Appendix A:

Modeling Report

Boggy Bayou

WBID: 692

Nutrients and Dissolved Oxygen

March 2011

Region4 serving the southeast

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1. Watershed Description

Choctawhatchee Bay is a bay in the Emerald Coast region of the Florida Panhandle. The bay is located within Okaloosa and Walton counties, has a surface area of 129 mi^2 (334 km^2). It is an inlet of the Gulf of Mexico, connected to it through East Pass (also known as Destin Pass), and it connects to Santa Rosa Sound in Fort Walton Beach, Florida, with the Gulf Intracoastal Waterway entering it at this point. East Pass is the only outlet of the bay into the Gulf of Mexico. The Choctawhatchee River flows into it, as do several smaller rivers and streams. Boggy Bayou is located in the northwest portion of Choctawhatchee Bay.

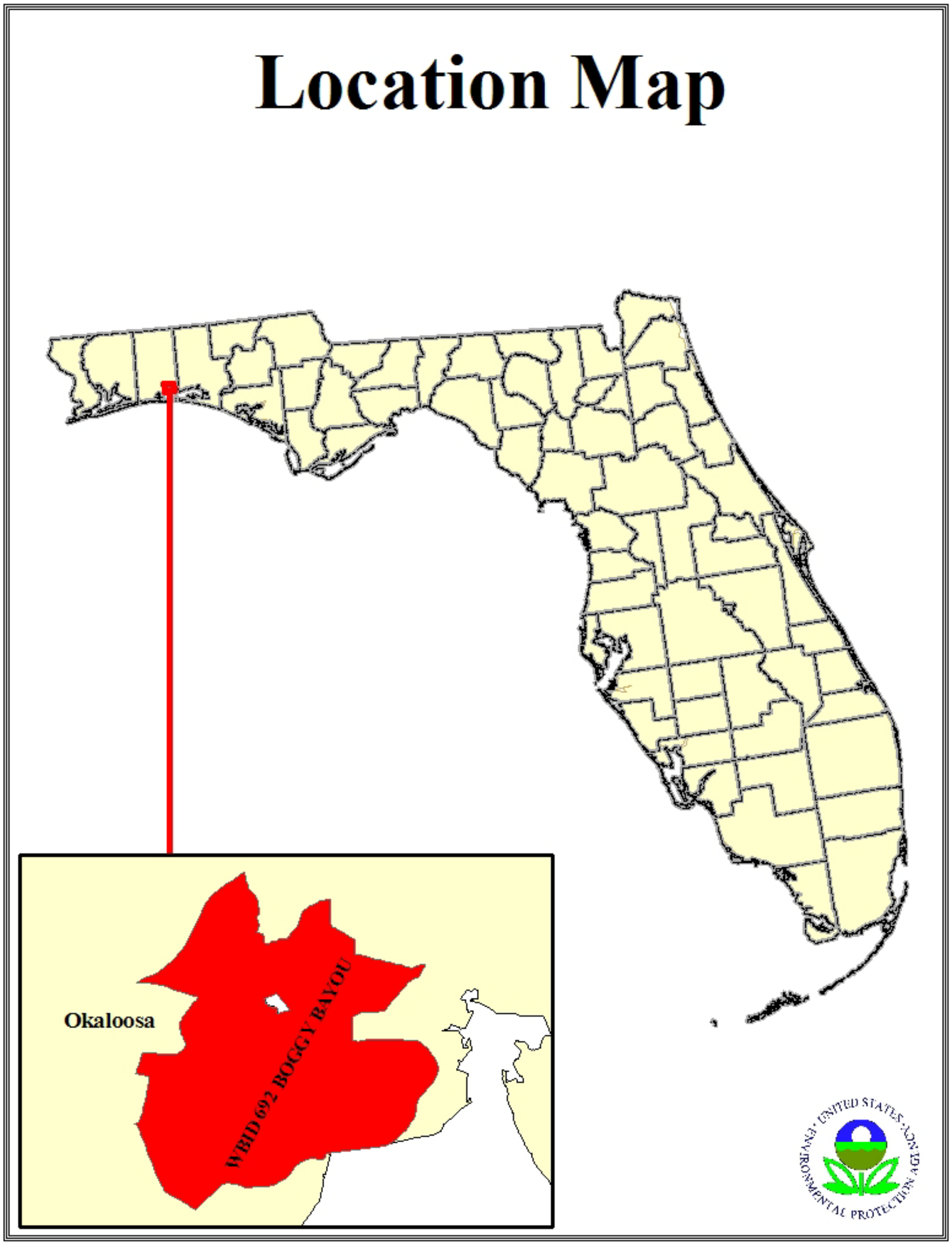

Figure 1 Location Map for Boggy Bayou

The landuse distribution for the Boggy Bayou watershed is presented in Figure 2.

