E049.

Table 4.1. NPDES Facilities in the Extended Lake Kissimmee Drainage Basin

CBP = Concrete batch plant; DW = Domestic wastewater; PET = potential evapotranspiration; IW = Industrial wastewater; MGD = Million gallons per day

Facility ID	Facility Name	Type	NPDES	MGD	County	Receiving Water
FLG110685	CEMEX LLC - Lake Wales Sand Mine	CBP	Yes	0.000	Polk	None
FLG110259	Florida Rock Industries Inc. - Poinciana Plant	CBP	Yes	0.000	Polk	None
FL0036862	TWA-Walnut Drive WRF	DW	Yes	0.850	Osceola	None
FLG110429	CEMEX LLC - Davenport 17/92	CBP	Yes	0.000	Polk	None
FLG110719	Maschmeyer Concrete Company	CBP	Yes	0.000	Osceola	None
FLG110347	CEMEX LLC - Davenport Sand Mine	CBP	Yes	0.000	Polk	None
FLG110833	Jahna Ranch Facility II	CBP	Yes	0.000	Polk	None
FLG110834	Jahna Ranch Readymix Facility I	CBP	Yes	0.000	Polk	None
FLG110650	CEMEX Construct Materials FL LLC – St. Cloud Ready Mix Plant	CBP	Yes	0.000	Osceola	None
FLG110179	Florida Rock - Campbell City CBP	CBP	Yes	0.002	Osceola	None
FLG110234	CEMEX Cnstr Mtrls FL LLC- Kissimmee Pug Mill Ready Mix Plant	CBP	Yes	0.000	Osceola	None
FLG110007	CEMEX Construct Mtrls FL LLC - Smith Street Ready Mix Plant	CBP	Yes	0.000	Osceola	None
FLG110490	Prestige - Kissimmee CBP	CBP	Yes	0.000	Osceola	None
FLG914151	South & East Service Area	PET	Yes	0.000	Orange	None
FLG110226	CEMEX Construct Materials FL LLC - W Orange Ready Mix Plant	CBP	Yes	0.000	Orange	None
FLG110327	Florida Rock - CR 545 CBP	CBP	Yes	0.000	Orange	None
FL0169986	WDW - Produced Groundwater Discharge	IW	Yes	0.000	Orange	None
FLG110581	Tarmac - South Orange CBP	CBP	Yes	0.018	Orange	None
FLG110613	CEMEX Construction Materials FL LLC - Regency	CBP	Yes	0.000	Orange	None
FL0622648	Seaworld - Discovery Cove	IW	Yes	0.000	Orange	None
FL0629332	Sea World Of Florida	IW	Yes	0.000	Orange	None
FL0622591	SeaWorld-Aquatica	IW	Yes	0.000	Orange	None
FLG110269	Bedrock Industries	CBP	Yes	0.044	Orange	None
FL0037711	Kinder Morgan LLC	IW	Yes	1.500	Orange	None
FLG110805	Orlando Ready Mix	CBP	Yes	0.000	Orange	None
FLG110159	Florida Rock Industries - Taft CBP	CBP	Yes	0.003	Orange	None
FLG914113	Avis Rent A Car	PET	Yes	0.000	Orange	None
FLG110496	Preferred Materials-East Orlando CBP	CBP	Yes	0.004	Orange	None
FLG110268	Florida Rock Industries - East Orlando CBP	CBP	Yes	0.000	Orange	None
FLG110217	CEMEX Construction Materials FL LLC – East Orlando CBP	CBP	Yes	0.003	Orange	None
FL0037133	OCUD-Orange County Landfill Leachate NPDES	IW	Yes	3.700	Orange	None
FLG110786	Tarmac-Orlando Downtown CBP	CBP	Yes	0.000	Orange	None
FLG110787	CEMEX Construct Mtrls FL LLC - Grant Street Ready Mix Plant	CBP	Yes	0.000	Orange	None
FLG110116	Preferred Materials-Division Street Ready Mix Plant	CBP	Yes	0.000	Orange	None
FLG110825	A - 1 Block Corp	CBP	Yes	0.000	Orange	None
FLG110735	CEMEX Construct Mtrls FL LLC - Atlanta Ave. Ready Mix Plant	CBP	Yes	0.000	Orange	None

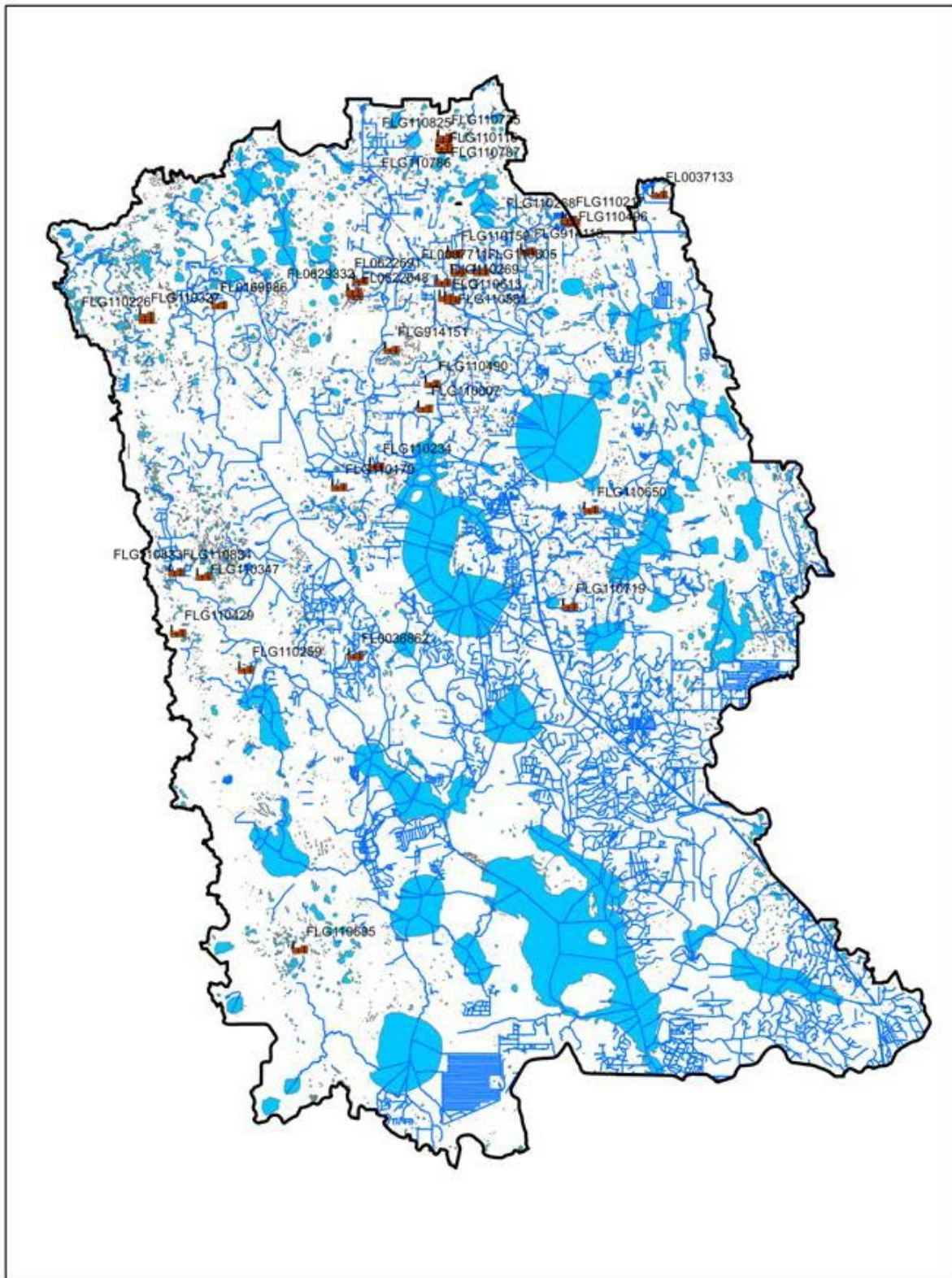


Figure 4.1. NPDES Facilities in the Extended Lake Kissimmee Basin

4.2.2 Nonpoint Sources and Land Uses

Unlike traditional point source effluent loads, nonpoint source loads enter at so many locations and exhibit such large temporal variations that a direct monitoring approach is often infeasible. For the Lake Jackson TMDL, all nonpoint sources were evaluated by the use of a watershed and lake modeling approach. Land use coverages in the watershed and subbasin were aggregated using the 1999 Florida Land Use, Cover, and Forms Classification System (FLUCCS) (FDOT 2009) 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 the 2000 land use coverage (scale 1:24,000) provided by the SFWMD.

Figure 4.2 shows the drainage area of Lake Cypress and the spatial distribution of land uses. The drainage area of Lake Cypress includes the Lake Cypress subbasin, Lake Tohopekaliga watershed, and Lake Gentry watershed. **Table 4.2** shows the existing areas of the various land use categories in the extended Lake Cypress watershed and the lake subbasin that were used in the model. The drainage area (296,391 acres) of Lake Tohopekaliga also included the two major tributaries with the drainage area (115,200 acres) of Shingle Creek at Campbell U.S. Geological Survey (USGS) gauge station (USGS website 2012) and the area of the East Lake Tohopekaliga watershed. The predominant land coverages for the Lake Cypress watershed include agriculture (21%), wetland (29%), forest/rangeland (18%), pastureland (8%), commercial/industrial (11%), high-density residential (2%), medium-density residential (5%), and low-density residential (6%).

Osceola County Population

According to the U.S. Census Bureau (2008), the county occupies an area of approximately 1,321.9 square miles. The total population in 2000 for Osceola County, including (but not exclusive to) the Lake Cypress watershed, was 172,493. The population density in Osceola County in 2000 was at or less than 130.5 people per square mile. The Census Bureau estimates the 2006 Osceola County population at 244,045 (185 people/square mile). For all of Osceola County (in 2006), the Bureau reported a housing density of 83 houses per square mile. Osceola County is well below the average housing density for Florida counties of 158 housing units per square mile.

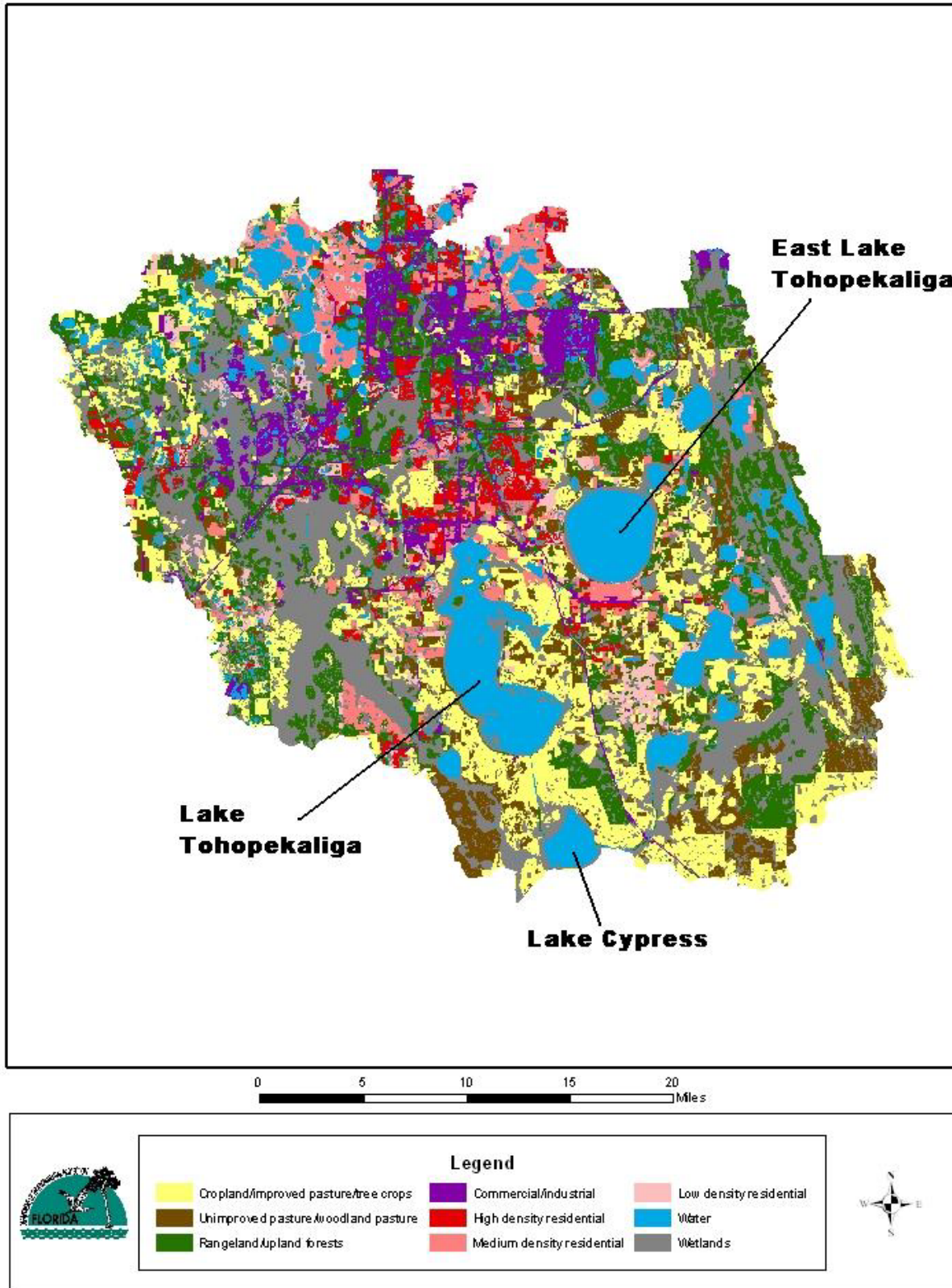


Figure 4.2. Lake Cypress Watershed Existing Land Use Coverage in 2000

Table 4.2. Land Use Description of Lake Cypress Extended Watersheds and Lake Subbasin

Land Use	Lake Toho Watershed (acres)	Lake Gentry Watershed (acres)	Lake Cypress Subbasin (acres)	Total Acreage (acres)	% Acreage
Agriculture	46,204	27,833	9,801	83,837	21%
Wetland	79,461	35,655	3,366	118,482	29%
Forest/rangeland	58,599	14,455	1,804	74,857	18%
Pastureland	17,118	13,973	1,043	32,134	8%
Commercial/industrial	42,933	418	157	43,508	11%
High-density residential	9,559	37	5	9,600	2%
Medium-density residential	20,645	797	0	21,442	5%
Low-density residential	21,871	2,866	0	24,737	6%
Subtotal	296,391	96,031	16,175	408,597	100%

Orange County Population

According to the U.S Census Bureau (2010), the county occupies an area of approximately 907.45 square miles. The total population estimate in 2000 (2010 Census data not yet available) for Orange County, including (but not exclusive to) the Lake Cypress watershed, was 896,354; the estimate for 2009 is 1,086,480, a 21% increase. The population density in Orange County in 2000 was at or less than 988 people per square mile. For all of Orange County (2009), the Bureau reported a housing density of 511 houses per square mile. Orange County is well above the average housing density for Florida counties of 164 housing units per square mile.

Polk County Population

According to the U.S Census Bureau (2008), the county occupies an area of approximately 1,875 square miles. As the model was run from 2000 to 2006, the 2000 Census data were used to estimate the total population in 2000 for Polk County, including (but not exclusive to) the Lake Cypress watershed and subbasin; there were 483,924 people. The population density in Polk County in 2000 was at or less than 258.2 people per square mile. The Bureau estimated the 2006 Polk County population at 561,606 (299 people/square mile). For all of Polk County (2006), the Bureau reported a housing density of 134 houses per square mile. Polk County is just below the average housing density for Florida counties of 158, with 134 housing units per square mile.

Septic Tanks

Onsite sewage treatment and disposal systems (OSTDS), including septic tanks, are commonly used in areas 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.

The CDM report (2008), *Section 2.5.2.1, Septic Tanks*, describes in detail how septic tanks were included in the HSPF model. In general, the assessment of septic tank contributions to impaired lakes was not directly accounted in the Upper Kissimmee Chain of Lakes HSPF model. No observed data accounting for the direct contribution of flow and nutrient loads from septic tanks to impaired waterbodies are currently available. The percent failure rate for septic tanks does not provide quantitative information on how much a failed septic tank leaks and the amount of flow and nutrients attenuated in soils and subsurface waters.

Instead, the model implicitly included septic tank contributions by estimating the nutrient contributions of low-, medium-, and high-density residential areas containing a degree of septic tanks and fertilizer uses to Lake Cypress. If necessary, individual contribution from anthropogenic sources of interest in the watershed can be quantified in more detail during the BMAP process. In addition, CDM also concluded that failing septic tanks did not have significant impacts on Lake Cypress and therefore did not explicitly include them in the model because (1) there is a limited amount of urban land in the area, (2) failure rates are typically low (10% failing or less), and (3) the amount of urban land thought to be served by septic tanks is also low in the area.

Osceola County Septic Tanks

As of 2006, Osceola County had a cumulative registry of 24,148 septic systems. Data for septic tanks are based on 1971 to 2006 Census results, with year-by-year additions based on new septic tank construction. The data do not reflect septic tanks that have been removed going back to 1970. For fiscal years 1994 to 2006, an average of 157.4 permits/year for repairs was issued in Osceola County (Florida Department of Health [FDOH] 2008). Based on the number of permitted septic tanks estimated for 2006 (24,148) and housing units (109,892) located in the county, approximately 78% of the housing units are connected to a central sewer line (*i.e.*, WWTF), with the remaining 22% utilizing septic tank systems.

Polk County Septic Tanks

As of 2006, Polk County had a cumulative registry of 115,838 septic systems. Data for septic tanks are based on 1971 to 2006 Census results, with year-by-year additions based on new septic tank construction. The data do not reflect septic tanks that have been removed going back to 1970. For fiscal years 1994 to 2006, an average of 1,246 permits/year for repairs was issued in Polk County (FDOH 2008). Based on the estimated number of permitted septic tanks (115,838) and housing units (269,410) located in the county, approximately 57% of the housing units are connected to a central sewer line (*i.e.*, WWTF), with the remaining 43% utilizing septic tank systems. **Table 4.3** lists the percent area of septic tanks implicitly used for each model basin.

Orange County Septic Tanks

As of 2010, Orange County had a cumulative registry of 106,238 septic systems. Data for septic tanks are based on 1971 to 2010 Census results, with year-by-year additions based on new septic tank construction. The data do not reflect septic tanks that have been removed going back to 1970. For fiscal years 2000 to 2010, an average of 1,141 permits/year for repairs was issued in Orange County (FDOH 2011). Based on the number of permitted septic tanks estimated for 2010 (106,238) and housing units (463,707) located in the county, approximately 78% of the housing units are connected to a central sewer line (*i.e.*, WWTF), with the remaining 22% utilizing septic tank systems.

Table 4.3. Septic Tank Coverage for Urban Land Uses

Note: Septic tank coverage estimated based on available septic tank and sewer service area information.

Receiving Water	HSPF Model Reach	Number of Commercial OSTDS	Number of High-Density Residential OSTDS	Number of Low-Density Residential OSTDS	Number of Medium-Density Residential OSTDS
Reedy Creek	100	14	1	30	7
Lake Speer	110	3	0	25	57
Lake Tibet and Sheen	120	2	13	32	15
Clear Lake	130	10	10	1	4
Lake Conway	140	7	9	23	17
Reedy Creek	150	9	2	20	9
Reedy Creek	160	10	10	9	17
Big Sand Lake	170	2	5	27	12
Shingle Creek	180	7	3	28	10
Boggy Creek	190	22	3	0	3
Boggy Creek	200	15	5	2	11
Reedy Creek	210	1	5	22	5
Shingle Creek	220	8	3	19	20
Shingle Creek	230	56	1	9	25
City Ditch Canal	240	29	3	0	7
Shingle Creek	250	11	3	31	25
Shingle Creek	260	10	17	15	19
Boggy Creek	270	0	0	29	21
Lake Myrtle	280	0	0	32	6
Lake Hart	290	9	0	17	16
East Lake Tohopekaliga	300	14	1	25	15
Lake Tohopekaliga	310	9	7	35	16
Alligator Lake	320	17	17	34	26
Lake Marion	330	18	2	22	12
Lake Marion Creek	340	23	3	15	8
Reedy Creek	350	8	1	4	4
Lake Gentry	360	0	0	0	0
S-63A	370	0	0	0	0
Cypress Lake	380	0	10	0	0

4.3 Estimating Point and Nonpoint Source Loadings

4.3.1 Model Approach

The HSPF model was utilized to estimate the nutrient loads within and discharged from the Lake Cypress 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 water quality parameters (impact parameters) simulated within the model for Lake Cypress include water quantity (surface runoff, interflow, and baseflow), and water quality (TN, organic nitrogen, ammonia nitrogen, nitrogen oxides [NO_x], TP, organic phosphorus, orthophosphorus, phytoplankton as biologically active *chl_a*, temperature, total suspended solids [TSS], DO, and ultimate carbonaceous biological oxygen demand [CBOD]). Datasets of land use, soils, topography and depressions, hydrography, USGS gauge and flow data, septic tanks, water use pumpage, point sources, ground water, atmospheric deposition, solar radiation, control structures, and rainfall (CDM 2008) 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.

IMPLND Module for Impervious Tributary Area

The IMPLND module of HSPF accounts for surface runoff from impervious land areas (*e.g.*, parking lots and highways). For the purposes of this model, each land use was assigned a typical percentage of directly connected impervious area (DCIA), as shown in **Table 4.4**, based on published values (CDM 2002). Four of the nine land uses contain some impervious areas.

Table 4.4. Percentage of DCIA

Note: Most of the water and wetland land uses in the system are modeled as a “reach” in HSPF.

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%

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 flow of water between a number of different storages, including surface storage, interflow storage, upper soil storage zone, lower soil storage zone, 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).

Hydrology for large waterbodies (*e.g.*, lakes) and rivers and streams that connect numerous lakes throughout the project area were modeled in RCHRES rather than PERLND (see *Section 4.3.1.3* of the 2008 CDM report). For each subbasin containing a main stem reach, a number of acres were removed from the water land use in PERLND that were modeled explicitly in RCHRES. The acres removed from these subbasins correspond to the areas of the lakes and the streams. In the reaches representing these waterbodies, HSPF accounted 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 stream flow 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 associated with surface runoff, as opposed to ground water flow. This would be appropriate for areas where receiving water inflows are highly responsive to rainfall events. Increasing UZSN can also affect the annual water balance by resulting in greater overall evapotranspiration.*

RCHRES Module for Stream/Lake Routing

The RCHRES module of HSPF conveys flows input from the PERLND and IMPLND modules, accounts for direct water surface inflow (rainfall) and direct water surface outflow (evaporation), and routes flows based on a rating curve supplied by the modeler. Within each subbasin of each planning unit model, a RCHRES element was developed that defines the depth-area-volume relationship for the modeled waterbody.

The depth-area-volume relationships for Lakes Alligator, Myrtle, Hart, Gentry, East Tohopekaliga, Tohopekaliga, Cypress, Hatchineha, and Kissimmee in the Upper Kissimmee Planning Unit were obtained from the *Upper Kissimmee Chain of Lakes Routing Model, Appendix B* (Post Buckley Schuh and Jernigan [PBSJ] *et al.* 2001). For all other major lakes and the impaired WBIDs in the project area, the stage-area-volume relationships were developed based on the lake's bathymetry data. *Section 4.2.10* of the CDM report (2008) provides more detailed information on how the lake bathymetry data were used to develop the depth-area-volume relationships.

For the lakes with hydraulic control structures, the design discharge rates were used in the depth-area-volume-discharge relationships once the lake stages were 1 foot or more than the target levels. When the lake stages were between 0 and 1 foot above the targets, the flows were assumed to vary linearly between 0 (0 feet above target) and the design flows (1 foot above target).

As discussed in the CDM report (2008), *Section 4.2.11*, the depth-area-volume relationships for the reaches in the Upper Kissimmee Planning Unit were developed based on the cross-section data extracted from the other models.

An initial Manning's roughness coefficient value of 0.035, typical for natural rivers and streams, was used in flow calculations. In some instances, the roughness coefficient value was adjusted during the model calibrations to reflect local conditions, such as smaller values for well-maintained canals and larger values for meandering, highly vegetated, and not well-defined streams. The slopes of water surface (S) were approximated with the reach bottom slopes, which were estimated based on the Digital Elevation Model data.

Implementation of Hydraulic Control Structure Regulation Schedules

To simulate the hydraulic control structure regulation schedules in the HSPF model, the stages were approximated with step functions, as described in detail in *Section 4* of the CDM report (2008). Variable step functions were used to approximate different regulation schedules. In each approximation, a step function was defined such that stage variations generally equaled 1 foot. In several instances, however, stage variations were less than 1 foot or less than 1.5 feet due to the stage variations in the original regulation schedules. For each hydraulic control structure, a sequential dataset was created to mimic the regulation schedules. Sequential datasets in this HSPF modeling application define the discharge column to evaluate from the FTABLE.

