Lake Lanier Model Scenarios

Description and Results for Nutrient Criteria Revisions

Georgia Environmental Protection Division
Atlanta, Georgia

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INTRODUCTION

Lake Lanier lies in the Upper Chattahoochee Watershed in North-Central Georgia, approximately 30 miles northeast of the city of Atlanta (Figure 1-1). Lake Lanier receives the majority of its inflow from the Chattahoochee and Chestatee Rivers. Downstream of Lake Lanier, the Chattahoochee River flows south to Apalachicola Bay in Florida. Lake Lanier is a US Army Corps of Engineers lake, and has been complete and operational since 1956. The Lake Lanier Dam impounds water from a 1,040 square mile drainage area, and has a normal pool elevation of 1,071 feet above mean sea level. Lake Lanier is considered a multi-use reservoir, and its uses include: flood control, hydropower generation, water supply, recreation, fish and wildlife management, and navigation. The Cities of Gainesville, Cornelia, Dahlonega, Demorest, Clarkesville, and White County depend on the Lake to meet the water usage needs of their populations. A total of 11 counties are located either completely or partially in the Lake Lanier Watershed, thus making the watershed very important to a wide-range of communities. Land cover in the drainage area is predominantly forested. However, there are dense residential and commercial areas in the watershed near Gainesville, Georgia (Figure 1-2). The area is located within the region of north Georgia that is experiencing rapid development and population growth from the expanding Atlanta Metropolitan Area. It is this growth that is posing a significant threat to the environmental quality and ultimate economic sustainability of the water resources of the area. There will be an ever-increasing need to balance water resources protection while allowing for smart economic development in the watershed.

Lake Lanier is the largest lake in Georgia, with a volume of 2,064,600 acre-feet at full pool. Water quality standards were established for the lake in 1999. Its designated use is Recreation and Drinking Water and the chlorophyll *a* and total nitrogen criteria for the lake are as follows:

> Chlorophyll a: For the months of April through October, the average of monthly mid-channel photic zone composite samples shall not exceed the chlorophyll a concentrations at the locations listed below more than once in a five-year period:
>
> 1. Upstream from the Buford Dam forebay — 5 µg/L
> 2. Upstream from the Flowery Branch confluence — 5 µg/L
> 3. At Browns Bridge Road (State Road 369) — 5 µg/L
> 4. At Bolling Bridge (State Road 53) on Chestatee River — 10 µg/L
> 5. At Lanier Bridge (State Road 53) on Chattahoochee River — 10 µg/L
>
> Total Nitrogen: Not to exceed 4 mg/L as nitrogen in the photic zone.

Lake Lanier has not met the chlorophyll *a* standards at three of these locations. The State of Georgia recently completed TMDL modeling to address these exceedances. When the preliminary TMDL reductions were applied, the growing season average chlorophyll *a* levels at Browns Bridge and Flowery Branch were still occasionally above 5.0 µg/L. Therefore, EPD is reevaluating these chlorophyll *a* criteria at these locations.

Two computer models were developed for Lake Lanier and its watershed. The models included a watershed model, an in-lake hydrodynamic model, and an in-lake water quality model. The watershed model of Lake Lanier was developed using the Loading Simulation Program in C++ (LSPC). This model includes all point sources that have a permitted discharge of 0.1 MGD or greater within the watershed. The watershed model simulates the effects of surface runoff on both water quality and flow and was calibrated to data collected from 2001 through 2007. The results of this model were used as tributary flow inputs in the hydrodynamic model, Environmental Fluid Dynamics Code (EFDC). EFDC was used to simulate the transport of water within the lake, flows into and out of Lake Lanier, the fate and transport of nutrients within the lake, and the uptake by phytoplankton. The growth and death of phytoplankton was measured through a surrogate parameter called chlorophyll *a*. The EFDC model was calibrated to nutrient and chlorophyll *a* concentrations measured in the lake during the 2001 through 2007

growing seasons. The setup, calibration and validation of these computer models are documented in the following two reports:

- *Watershed Hydrology and Water Quality Modeling Report for the Chattahoochee River Watershed, Georgia – REV2 (Tetra Tech 2011)*
- *Hydrodynamic and Water Quality Modeling Report for Lake Lanier, Georgia – REV4 (Tetra Tech 2012)*

Once the models were calibrated for Lake Lanier and its watershed, various scenarios were run and analyzed. The following section describes these scenarios.