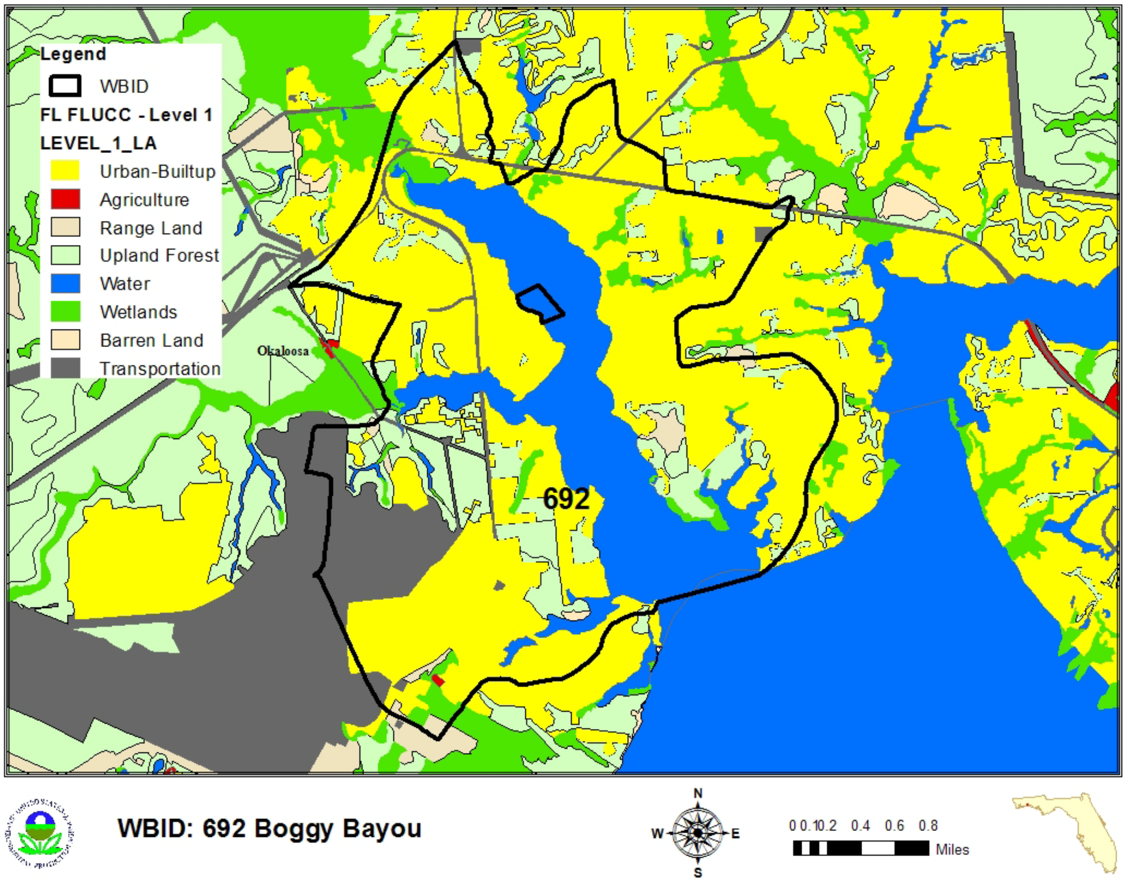

Figure 2 Landuse Distribution for Boggy Bayou Watershed

2. TMDL Targets

The TMDL reduction scenarios will be done to achieve a dissolved oxygen concentration of 4 mg/L and daily average of 5 mg/L in within Boggy Bayou or establish the natural condition.