An FTABLE is a table in the HSPF model input file that summarizes the geometric and hydraulic properties of a reach. Normally, an FTABLE has at least three columns: depth, surface area, and volume. For the FTABLE associated with a reach with a control structure, Columns 4 through 8 can be used to define control structure operation flow rates for different operation zones. For example, the approximated operation schedule for a given lake may have four operation zones (1 through 4). For each year from January 1 to April 5 (Zone 1), the sequential dataset instructs the HSPF model to use the discharge rate in Column 4 in the FTABLE. Similarly, Columns 5, 6, and 7 in the FTABLE are used as the operation schedule progresses into Zones 2, 3, and 4, respectively.

Lake Cypress Existing Land Use Loadings

The HSPF simulation of pervious lands (PERLND) and impervious lands (IMPLND) calculates hourly values of runoff from pervious and impervious land areas, and interflow and baseflow from pervious lands, plus the loads of water quality constituents associated with these flows. For PERLND, TSS (sediment) was simulated in HSPF by accounting for sediment detachment caused by rainfall, and the subsequent wash off of detached sediment when surface runoff occurs. Loads of other constituents in PERLND runoff were calculated in the GQUAL (general quality constituent) model of HSPF, using a

“potency factor” approach (*i.e.*, defining how many pounds of constituent are washed off per ton of sediment washed off).

One exception occurs for DO, which HSPF evaluates at the saturation DO concentration in surface runoff. For PERLND, concentrations of constituents in baseflow were assigned based on typical values observed in several tributaries in the area such as Boggy Creek and Reedy Creek, and interflow concentrations were set at values between the estimated runoff and baseflow concentrations. For IMPLND, TSS (sediment) is simulated by a “buildup-wash off” approach (buildup during dry periods, wash off with runoff during storm events), and again the “potency factor” approach was used in the IQUAL module for other constituents except DO, which again was analyzed at saturation.

The “general” water quality constituents that were modeled in HSPF include the following:

- *Ammonia nitrogen.*
- *Nitrate nitrogen.*
- *CBOD (ultimate).*
- *Orthophosphate.*
- *Refractory organic nitrogen.*

One feature of HSPF is that the CBOD concentration has associated concentrations of organic-N and organic-P. Consequently, the TN concentration is equal to the sum of ammonia-N, nitrate-N, refractory organic-N, and a fraction of the CBOD concentration. Similarly, the TP concentration is equal to the sum of ortho-P and a fraction of the CBOD concentration.

Chapter 5: DETERMINATION OF ASSIMILATIVE CAPACITY

5.1 Determination of Loading Capacity

Nutrient enrichment and the resulting problems related to eutrophication are generally widespread and 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 time span 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 Lake Cypress will meet the narrative nutrient criterion and thus maintain its function and designated use as a Class III water. To achieve the goal and address public comments from the August 18, 2011, public workshop, the Department decided to update the model that was developed by CDM (2008) by focusing on the water and nutrient budgets of the lakes with nutrient impairments. The model inputs were reconstructed by utilizing hourly input data, and the hydrology and water quality calibrations were significantly improved by adding additional stations for calibration.

The HSPF model input data (meteorological data) were compiled from December 1997 to August 2009 at different weather stations, and the model was run from 2000 to 2006 on an hourly time step. The model results obtained from the revised HSPF were compared with the observed data and the independent model results simulated by the Watershed Assessment Model (WAM) that was recently updated by Soil and Water Engineering Technology, Inc. (SWET) for the South Florida Nutrient Budget Analysis for the Lake Okeechobee watershed.

The entire watershed area in the Kissimmee Chain of Lakes (KCOL) HSPF TMDL model covers more than 900,000 acres and consists of 41 subbasins in the model domain. Given this large model domain and the use of the model to develop long-term average TMDL conditions for the impaired lakes, it is impossible at this time to address many of the issues for smaller pieces of land embedded within the 41 larger subbasins. This is because the model is set up with large subbasins, and all the area for each land use within each subbasin is aggregated into one total area for each land use type, and then the subbasin-scale nutrient loads to the impaired waterbodies are estimated for TMDL development.

5.1.1 Meteorological Data

The meteorological data for the revised model were obtained from the stations of the Florida Automatic Weather Network (FAWN), an observation platform owned by the University of Florida. The hourly meteorological data from December 1997 to August 2009 obtained from this station were included as follows: solar radiation, wind speed, dew point temperature, and air temperature (**Table 5.1**). Pan evaporation 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.

Table 5.1. General Information on Weather Stations for the KCOL HSPF Modeling

Location Name	Start Date	End Date	Frequency	Facility	County	Comment
Avalon	12/15/1997	Present	Hourly	FAWN	Orange	Meteorological data
Lake Alfred	12/31/1997	Present	Hourly	FAWN	Polk	Meteorological data

To estimate lake evaporation, Lee and Swancar (1997) derived pan coefficients for lakes in central Florida, ranging from 0.70 to 0.77 for Lake Lucerne and 0.71 to 0.75 for Lake Alfred. On an annual basis, the long-term annual average coefficient of 0.74 was derived by Farnsworth *et al.* (1982). Treommer *et al.* (1999) also used a coefficient of 0.75 applied to pan evaporation data from the Bradenton 5 ESE weather station to estimate evaporation for Ward Lake in Manatee County, Florida.

Given the range in Florida values of 0.70 to 0.77, a pan coefficient of 0.75 was used for the KCOL TMDL modeling. Hourly meteorological data as inputs for HSPF were created using the water management district utility program that provides operational capabilities for the input time-series data necessary for HSPF. **Figures 5.1** and **5.2** show selected time-series input data for hourly air temperature and wind speed. Meteorological data gaps in the period from 2000 to 2006 from the stations were found to be minimal. However, if data during the period of record at a given station were missing for a month or longer, the data from the closest station were used to complete the dataset. 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.

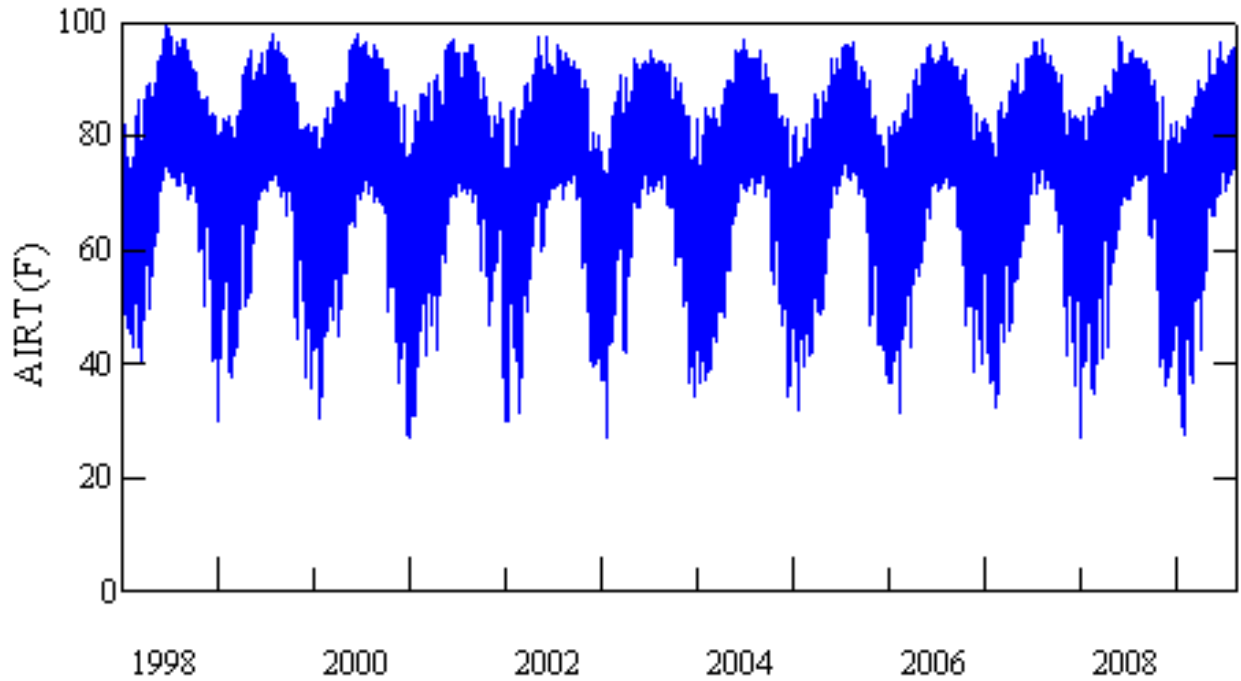


Figure 5.1. Hourly Observed Air Temperature (°F.), 1998–2009

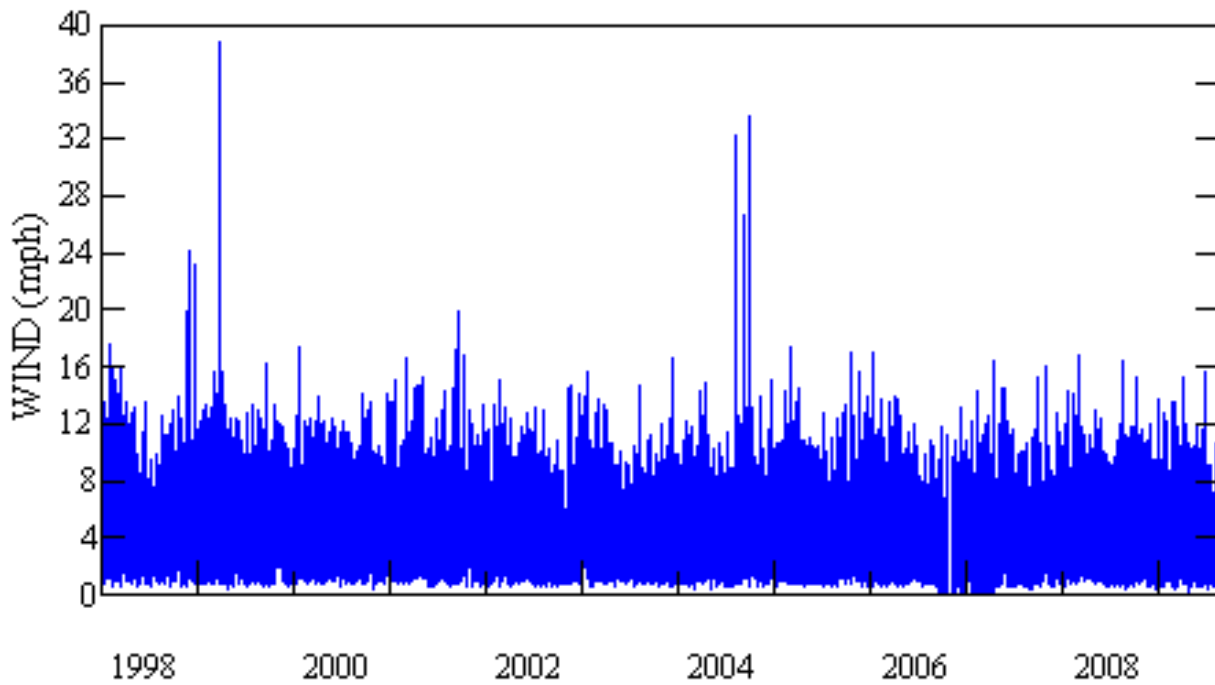


Figure 5.2. Hourly Observed Wind Speed (miles per hour), 1998–2009

Rainfall is the predominant factor contributing to the hydrologic balance of a watershed. It is the primary source of surface runoff and baseflow from the watershed to the receiving waters, as well as a direct contributor to the surface of receiving waters. The Department maintains a rainfall dataset that combines radar observations from the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service Weather Surveillance Radar 88 Doppler (WSR-88Ds) and hourly rainfall observations from an operational *in situ* rain gauge network. The rainfall data were extracted for the project area for use in the model.

The Department's multisensor rainfall dataset was checked against (and supplemented by) the hourly rainfall data obtained from the SFWMD for 51 rainfall stations located within Glades, Highlands, Okeechobee, Osceola, Orange, and Polk Counties. The data from these stations were collected between January 1991 and December 2006. For the revised calibration, the same hourly rainfall data were used as in the previous model, since the previous rainfall data are subbasin specific, and the data are not different from the two different sources of the rainfall data. The CDM report (2008) contains additional information and describes how the rainfall data were used in the model.

Figure 5.3 shows hourly rainfall assigned in the model to the Lake Cypress subbasin. During the period of model simulation from 2000 to 2006, total annual average rainfall varied from 24.0 to 63.3 inches, with average annual rainfall of 46.8 ± 14.0 inches (**Figure 5.4**). The 7-year average rainfall during this period was lower than the 100-year state average rainfall (54 inches) (Southeast Regional Climate Center [SERCC] 2010). The noticeable deficiency in annual rainfall from the long-term (100-year) average was identified in 2000, 2001, and 2006, when the annual rainfall recorded was 32.8, 46.1, and 24.0 inches, respectively. The comparison between the local 7-year rainfall data and the state's long-term average rainfall data indicated that the model covered dry years in 2000, 2001, and 2006, and wet years in 2004 and 2005 during the simulation period.

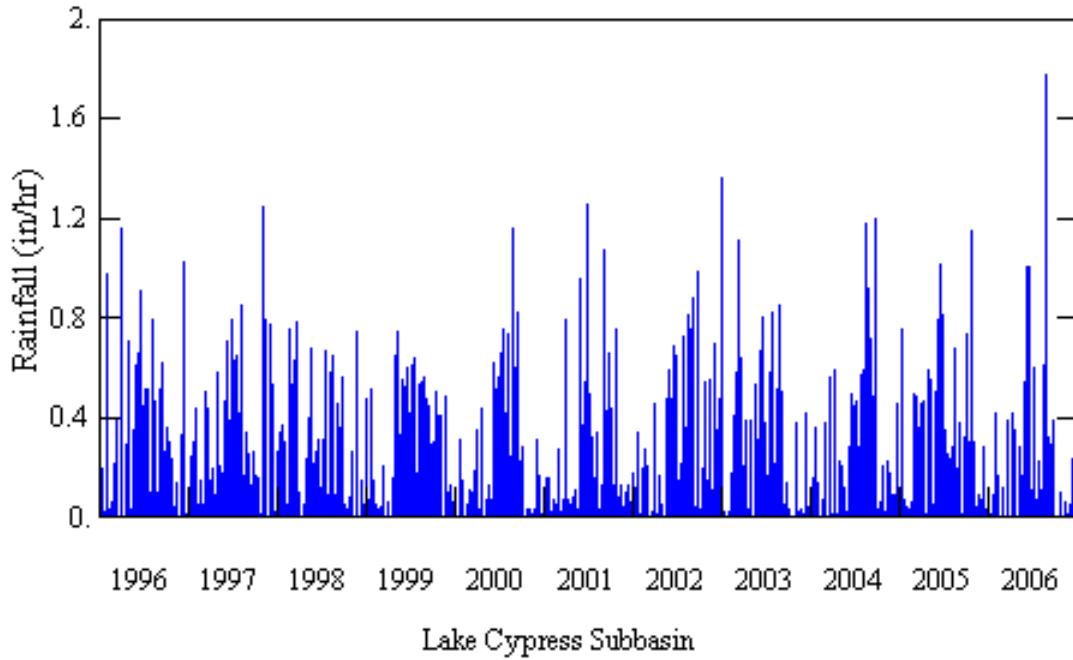


Figure 5.3. Hourly Rainfall (inches) for the Lake Cypress Subbasin, 1996–2006

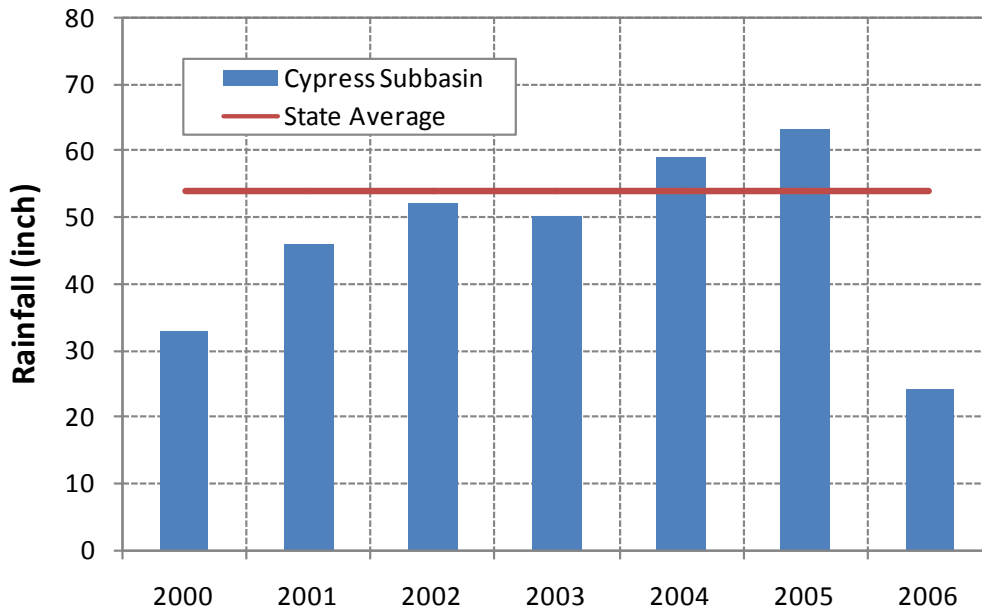


Figure 5.4. Annual Rainfall (inches) for the Lake Cypress Subbasin During the Simulation Period and Long-Term (1909–2009) State Average Annual Rainfall (54 inches)

5.2 Model Calibration

5.2.1 Temperature Calibration for Lake Cypress

Water temperature itself is considered as a conservative parameter that does not undergo chemical reactions in the system. Water temperature is a critical habitat characteristic for fish and other organisms, and affects the rates of biogeochemical processes of functional importance to the 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 the water temperature in a stream is a result of both the heat balance along with the water movement in the air-land-stream system. Key parameters controlling the energy balance for water temperature are as follows: short- and long-wave radiation, conduction, convection, evaporation, and ground conduction (Bicknell *et al.* 2001).

For Lake Cypress, parameters PSTEMP, IWTGAS, and RCHRES (KATRAD, KCOND, KEVAP) were adjusted for temperature calibration. As a result, the simulated daily average lake temperature was in good agreement with the observed daily average temperature (**Figures 5.5** and **5.6**). The box and whisker plot shows that the 7-year mean (24.4 °C.) of the observed lake temperature is similar to that (23.1 °C.) of the simulated lake temperature (**Figure 5.7**). Overall, it was decided that the model calibration for temperature was acceptable.

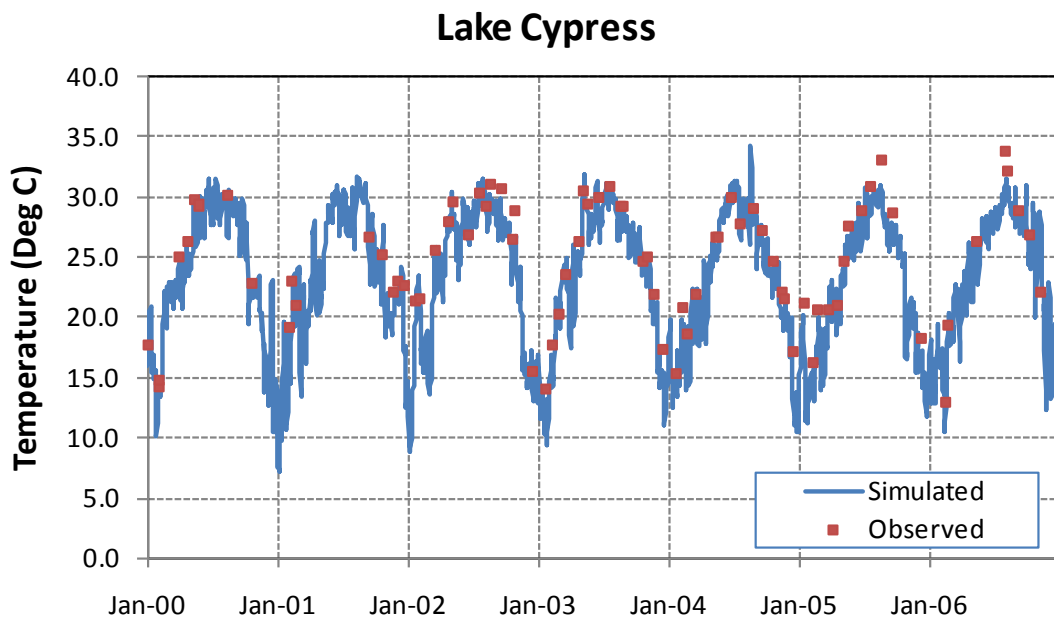


Figure 5.5. Observed Versus Simulated Daily Lake Temperature (°C.) in Lake Cypress During the Simulation Period, 2000–06

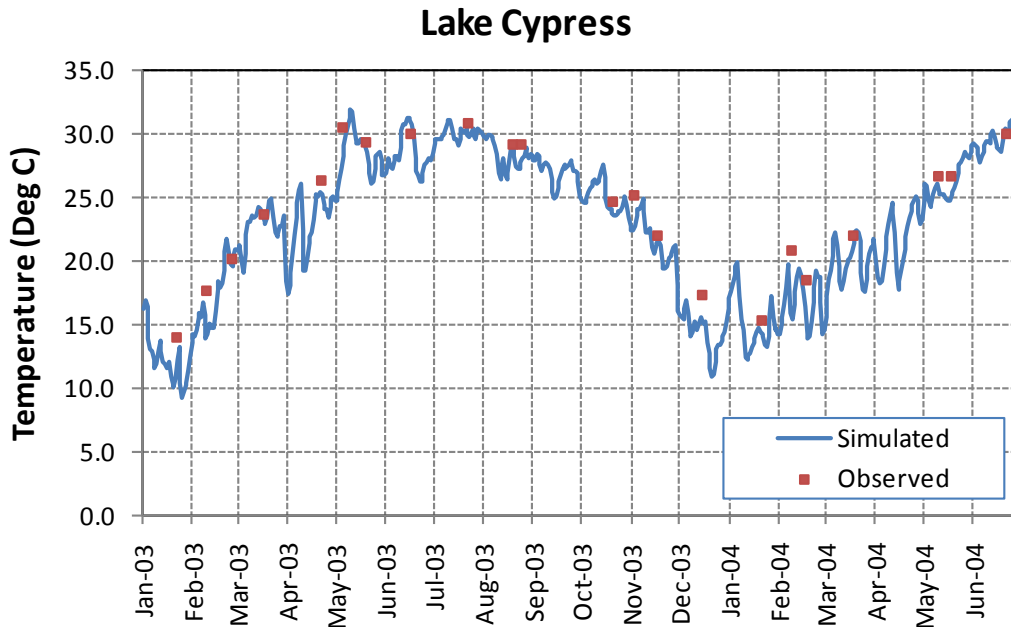


Figure 5.6. Monthly Variation of Observed Versus Simulated Daily Lake Temperature (°C.) in Lake Cypress During the Selected Simulation Period, January 2003–June 2004

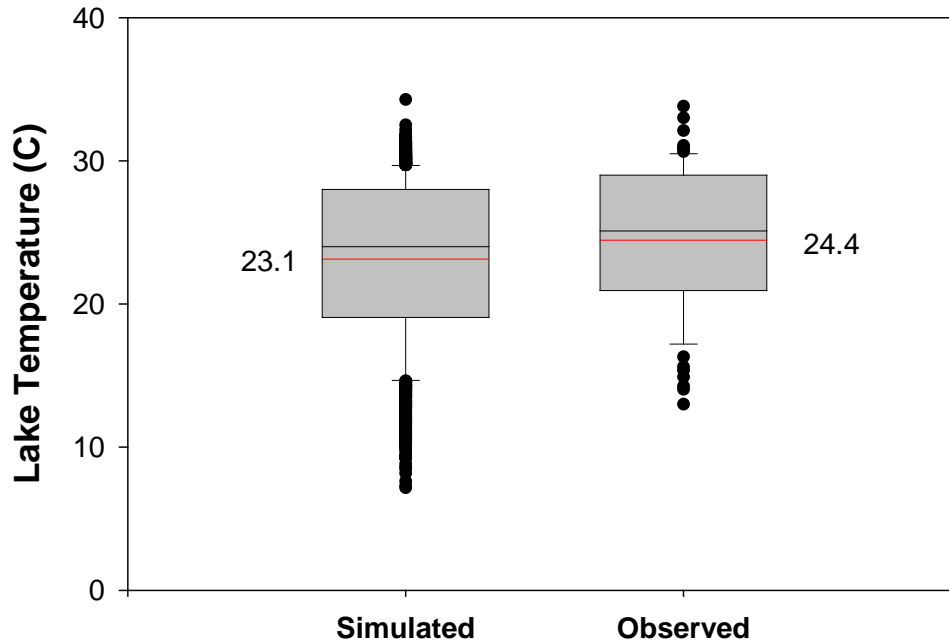


Figure 5.7. Box and Whisker Plot of Simulated Versus Observed Lake Temperature (°C.) in Lake Cypress, 2000–06 (red line represents mean concentration of each series)

5.2.2 Hydrology Calibration for Lake Cypress

The HSPF model, based on the aggregated land use categories, was used to simulate watershed hydraulic and hydrology. Because the study area is largely pervious land, the calibration process focused on the development of appropriate pervious area hydrologic parameters. Initial parameter values were determined based on previous modeling efforts (CDM 2003). Values were then adjusted to improve the match between measured and modeled stream flows. Parameter values were largely maintained within a range of possible values based on CDM’s previous experience with the HSPF hydrologic model and on BASINS Technical Note 6 (Hartigan 1983; Hartigan *et al.* 1983a; Hartigan *et al.* 1983b; Wagner 1986; CDM 2002; EPA 2000).