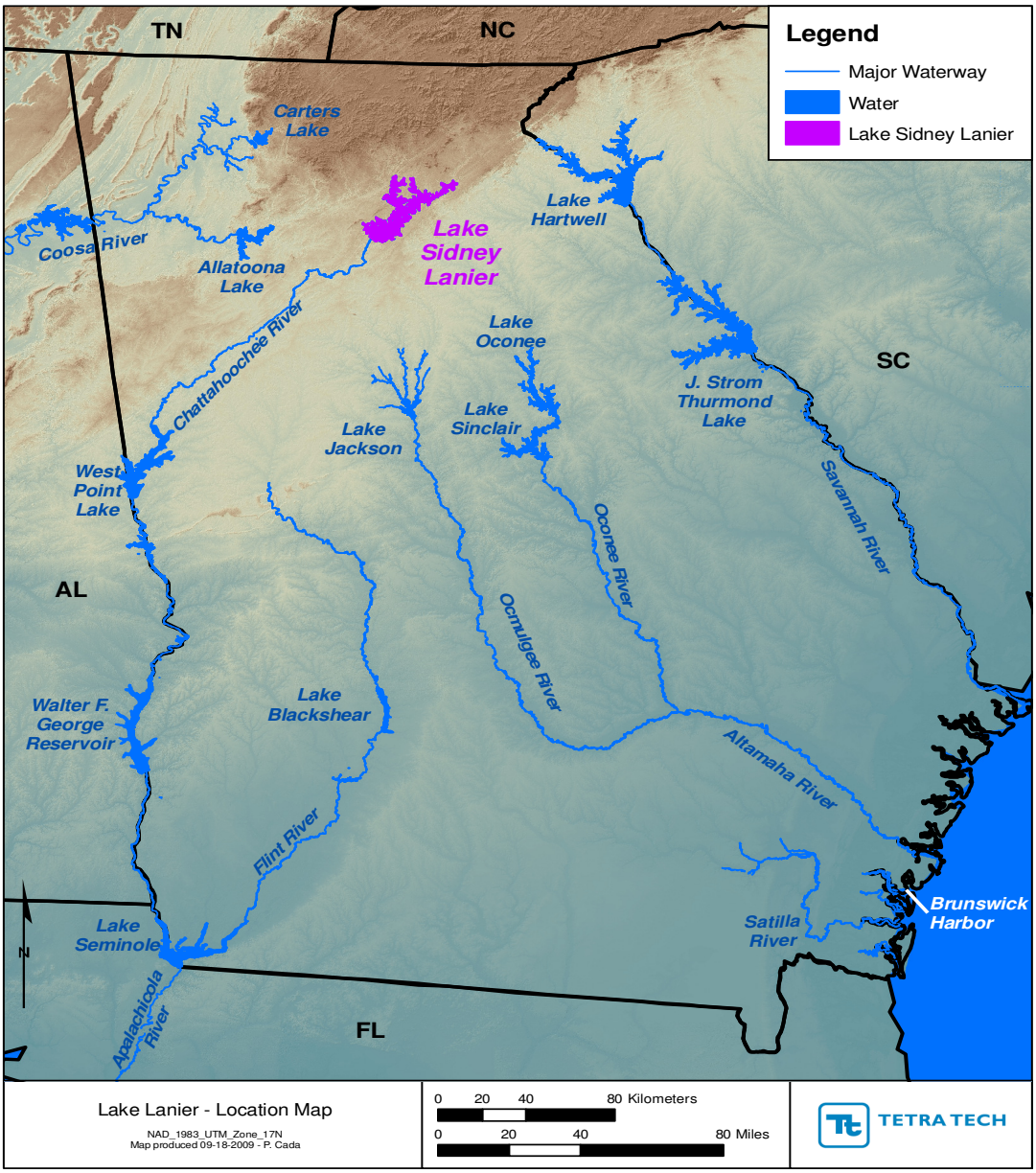

Figure 1-1 Location of Lake Lanier

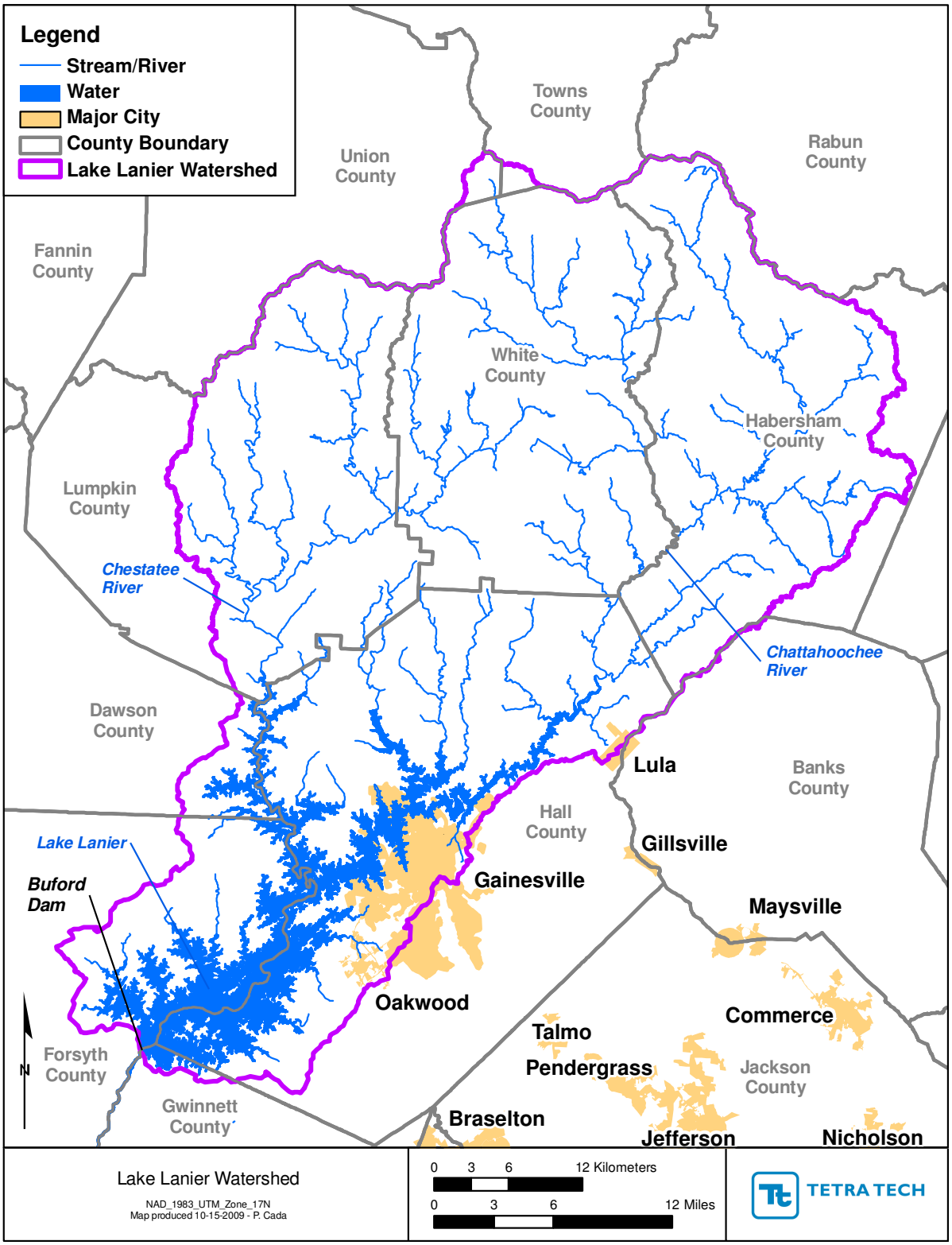

Figure 1-2 Lake Lanier Watershed

2.0 DESCRIPTION OF SCENARIOS

Eight scenarios were run using the models developed for the Lake Lanier TMDL to explain the sources and contributions of chlorophyll *a* levels observed, and for use in revising the chlorophyll *a* and nutrient criteria. For each scenario, both hydrology and water quality outputs from the LSPC model were examined at two tributary locations in the Lake Lanier Watershed (Figure 2-1 and Table 2-1). The outputs were examined from January 1, 2001 through December 31, 2007. Watershed flows were evaluated based on monthly and annual average flows and percentiles of daily average flows. Watershed water quality was evaluated based on annual and monthly loading, annual and monthly concentrations, and percentiles of daily average concentrations. Watershed flows and water quality were then input into the EFDC model. The outputs for the EFDC model were evaluated at ten locations (Figure 2-2 and Table 2-2) around Lake Lanier from 2001 through 2007. Results for chlorophyll *a* were evaluated based on growing season averages (April 1 through October 31). A short description of each scenario is presented below.

2.1 Scenario 1A (Calibration)

Scenario 1A was performed using the calibrated Lake Lanier Watershed hydrology and water quality model (LSPC) and the calibrated Lake Lanier model (EFDC). The calibrated LSPC model was run using monthly flow data for watershed water withdrawals, as well as daily and/or monthly flow and water quality data from point source discharges. If no data were available for the point source discharges, values were input at the permitted limits, or in some cases values were assumed if no permit limit existed.

2.2 Scenario 1B (Current Permit)

Scenario 1B was performed using the calibrated (Scenario 1A) Lake Lanier Watershed hydrology and water quality model (LSPC) and the calibrated Lake Lanier model (EFDC) as a starting point. Point source discharges and water withdrawals were then input at their current permitted limits.

2.3 Scenario 1C (TMDL)

Scenario 1C was performed by taking Scenario 1B and reducing both the urban nutrient loading and the agricultural nutrient loading until all five lake water quality standard stations were in compliance with the chlorophyll *a* water quality standards.

To meet the chlorophyll *a* criteria in the upper portions of the lake at Lanier Bridge, a reduction in the nutrient loading of two point sources located in the Upper Chattahoochee Watershed were made, followed by a reduction in the agricultural nutrient loading. An urban nutrient loading reduction was then made to bring the Flowery Branch site into compliance. In the end, a 70% reduction in the urban nutrient loading and a 40% reduction in the agricultural nutrient loading were needed. In addition, failing septic tanks were reduced by 50%. However, the Browns Bridge and Flowery Branch sites were still not in compliance, which will be discussed later.

2.4 Scenario 1D (All Forest)

Scenario 1D was an all forested scenario. This scenario was performed using the calibrated (Scenario 1A) Lake Lanier Watershed hydrology and water quality model (LSPC) and the calibrated Lake Lanier model (EFDC) as a starting point. Point source discharges, water withdrawals, and septic tanks were then removed and all landuse was converted to forest.

2.5 Scenario 1E (No Point Sources – Current Landuse)

Scenario 1E was a No Point Source scenario. This scenario was performed using the calibrated (Scenario 1A) Lake Lanier Watershed hydrology and water quality model (LSPC) and the calibrated Lake Lanier model (EFDC) as a starting point. Point source discharges and water withdrawals were then removed.

2.6 Scenario 1F (2035 Permit and Landuse)

Scenario 1F was a 2035 Point Source and Landuse scenario. This scenario was performed using the calibrated (Scenario 1A) Lake Lanier Watershed hydrology and water quality model (LSPC) and the Lake Lanier model (EFDC), but with landuse from year 2040. The 2040 Georgia Landuse Trends (GLUT) dataset was obtained from the University of Georgia. Point source discharges, withdrawals, and septic tanks were set at either the 2035 flows outlined in the Metro District Plan or 2040 flows forecasted for the State Water Plan.

2.7 Scenario 1G (2035 Permit and Landuse with the TMDL)

Scenario 1G was a 2035 Point Source and Landuse scenario with the TMDL reductions. This scenario was performed using the Scenario 1F Lake Lanier Watershed hydrology and water quality model (LSPC) and the Lake Lanier model (EFDC) as a starting point. A TMDL reduction of 70% in the urban nutrient load, 40% in the agricultural nutrient load, and 50% in failing septic tanks, along with a load reduction from two point sources, was applied.

2.8. Scenario IH (Total Nitrogen Increase)

Scenario 1H was performed using Scenario 1C (TMDL) and increasing the nitrogen load to the lake to a growing season average of 4 mg/L.

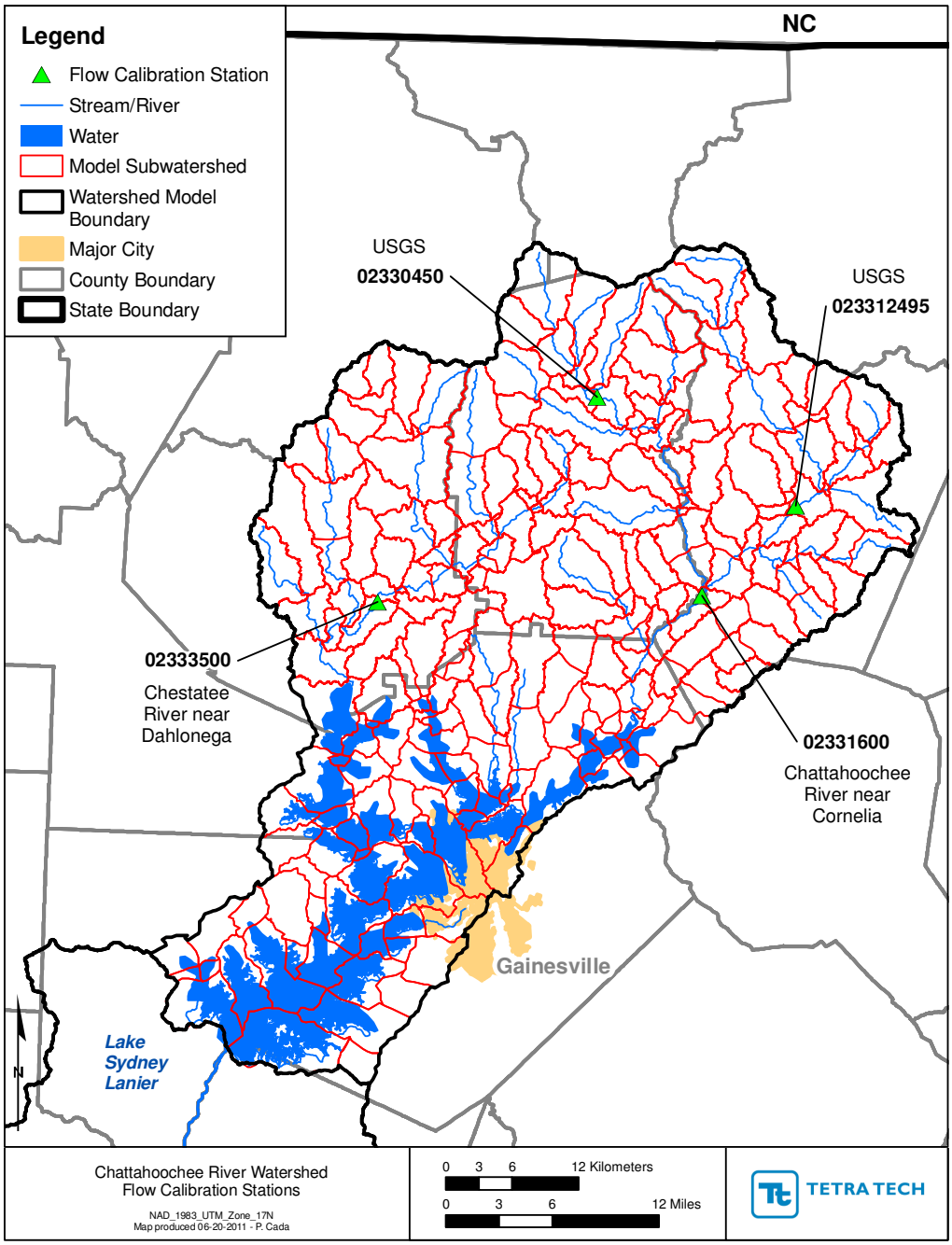

Figure 2-1 Lake Lanier Watershed Assessment Sites

Table 2-1 Summary of Lake Lanier Watershed Assessment Sites

Station Name	Station Number	Drainage Area (Acres)	LSPC Subbasin
Chestatee River Near Dahlonega, GA	02333500	97,920	1051
Chattahoochee River Near Cornelia, GA	02331600	201,600	1141