3. Modeling Approach

A coupled watershed (LSPC) and three dimensional hydrodynamic (EFDC) and water quality modeling (WASP) framework was used to simulate biological oxygen demand (BOD), nutrients (total nitrogen and total phosphorus), and chlorophyll a (Chla) and dissolved oxygen for the time period of 2002 through 2009. The watershed model provides daily runoff, nutrient and BOD loadings from the Boggy Bayou Watersheds. The predicted results from the LSPC model are transferred forward to both the hydrodynamic and water quality model. A model of the entire Choctawhatchee Bay was developed to capture the detailed transport and vertical gradients in the system. Once the entire bay model was calibrated to existing loads (entire watershed), a smaller section of the main grid was used to look at detailed water quality in Boggy Bayou. EFDC predicts the complex transport patterns as a function of wind, tides, freshwater inflow, temperature and salinity, this detailed transport predictions are passed onto the water quality model. The water quality model combines the transport information with the loading predictions from the watershed model to predict water quality (nitrogen, phosphorus, chlorophyll a and dissolved oxygen). Two scenarios were simulated with EFDC, LSPC and WASP; 1) existing conditions, 2), a natural condition were all anthropogenic sources are removed. The WASP model will be used to determine the percent reduction in loadings that would be needed to meet water quality standards.

3.1. Boggy Bayou Watershed Model

The goal of this watershed modeling effort is to estimate runoff (flow), nutrient (total nitrogen & total phosphorus) and BOD loads and concentrations from the upstream watersheds flowing into the Boggy Bayou. The Loading Simulation Program C++ (LSPC) as the watershed model.

LSPC is the Loading Simulation Program in C++, a watershed modeling system that includes streamlined Hydrologic Simulation Program Fortran (HSPF) algorithms for simulating hydrology, sediment, and general water quality on land as well as a simplified stream fate and transport model. LSPC is derived from the Mining Data Analysis System (MDAS), which was originally developed by EPA Region 3 (under contract with Tetra Tech) and has been widely used for TMDLs. In 2003, the U.S. Environmental Protection Agency (EPA) Region 4 contracted with Tetra Tech to refine, streamline, and produce user documentation for the model for public distribution. LSPC was developed to serve as the primary watershed model for the EPA TMDL Modeling Toolbox.

3.1.1. Boggy Bayou Watershed Delineation and Landuse

The surrounding watershed that drains directly to the Boggy Bayou is presented in Figure 3. This WBID was delineated into 226 LSPC sub basins to simulate the runoff and pollutant loads.

Figure 3 Boggy Bayou Watershed Delineation

3.2. Boggy Bayou Watershed Runoff

The LSPC watershed model was developed to simulate hydrologic runoff and pollutant loadings in response to recorded precipitation events for the current and natural conditions.

3.2.1. Meteorological

Rainfall and other pertinent meteorological data was obtained from the 11 National Weather Service (NWS) WBAN stations.

Table 1provides a time series plot of daily rainfall for the simulation period.

Table 1 Rainfall Gages in Choctawhatchee Watershed

Station #	Name
010252	Andalusia, AL
012577	Elba, AL
012675	Enterprise, AL
013251	Geneva, AL
013261	Headland, AL
014431	Kinston, AL
081544	Chipley, FL
081986	Crestview Bob Sikes, FL
082220	De Funiak Springs, FL

086129	New Hope, FL
086240	Niceville, FL

3.3. EFDC

EFDC is a hydrodynamic modeling package for simulating one-dimensional, two-dimensional, and three-dimensional flow and transport in surface water systems including: rivers, lakes, estuaries, reservoirs, wetlands, and nearshore to shelf scale coastal regions. The EFDC model was originally developed at the Virginia Institute of Marine Science for estuarine and coastal applications and is considered public domain software.

3.4. Model grid

The bay was segmented into curvilinear orthogonal computational grid cells representing horizontal dimensions for the hydrodynamic model. The waterbody was segmented into 788 horizontal grid cells, using 5 layers (3940 total cells). Figure 4 depicts the Choctawhatchee Bay model grid.