Besides the 16 major hydraulic control structures discussed in *Section 4.2.5* of the CDM report (2008), many local small hydraulic control structures throughout the Reedy Creek and Boggy Creek watersheds in the Upper Kissimmee Planning Unit were identified by other studies (URS Greiner 1998; USGS 2002). It appears that measurements made at the flow stations with the most flow measurements in the project area were somewhat affected by the hydraulic control structures. Ideally, flow stations that are not affected by any hydraulic control structures should be selected for hydrologic model calibrations.

To minimize the effects from hydraulic control structures, the initial calibration focused on three gauged subbasins in the northern part of the study area in the Upper Kissimmee Planning Unit (Reedy Creek, Shingle Creek, and Boggy Creek), which are not largely influenced by hydraulic control structures. Parameters were established for these subbasins that provided a reasonable match to measured data. These parameter values and relationships to land use were then uniformly applied to all the subbasins in the planning units. Furthermore, subbasin-specific parameters such as LZSN, UZSN, and INFILT were developed based on local hydrologic soil group information. Further flow calibrations at the control structures were completed by adjusting control structure flow rates and lake volumes, when appropriate. A detailed discussion of this method is included in *Section 4.5* of the CDM report (2008).

To increase the reliability of the model, calibration efforts focused on several key stations. For example, as Lake Tohopekaliga (Toho) and Lake Gentry directly discharge to Lake Cypress, their lake levels and outflows to Lake Cypress were first calibrated by comparisons between observed and simulated results, and then the lake elevation and the outflow from Lake Cypress were calibrated to obtain the water budgets of Lake Cypress. **Table 5.2** shows model calibration stations for upstream flows and lake levels of the connected lakes contributing to Lake Cypress. The HSPF model outputs at these stations were calibrated using the observed data and independent model outputs simulated by WAM. The independent simulated results from WAM would especially help at locations where there are no measured data available for the HSPF hydrology calibration. All hydrologic outputs and model calibrations for the impaired lake and its connected lakes are shown in **Appendix D**.

Table 5.2. General Information on Key Stations for Model Calibration

NA = Not applicable

Station	Station Name	Agency	County	Type
S59_H	E. Lake Toho	SFWMD	Osceola	Stage
S61_H	Lake Toho	SFWMD	Osceola	Stage
LCYP19	Lake Cypress	SFWMD	Osceola	Stage
SHING.AP	Shingle Creek near Airport	USGS	Osceola	Flow
SHING.CA	Shingle Creek at Campbell	USGS	Osceola	Flow
S63A_S	Lake Gentry Outflow	SFWMD	Osceola	Flow
S61_S	Lake Toho Outflow	SFWMD	Osceola	Flow
S59_S	E. Lake Toho Outflow	SFWMD	Osceola	Flow
LCYPRE	Lake Cypress Outflow	NA	Osceola	Flow

The predicted lake level was a result of the water balance between water input from the watershed and losses from the lake. The simulated lake levels in Lake Cypress were calibrated with the observed lake levels obtained from January 2000 to December 2006. **Figure 5.8** shows a good agreement between the daily time-series of observed versus simulated lake levels, and **Figure 5.9** indicates a good relationship between the observed lake level and the simulated lake elevation, with a correlation coefficient of 0.89 ($n = 2545$). In general, simulated lake levels varied from 47.6 to 53.0 feet, with a 7-year average of 50.4 feet ($n = 2560$) over the simulation period (**Table 5.3**). Similarly, the observed data showed that lake levels ranged from 48.1 to 54.4 feet and averaged about 50.1 feet ($n = 2545$). It should be noted that both simulated and observed annual lake levels were lowest at in 2006 (**Table 5.3**). This is attributable to the dry conditions that occurred in 2006 when annual rainfall was only 24.0 inches. Overall, the model simulation well represents the short- and long-term average stage for Lake Cypress.

Flow comparisons of observed daily flow and simulated daily flow were also performed at several calibration stations where the incoming and outgoing flows of the impaired lakes primarily occur (**Table 5.2**). As Lake Toho is a major contributor of water and nutrients to Lake Cypress, incoming and outgoing flows to and from Lake Toho were first calibrated with the observed gauge flows (**Appendix D**). For Lake Cypress, three calibration stations were selected for calibration: two incoming flows to Lake Cypress, S61 and S63A, and an outgoing flow, LCYPRE. At each station, simulated flows using HSPF were compared with both observed flow values and simulated flow results by WAM. The outgoing flow from Lake Cypress was calibrated with the WAM-generated outflow from Lake Cypress because no measured flow data are available for the comparison. **Figures 5.10** through **5.16** show selected comparison results and calibration statistics for the Lake Cypress hydrology calibration.

Figure 5.10 shows the observed and simulated cumulative daily flows at S61, Lake Toho Outflow, from 2000 to 2006. The simulated monthly mean flows over time were also compared with the observed monthly flow to show the monthly and seasonal variations in the incoming flow to Lake Cypress (**Figure 5.11**). Seasonality in both the simulated and observed monthly flows was well matched, showing that most peak flows occur during the third quarter each year, with a pattern well representing the dry and wet seasons of each year. The simulated monthly flow correlated well with the observed monthly flow, with a correlation coefficient of 0.898 ($n = 84$) (**Figure 5.12**). Overall, the 7-year simulated flow had similar patterns to the observed flow for S61, a major incoming flow to Lake Cypress, indicating that the long-term and seasonal variation in the incoming flow to Lake Cypress was well represented.

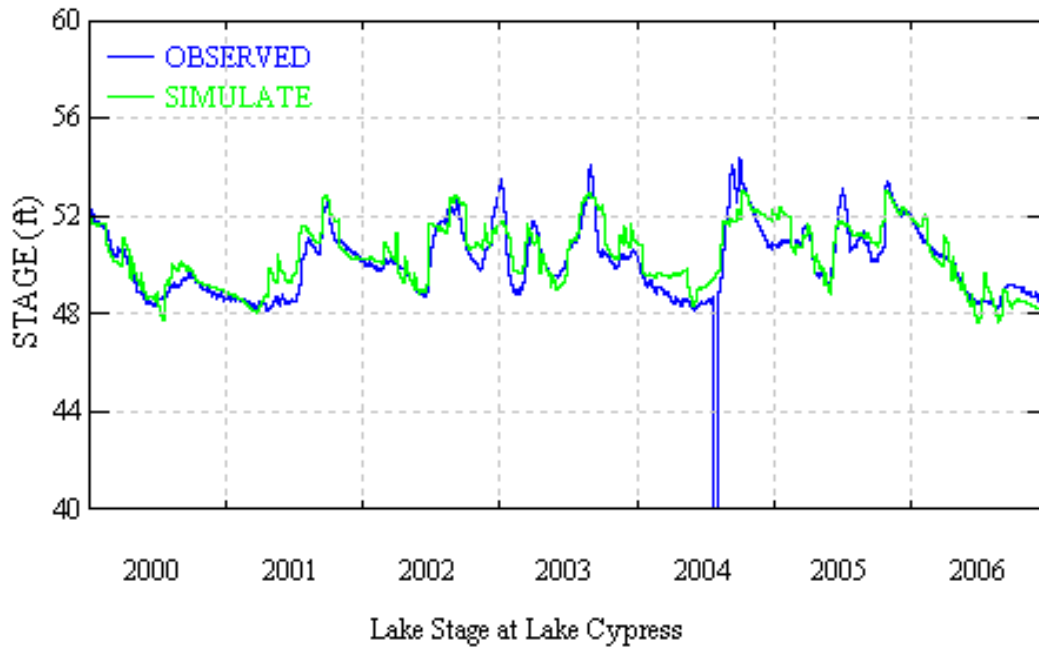


Figure 5.8. Time-Series Observed Versus Simulated Lake Stage (feet, National Geodetic Vertical Datum [NGVD]) in Lake Cypress During the Simulation Period, 2000–06

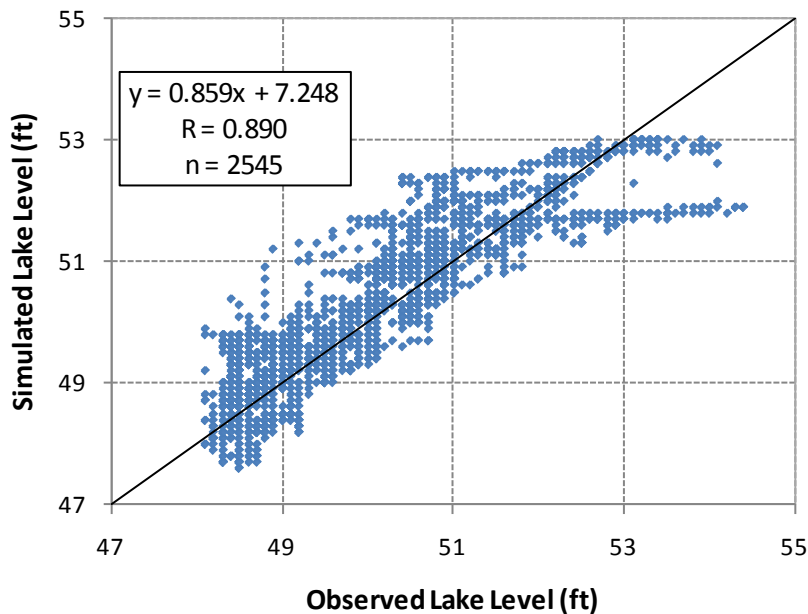


Figure 5.9. Daily Point-to-Point Paired Calibration on Lake Level (feet) During the Simulation Period, 2000–06 (solid line indicates the ideal 1 to 1 line, R represents a correlation coefficient of the best-fit between observed and simulated lake levels, and n indicates the number of observations)

Table 5.3. Observed and Simulated Annual Mean Lake Level (feet, NGVD) and Standard Deviation for Lake Cypress

Year	Observed Stage (feet)	Standard Deviation (+/-)	Simulated Stage (feet)	Standard Deviation (+/-)
2000	49.6	1.1	49.7	1.0
2001	49.6	1.3	50.0	1.3
2002	50.5	1.1	50.7	1.1
2003	50.6	1.2	50.9	1.1
2004	50.1	1.8	50.5	1.4
2005	51.1	1.0	51.3	0.9
2006	49.4	1.0	49.3	1.3
Average	50.1	1.2	50.4	1.1

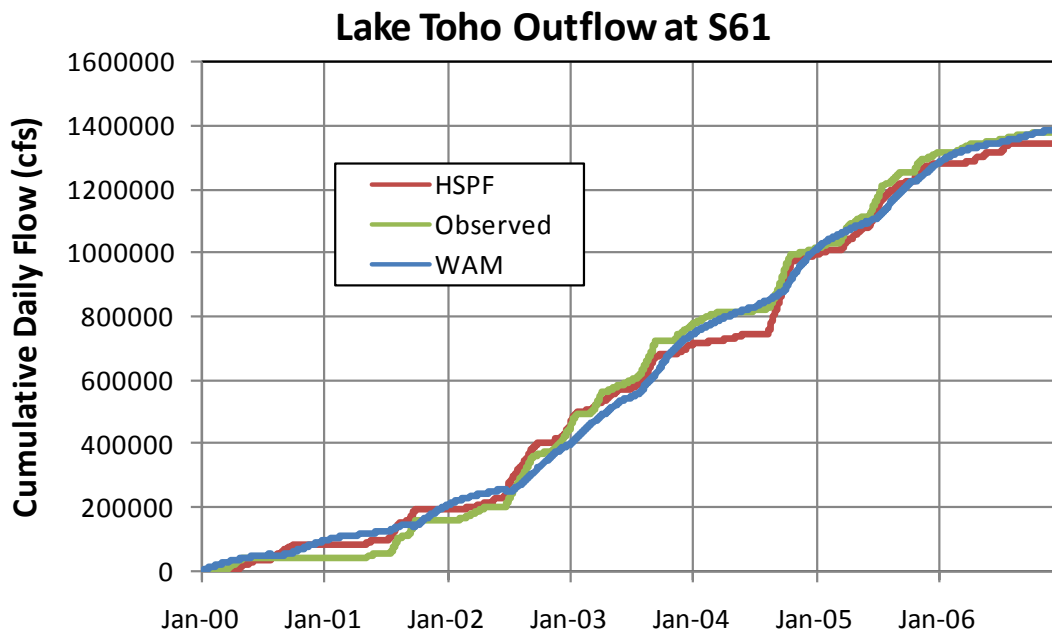


Figure 5.10. Comparison Between Cumulative Observed Flow and Simulated Flows Using HSPF and WAM at S61, Lake Toho Outflow, 2000–06

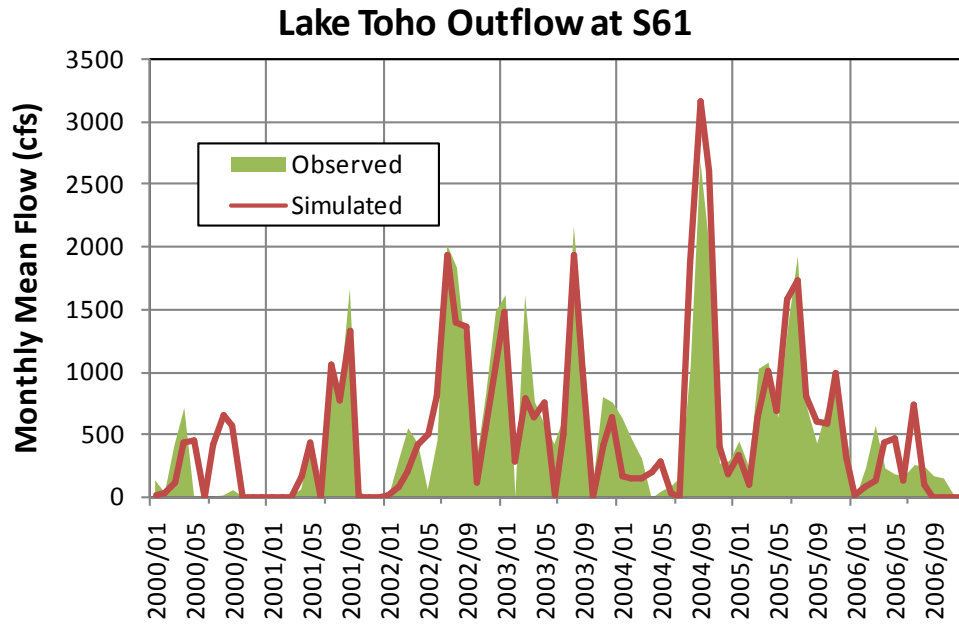


Figure 5.11. Comparison Between Monthly Observed Mean Flow and Monthly Simulated Mean Flow at S61, Lake Toho Outflow, 2000–06

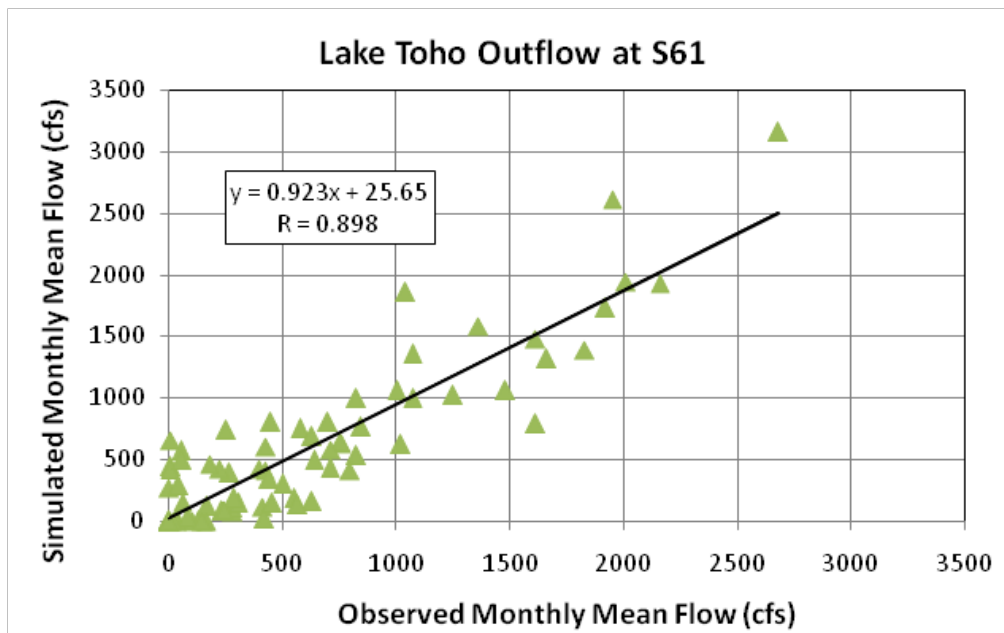


Figure 5.12. Correlation Between Observed and Simulated Monthly Mean Flows at S61 (R represents a correlation coefficient of the best-fit equation)

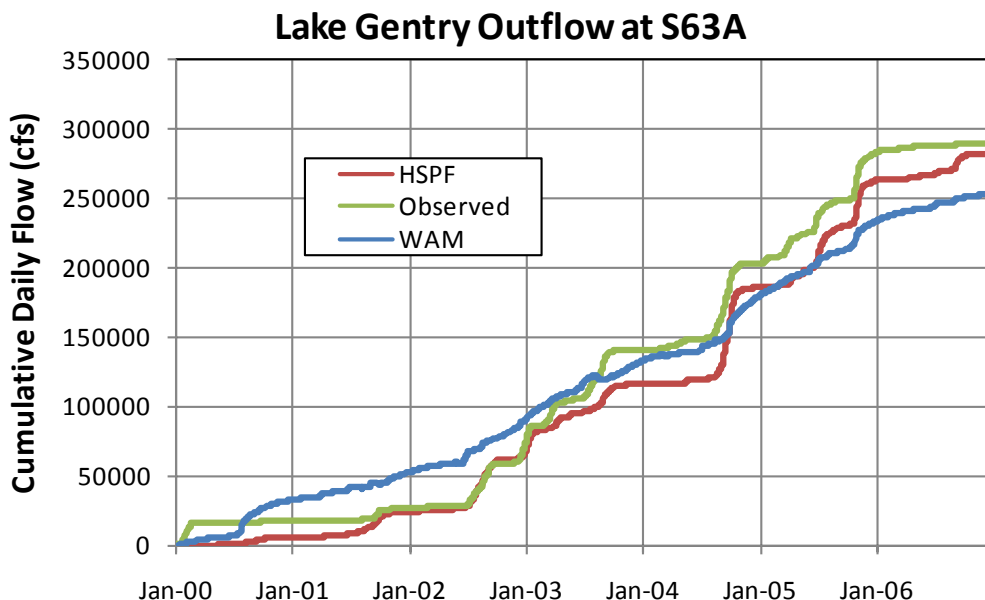


Figure 5.13. Comparison Between Cumulative Observed Flow and Simulated HSPF and WAM Flows at S63A, Lake Gentry Outflow, 2000–06

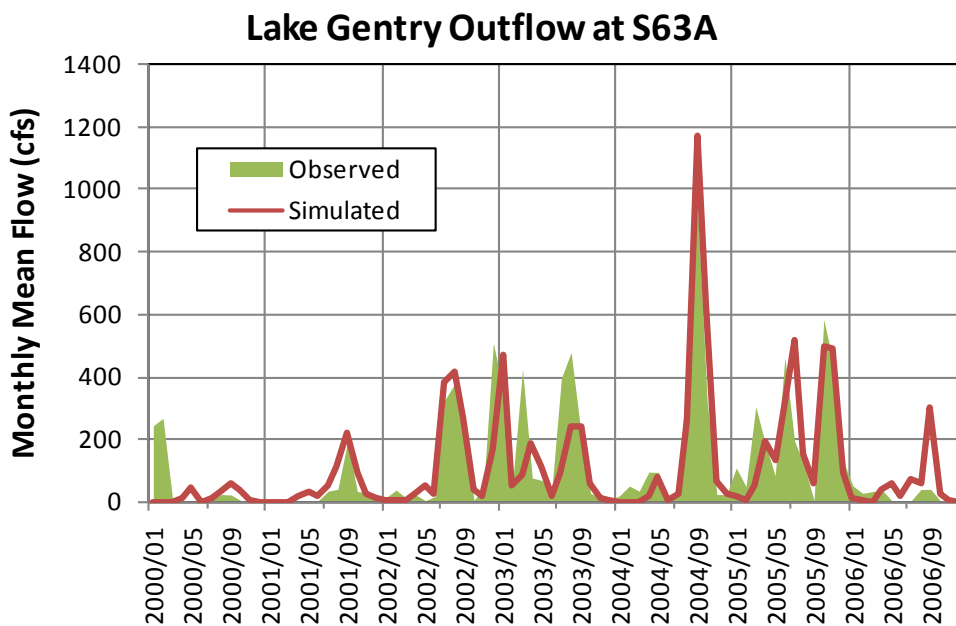


Figure 5.14. Comparison Between Monthly Observed Mean Flow and Monthly Simulated Mean Flow at S63A, Lake Gentry Outflow, 2000–06

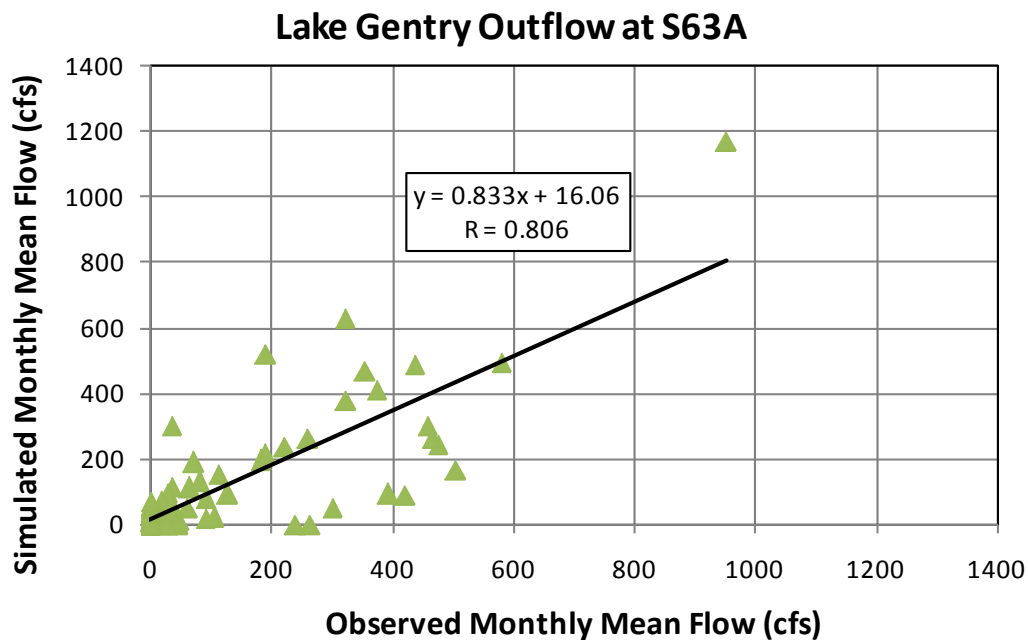


Figure 5.15. Correlation Between Observed and Simulated Monthly Mean Flows at S63A (R represents a correlation coefficient of the best-fit equation)

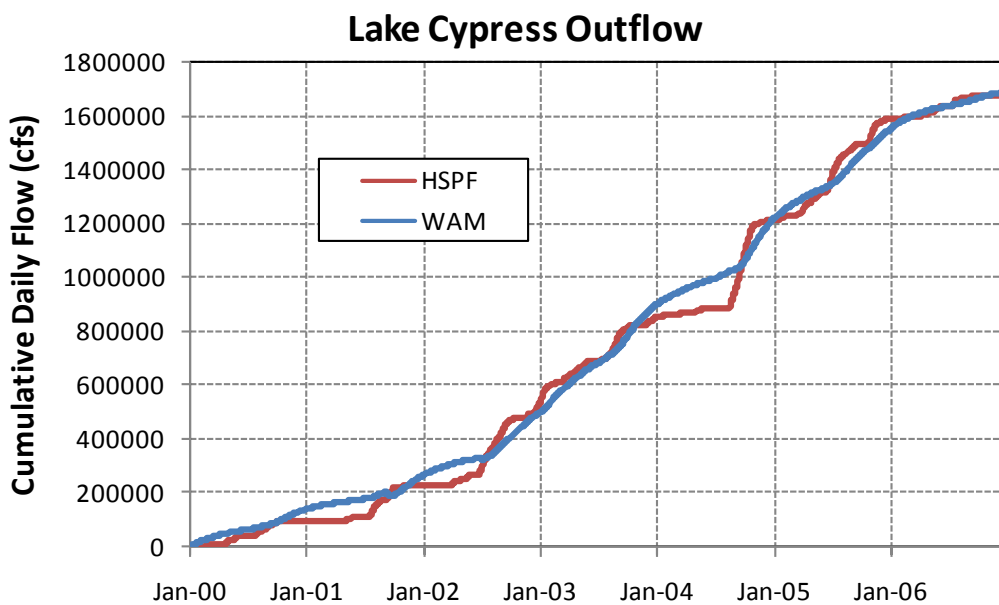


Figure 5.16. Cumulative Daily Flows Obtained by HSPF and WAM at Lake Cypress Outflow, 2000–06

The simulated flow results from both HSPF and WAM were also calibrated with the observed data for the control structure at S63A, another tributary contributing to Lake Cypress (**Figures 5.13** through **5.15**). As expected, the time-series of the simulated flows were similar to the overall patterns of the observed flow throughout the modeling period. Simulated monthly flow well represented the seasonal pattern of the observed flow (**Figures 5.14** and **5.15**). Based on the simulated results for the 2 incoming flows to Lake Cypress over the 7-year simulation period, the incoming flow from Lake Toho accounted for about 83% of the total tributary inflow to Lake Cypress, while the inflow from Lake Gentry comprised about 17% of the total inflow. Although no outgoing flow leaving Lake Cypress was measured, the simulated outgoing flow estimated by HSPF was validated by the results from WAM, an independent model (**Figure 5.16**).