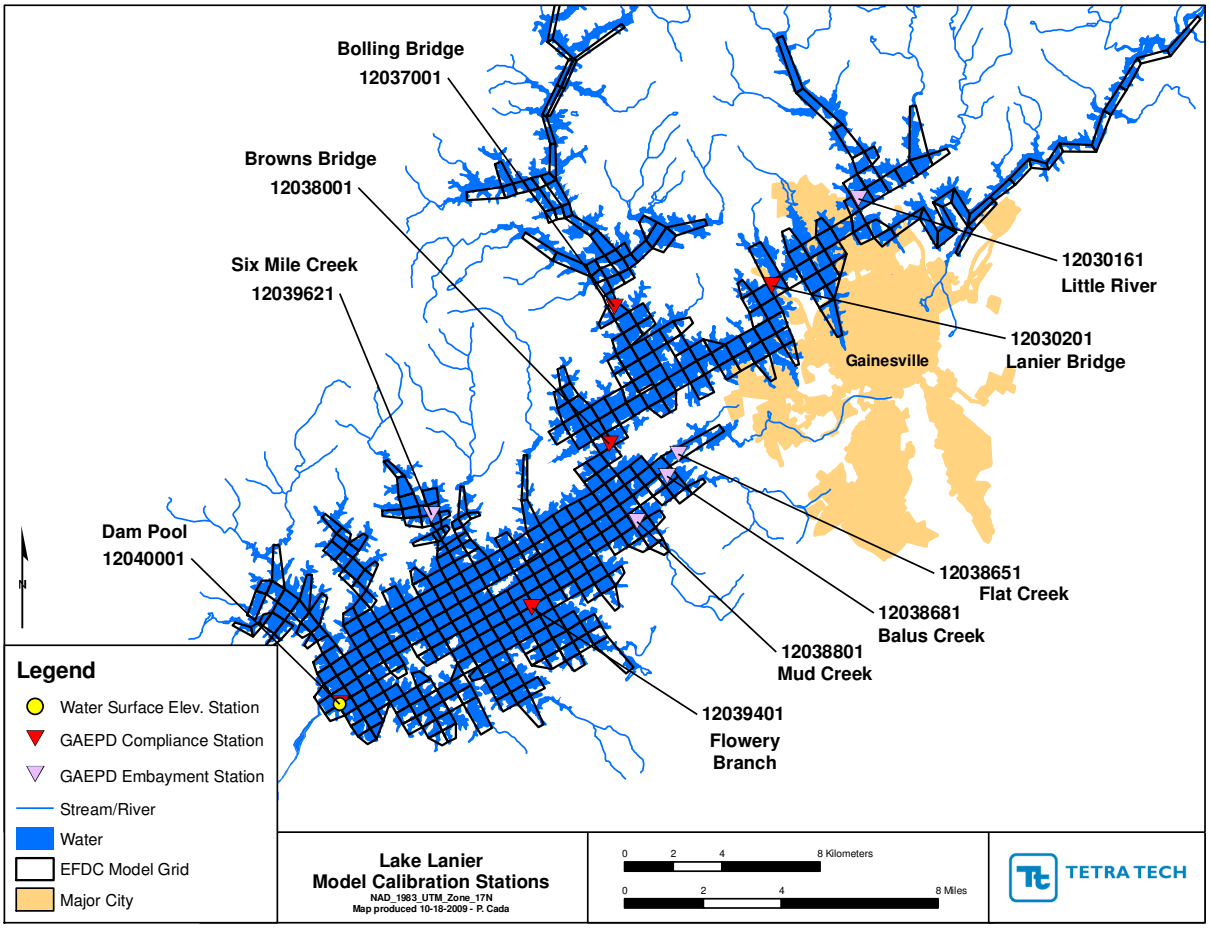

Figure 2-2 Lake Lanier Evaluation Sites

Table 2-2 Summary of Lake Lanier Evaluation Sites

Station Name	Station Number	EFDC Cell		Layers
		I-Value	J-Value	
Lake Lanier Dam Pool	12040001	34	10	10
Lake Lanier Upstream from Flowery Branch	12039401	36	24	8
Lake Lanier at Browns Bridge	12038001	28	34	8
Lake Lanier at Bolling Bridge	12037001	21	39	6
Lake Lanier at Lanier Bridge	12030201	25	48	6
Lake Lanier at Little River Embayment	12030161	23	55	5
Lake Lanier at Flat Creek Embayment	12038651	32	37	4
Lake Lanier at Balus Creek Embayment	12038681	33	36	5
Lake Lanier at Mud Creek Embayment	12038801	34	33	5
Lake Lanier at Six Mile Creek Embayment	12039621	8	25	6

3.0 ANALYSIS OF SCENARIOS

3.1 Chlorophyll *a* Standards

The watershed and lake models were used to predict the effect of various nutrient loads and sources on the lake chlorophyll *a* levels. The data indicate there were chlorophyll *a* violations at Lanier Bridge, Browns Bridge, Flowery Branch, and the Dam Pool. The models were then run at full permitted loads to predict the chlorophyll *a* levels in the lake, and again there were chlorophyll *a* violations at these same four locations (see Figures 3-1 through 3-5). When the preliminary TMDL reductions were applied, which included the reduction of two point sources in the Upper Chattahoochee Watershed, a 70% reduction in the urban nutrient load, a 40% reduction in the agricultural nutrient load, and a 50% reduction in failing septic tanks, the growing season average chlorophyll *a* levels at Browns Bridge and Flowery Branch were still occasionally above 5.0 µg/L. For example, in 2003 and 2005, the Browns Bridge growing season average chlorophyll *a* concentrations were 5.48 and 5.16 µg/L, respectively (Figure 3-3). In 2003, the Flowery Branch growing season average chlorophyll *a* was 5.43 µg/L (Figure 3-4). Technically, there are no exceedances of the standard with the preliminary TMDL based on significant figures. However, it should be noted that the calibrated data for the Browns Bridge site were below the measured data, which may be related to model uncertainty. Therefore, even if the TMDL reductions are applied, the chlorophyll *a* levels at this and other stations may still be above the predicted TMDL levels. These results also indicate there is no margin of safety with regards to the current chlorophyll *a* standards at these two stations. It's also worth noting that the Browns Bridge and Flowery Branch stations are transitional zones between the upper portions of the lake that are more riverine and the deeper portions of the lake at the Dam Pool. These results indicate that the chlorophyll *a* criteria for these two stations need to be adjusted.

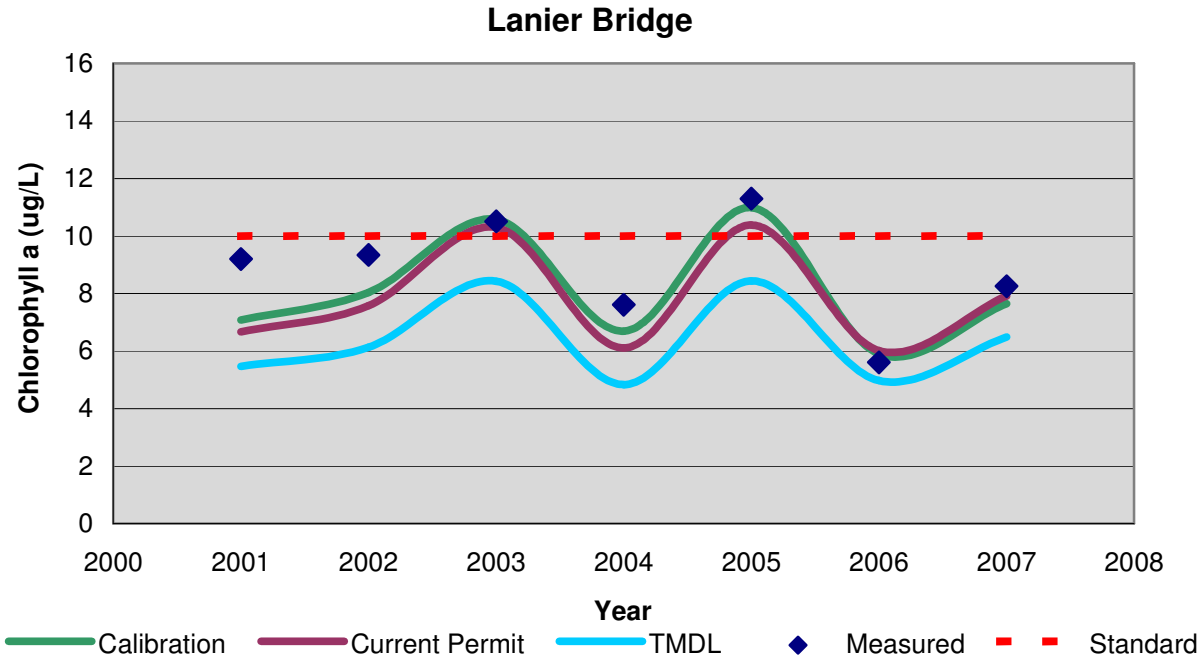

Figure 3-1 Lanier Bridge Chlorophyll *a* Levels from Model Runs 1A (Calibration), 1B (Current Permit), and 1C (TMDL) in relation to the Current Standard and Measured Values