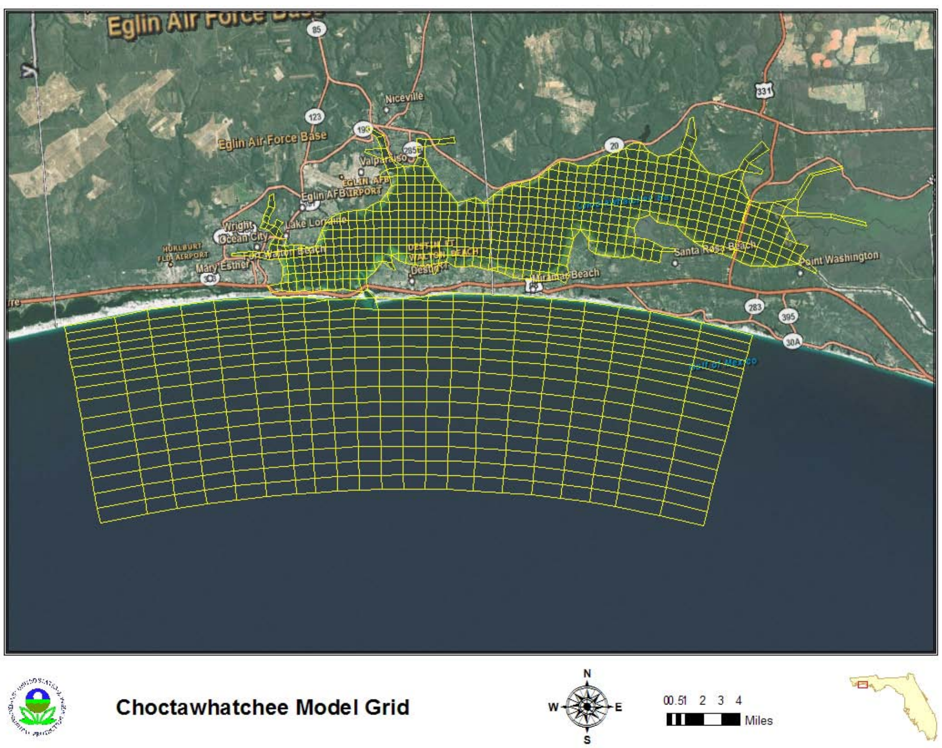

Figure 4 Choctawhatchee Bay Model Grid

Using the main bay grid to drive hydrodynamics, a smaller sub-grid was fed forward to WASP to predict water quality in Boggy Bayou (Figure 5). A smaller sub-grid consisting of 24 horizontal cells and 5 layers were used to develop the TMDL for Boggy Bayou.

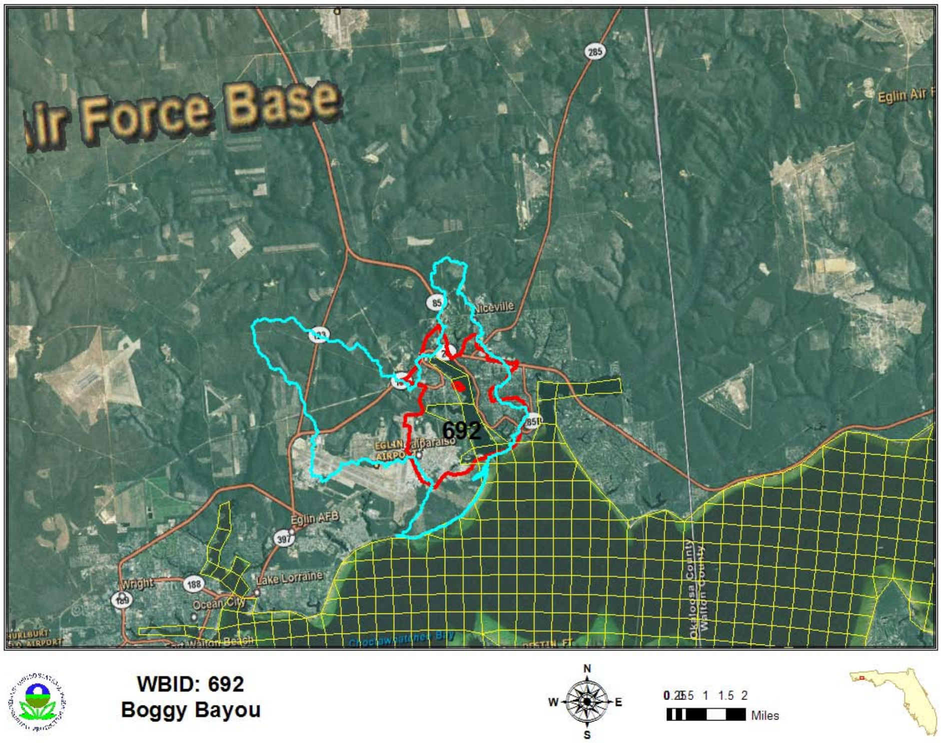

Figure 5 Boggy Bayou Sub-Grid

3.4.1. BOD and Nutrient Loadings

The pollutagraph was generated using event mean concentrations for total nitrogen, total phosphorus and BOD (Table 3). The initial EMC values were derived for each landuse type from Harpers Report (Harper, 1994) and then calibrated to all data available for the watershed.