In summary, the simulated flow results were obtained from both HSPF and WAM, and compared with the observed flow obtained for the same period as the simulation (**Table 5.4**). The observed cumulative daily flow at S61 was 1,379,896 cubic feet per second (cfs) over the 7-year period, similar to 1,340,458 cfs simulated by HSPF and 1,389,423 cfs obtained by WAM, respectively. Percent error, calculated as $100 \times ((\text{the observed daily cumulative flow} - \text{the simulated daily cumulative flow}) / \text{the observed daily cumulative flow})$, was estimated to be 3% for HSPF and 1% for WAM, indicating that both models performed well. Based on the simulated results, the Department was able to construct a water budget for Lake Cypress, indicating that incoming and outgoing waters are reasonably balanced (**Table 5.5**). The estimated total inflow to Lake Cypress varied from 171,459 ac-ft/yr in 2006 to 766,884 ac-ft/yr in 2005, with a 7-year average of 491,482 ac-ft/yr.

As shown in **Table 5.5**, during wet years in 2004 and 2005 when annual rainfall was high (59 inches in 2004 and 63 inches in 2005), the simulated total annual inflows via upstream inflows (runoff), surface runoff, interflow, and baseflow were estimated to be 4 times as high as in the dry years of 2000 and 2006. As a result, the lake discharged more in 2004 and 2005, peaking at 746,687 ac-ft/yr in 2005. **Figure 5.17** shows the relative importance of incoming flows to the lake. Total annual inflows and outflows were estimated to construct the water budget of Lake Cypress during the simulation period. On average, upstream flow is the largest contributor of water at 93%, followed by direct rainfall (3.2%), subbasin interflow (1.7%), subbasin baseflow (0.9%), and subbasin runoff (0.5%). Therefore, incoming flows via S61 and S63A are the major pathways carrying water and its constituents, including nutrients and other pollutants, to the lake and in maintaining the lake water level.

Table 5.4. Cumulative Daily Mean Flow (cfs) Obtained by Observed Flow Data, HSPF and WAM, 2000–06

Correlation coefficient (r) is based on observed monthly mean flow versus simulated monthly mean flow by HSPF.
 NA = Not available

Station ID	Observed Cumulative Daily Flow	HSPF Cumulative Daily Flow	WAM Cumulative Daily Flow	HSPF % Error	WAM % Error	Correlation Coefficient (r) in Observed Versus Simulated Monthly Mean Flow
Shingle Campbell	647,672	593,435	599,043	8%	8%	0.933
E Toho Outflow_S59	464,614	461,799	580,543	1%	25%	0.847
Toho Outflow_S61	1,379,896	1,340,458	1,389,423	3%	1%	0.898
Gentry outflow_S63A	289,801	282,859	252,784	2%	13%	0.806
Cypress outflow	NA	1,675,048	1,690,282	NA	NA	NA

Table 5.5. Simulated Annual Total Inflow and Outflow (ac-ft/yr) for Lake Cypress During the Simulation Period, 2000–06

- = Empty cell/no data

Year	Subbasin Runoff (ac-ft/yr)	Subbasin Interflow (ac-ft/yr)	Subbasin Baseflow (ac-ft/yr)	Upstream Inflows (ac-ft/yr)	Direct Precipitation (ac-ft/yr)	Evaporation (ac-ft/yr)	Outflow (ac-ft/yr)
2000	439	3,642	2,959	174,891	9,521	-18,222	-188,192
2001	688	6,525	3,868	262,586	14,903	-18,923	-264,785
2002	1,034	10,513	5,920	594,772	18,323	-19,741	-605,734
2003	2,959	9,616	5,944	610,672	17,910	-19,179	-630,517
2004	7,907	14,550	5,758	695,611	20,525	-19,586	-719,352
2005	5,072	13,964	6,918	718,683	22,248	-21,115	-746,687
2006	250	1,236	769	162,530	6,674	-17,443	-166,982
Average	2,621	8,578	4,591	459,963	15,729	-19,173	-474,607
%	0.5%	1.7%	0.9%	93.6%	3.2%	-	-

Percent Inflow Contribution

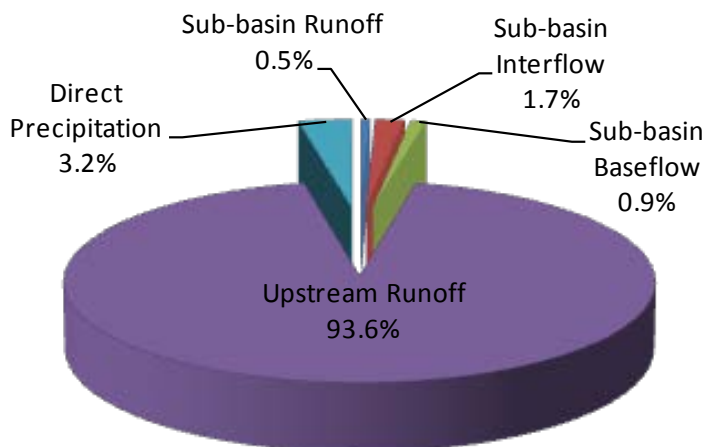


Figure 5.17. Long-Term (7-year) Averaged Annual Percent Inflows to Lake Cypress During the Simulation Period, 2000–06

5.2.3 Lake Cypress Nonpoint Source Loadings

Nonpoint source loads of TN and TP from different types of land use were estimated for the existing conditions of the Lake Cypress watershed based on the HSPF PERLND and IMPLND flows and the corresponding concentrations of each land use category. The estimated TN and TP loading coefficients for land use types were compared with literature values to make sure that the calibrated loading rates of TN and TP from each land use were reasonable.

Tables 5.6 and 5.7 show the estimated average loading rates of TN and TP from the nine land use categories over the simulation period. Loading coefficients of TN and TP for rangeland/upland forest were estimated to be 2.2 and 0.07 lbs/ac/yr, respectively. These estimated coefficients are comparable to the literature values for the forest land use type, with load coefficients of 2.1 ± 0.4 lbs/ac/yr for TN and 0.1 ± 0.03 lbs/ac/yr for TP (Frink 1991), and export rates of 2.4 lbs/ac/yr for TN and 0.04 lbs/ac/yr for TP (Donigian 2002). The agreements between the simulated loading rates and the literature values indicate that the estimated TN and TP loadings for natural land use types for the Lake Cypress watershed are acceptable. For cropland/improved pasture/tree crops, export coefficients of TN and TP were estimated to be about 9.1 and 0.74 lbs/ac/yr, respectively. For unimproved pastureland/woodland

pastureland, estimated TN and TP loading rates were about 5.3 and 0.29 lbs/ac/yr, respectively. These estimated rates for anthropogenic land uses are comparable to the literature values categorized as agriculture (Frink 1991; Donigian 2002).

Table 5.6. Comparison of Simulated TN Loading Rates for the Lake Cypress Subbasin and Nonpoint TN Loading Rates with the Expected Ranges from the Literature

Land Use Type	Simulated TN Loading Rate for Lake Cypress Subbasin (lbs/ac/yr)	TN Loading Rate (lbs/ac/yr) by Donigian (2002)
High-density residential	4.5	8.5 (5.6-15.7) for urban
Commercial/industrial	3.8	8.5 (5.6-15.7) for urban
Unimproved pastureland/woodland pasture	5.3	5.9 (3.4-11.6) for agriculture
Cropland/improved pasture/tree crops	9.1	5.9 (3.4-11.6) for agriculture
Wetlands	1.8	2.2 (1.4-3.5)
Rangeland/upland forest	2.2	2.4 (1.4-4.3)

Table 5.7. Comparison of Simulated TP Loading Rates for the Lake Cypress Subbasin and Nonpoint TP Loading Rates with the Expected Ranges from the Literature

Land Use Type	Simulated TP Loading Rate for Lake Cypress Subbasin (lbs/ac/yr)	TP Loading Rate (lbs/ac/yr) by Donigian (2002)
High-density residential	0.48	0.26 (0.20-0.41) for urban
Commercial/industrial	0.49	0.26 (0.20-0.41) for urban
Unimproved pastureland/woodland pasture	0.29	0.30 (0.23-0.44) for agriculture
Cropland/improved pasture/tree crops	0.74	0.30 (0.23-0.44) for agriculture
Wetlands	0.05	0.03 (0.02-0.05)
Rangeland/upland forest	0.07	0.04 (0.03-0.08)

Tables 5.8 and **5.9** show the annual average TN and TP loads from various transport pathways to Lake Cypress, indicating that upstream inflow is the major contributor supplying a 7-year averaged annual TN load of 1,342,108 lbs/year and a TP load of 70,787 lbs/year. These TN and TP loads accounted for about 90.7% of the total TN loads and about 88.8% of the total TP loads to the lake during the simulation period (**Figures 5.18** and **5.19**). TN and TP contributions from the immediate Lake Cypress subbasin accounted for only 8% for TN and 10% for TP of the total watershed. The model results indicate a strong association between existing TN and TP loads and annual rainfall (**Figures 5.20** and **5.21**). For example, higher nutrient loads were found during wet years, especially in 2004 and 2005, while lower TN and TP loads were estimated during dry years in 2000 and 2006. Overall, rainfall-driven runoff such as surface runoff and interflow are the most important means to deliver TN and TP to the lake. Under the existing conditions, the simulated total watershed loads of TN and TP to Lake Cypress, on a long-term average, were estimated to be 1,447,259 and 78,731 lbs/year, respectively (**Tables 5.8** and **5.9**).

5.2.4 In-Lake Water Quality Calibration

As discussed in **Chapter 4**, in the evaluation of nutrients and phytoplanktonic algae (as chl a), the HSPF model accounts for the following water quality constituents:

- *Organic nitrogen (organic N).*
- *Ammonia nitrogen (ammonia N).*
- *Nitrite + nitrate nitrogen (nitrate N).*
- *Organic phosphorus (organic P).*
- *Inorganic phosphorus (inorganic P).*
- *Phytoplanktonic algae (chl a).*

Organic N and organic P in the model are associated with several water quality constituents, including ultimate CBOD, phytoplankton, and refractory organics that result from the death of algae. The following key processes affect the model simulation of phytoplankton concentration in receiving waters: phytoplankton growth, phytoplankton respiration, phytoplankton death, and phytoplankton settling. Phytoplankton growth is modeled based on a specified maximum growth rate, which is adjusted by the model based on water temperature, and is limited by the model based on available light and inorganic N

and P. Similarly, death and respiration are modeled based on specified rates that are adjusted for water temperature. A higher death rate may be applied by the model under certain conditions (e.g., high water temperature, high chl_a concentration). Settling is modeled based on a constant settling rate. Growth increases the concentration of phytoplankton, while the other processes reduce the concentration of phytoplankton.

Table 5.8. Simulated Annual TN Loads (lbs/yr) to Lake Cypress Via Various Transport Pathways under the Current Condition

Year	TN Load by Subbasin Runoff (lbs/yr)	TN Load by Subbasin Interflow (lbs/yr)	TN Load by Subbasin Baseflow (lbs/yr)	TN Load Upstream Inflow (lbs/yr)	TN Load by Direct Precipitation (lbs/yr)	Total Incoming TN Load (lbs/yr)
2000	12,582	25,497	7,306	562,458	19,984	627,828
2001	20,020	46,135	9,454	818,564	31,301	925,474
2002	35,435	70,700	14,304	1,656,403	38,520	1,815,363
2003	47,946	64,468	14,334	1,671,977	37,668	1,836,393
2004	73,239	92,852	13,793	2,045,432	43,287	2,268,603
2005	64,797	91,341	16,612	2,094,347	46,933	2,314,031
2006	3,075	9,484	1,975	545,576	14,025	574,136
Average	36,728	57,211	11,111	1,342,108	33,103	1,480,261

Table 5.9. Simulated Annual TP Loads (lbs/yr) to Lake Cypress Via Various Transport Pathways under the Current Condition

Year	TP Load by Subbasin Runoff (lbs/yr)	TP Load by Subbasin Interflow (lbs/yr)	TP Load by Subbasin Baseflow (lbs/yr)	TP Load Upstream Inflow (lbs/yr)	TP Load by Direct Precipitation (lbs/yr)	Total Incoming TP Load (lbs/yr)
2000	129	3,119	441	25,047	597	29,333
2001	197	5,656	569	39,156	935	46,513
2002	305	8,557	859	89,069	1,151	99,940
2003	513	7,796	860	89,318	1,125	99,612
2004	715	11,076	826	114,009	1,293	127,920
2005	650	10,970	996	112,143	1,402	126,161
2006	70	1,185	120	26,765	419	28,559
Average	368	6,908	667	70,787	989	79,720

Percent TN Contribution by Pathways

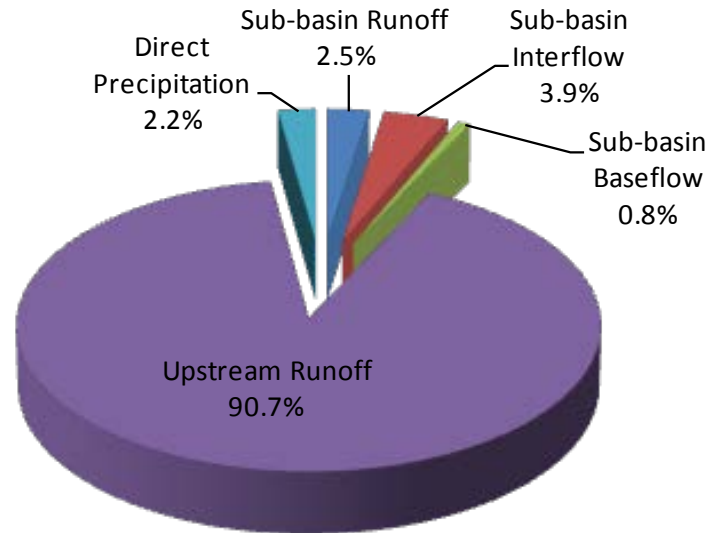


Figure 5.18. Percent TN Contribution to Lake Cypress under the Existing Condition During the Simulation Period, 2000–06

Percent TP Contribution by Pathways

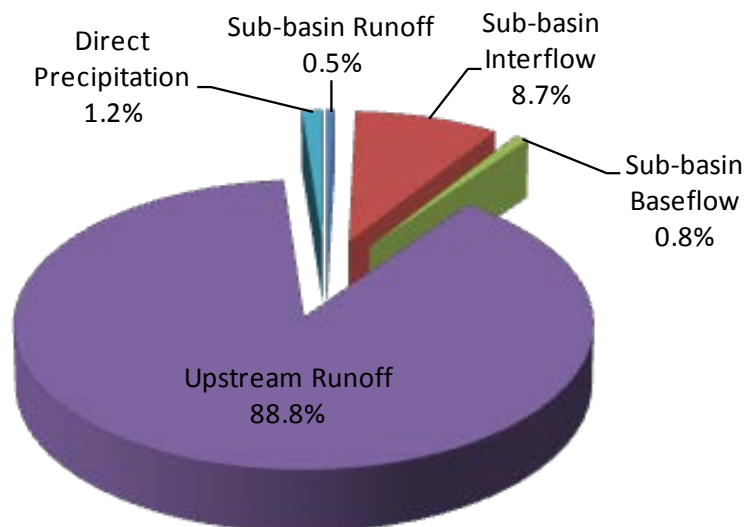


Figure 5.19. Percent TP Contribution to Lake Cypress under the Existing Condition During the Simulation Period, 2000–06

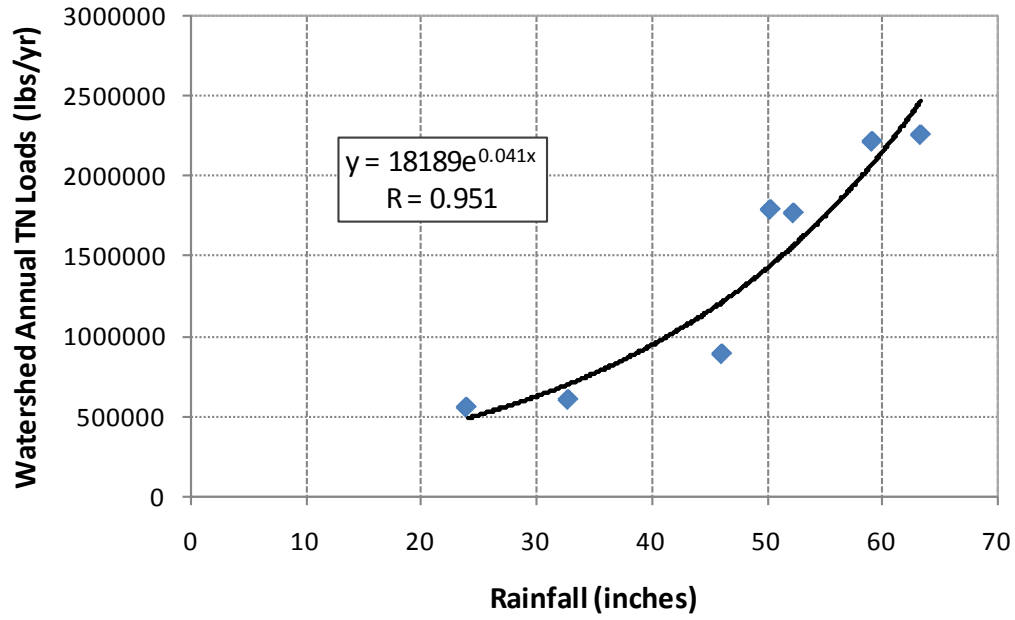


Figure 5.20. Relationship Between Rainfall Versus Watershed Annual TN Loads to Lake Cypress under the Existing Condition During the Simulation Period, 2000–06

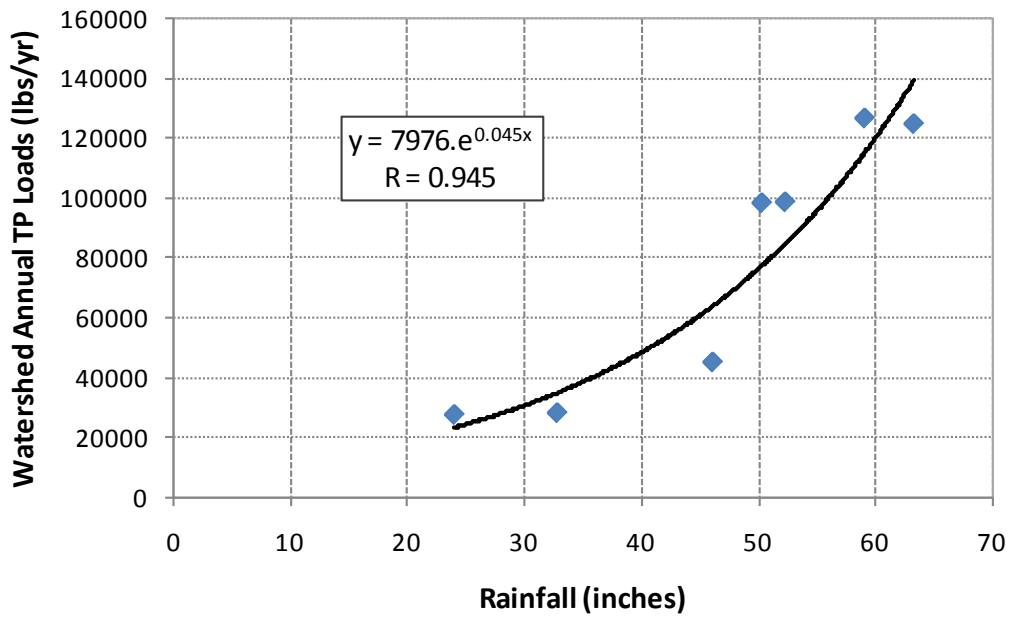


Figure 5.21. Relationship Between Rainfall Versus Watershed Annual TP Loads to Lake Cypress under the Existing Condition during the Simulation Period, 2000–06

The key processes affecting the model simulation of nitrogen concentrations in receiving waters include the following:

- *First-order decay of BOD (organic N associated with BOD is converted to ammonia N in this process).*
- *BOD settling (organic N associated with BOD is lost to lake sediments).*
- *Phytoplankton growth (inorganic N is converted to phytoplankton N).*
- *Phytoplankton respiration (phytoplankton N is converted to ammonia N).*
- *Phytoplankton death (phytoplankton N is converted to BOD and/or refractory organic N).*
- *Phytoplankton settling (phytoplankton N is lost to lake sediments).*
- *Refractory organic N settling to lake sediments.*
- *Nitrification (conversion of ammonia N to nitrate N).*
- *Sediment flux (ammonia N is released from sediment to overlying water).*

Ultimately, the rate at which nitrogen is removed from the receiving water depends on the rate at which inorganic N is converted to organic N (by phytoplankton growth) and the rate at which the organic N forms (as BOD, as refractory organic N, and as phytoplankton N) settle to the lake sediments.

The key processes affecting the model simulation of phosphorus concentrations in the lake include the following:

- *First-order decay of BOD (organic P associated with BOD is converted to inorganic P in this process).*
- *BOD settling (organic P associated with BOD is lost to lake sediments).*
- *Phytoplankton growth (inorganic P is converted to phytoplankton P).*
- *Phytoplankton respiration (phytoplankton P is converted to inorganic P).*

- *Phytoplankton death (phytoplankton P is converted to BOD and/or refractory organic P).*
- *Phytoplankton settling (phytoplankton P is lost to lake sediments).*
- *Refractory organic P settling to lake sediments.*
- *Sediment flux (inorganic P is released from sediment to overlying water).*

Ultimately, the rate at which phosphorus is removed from the lake water depends on the rate at which inorganic P is converted to organic P (by phytoplankton growth) and the rate at which the organic P forms (as BOD, as refractory organic P, and as phytoplankton P) settle to the lake sediments.

Lake Cypress has an extended watershed including other lakes and streams. Waterbodies with long mean residence times (months or years), allow substantial time and relatively quiescent conditions for phytoplankton growth. In contrast, these processes are expected to have little impact in free-flowing stream reaches with short residence times (a day or less) and relatively turbulent conditions. However, it is possible to see high phytoplankton levels in streams during dry weather periods, if the stream has some areas of standing water. Lake Cypress has an average residence time less than one month and under more natural loading conditions (as presented later) would not be expected to have the elevated levels of *cchl_a* that are evident in the measured data.

Reaeration is a process of exchange between the water and the overlying atmosphere that typically brings oxygen into the receiving water (unless the receiving water DO concentration is above saturation levels). In the long term, phytoplankton growth and respiration typically provide a net DO benefit (*i.e.*, more DO is introduced through growth than is depleted through respiration). The other three processes take oxygen from the receiving water. The results of the modeling suggest that reaeration and sediment oxygen demand (SOD) are often the key processes in the overall DO mass balance, though the other processes may be important in lakes with relatively high loadings.

The model simulates flows and associated loads from the tributary area into the Lake Cypress reach (RCHRES 380) to perform HSPF water quality calculations. Simulations included concentrations of water quality constituents, including phytoplankton and various forms of nitrogen and phosphorus. During HSPF calibration, water quality input parameters that represent the physical and biological processes in the lake were set so that the simulated concentrations were comparable to the available measured water quality data for Lake Cypress.