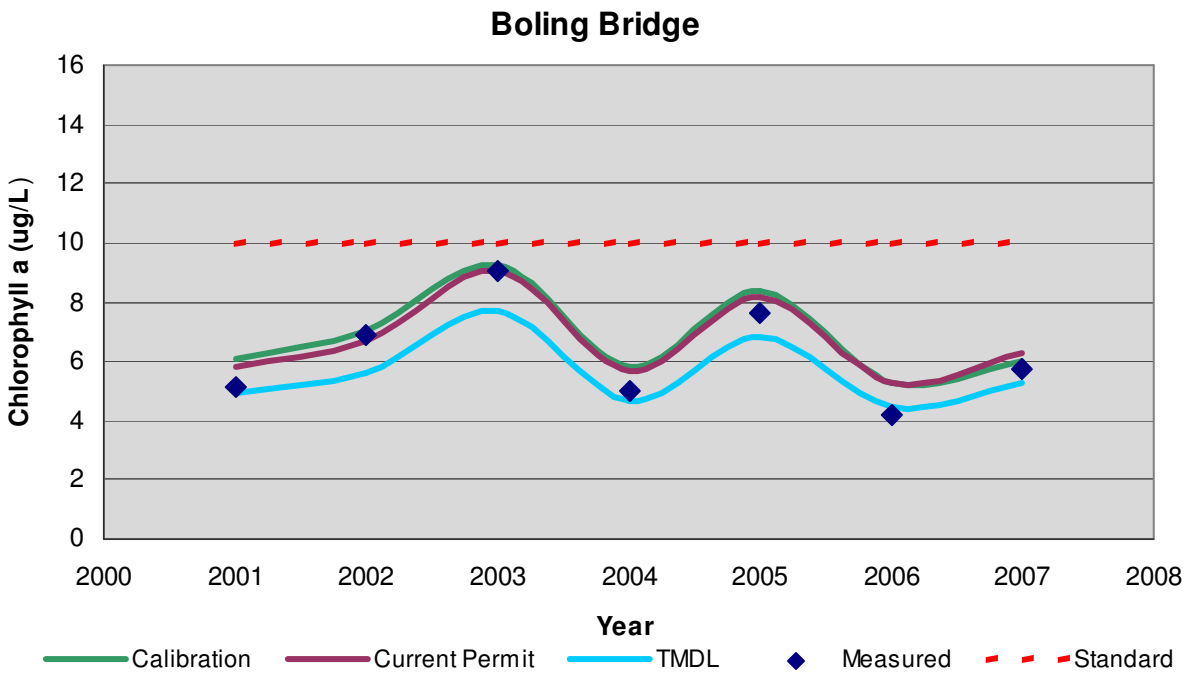

Figure 3-2 Boling Bridge Chlorophyll *a* Levels from Model Runs 1A (Calibration), 1B (Current Permit), and 1C (TMDL) in relation to the Current Standard and Measured Values

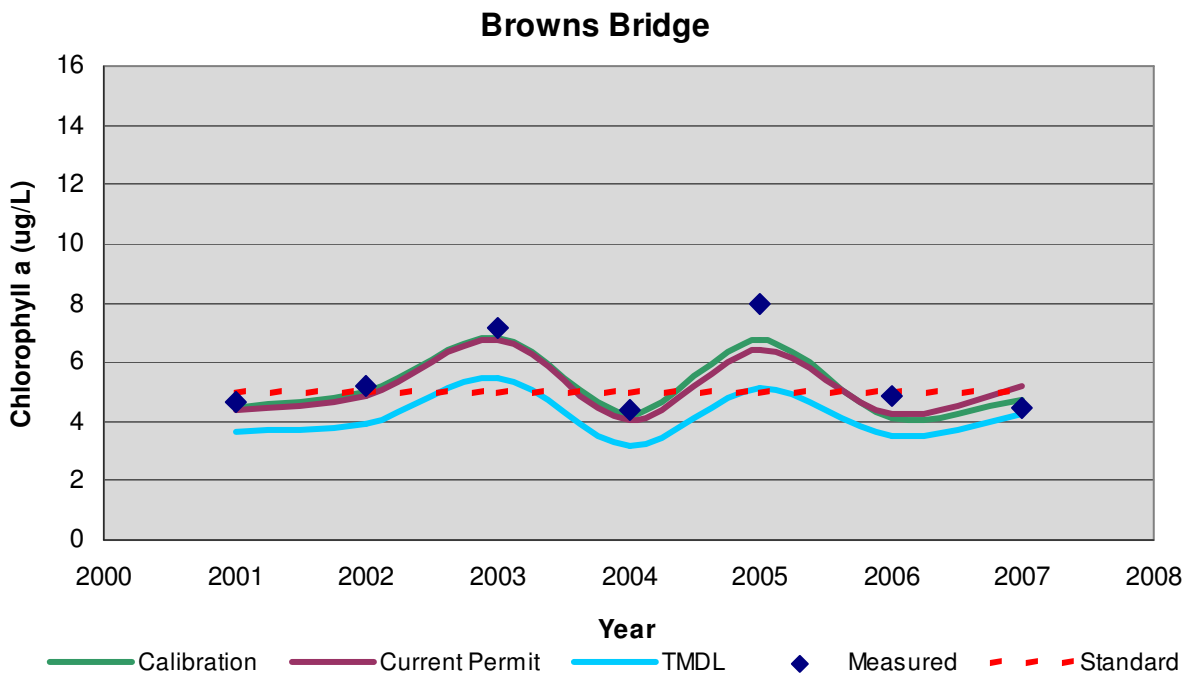

Figure 3-3 Browns Bridge Chlorophyll *a* Levels from Model Runs 1A (Calibration), 1B (Current Permit), and 1C (TMDL) in relation to the Current Standard and Measured Values

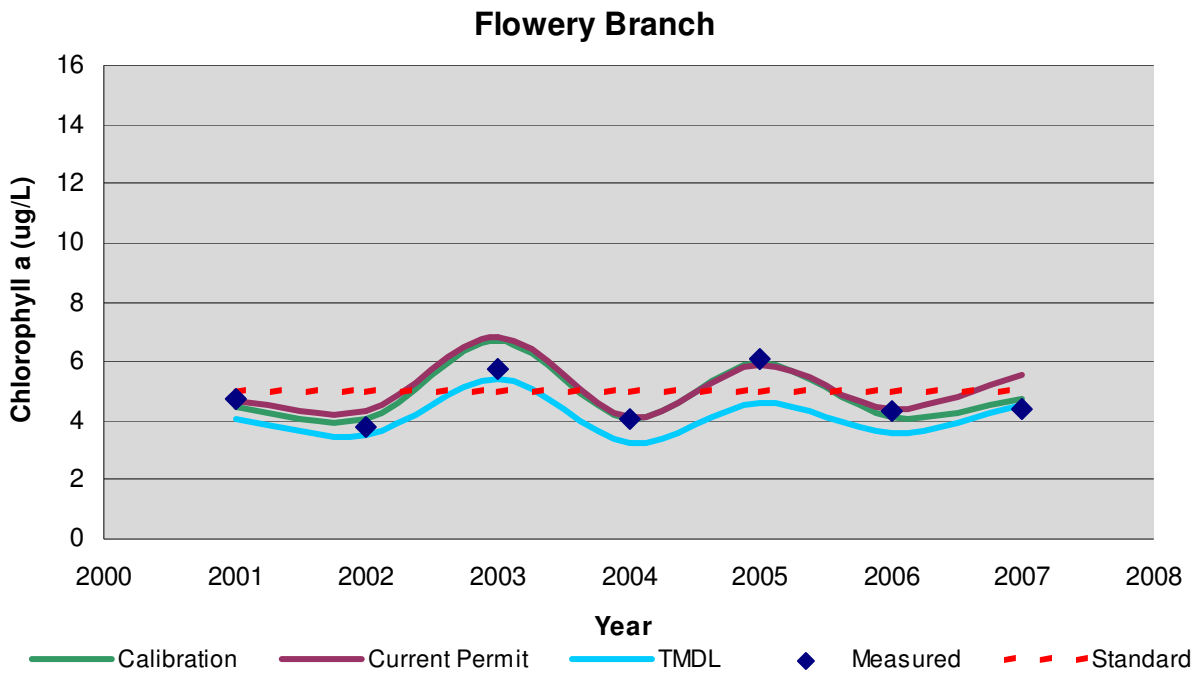

Figure 3-4 Flowery Branch Chlorophyll *a* Levels from Model Runs 1A (Calibration), 1B (Current Permit), and 1C (TMDL) in relation to the Current Standard and Measured Values

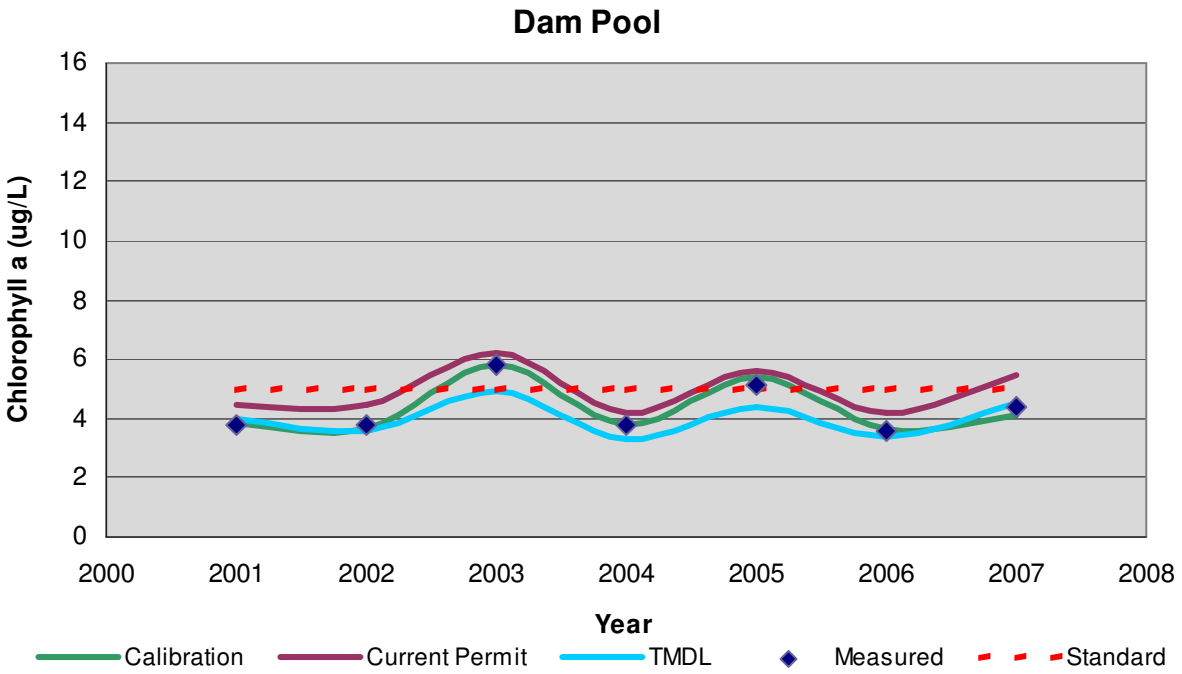

Figure 3-5 Dam Pool Chlorophyll *a* Levels from Model Runs 1A (Calibration), 1B (Current Permit), and 1C (TMDL) in relation to the Current Standard and Measured Values

In order to determine the appropriate chlorophyll *a* criteria, the watershed was modeled as if it were all forested to see what the 'natural' growing season chlorophyll *a* levels are. This was done by converting all landuse in the Lake Lanier watershed to forest (Scenario 1D). Figure 3-6 provides the modeled growing season average concentrations for each of the monitoring stations.