Table 2 Event Mean Concentration for Landuse Classifications

Landuse	Total Nitrogen	Total Phosphorus	BOD
Agriculture	2.2	0.6	10
Barren Land	2	0.6	10
Rangeland	2.2	0.34	10
Transportation	1	0.30	10
Upland Forest	2.2	0.16	3
Urban Area	2.2	0.40	10
Water	1	0.10	3
Wetlands	1	0.4	10

BOD and nutrient watershed runoff were determined using EMCs for surface water runoff and interflow runoff and baseflow concentrations for groundwater flow. Table 4 provides the annual average total nitrogen, total phosphorus and BOD loads for the period of record 2002 through 2009. It is these loadings that the TMDL load reduction will be calculated from.

Table 3 Boggy Bayou Nutrient Loads (2002-2009)

	Existing Condition	
Constituent	WLA (kg/yr)	LA (kg/yr)
Total Nitrogen	NA	6,088
Total Phosphorus	NA	362
BOD	NA	15,052

3.5. Boggy Bayou Water Quality Model

The Boggy Bayou WASP water quality model integrates the predicted flows and loads from the LSPC model to simulate water quality responses in: nitrogen, phosphorus, chlorophyll a and dissolved oxygen. A 3 segment WASP water quality model was setup to include the 3 Boggy Bayou sub basins.

3.5.1. WASP Model

The WASP water quality model uses the kinematic wave equation to simulate flow and velocity and the basic eutrophication module to predict dissolved oxygen and Chlorophyll a responses to the BOD, total nitrogen and total phosphorus loadings. Widths were taken from satellite imagery and depths from the measured water quality data. Table 4 provides the basic kinetic rates used in the model.

Table 4 WASP Kinetic Rates

WASP Kinetic Parameters	Value
Global Reaeration Rate Constant @ 20 °C (per day)	1.0
Sediment Oxygen Demand (g/m2/day)	2 for stream segments
Phytoplankton Maximum Growth Rate Constant @20 °C (per day)	2
Phytoplankton Carbon to Chlorophyll Ratio	75
BOD (1) Decay Rate Constant @20 °C (per day)	0.06
Ammonia, nitrate, phosphorus rates @20 °C (per day)	0.05 to 0.1

The WASP model was calibrated to all available data from IWR 40.

Table 5 provides a comparison of predicted annual average concentrations versus the annual average concentrations of the measured data. It should be noted that only a single year of data was available from Florida's Impaired Waters Rule database version 40.

Table 5 Existing Condition Annual Average Concentrations Observed and Predicted

Constituent	Existing	Observed
Total Nitrogen (mg/L)	0.579	0.375
Total Phosphorus (mg/L)	0.06	0.017
BOD (mg/L)	0.898	1.099
DO (mg/L)	5.35	6.785
Chlorophyll a (ug/L)	2.92	5.027

Figure 6 through Figure 10 depict the calibration which compares the observed versus the predicted concentrations.