The time-series of simulated TN over the simulation period reasonably predicted both the seasonal variation and interannual trends (**Figures 5.22** through **5.24**). Based on the box and whisker plot (**Figure 5.23**), the mean, median, and distribution percentiles of simulated TN matched those of observed TN. The 7-year mean and standard deviation for the observed TN were 1.44 ± 0.51 mg/L, similar to those of simulated TN (1.25 ± 0.22 mg/L). The 10th and 90th percentiles of the observed TN were 0.94 and 1.94 mg/L, respectively. Similarly, the 10th and 90th percentiles of the simulated TN values were 1.05 and 1.59 mg/L, respectively. As calculated based on quarterly means for each year, a similar annual variation within 1 standard deviation was observed, ranging from 1.31 ± 0.256 mg/L to 1.72 ± 0.596 mg/L for the observed TN, and from 1.09 ± 0.038 mg/L to 1.46 ± 0.240 mg/L for the simulated TN (**Figure 5.24**).

Following the same procedures, the time-series of simulated TP was calibrated against observed TP (**Figure 5.25**). Compared with the simulated time-series of daily TP, the observed TP showed a wide range of variation in concentration over the period. Although the observed daily TP values fluctuated widely in most of years, the box and whisker plot and the annual means for TP also indicated that the mean, median, and the 10th and 90th percentiles between simulation and observation are in good agreement (**Figures 5.26** and **5.27**). The mean and median of the simulated TP over the simulation period of 0.079 ± 0.02 mg/L and 0.073 mg/L, respectively, matched reasonably well the mean (0.083 ± 0.04 mg/L) and median (0.073 mg/L) of the observed TP. Annual variations of the observed and simulated annual TP were also in reasonable agreement, *i.e.*, within 1-sigma standard deviation (**Figure 5.27**). For example, the mean concentration of the observed TP in 2000 was 0.095 ± 0.059 mg/L, with the coefficient of variance (CV) of about 62%, while the annual mean of 0.075 ± 0.008 mg/L was simulated by the model for 2000, with a CV of about 10%.

The time-series of simulated *cchl_a* for Lake Cypress, plotted against the observed *cchl_a*, demonstrated a reasonable agreement over the simulation period (**Figure 5.28**). The model reasonably predicted both the peak concentrations of observed *cchl_a* during the growing season and the lower concentrations of observed *cchl_a* in the winter. The box and whisker plots also indicated that the mean, median, and distribution percentiles of simulated *cchl_a* over the period of simulation were very similar to those of the observed *cchl_a* (**Figure 5.29**). There were excellent agreements in the mean, median, and 10th and 90th percentiles of simulated versus observed *cchl_a*. For example, the mean and median for observed *cchl_a* were 32.1 ± 24.60 µg/L and 28.9 µg/L, similar to 37.9 ± 10.6 µg/L and 37.7 µg/L for simulated *cchl_a*. The 10th and 90th percentiles of observed *cchl_a* values were 8.6 and 58.8 µg/L, respectively, while the 10th and 90th percentiles of simulated values in the range were 24.1 and 51.7 µg/L, respectively. The

predicted annual mean concentrations for each year also agreed with the observed annual mean concentration, *i.e.*, within 1 standard error over the simulation period (**Figure 5.30**).

Based on the simulated TN, TP, and *cchl_a* concentrations, simulated annual TSIs for Lake Cypress were calculated and compared with those calculated for the observed TN, TP, and *cchl_a* concentrations (**Figure 5.31**). The simulated TSI for the lake ranged from 64.2 to 67.9, with a 7-year average of 65.3 ± 1.5 ($n = 7$). This long-term predicted average TSI agreed with the 6-year average observed TSI of 65.5 ± 2.3 ($n = 6$), indicating that the model calibration was acceptable.

5.3 Background Conditions

HSPF was used to evaluate the “natural land use background condition” for the Lake Cypress watershed. For this simulation, all current land uses were “reassigned” to a mixture of forest and wetland. The current condition was maintained the same as in the calibrated model for all waterbody physical characteristics. From this point forward, natural land use background is referred to as “background.”

As discussed earlier, for existing conditions, the threshold TSI value of 60 was exceeded in all 7 years of the simulation (as well as the measured data), and the lake is considered co-limited by nitrogen and phosphorus (average ratio of 17). Based on the background model run results, the predevelopment lake should have had annual average TP concentrations ranging from 0.026 to 0.044 mg/L, with a long-term average of 0.033 mg/L. The predevelopment annual average TN concentrations ranged between 0.86 and 1.26 mg/L, with a long-term average of 1.01 mg/L. The predevelopment annual average *cchl_a* ranged from 13.0 to 14.7 µg/L, with an average of 13.8 µg/L. The resulting annual average TSI values ranged between 54.0 and 56.1, with a long-term average of 54.9.

5.4 Selection of the TMDL Target

It should be recognized that the direct application of background as the target TSI would not allow for any assimilative capacity. The IWR uses, as one measure of impairment in lakes, a 10-unit change in the TSI from “historical” levels. This 10-unit increase is assumed to represent the transition of a lake from one trophic state (*e.g.*, mesotrophic) to another nutrient-enriched condition (eutrophic). The Department has assumed that allowing a 5-unit increase in TSI over the background condition would prevent a lake from becoming impaired (changing trophic states) and reserves 5 TSI units to allow for future changes in the basin and as part of the implicit margin of safety (MOS) in establishing the assimilative capacity.

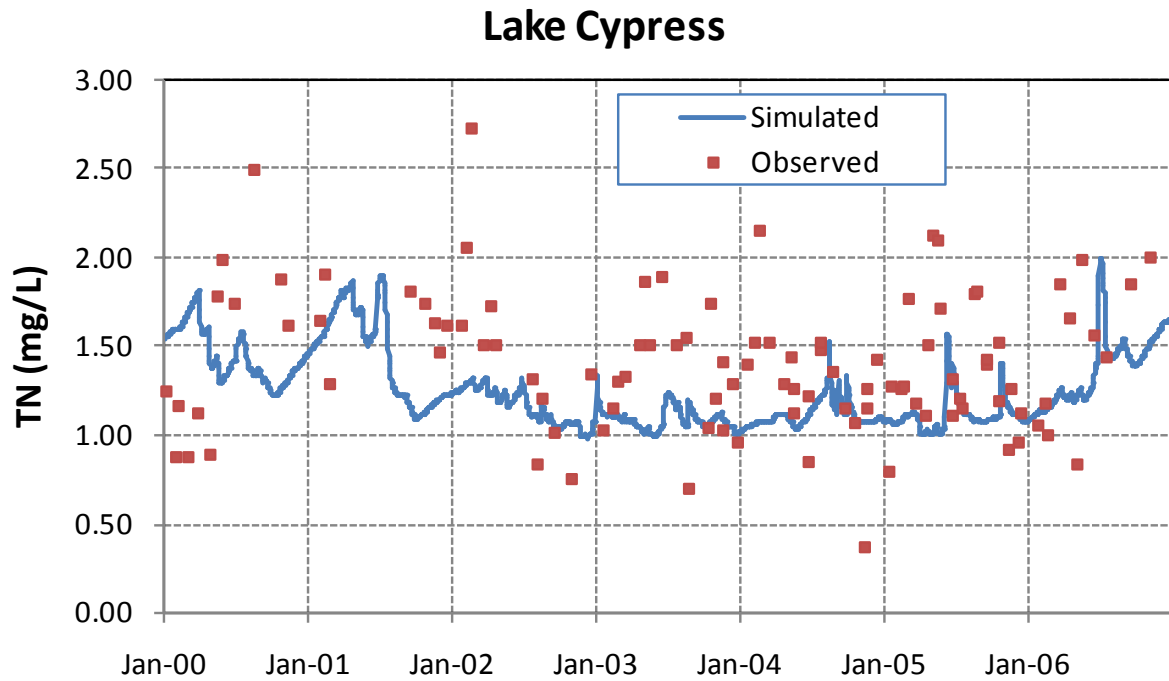


Figure 5.22. Time-Series of Observed Versus Simulated Daily TN Concentrations in Lake Cypress During the Simulation Period, 2000–06

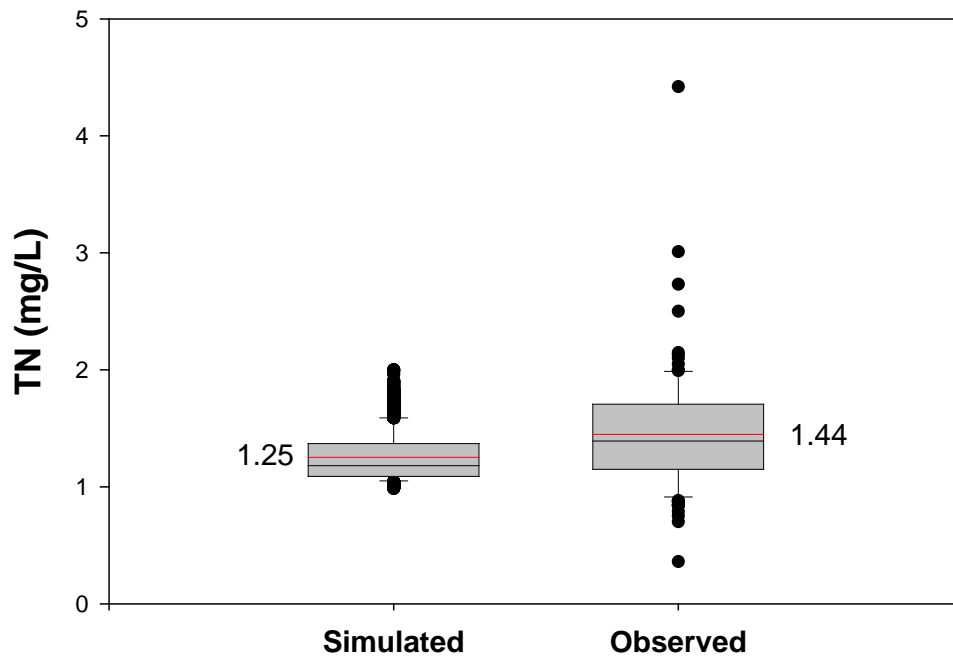


Figure 5.23. Box and Whisker Plot of Simulated Versus Observed TN in Lake Cypress, 2000–06 (red line represents mean concentration of each series)

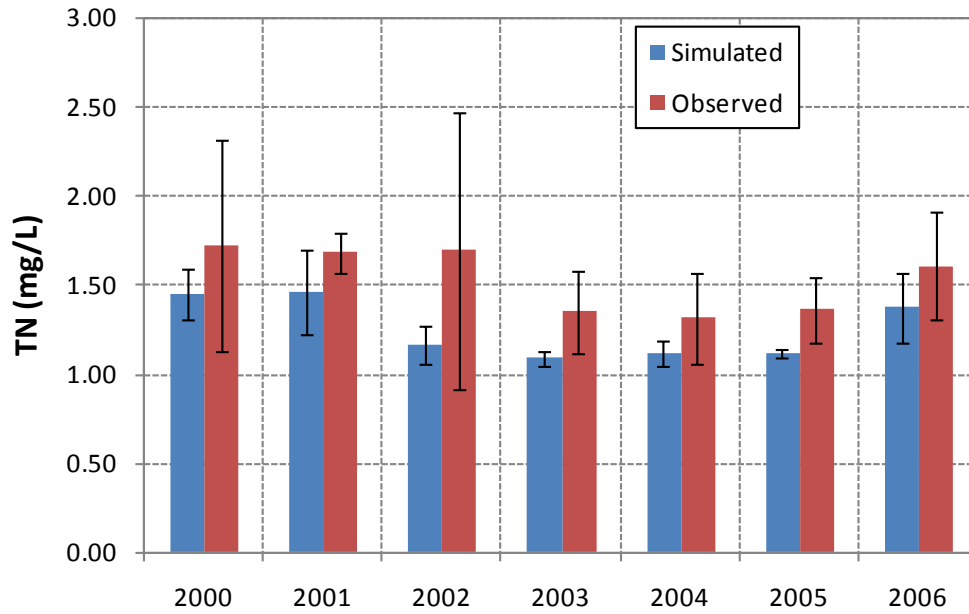


Figure 5.24. Annual Mean Concentrations of Observed Versus Simulated TN in Lake Cypress During the Simulation Period, 2000–06 (error bars represent 1-sigma standard deviation)

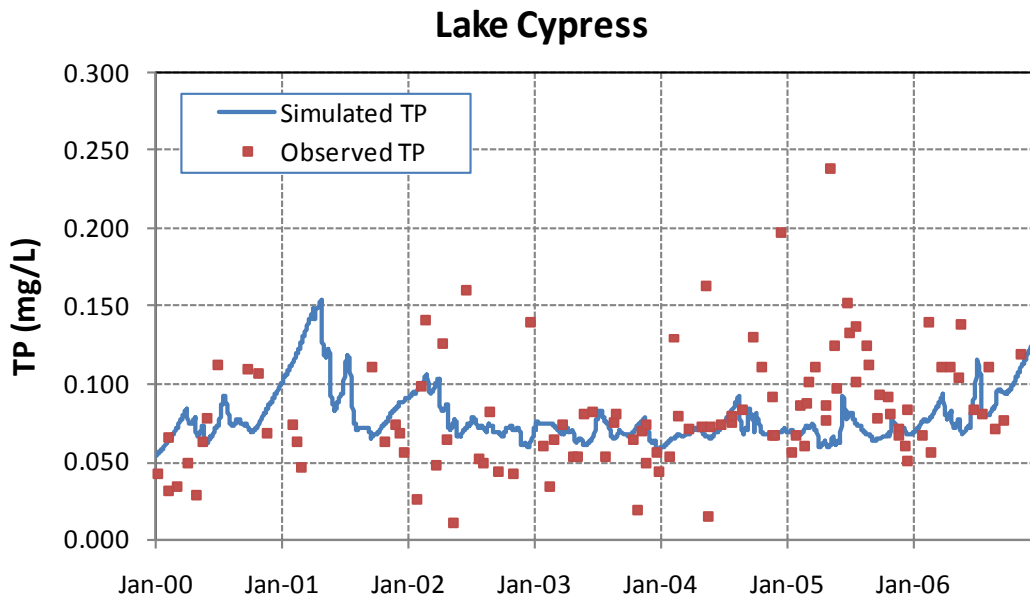


Figure 5.25. Time-Series of Observed Versus Simulated Daily TP Concentrations in Lake Cypress During the Simulation Period, 2000–06

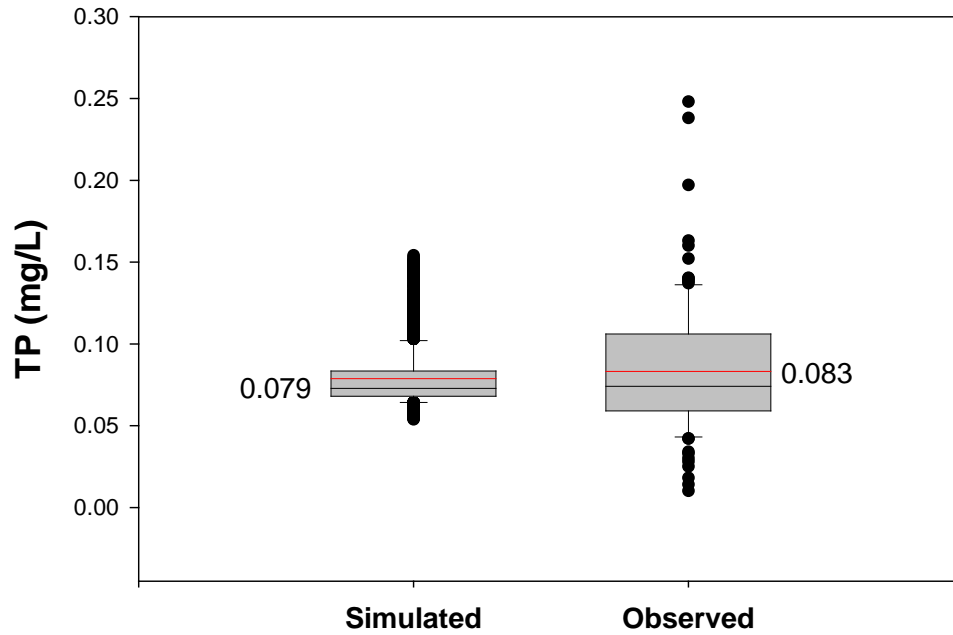


Figure 5.26. Box and Whisker Plot of Simulated Versus Observed TP in Lake Cypress, 2000–06 (red line represents mean concentration of each series)

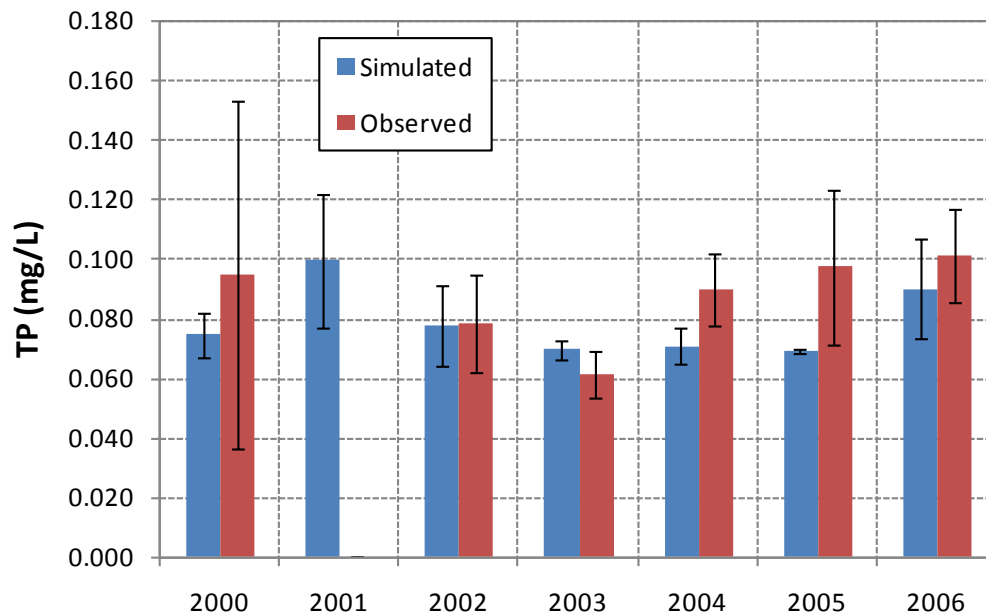


Figure 5.27. Annual Mean Concentrations of Observed Versus Simulated TP in Lake Cypress During the Simulation Period, 2000–06 (error bars represent 1-sigma standard deviation)

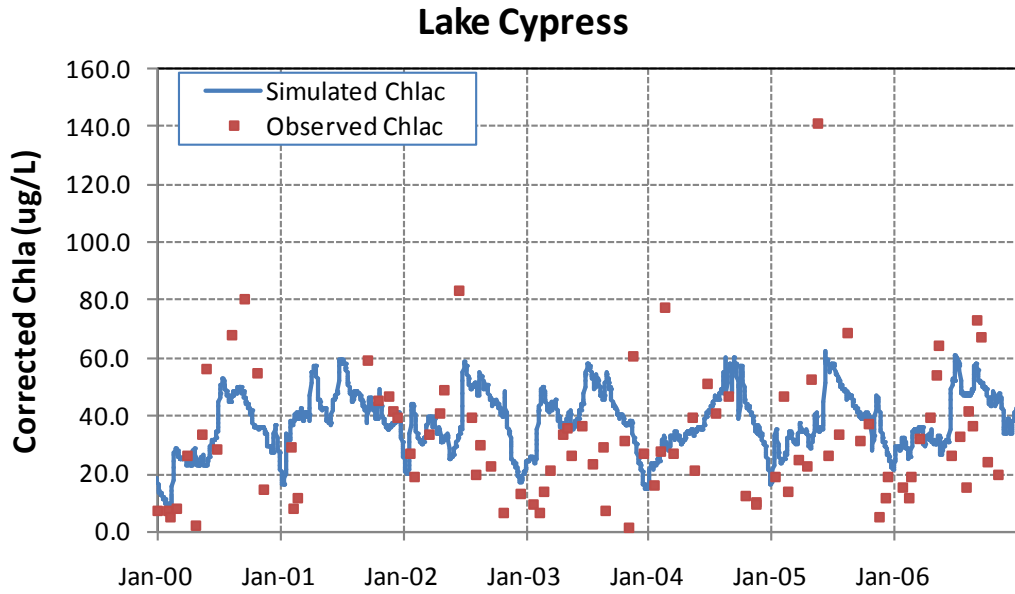


Figure 5.28. Time-Series of Observed Versus Simulated Daily CChla Concentrations in Lake Cypress During the Simulation Period, 2000–06

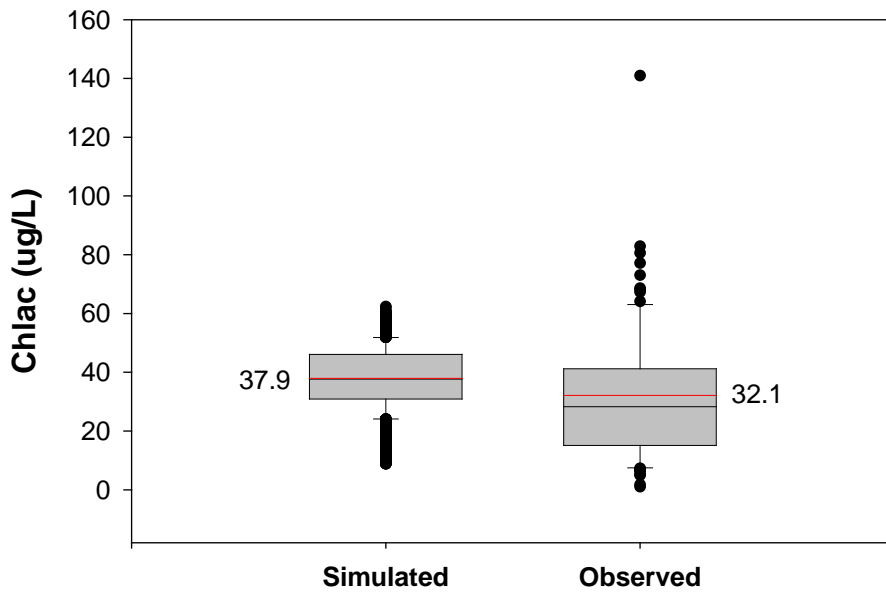


Figure 5.29. Box and Whisker Plot of Simulated Versus Observed CChla in Lake Cypress, 2000–06 (red line represents mean concentration of each series)

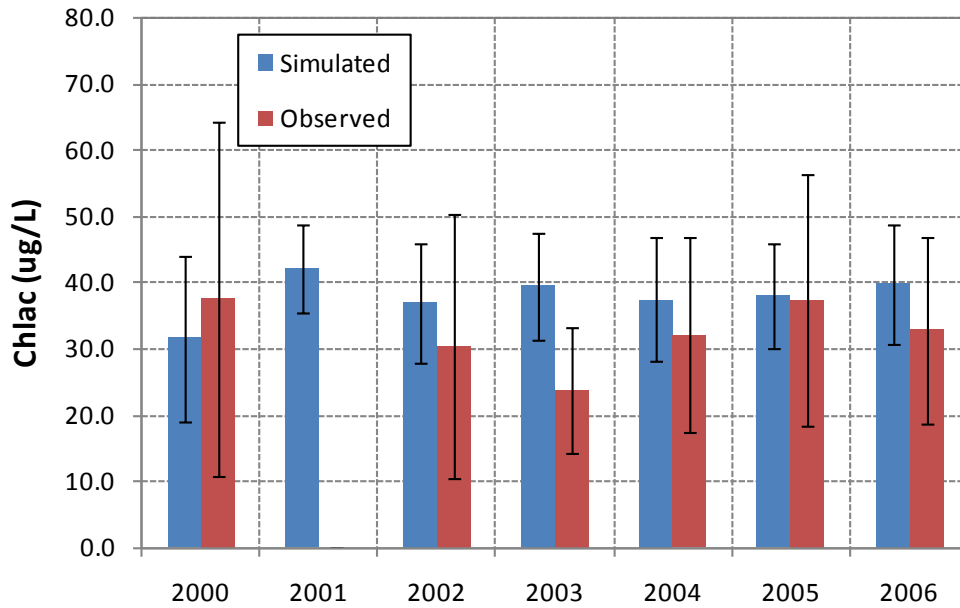


Figure 5.30. Annual Mean Concentrations of Observed Versus Simulated CChla in Lake Cypress During the Simulation Period, 2000–06 (error bars represent 1-sigma standard deviation)

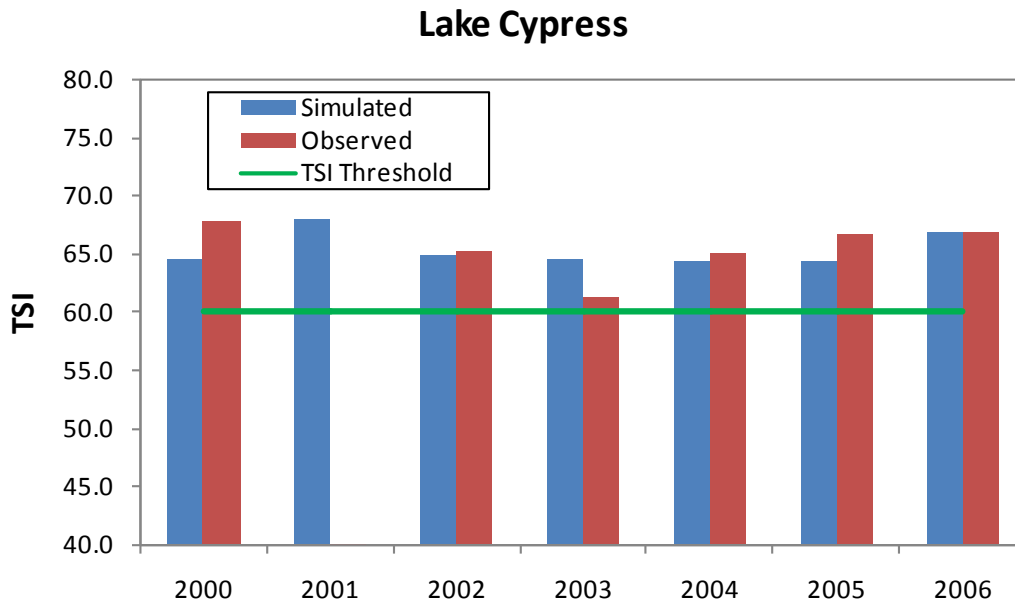


Figure 5.31. Observed Versus Simulated Annual TSIs in Lake Cypress During the Simulation Period, 2000–06 (solid line indicates TSI threshold of 60)

The final target developed for the restoration of Lake Cypress includes achieving a long-term average TSI less than or equal to 59.9 (background of 54.9 plus 5). Serial reductions in loadings were implemented until the load reduction resulted in the lake meeting the requirements of the TSI target. **Figure 5.32** depicts the TSI results for the existing condition, background condition, and TMDL condition. **Table 5.10** shows the summary statistics of the TSIs for different conditions. To meet the long-term TSI target of 59.9, the existing watershed TN and TP loads were reduced by 5% for TN and 35% for TP, resulting in the long-term average TSI of 59.7. After applying these reductions, the long-term average in-lake concentrations in Lake Cypress are expected to be 1.07 mg/L for TN, 0.049 mg/L for TP, and 25.7 µg/L for *cchl_a*. Therefore, it was decided that the watershed load reductions of 5% for TN and 35% for TP, which met the TSI target, would best represent the assimilative capacity for the waterbody, resulting in the achievement of aquatic life-based water quality criteria. Under the TMDL condition for Lake Cypress, water quality in both Lake Hatchineha and Lake Kissimmee—which are fed by Lake Cypress—is expected to improve from the existing TSI of 59.7 to 56.8, and 60.0 to 58.0, respectively.