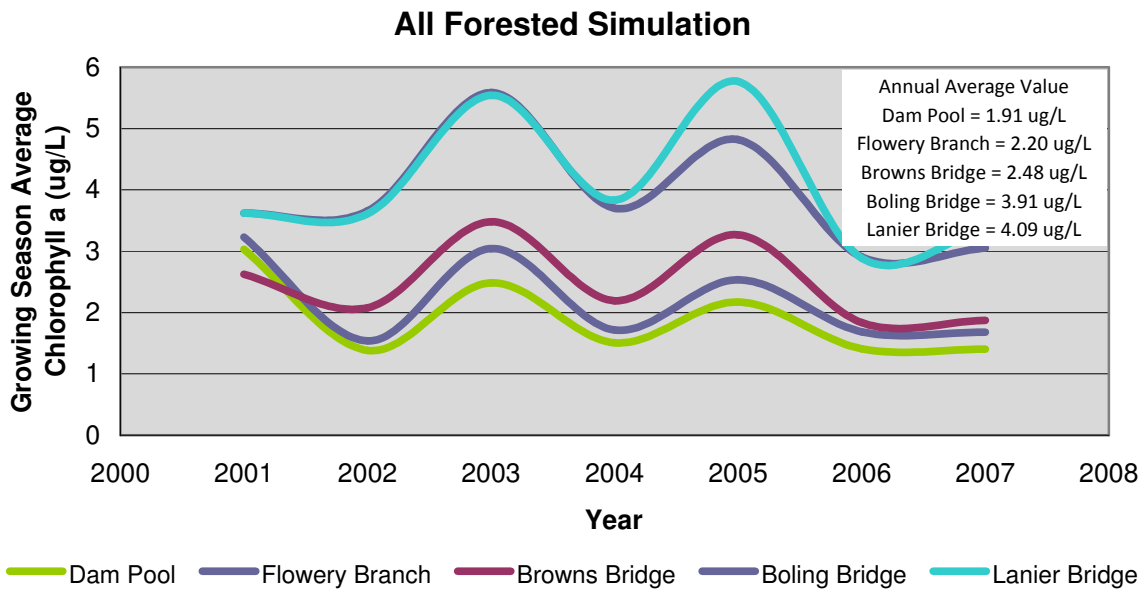

Figure 3-6 Chlorophyll *a* Levels from Model Run 1D (All Forested)

Table 3-1 provides the current chlorophyll *a* criteria for each monitoring station, as well as the average of the annual growing season average chlorophyll *a* levels for each station from the all forested model scenario (Scenario 1D). The all forested model results represents 'natural' chlorophyll *a* concentrations at each station. The all forested chlorophyll *a* levels were then normalized using the Dam Forebay chlorophyll average (i.e., 1.91), allowing the chlorophyll levels ratios at each monitoring site to be determined. These ratios, or normalization factors, are then used to determine the appropriate chlorophyll *a* criteria for each station by multiplying them by the current Dam Pool criteria of 5 µg/L. It should be noted that any value (in Column 2) could be used to determine the ratio of 'natural' chlorophyll at each station relative to the current criteria. Based on these results, the Flowery Branch and Browns Bridge chlorophyll *a* criteria should be revised to 6 and 7 µg/L, respectively. These criteria are still protective of the Recreation and Drinking Water designated uses.

Table 3-1 Proposed Chlorophyll Criteria Based on Chlorophyll Levels from the All Forested (1D) Scenario

Monitoring Station	Current Chlorophyll Criteria (µg/L)	Average of the Growing Season Chlorophyll Averages from the All Forested Scenario (µg/L)	Normalized Chlorophyll Factor	Proposed Chlorophyll Criteria (µg/L)
Dam Forebay	5	1.91	1.0	5
Flowery Branch	5	2.20	1.2	6
Browns Bridge	5	2.48	1.3	7
Boling Bridge	10	3.91	2.0	10
Lanier Bridge	10	4.09	2.1	10

These proposed criteria were then evaluated with both 2040 landuse data and point source flows from either the 2035 Metro District Plan or the State Water Plan (Scenario 1F). The TMDL was then applied to these future landuse changes and point sources (Scenario 1G). These model results indicate that future landuse and permit loads with the TMDL reductions will still meet the proposed criteria (Figures 3-7 through 3-11).