The 7-year averaged existing watershed loads, not including direct precipitation, were estimated to be 1,447,159 lbs/year for TN and 78,731 lbs/year for TP. A 5% watershed load reduction in TN resulted in an allowable load of 1,374,801 lbs/year. A 35% watershed load reduction in TP resulted in an allowable load of 51,175 lbs/year. The resulting percent reductions applied to the existing watershed load will be applied to both the load allocation (LA) and stormwater wasteload allocation (MS4) components of the TMDL.

Table 5.11 contains a summary of the impairment and TMDL conditions among Lakes Kissimmee, Cypress, Marian, Jackson, and Hatchineha.

5.5 Critical Conditions

The estimated assimilative capacity was based on annual average conditions (*i.e.*, values from all four seasons in each calendar year) rather than critical/seasonal conditions because (1) the methodology used to determine assimilative capacity does not lend itself very well to short-term assessments; (2) for lakes, the Department is generally more concerned with the net change in overall primary productivity, which is better addressed on an annual basis; and (3) the methodology used to determine impairment in lakes is based on an annual average and requires data from all four quarters of a calendar year.

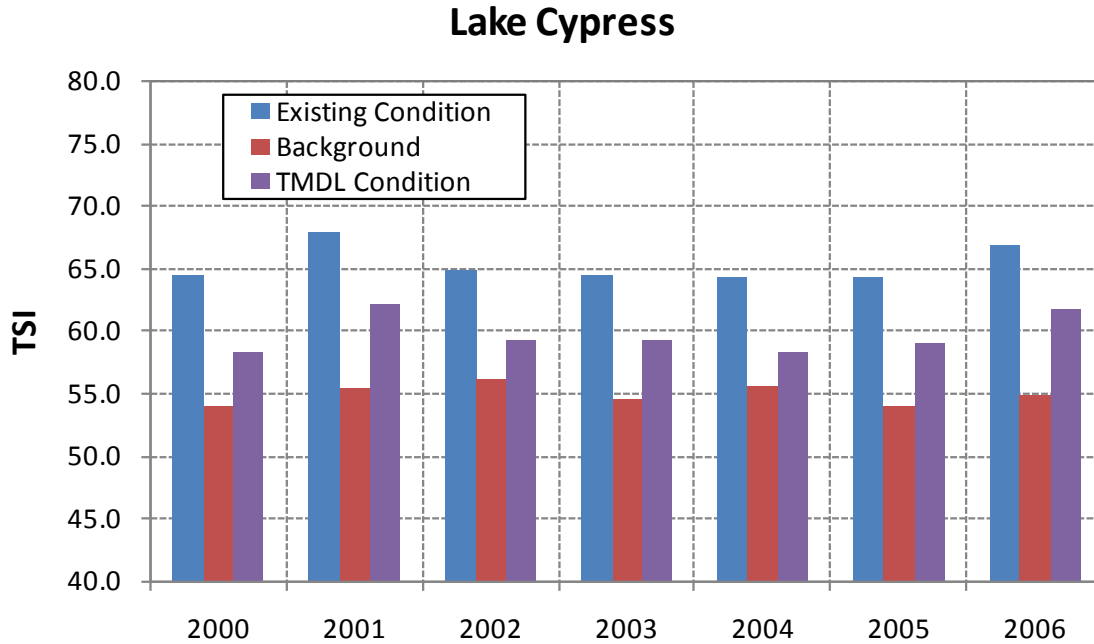


Figure 5.32. Estimated TSIs for the Existing Condition, Background Condition, and TMDL Condition for Lake Cypress During the Simulation Period, 2000–06

Table 5.10. Summary Statistics of Simulated TSIs for the Existing Condition, Background Condition, and TMDL Condition

Statistic	Existing TSI	Background TSI	TMDL TSI
Count	7.0	7.0	7.0
Median	64.6	54.8	59.1
Average	65.3	54.9	59.7
Standard deviation	1.5	0.8	1.6
Minimum	64.2	54.0	58.3
Maximum	68.0	56.1	62.2
CV (%)	2.3%	1.5%	2.6%

Table 5.11. Simulated TSIs for the Existing Condition, Background Condition, and TMDL Condition with Percent Reductions in the KCOL System

- = Empty cell/no data

TSI and % Reduction	Lake Cypress	Lake Kissimmee	Lake Jackson	Lake Marian	Lake Hatchineha
Background TSI (2000–06)	54.9	50.1	54.7	53.1	50.1
Target TSI (background TSI + 5)	59.9	55.1	59.7	58.1	55.1
Calibrated existing TSI	65.3	60.0	67.1	70.3	59.7
Lake Marian TMDL % reduction	-	59.83 (by Marian)	61.7 (by Marian)	58.1 (TN55/TP53)	-
Lake Jackson TMDL % reduction	-	59.77 (by Jackson)	59.7 (TN20/TP25)	-	-
Lake Cypress TMDL % reduction	59.7 (TN05/TP35)	58.0 (by Cypress)	-	-	56.8 (by Cypress)
Lake Kissimmee TMDL % reduction	-	55.0 (TN15/TP17)	-	-	-

Chapter 6: DETERMINATION OF THE TMDL

6.1 Expression and Allocation of the TMDL

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:

$$\text{TMDL} \cong \sum \square \text{WLA}_{\text{wastewater}} + \sum \square \text{WLA}_{\text{NPDES Stormwater}} + \sum \square \text{LAs} + \text{MOS}$$

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

WLAs for stormwater discharges are typically expressed as “percent reduction” because it is very difficult to quantify the loads from MS4s (given the numerous discharge points) and to distinguish loads from MS4s from nonpoint sources (given the nature of stormwater transport). The permitting of MS4 stormwater discharges is also different than the permitting of most wastewater point sources. Because MS4 stormwater discharges cannot be centrally collected, monitored, and treated, they are not subject to the same types of effluent limitations as wastewater facilities, and instead are required to meet a performance standard of providing treatment to the “maximum extent practical” through the implementation of Best Management Practices (BMPs).

This approach is consistent with federal regulations (40 Code of Federal Regulations § 130.2[I]), which state that TMDLs can be expressed in terms of mass per time (*e.g.*, pounds per day), toxicity, or **other appropriate measure**. The NPDES stormwater WLA is expressed as a percent reduction in the stormwater from MS4 areas. The TMDL is the site-specific numeric interpretation of the narrative nutrient criterion pursuant to Paragraph 62-302.531(2)(a), F.A.C. The TMDL for Lake Cypress is expressed as loads and percent reductions and represents the long-term annual average load of TN and TP from all watershed sources that the waterbody can assimilate and maintain the Class III narrative

nutrient criterion (**Table 6.1**). The expression and allocation of the TMDL in this report are based on the loadings necessary to achieve the water quality criteria and designated uses of the surface waters.

Table 6.1. Lake Cypress Load Allocations

NA = Not applicable

WBID	Parameter	WLA for Wastewater (lbs/yr)	WLA for Stormwater (% reduction)	LA (% reduction)	MOS	TMDL (lbs/yr)
3180A	TN	NA	5%	5%	Implicit	1,374,801
3180A	TP	NA	35%	35%	Implicit	51,175

The LA and TMDL daily load for TN is 3,767 lbs/day, and for TP, 140 lbs/day.

These reductions are based on long-term (7-year) averages of data from 2000 to 2006. Based on the TMDL modeling conducted for this report (reductions of watershed loadings), the long-term average lake concentration for TP is 0.049 mg/L, for TN 1.07 mg/L, and for *cchl_a* 25.7 µg/L. As these reductions are provided as a percentage, they are applicable over any time frame, including daily. The Department acknowledges that there may be more than one way to achieve the *cchl_a* restoration goal. For example, hydrologic restoration that includes restoring historical lake water levels and reconnecting the lake to historical wetlands could achieve the *cchl_a* target with different in-lake concentrations of nutrients.

6.2 Load Allocation (LA)

Because the exact boundaries between those areas of the watershed covered by the WLA allocation for stormwater and the LA allocation are not known, both the LA and the WLA for stormwater will receive the same percent reduction. The LA is a 35% reduction in TP and a 5% reduction in TN of the total nonpoint source watershed loadings for the period from 2000 to 2006. As the TMDL is based on the percent reduction in total watershed loading and any natural land uses are held harmless, the percent reductions for the anthropogenic sources may be greater. It should be noted that the LA may include loading from stormwater discharges regulated by the Department and the SFWMD that are not part of the NPDES Stormwater Program (see **Appendix A**).

6.3 Wasteload Allocation (WLA)

6.3.1 NPDES Wastewater Discharges

As noted in **Chapter 4, Section 4.2.1**, there are no active NPDES-permitted facilities located within the Lake Cypress watershed that discharge surface water within the watershed. Therefore, the WLA_{wastewater} for the Lake Cypress TMDL is “not applicable” because there are no wastewater or industrial wastewater NPDES facilities that discharge directly to Lake Cypress.

6.3.2 NPDES Stormwater Discharges

The stormwater collection systems in the Lake Cypress watershed, which are owned and operated by Polk County in conjunction with FDOT District 1, are covered by NPDES Phase I MS4 Permit Number FLS000015. The collection systems owned and operated by Osceola County and the city of St. Cloud are covered by NPDES Phase II MS4 Permit Number FLR04E012. The collection system for the city of Orlando is covered by NPDES Phase I Permit Number FLS000014. The collection systems for Orange County, FDOT District 5, and the city of Belle Isle are covered by NPDES Phase I Permit Number FLS000011. The collection system for the city of Kissimmee is covered by NPDES Phase II Permit Number FLR04E64. The collection system for the Florida Turnpike is covered by NPDES Phase II-C Permit Number FLR04E049. The wasteload allocation for MS4 stormwater discharges is a 35% reduction in TP and a 5% reduction in TN of the total watershed loading for the period from 2000 to 2006; these are the required percent reductions from MS4 stormwater sources.

It should be noted that any MS4 permittee is only responsible for reducing the anthropogenic loads associated with stormwater outfalls that it owns or otherwise has responsible control over, and it is not responsible for reducing other nonpoint source loads within its jurisdiction. As the TMDL is based on the percent reduction in total watershed loading and any natural land uses are held harmless, the percent reduction for only anthropogenic sources may be greater.

6.4 Margin of Safety (MOS)

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

The MOS can either be implicitly accounted for by choosing conservative assumptions about loading or water quality response, or explicitly accounted for during the allocation of loadings. Consistent with the recommendations of the Allocation Technical Advisory Committee (Department 2001), an implicit MOS was used in the development of the Lake Cypress TMDL because the TMDL was based on the conservative decisions associated with a number of modeling assumptions and the allowance of only a 5 TSI unit increase above background conditions in determining assimilative capacity (*i.e.*, loading and water quality response) for Lake Cypress.

Chapter 7: NEXT STEPS: IMPLEMENTATION PLAN

DEVELOPMENT AND BEYOND

7.1 Basin Management Action Plan

Following the adoption of the TMDL by rule, the Department will work cooperatively with stakeholders to develop a plan to restore the waterbody. This will be accomplished by creating a Basin Management Action Plan. 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. The BMAP will be designed to identify the actions needed to achieve restoration goals, including steps to meet a long-term average *cchl_a* concentration in the lake of no greater than 13.7 µg/L.

The implementation of these projects will depend heavily on the active participation of the SFWMD, local governments, businesses, and other stakeholders. While the required percent reduction for nutrients is specified in **Chapter 6**, no specific projects have been identified at this time. The Department will work with these organizations and individuals during the development of the BMAP to identify specific projects directed towards achieving the established TMDL for the impaired waterbody.

The 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. **Section 7.2** provides a framework of the issues and activities that need to be completed as part of the development of the BMAP.

Once adopted by order of the Department Secretary, BMAPs are enforceable through wastewater and MS4 permits for point sources and through BMP implementation for nonpoint sources. Among other components, BMAPs typically include the following:

- *Water quality goals.*
- *Appropriate load reduction allocations 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 (if any) to achieve the TMDL.*
- *Timetables for implementation.*
- *Confirmed and potential funding mechanisms.*
- *An evaluation of future increases in pollutant loading due to population growth.*
- *Any applicable signed agreement(s).*
- *Local ordinances defining actions to be taken or prohibited.*
- *Any applicable local water quality standards, permits, or load limitation agreements.*
- *Implementation milestones, project tracking, water quality monitoring, and adaptive management procedures.*
- *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 Next Steps for TMDL Implementation

The Department will establish the detailed allocation for the WLA for stormwater and the LA for nonpoint sources pursuant to Paragraph 403.067(6)(b), F.S.

As part of BMAP development, the Department will work with stakeholders to identify the water quality monitoring locations appropriate for assessing progress towards lake restoration. The BMAP will be developed over a period sufficient to allow for the collection and analysis of any necessary additional information. The development of the BMAP pursuant to Paragraph 403.067(6)(b), F.S., does allow time

for further monitoring, data analysis, and modeling to develop a better understanding of the relationship between watershed loadings, impacts from permitted WWTFs, proposed hydrologic modifications, proposed reconnection to wetlands, and the resulting algae (*cchla*) concentration. As is the case when any modeling approach is used, some uncertainty always remains in the existing data and model predictions, and this may lead the Department to support gathering additional data or information.

For lakes within the Kissimmee Chain of Lakes, water quality targets may need to be refined, and making this decision should be a high priority. This element should be investigated prior to any determination calling for new projects, to ensure that the outcome of such projects will provide the expected or implied water quality benefit and help achieve system restoration goals.

The future BMAP planning process may need to consider the issue of the related stresses of nutrient loading within the complexities of hydrologic alteration. For example, in some cases reductions in Florida lake elevations over the last several decades have likely led to reduced tannin levels and influenced assimilative capacities for nutrient loading (D. Tomasko, 2013, pers. comm.), factors not addressed in current TMDLs. Lakes Cypress and Marian, for example, have dropped approximately 2 to 3 feet in lake elevation since the 1940s and 1950s, respectively. In Lake Cypress, the TP-rich sediments are 55% more likely to be resuspended into the water column in their recent, lowered stages, than if lake levels had remained at historical levels. As such, nutrient load reduction targets based on water quality models that used TSI criteria could be problematic for lakes where hydrologic restoration might improve water quality by decreasing the frequency of bottom resuspension and increasing the amounts of tannins.

7.3 Restoration Goals

The impairments in Lakes Cypress, Jackson, Kissimmee, and Marian are linked to the Department's nutrient criterion and, as stated in **Chapter 3**, Florida's nutrient criterion is narrative only. Accordingly, a nutrient-related target is needed to represent levels at which an imbalance in flora or fauna is expected to occur. While the IWR provides a threshold for nutrient impairment for lakes based on annual average TSI levels, these thresholds are not standards and are not required to be used as the nutrient-related water quality target for TMDLs. 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 draft TMDLs are based on maintaining the current lake levels and color.

The stakeholders have requested that the Department include as a component of the BMAP the evaluation of alternative restoration goals that might result if lake levels and lake color were increased as a result of other restoration projects. The stakeholders are seeking to restore to the extent practicable the historical lake levels, seasonal variations in stage, and connections to wetlands that have been isolated from the lakes due to the current lake stage operational criteria. An adaptive management approach to restoration, in which the Department considers hydrologic restoration—and its effects on tannin levels—is a viable consideration to be evaluated in achieving the TMDL.

One of the major restoration efforts under way in the region is the Kissimmee River Restoration Project. Lakes Kissimmee, Hatchineha, and Cypress are part of the Central and Southern Florida (C&SF) Project operated by the SFWMD pursuant to regulations prescribed by the Secretary of the Army. Modifications to C&SF waterbody regulation schedules require evaluations of environmental effects that meet National Environmental Policy Act (NEPA) procedural requirements for a proposed federal action.

The authorized headwaters component of the Kissimmee River Restoration Project increases the regulatory range of water levels on Lakes Kissimmee, Hatchineha, and Cypress by 1.5 feet and modifies the stage regulation schedule in a manner that increases the seasonal variations in stage and the connections to wetlands that have been isolated from the lakes as a result of current lake stage regulation. These changes may restore lake stage and color to a more natural condition over time, and may also have the potential to alter the relationship between watershed loading and the resulting in-lake concentrations of *chl_a*. Plans to alter the hydrology of C&SF Project lakes must meet NEPA procedural requirements, which include input from stakeholders and evaluation of the effects of proposed actions on water quality, water supply, and flood protection.

Additionally, another way of determining if returning to a more natural lake stage and color level would alter restoration goals is to conduct paleolimnological studies on lake sediments to identify historical water quality conditions. If agreed to as part of the BMAP process, the Department may take the lead and conduct these studies in Lake Tohopekaliga (WBID 3173A), Lake Cypress (WBID 3180A), and/or Lake Kissimmee (WBID 3183B), and re-evaluate restoration goals before making any final allocation of load reductions under the BMAP. Additionally, the Department will not move forward with setting final specific allocations of load reductions under the BMAP for Lake Marian or Lake Jackson without determining whether there is a need for further studies to identify historical water quality conditions in these lakes.

References

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Appendices

Appendix A: Background Information on Federal and State Stormwater Programs

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

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, stormwater PLRGs have been established for Tampa Bay, Lake Thonotosassa, the Winter Haven Chain of Lakes, the Everglades, Lake Okeechobee, and Lake Apopka. To date, no PLRG has been developed for Lake Kissimmee.

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 the 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 FDOT 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 the state's stormwater/ERP 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: Electronic Copies of Measured Data and CDM Report (2008) for the Lake Cypress TMDL

All information gathered by CDM, and the HSPF model setup and calibration/validation, are contained in the document, *Kissimmee River Watershed TMDL Model Development Report* (CDM 2008), available upon request (~100 megabytes on disk). Lake Cypress is included in the HSPF model project termed UKL_Open.UCI.

The CDM 2008 report and all data used in the Lake Cypress TMDL report is available upon request. Please contact the individual listed below to obtain this information.

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Fax: (850) 245-8536

Appendix C: List of HSPF Parameters

HSPF Variables	Units	Value	Source
CFSAEX	none	0.65-0.88	Calibration
KATRAD	none	9.57	Calibration
KCOND	none	6.12	Calibration
KEVAP	none	2.24	Default
KSAND	complex	0.5	Previous studies
EXPSND	complex	2.0	Previous studies
W	in/s	0.02	Previous studies
TAUCD	lb/ft ²	0.05-0.09	Calibration
TAUCS	lb/ft ²	0.32-0.48	Calibration
M	lb/ft ² /day	0.02	Calibration
W	in/s	0.000003	Previous studies
TAUCD	lb/ft ²	0.05-0.09	Calibration
TAUCS	lb/ft ²	0.31-0.48	Previous studies
M	lb/ft ² /day	0.02	Calibration
KBOD20	hr ⁻¹	0.012-0.025	Calibration
TCBOD	none	1.037	Calibration
KODSET	ft/hr	0.000	Calibration
BENOD	mg/m ² /hr	8.4-25.2	Calibration
TCBEN	none	1.037	Calibration
KTAM20	hr ⁻¹	0.001-0.03	Previous studies
TCNIT	None	1.07	Default
RATCLP	none	1.0-3.0	Calibration
NONREF	none	0.70-1.00	Calibration
ALNPR	none	0.75	Calibration
EXTB	ft ⁻¹	0.05-0.68	Calibration
MALGR	hr ⁻¹	0.105-0.158	Calibration
CMLLT	ly/min	0.033	Default
CMMN	mg/l	0.045	Default
CMMNP	mg/l	0.028	Default
CMMP	mg/l	0.015	Default
TALGRH	deg F	93	Calibration
TALGRL	deg F	43	Calibration
TALGRM	deg F	83	Calibration
ALR20	hr ⁻¹	0.003	Calibration
ALDH	hr ⁻¹	0.002-0.009	Calibration
ALDL	hr ⁻¹	0.0020-0.0028	Calibration
CLALDH	ug/l	60-90	Default
PHYSET	ft/hr	0.0005-0.0800	Calibration
REFSET	ft/hr	0.000-0.004	Calibration
CVBO	mg/mg	1.31	Previous studies
CVBPC	mols/mol	106	Previous studies
CVBPN	mols/mol	10	Previous studies
BPCNTC	none	49	Previous studies

Appendix D: All Hydrologic Outputs and Model Calibrations for the Impaired Lake and Its Connected Lakes

Flow Calibration

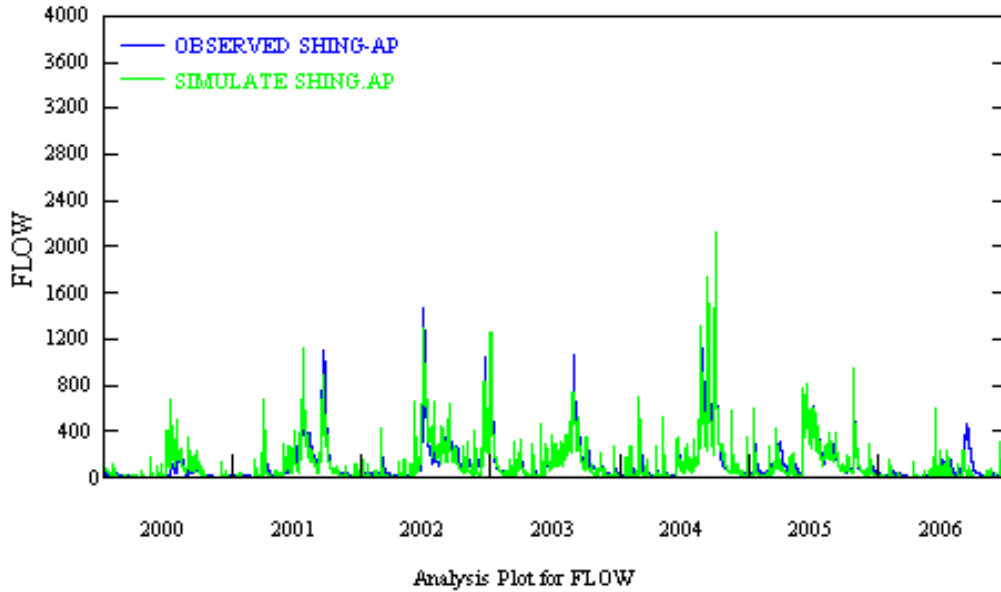


Figure D-1. Observed Versus Simulated Daily Flow (cfs) at Shingle Creek near Airport, 2000–06