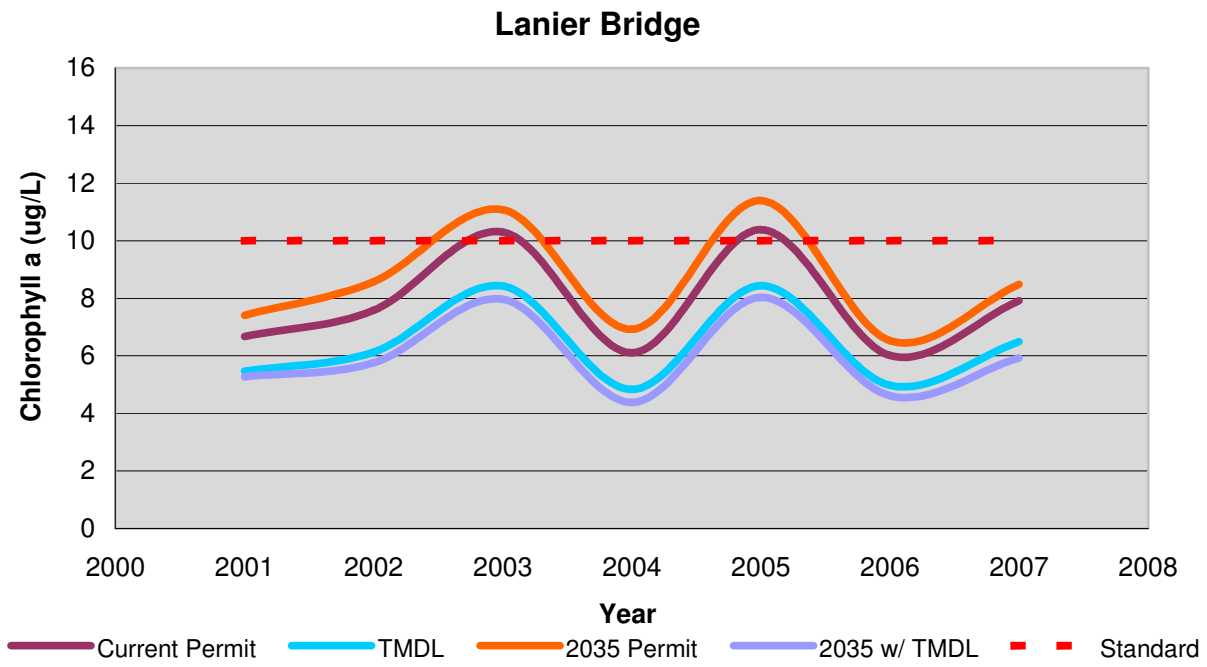

Figure 3-7 Current (1B and 1C) and 2035 Scenarios (1F and 1G) at Lanier Bridge

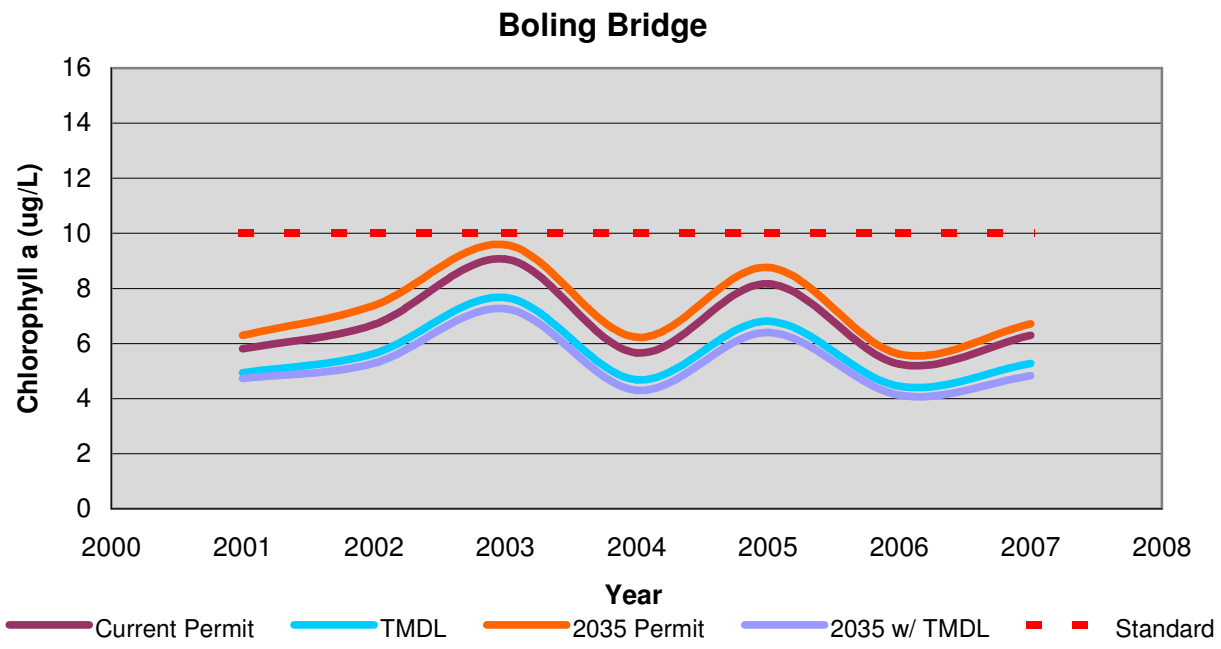

Figure 3-8 Current (1B and 1C) and 2035 Scenarios (1F and 1G) at Boling Bridge

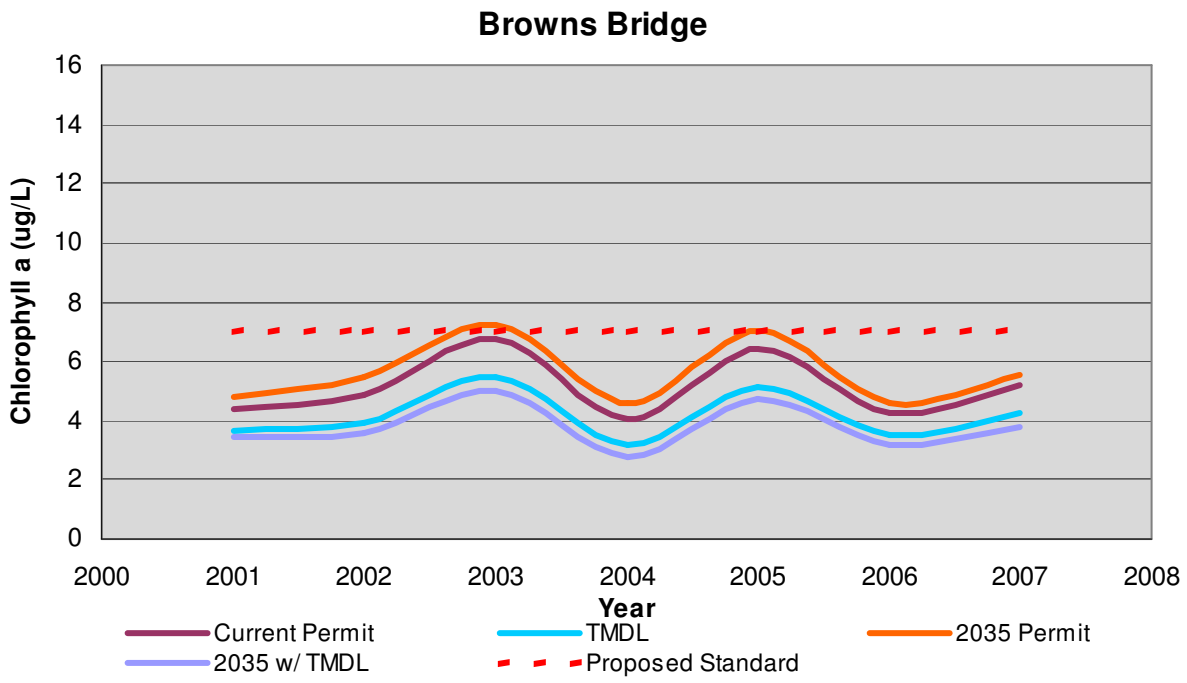

Figure 3-9 Current (1B and 1C) and 2035 Scenarios (1F and 1G) at Browns Bridge

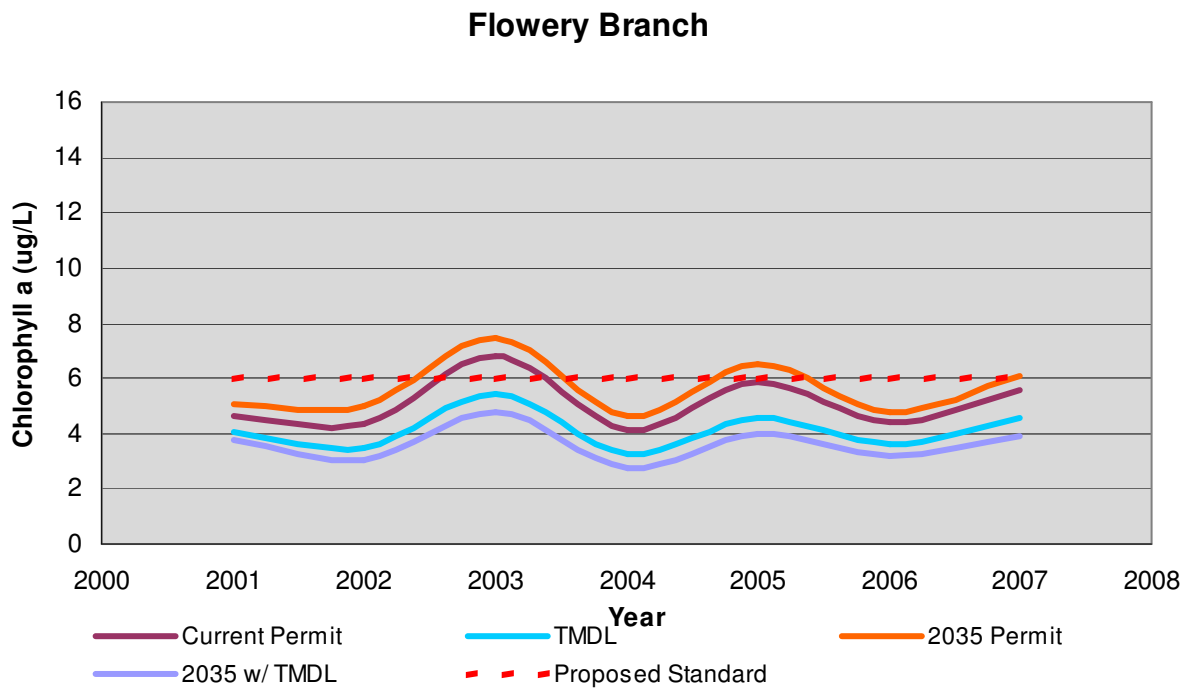

Figure 3-10 Current (1B and 1C) and 2035 Scenarios (1F and 1G) at Flowery Branch

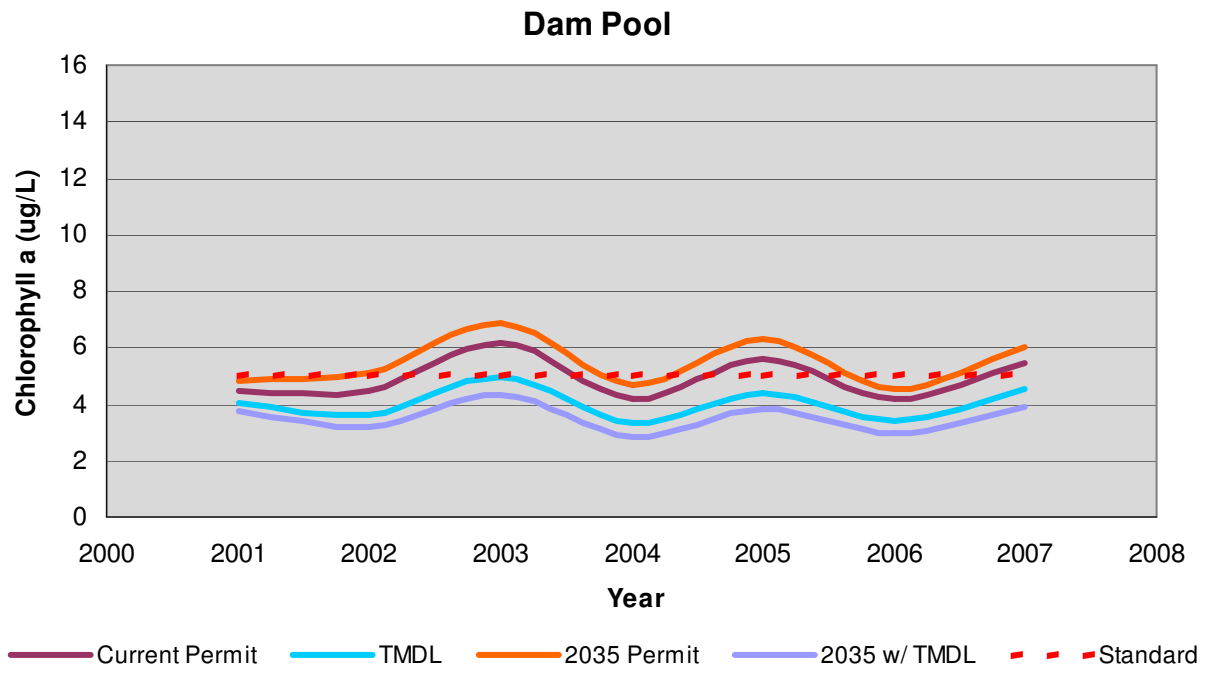

Figure 3-11 Current (1B and 1C) and 2035 Scenarios (1F and 1G) at Dam Pool

3.2 Total Nitrogen Standard

The modeling results were evaluated to examine whether the current 'anytime, anyplace' nitrogen standard of not to exceed 4 mg/L is protective of the lake. For each model scenario, the total nitrogen growing season average was evaluated from 2001 to 2007. The results indicate a growing season average of 2 mg/L as total nitrogen in the photic zone could be met. However, increasing the total nitrogen concentration in the lake to a growing season average of 4 mg/L did not have any affect the Lake Lanier chlorophyll *a* levels. Thus, this criterion was found to be protective of the Recreation and Drinking Water designated uses in Lake Lanier.

Please note that this criterion does not take into consideration modeling not yet to be completed for the downstream reservoirs (Lake Walter F. George and Lake Seminole). Once the entire Chattahoochee River Basin has calibrated watershed and lake models that will allow for a complete understanding of the nitrogen dynamics in the Basin, then the current total nitrogen standard (not to exceed 4 mg/L) will be re-evaluated and a protective and scientifically, defensible total nitrogen standard will be proposed when this modeling effort is complete.

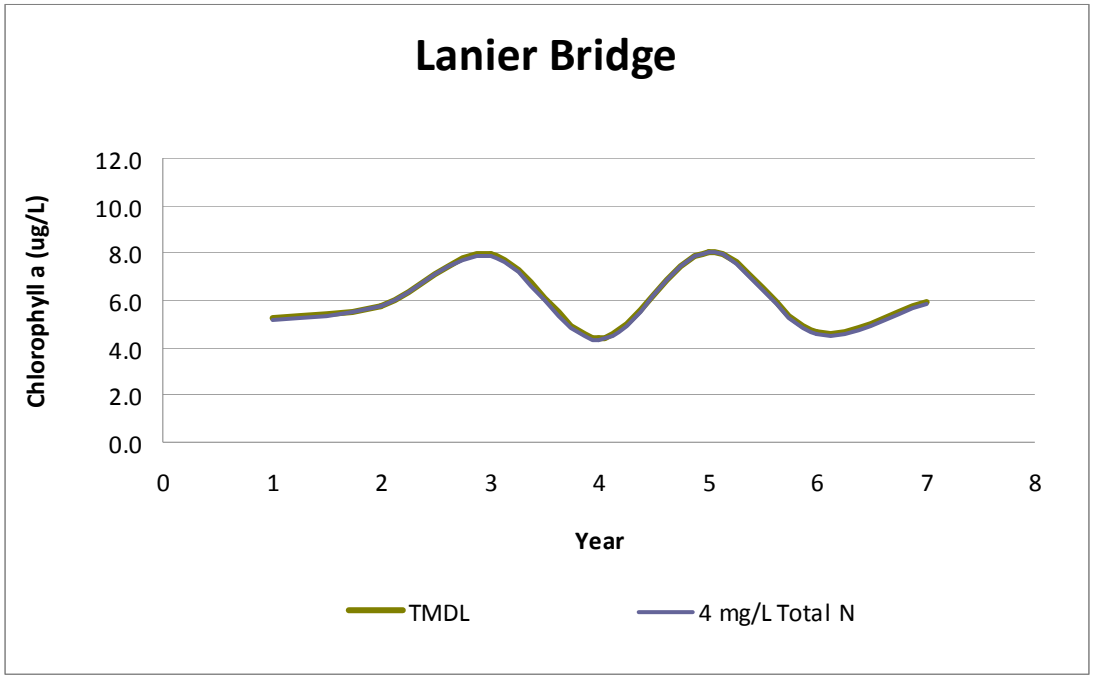

Figure 3-12 Chlorophyll Levels at Lanier Bridge from the TMDL (Scenario 1C) and Increasing the Total Nitrogen Load to the Current Standard (Scenario 1H)

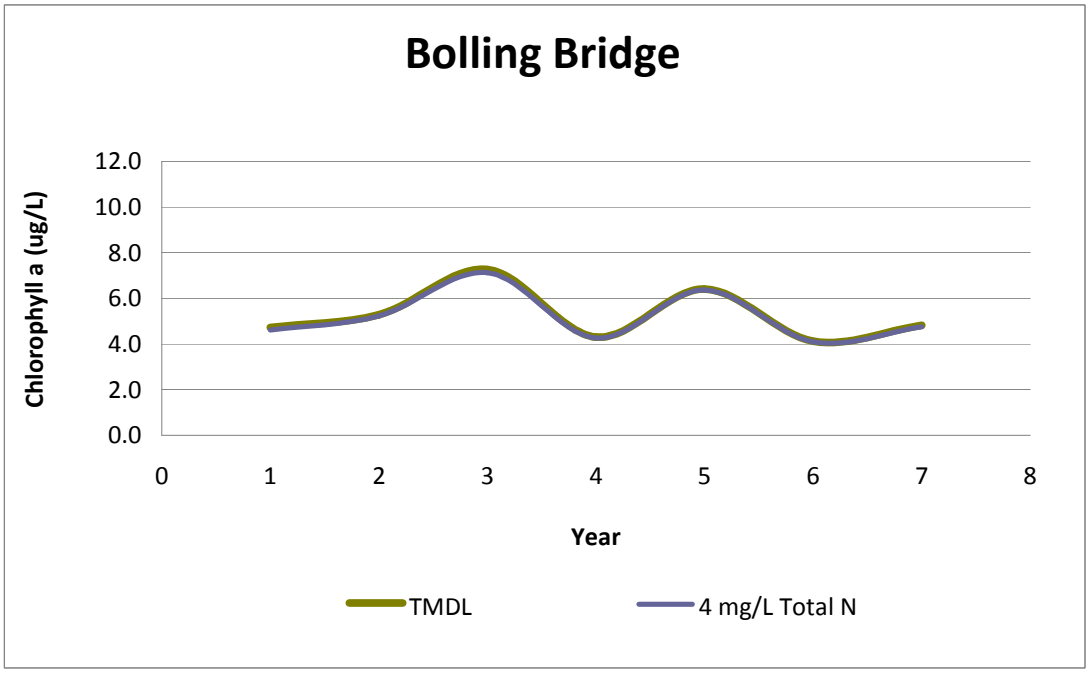

Figure 3-13 Chlorophyll Levels at Bolling Bridge from the TMDL (Scenario 1C) and Increasing the Total Nitrogen Load to the Current Standard (Scenario 1H)

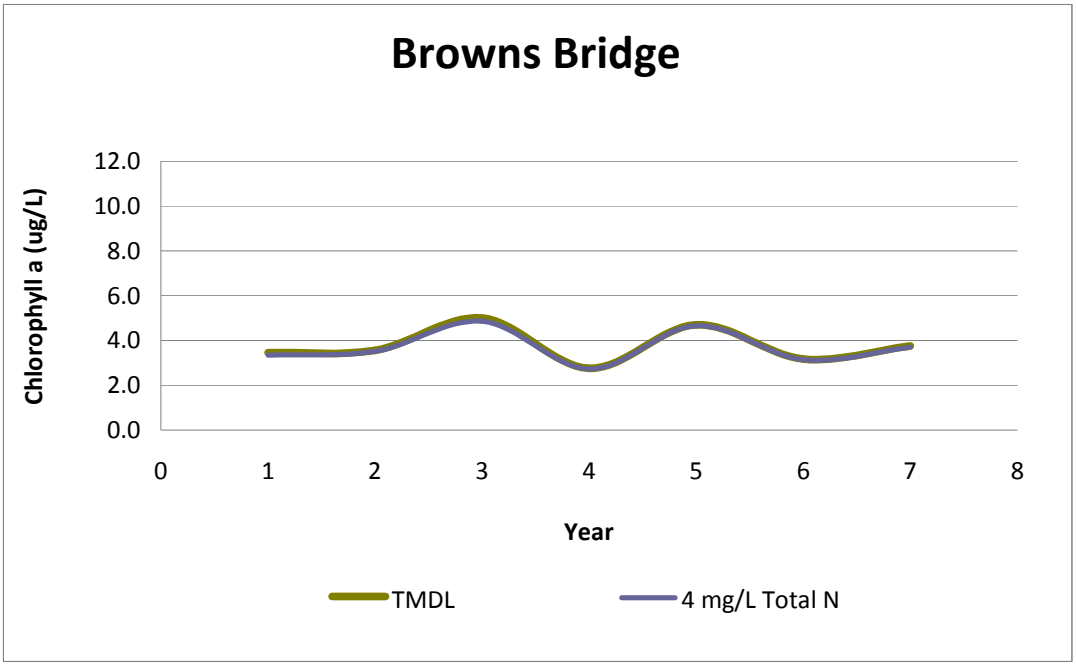

Figure 3-14 Chlorophyll Levels at Browns Bridge from the TMDL (Scenario 1C) and Increasing the Total Nitrogen Load to the Current Standard (Scenario 1H)

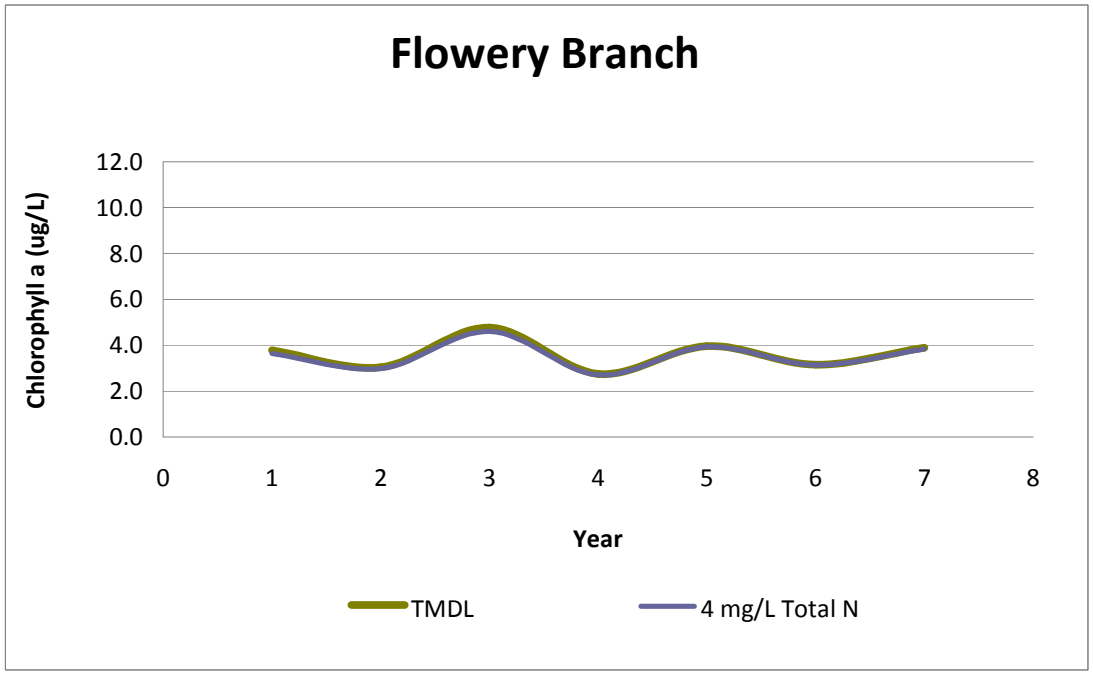

Figure 3-15 Chlorophyll Levels at Flowery Branch from the TMDL (Scenario 1C) and Increasing the Total Nitrogen Load to the Current Standard (Scenario 1H)