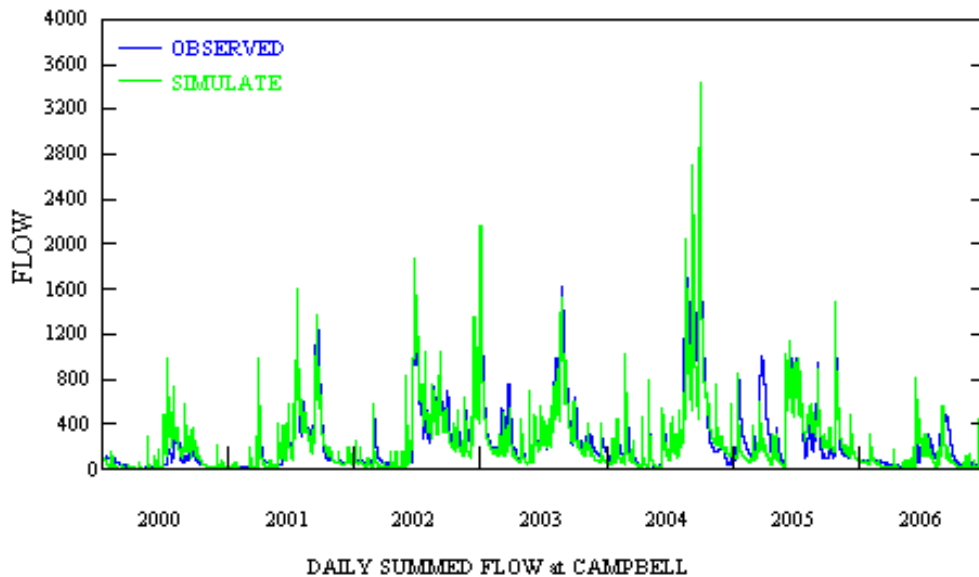


Figure D-2. Observed Versus Simulated Daily Flow (cfs) at Campbell Station in Shingle Creek, 2000–06

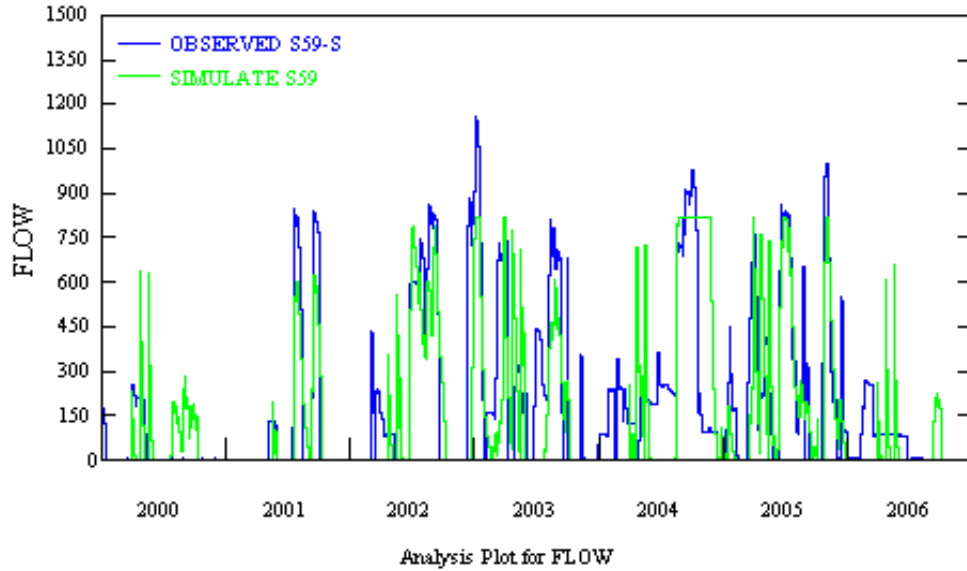


Figure D-3. Observed Versus Simulated Daily Flow (cfs) at S59 for East Lake Tohopekaliga Outflow, 2000–06

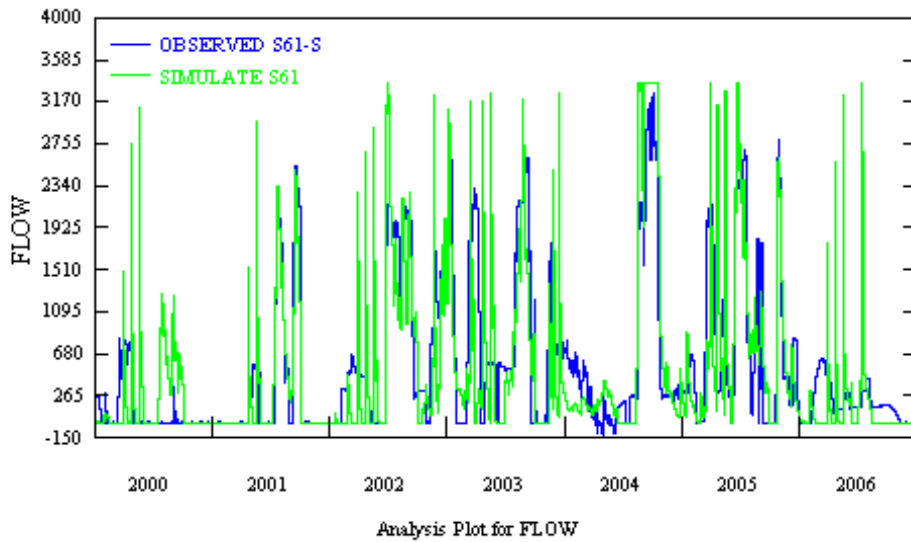


Figure D-4. Observed Versus Simulated Daily Flow (cfs) at S61-S for Lake Tohopekaliga Outflow, 2000–06

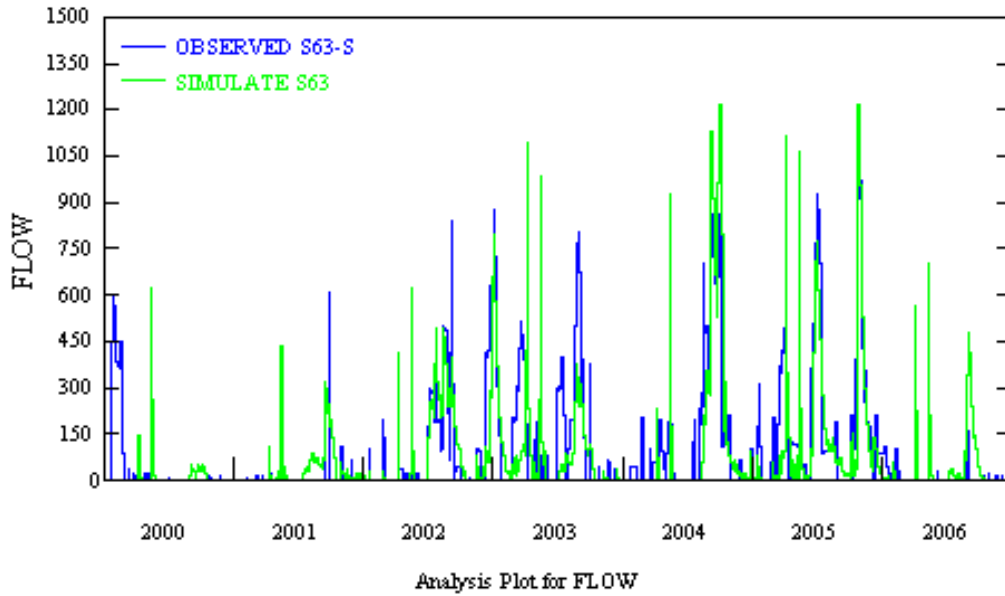


Figure D-5. Observed Versus Simulated Daily Flow (cfs) at S63 for Lake Gentry Outflow, 2000–06

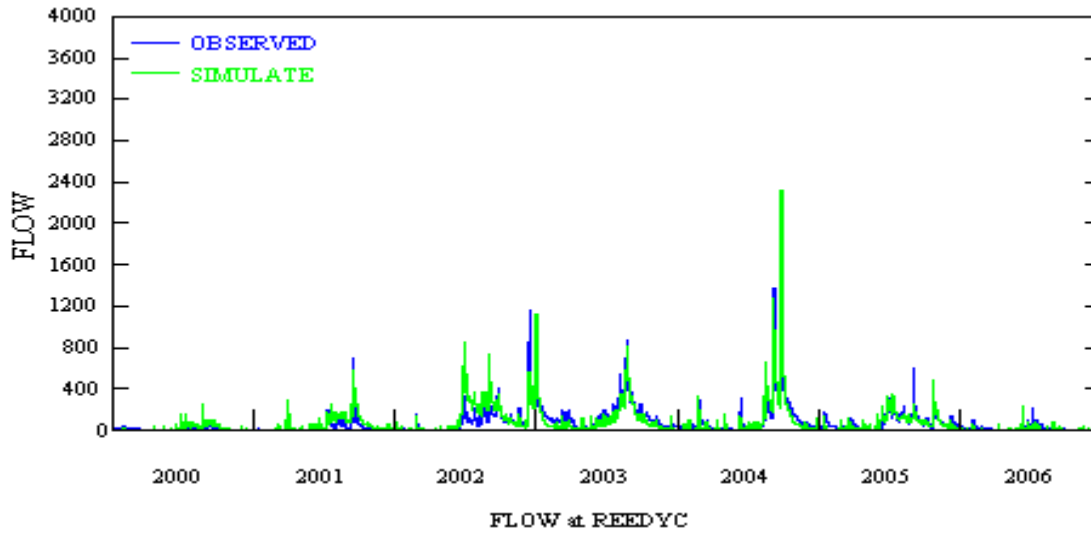


Figure D-6. Observed Versus Simulated Daily Flow (cfs) at Reedy Creek Station, 2000–06

Statistics for Hydrologic Calibration/Validation

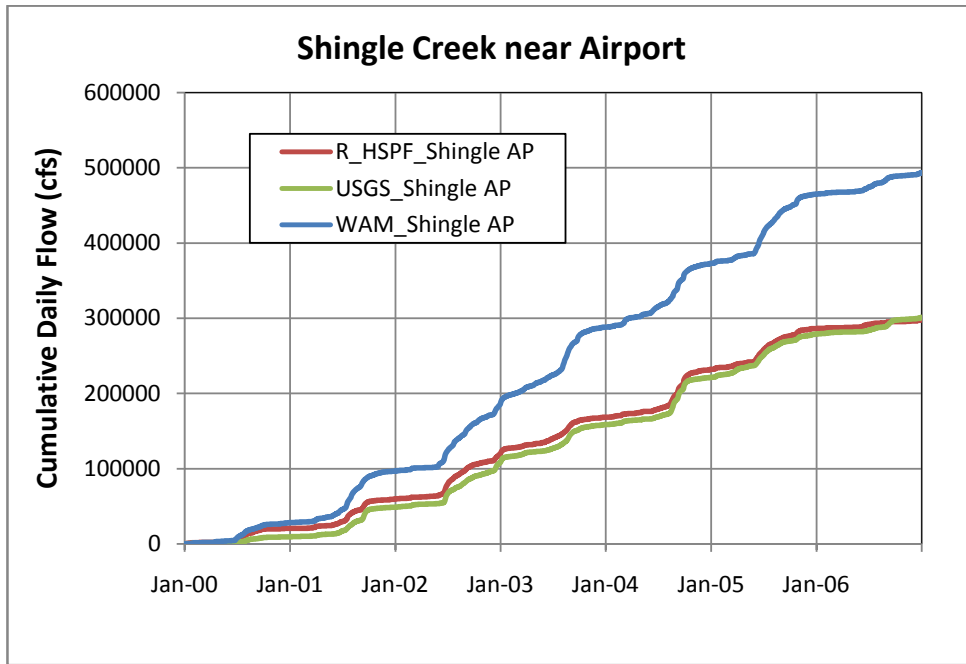


Figure D-7. Observed Versus Simulated Cumulative Daily Flows for Shingle Creek near Airport, 2000–06

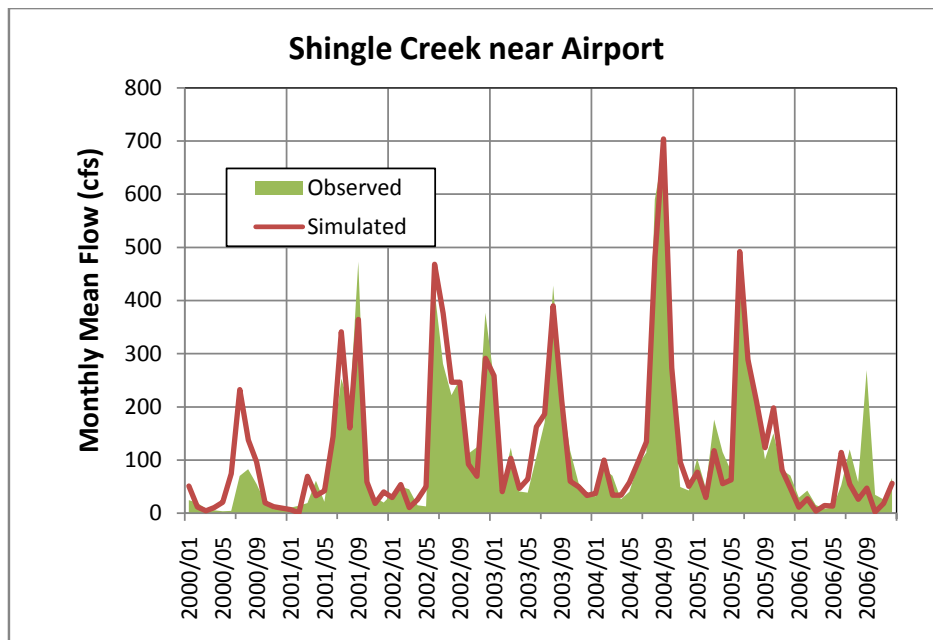


Figure D-8. Observed Versus Simulated Monthly Flows for Shingle Creek near Airport, 2000–06

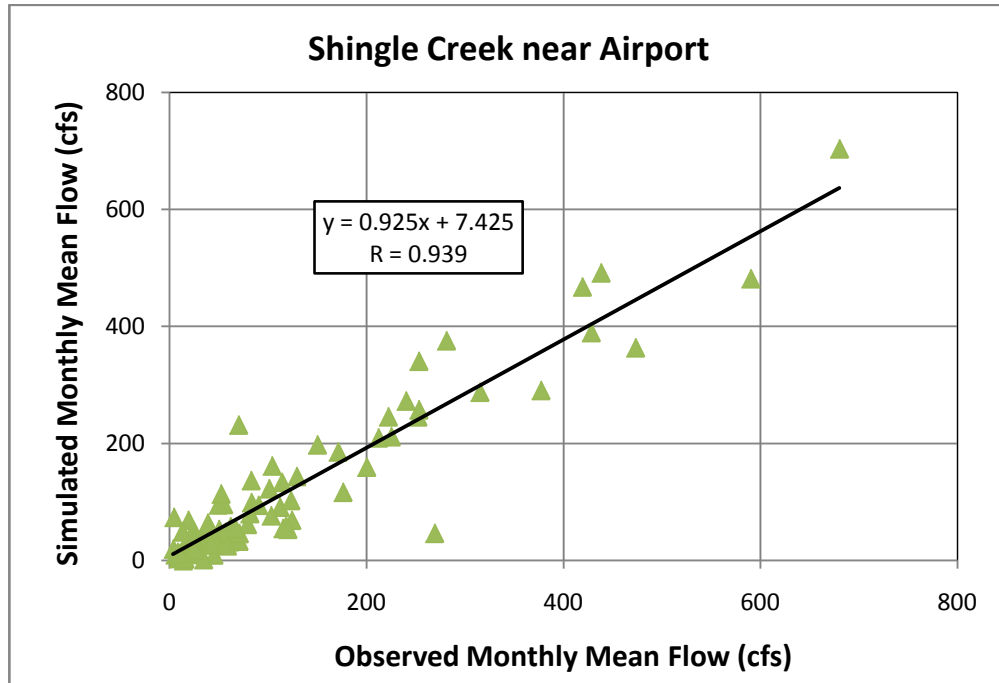


Figure D-9. Relationship Between Observed and Simulated Monthly Flows for Shingle Creek near Airport, 2000–06

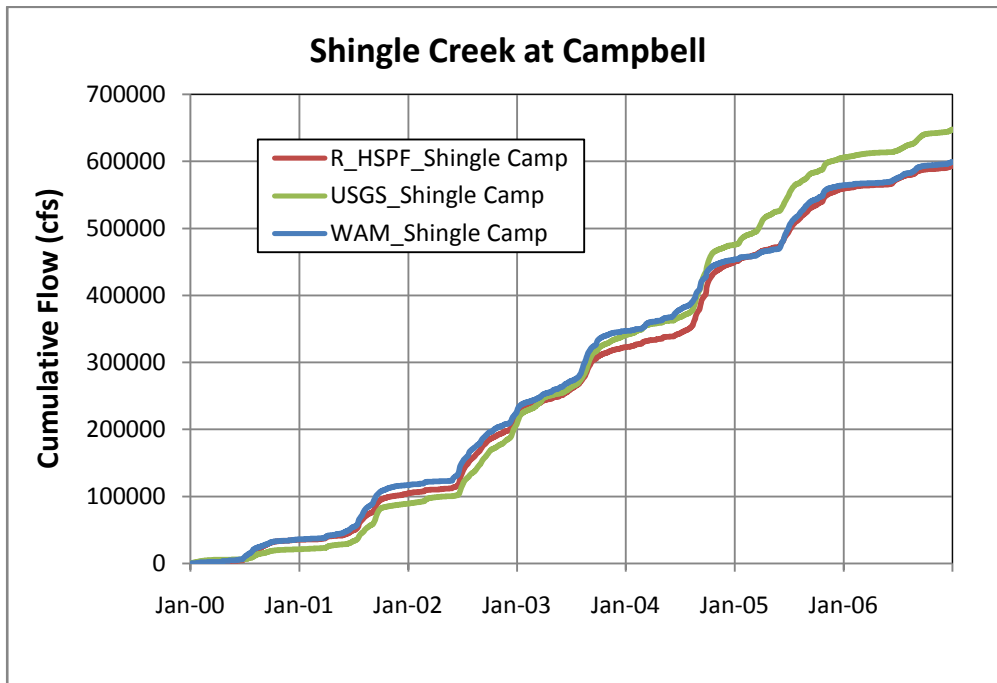


Figure D-10. Observed Versus Simulated Cumulative Daily Flows for Shingle Creek at Campbell, 2000–06

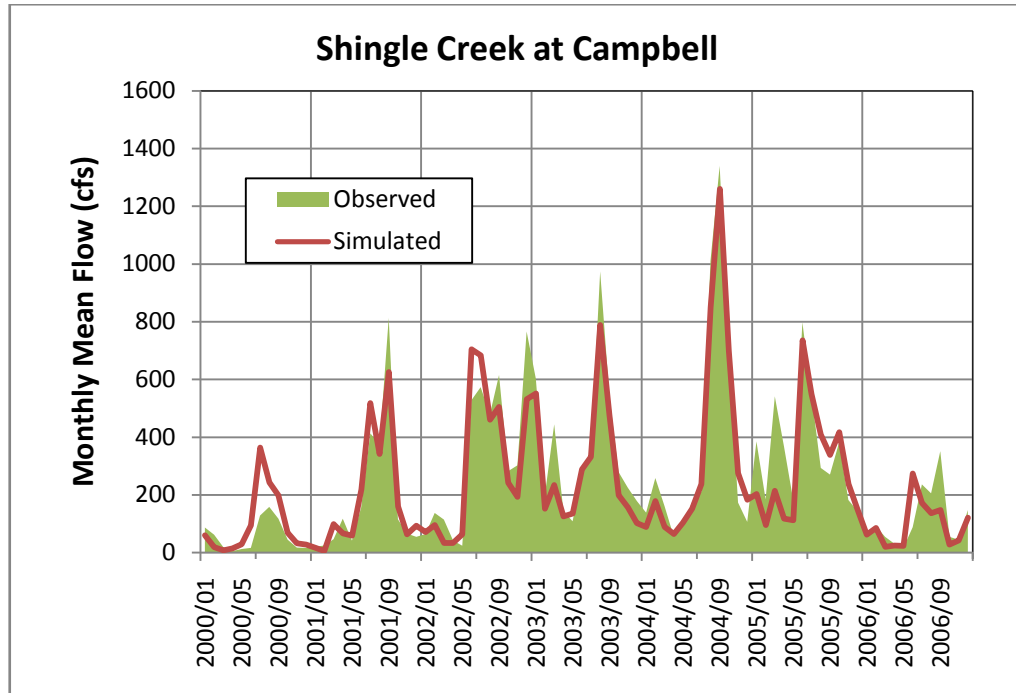


Figure D-11. Observed Versus Simulated Monthly Flows for Shingle Creek at Campbell, 2000–06

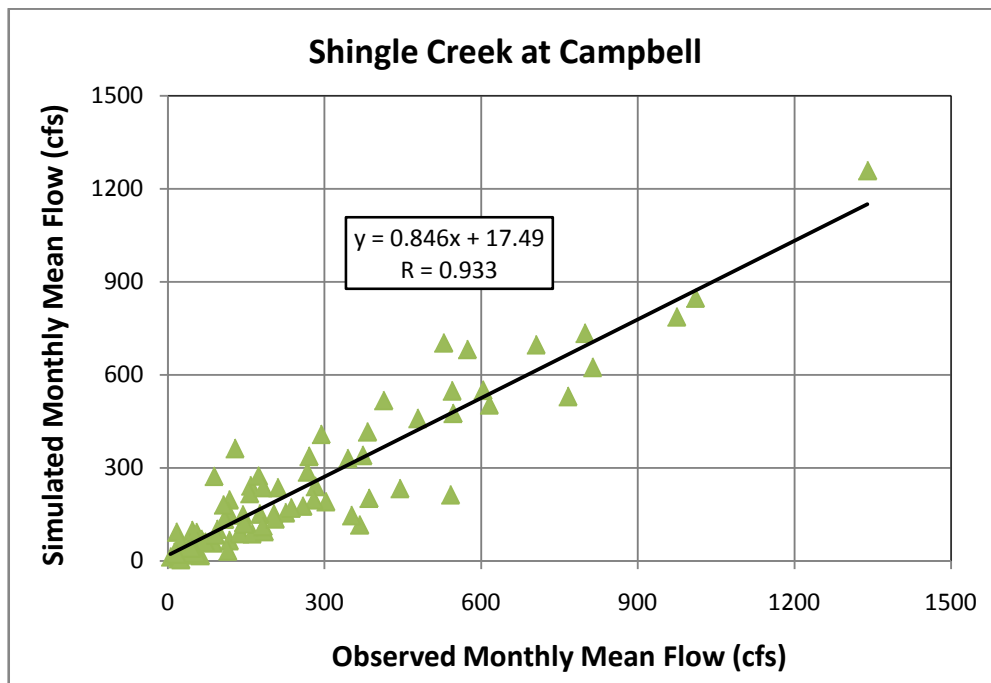


Figure D-12. Relationship Between Observed and Simulated Monthly Flows for Shingle Creek at Campbell, 2000–06

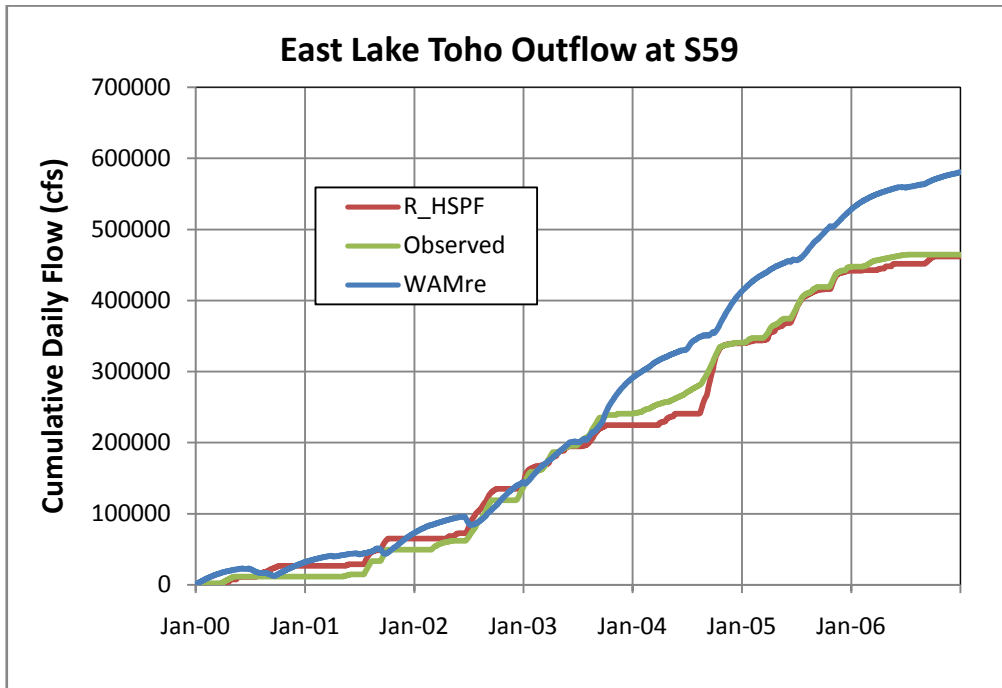


Figure D-13. Observed Versus Simulated Cumulative Daily Flows for East Lake Tohopekaliga Outflow at S59, 2000–06

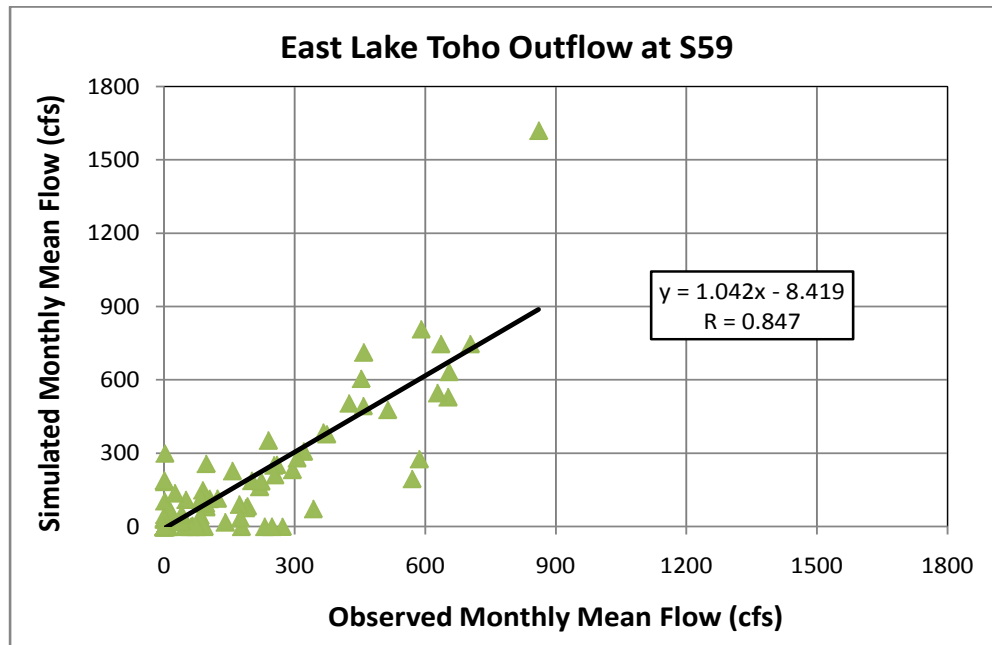


Figure D-14. Relationship Between Observed and Simulated Monthly Flows for East Lake Tohopekaliga Outflow at S59, 2000–06

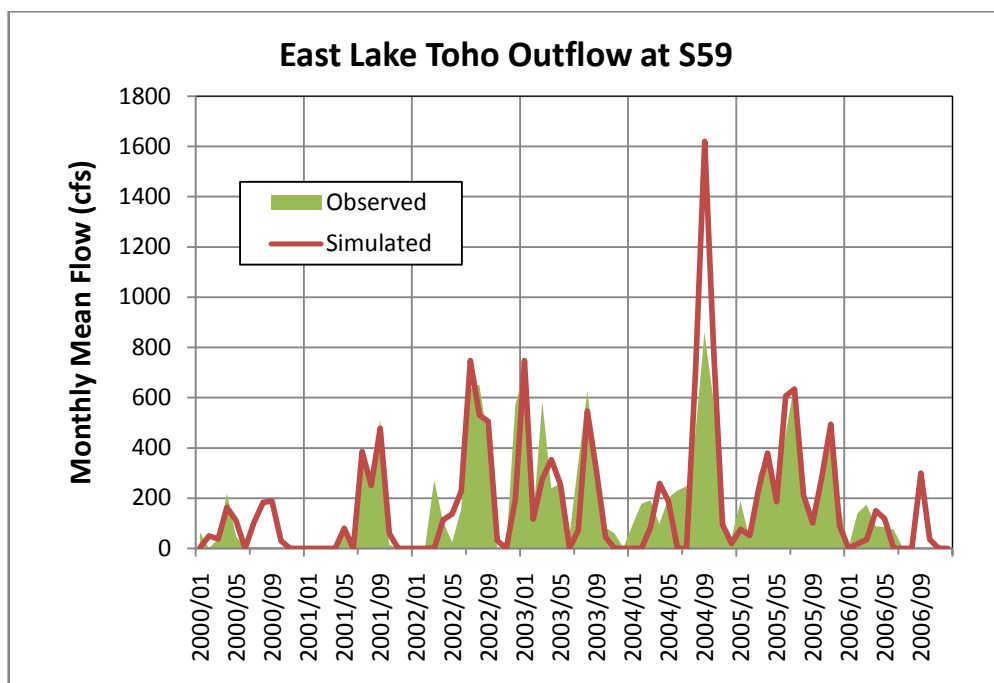


Figure D-15. Observed Versus Simulated Monthly Flows for East Lake Tohopekaliga Outflow at S59, 2000–06

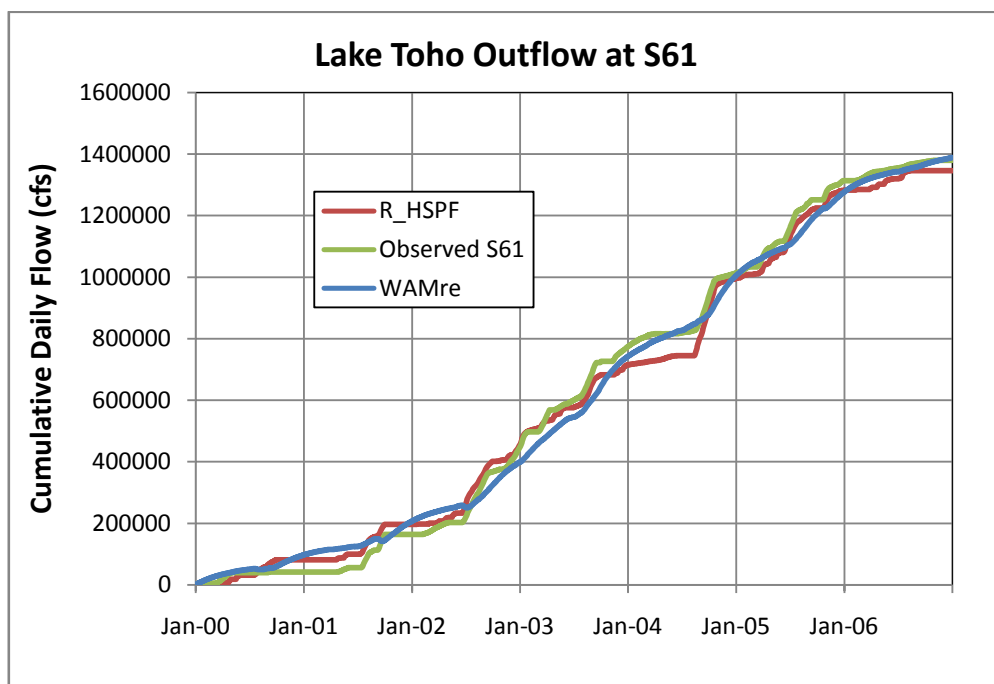


Figure D-16. Observed Versus Simulated Cumulative Daily Flows for Lake Tohopekaliga Outflow at S61, 2000–06

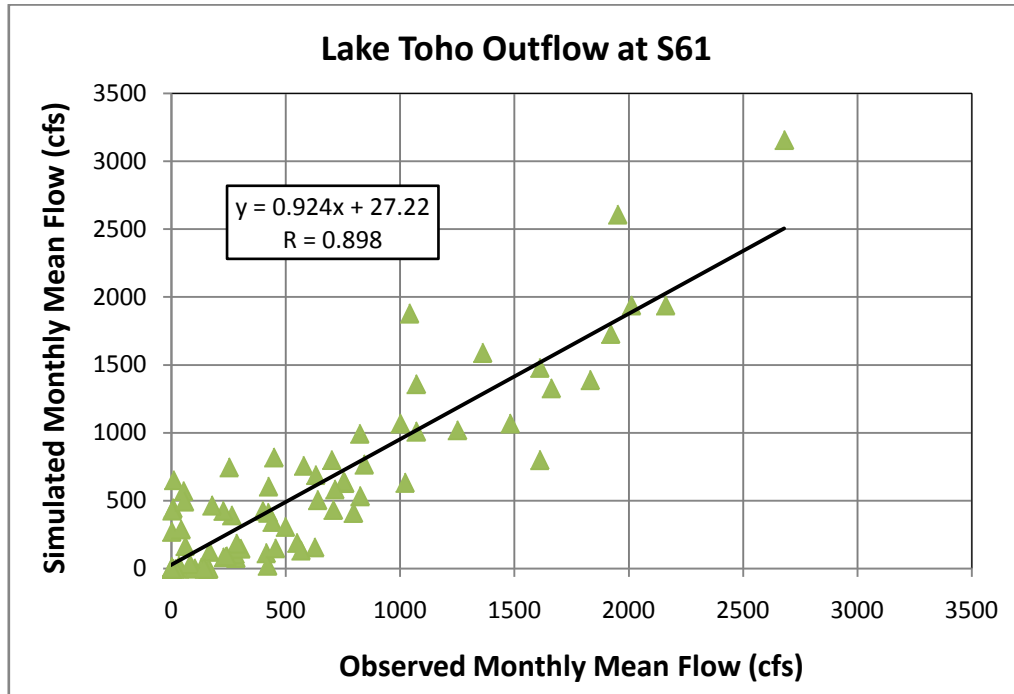


Figure D-17. Relationship Between Observed and Simulated Monthly Flows for Lake Tohopekaliga Outflow at S61, 2000–06

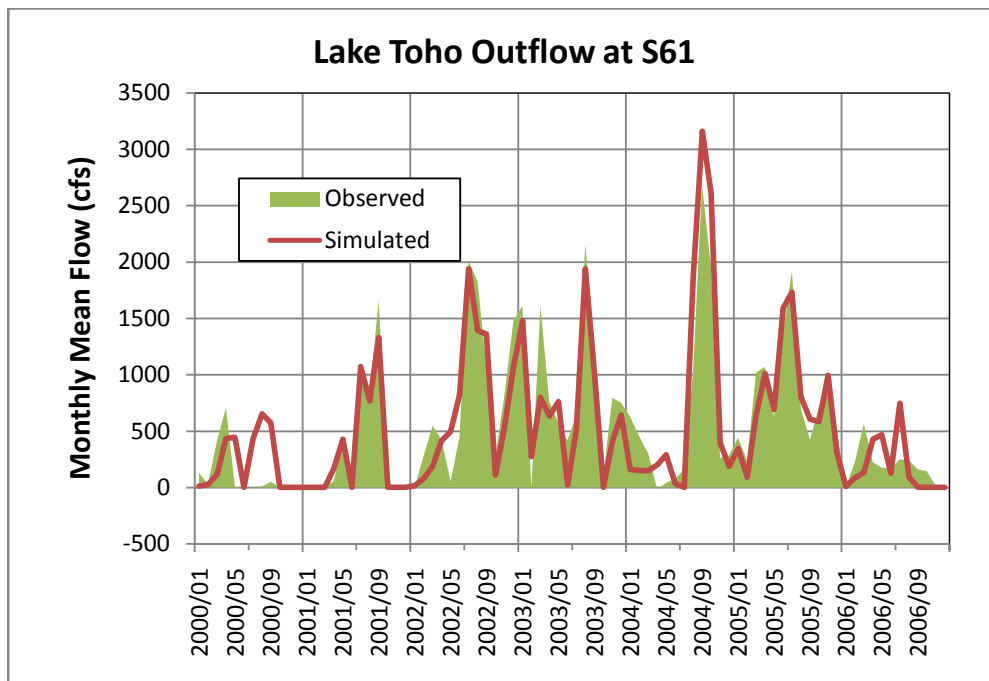


Figure D-18. Observed Versus Simulated Monthly Flows for Lake Tohopekaliga Outflow at S61, 2000–06

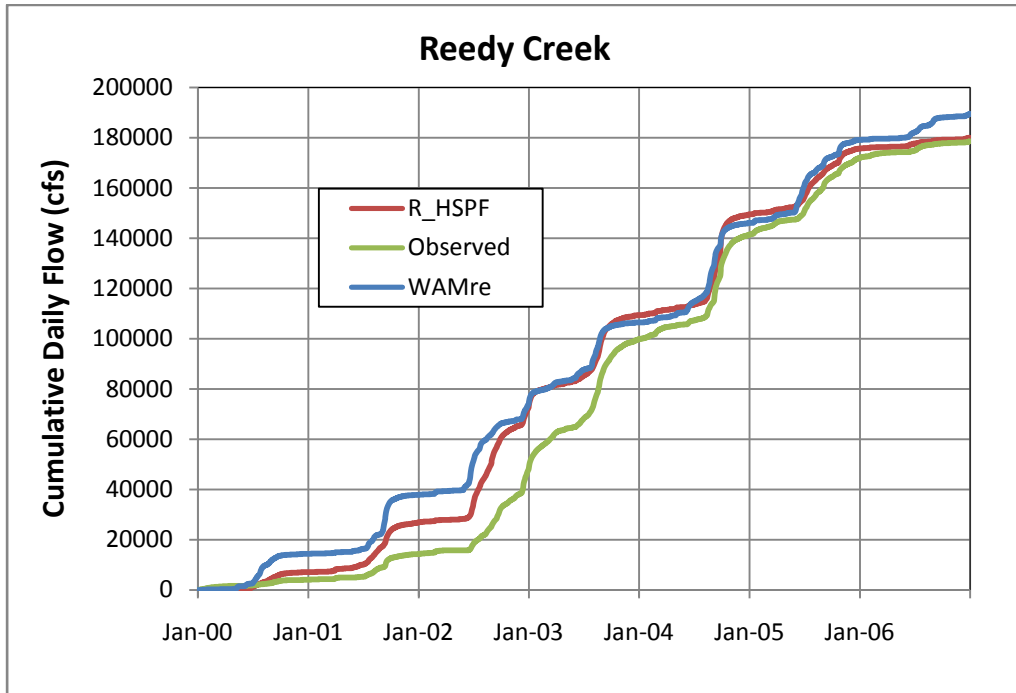


Figure D-19. Observed Versus Simulated Cumulative Daily Flows for Reedy Creek, 2000–06

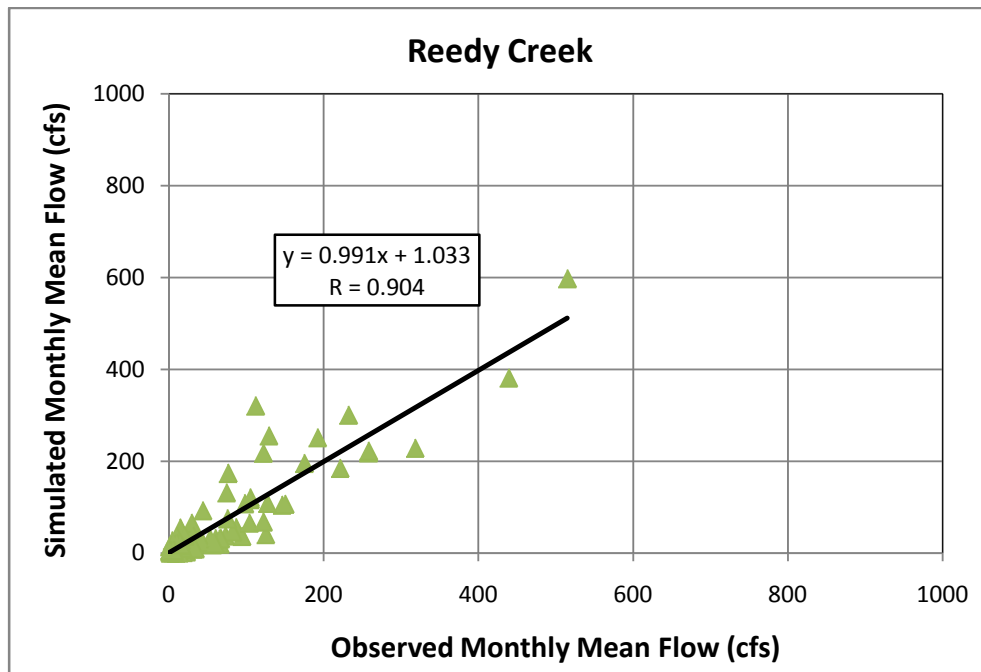


Figure D-20. Relationship Between Observed and Simulated Monthly Flows for Reedy Creek, 2000–06

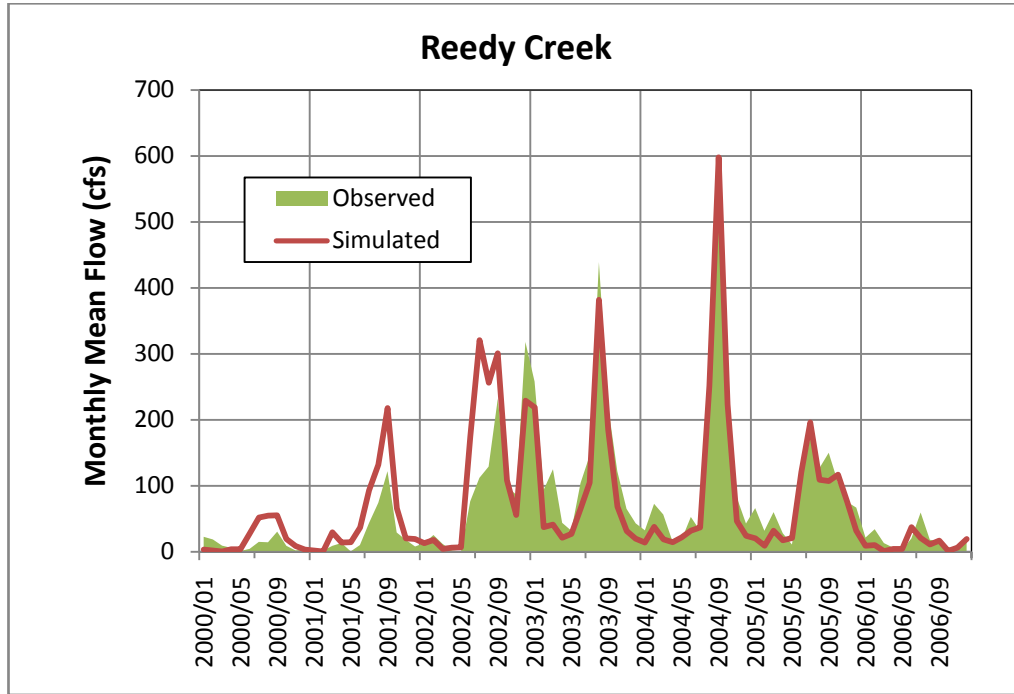


Figure D-21. Observed Versus Simulated Monthly Flows for Reedy Creek, 2000–06

Stage Calibration

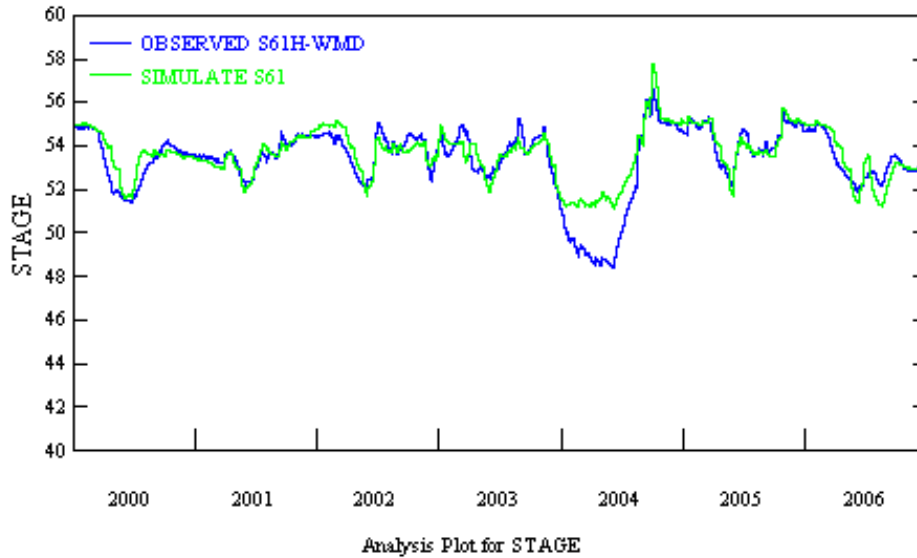


Figure D-22. Observed Versus Simulated Lake Elevation in Lake Tohopekaliga, 2000–06

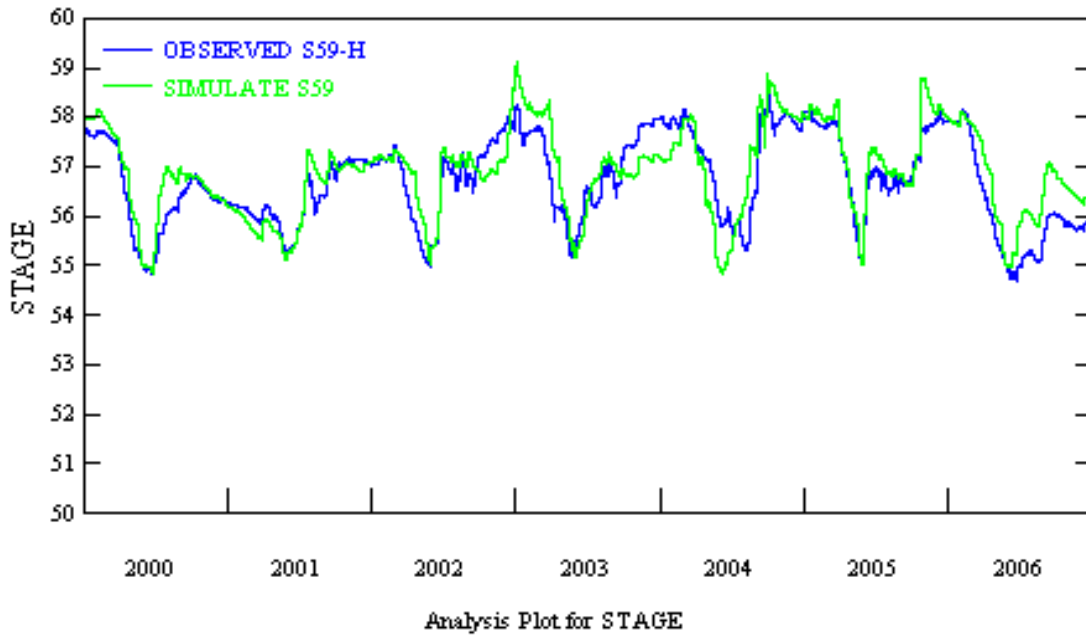


Figure D-23. Observed Versus Simulated Lake Elevation in East Lake Tohopekaliga, 2000–06

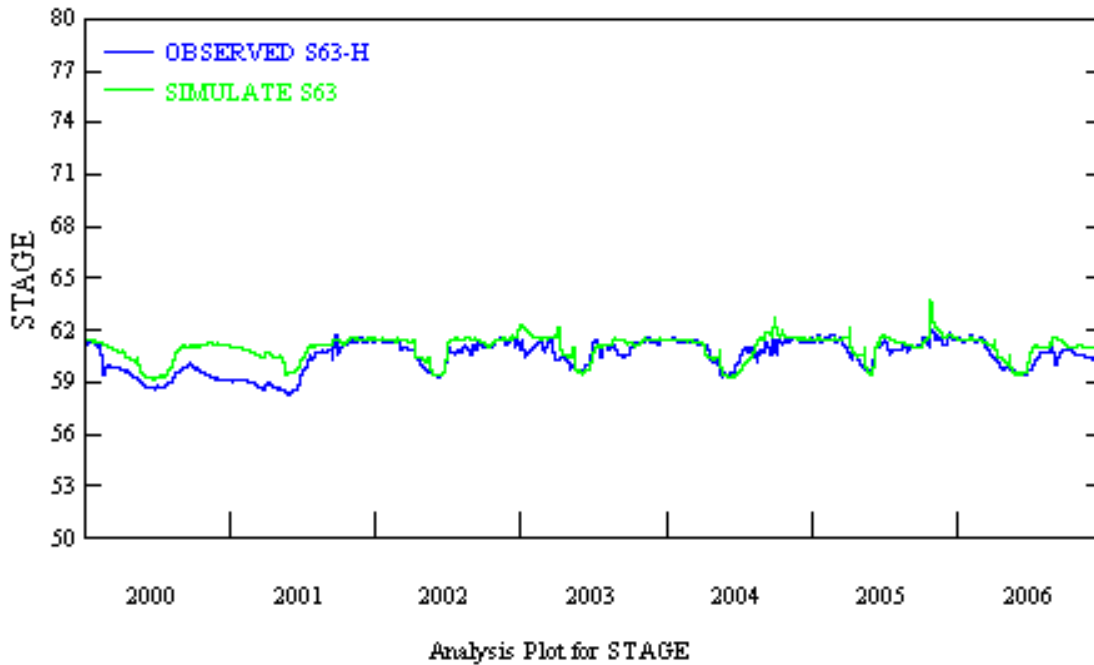


Figure D-24. Observed Versus Simulated Lake Elevation in Lake Gentry, 2000–06