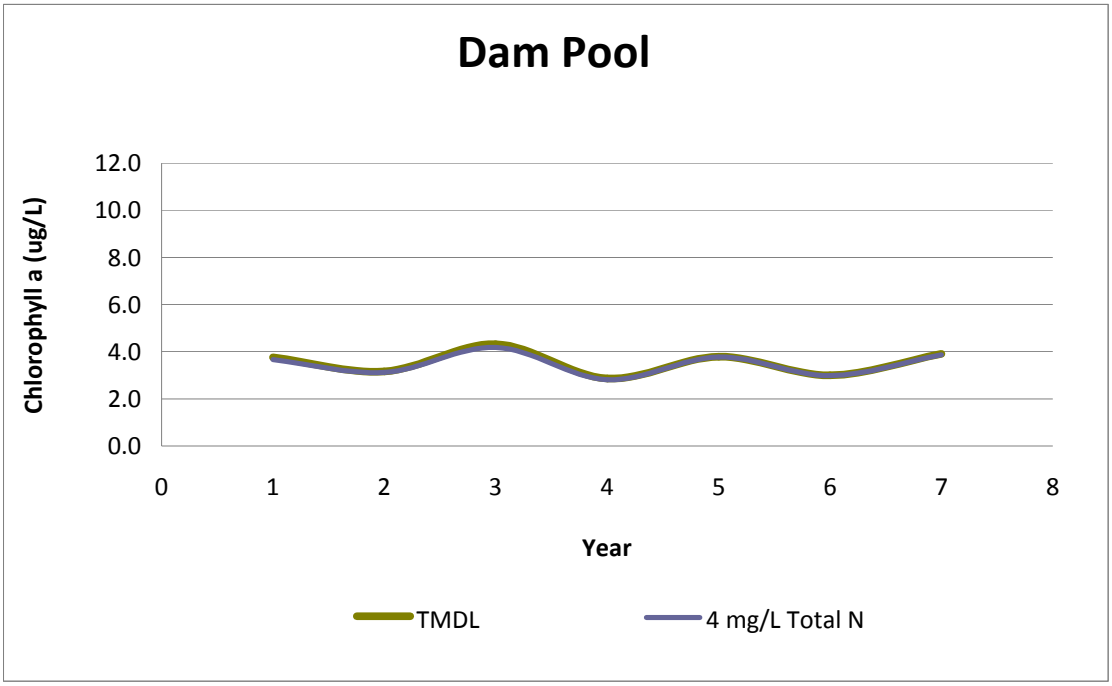

Figure 3-16 Chlorophyll Levels at the Dam Pool from the TMDL (Scenario 1C) and Increasing the Total Nitrogen Load to the Current Standard (Scenario 1H)

4.0 DESIGNATED USE SUPPORT

4.1 Recreational Use Support

There have been no recreational closures due to algal blooms at any of the U.S. Army Corps of Engineers beaches on Lake Lanier (personal communication, COE).

4.2 Fisheries Use Support

There have been no fish kills in Lake Lanier due to dissolved oxygen deficiency since nutrient standards were adopted. This lake has both a warm water and cool water fishery. The black bass fishery is good, with spotted bass dominating the population. Spotted bass prefer clear, cool water and utilize deeper water than largemouth bass or crappie. Largemouth bass and crappie are more abundant in the upper one-third of the reservoir where nutrient inflows are greatest.

The Lanier cool water fishery is supported through WRD stocking, and in 2012, 130,000 striped bass and 224,000 walleye fingerlings were stocked to maintain these fisheries. Striped bass require a minimum critical habitat having temperatures of less than 25 ℃ and with greater than 3 mg/L of dissolved oxygen. Water temperatures of 22 ℃ or less with dissolved oxygen concentrations of 5 mg/L or more are optimal for this species. Following the spring spawn the larger striped bass spend the remainder of the summer in cold-water refuges typically found in depths greater than 25 feet.

WRD biologists have noted that conditions that have provided good cool water habitat through the summer months for striped bass result in better growth, health and survival, and tend to occur when late winter/spring inflows to the lake are low. In years with high winter/spring inflows such as 2005, the cool water habitat conditions were poor. Table 4-1 is a WRD tabulation of its early September striped bass critical habitat ratings and depth (where water temperature was less than 25 °C and dissolved oxygen was greater than 3 mg/L), and the number of stations exceeding the chlorophyll *a* standard for those years (as shown in Figure 4-1). These qualitative results show no definitive connection with chlorophyll a levels and striped bass habitat quality. Thus, marginally increasing the chlorophyll a criteria at the Flowery Branch and Browns Bridge Road stations would still be protective of the striped bass fishery.

Table 4-1 WRD Fisheries Striped Bass Habitat Rating for Lake Lanier

September 1; Year	Habitat Rating *	Critical Habitat Depth [T<25 and DO > 3]	Optimal Habitat Depth [T<22 and DO>5]	Number of Stations With Chlorophyll *a* Exceedances
2000	Good	9 meters	2 meters	One (Browns Bridge)
2001	Good	18 meters	16 meters	None
2002	Fair	10 meters	0 meters	None
2003	Poor	1 meter	0 meters	Four (Dam Forebay, Midlake, Browns and Lanier Bridges)
2004	Good	12 meters	1 meter	None
2005	Poor	0 meters	0 meters	Three (Midlake, Browns and Lanier Bridges)
2006	Fair	3 meters	0 meters	None
2007	Good	16 meters	5 meters	None
2008	Fair	12 meters	0 meters	None
2009	Good	14 meters	1 meter	None
2010	Good	38 meters	27 meters	None
2011	Poor	2 meters	1 meter	One (Browns Bridge)
2012	Good	22 meters	5 meters	None

* Habit rating is based on a qualitative matrix. "Good" habitat is that which has critical habitat depth greater than three meters and any level of optimal habitat depth present. "Fair" habitat is that which has three or more meters of critical habitat depth but no optimal habitat depth. "Poor" habitat is that which has less than three meters of critical habitat depth.

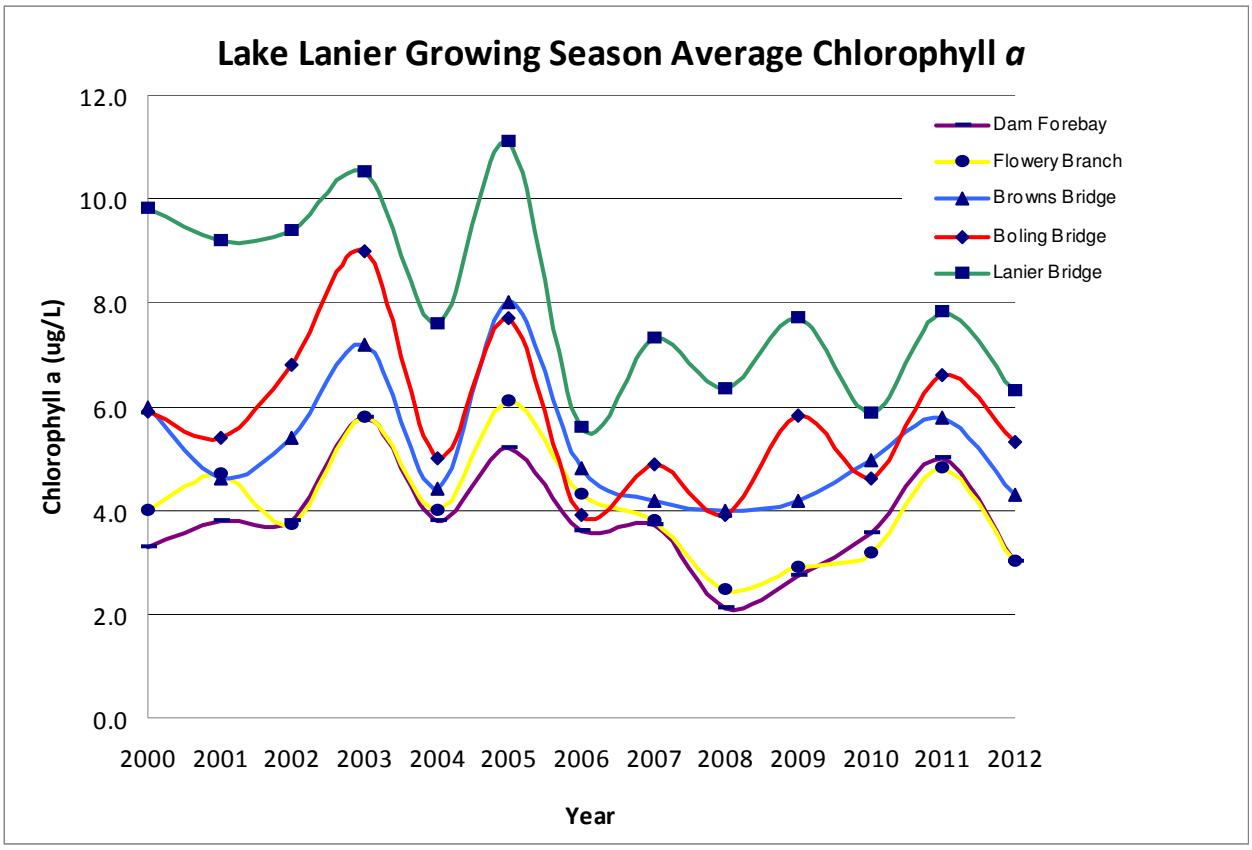

Table 4-1 Historic Lake Lanier Growing Season Average Chlorophyll a

4.3 Drinking Water Source Use Support

The City of Gainesville is minimally impacted by any algal blooms in Lake Lanier due to the ability to draw water from multiple depths in the lake. The city seldom experiences any algal-related drinking water problems since high algal concentrations occur very infrequently in the lake.