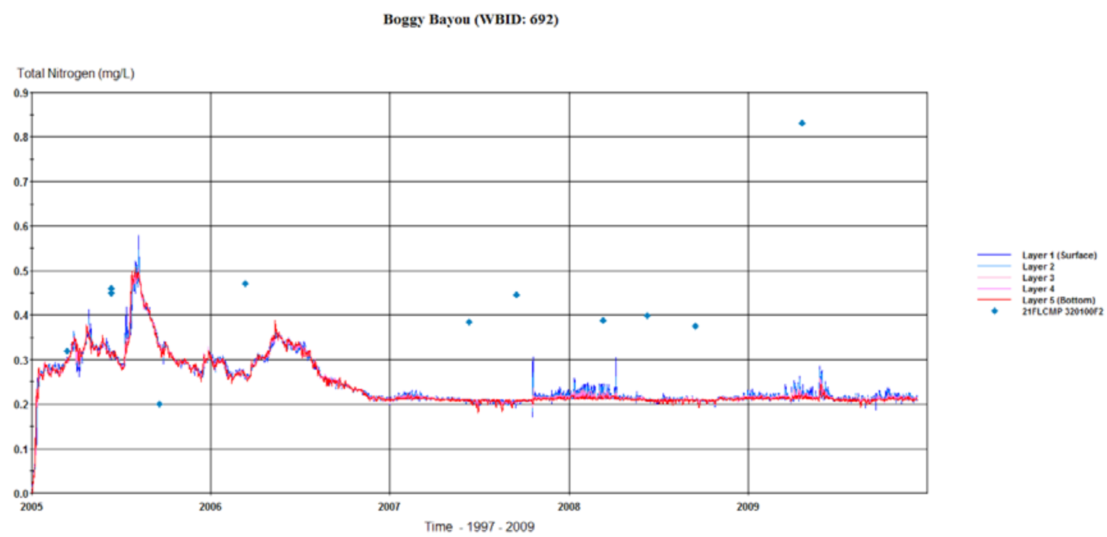

Figure 6 WASP Calibration for Total Nitrogen in Boggy Bayou

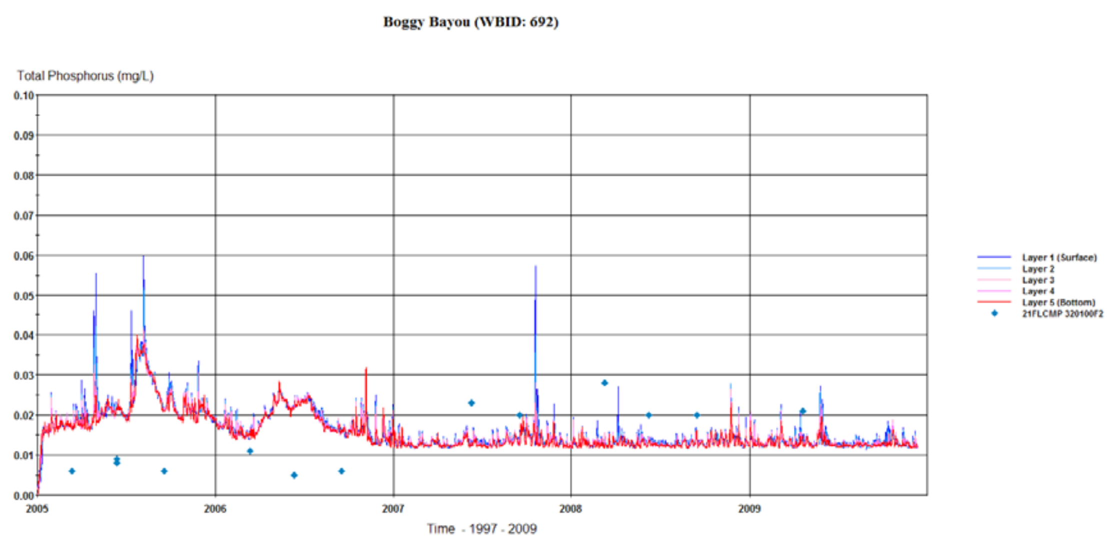

Figure 7 WASP Calibration for Total Phosphorus in Boggy Bayou

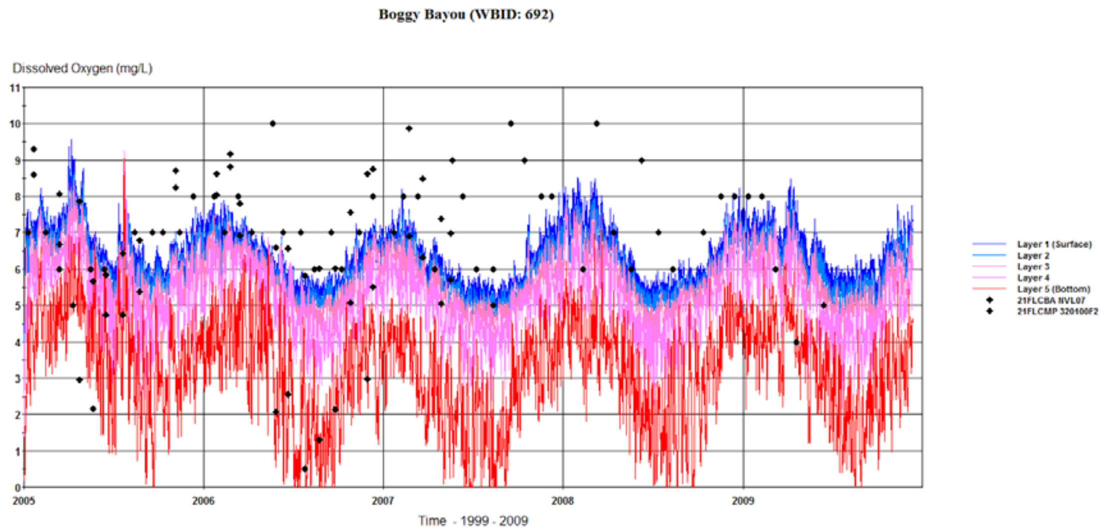

Figure 8 WASP Calibration for Dissolved Oxygen in Boggy Bayou

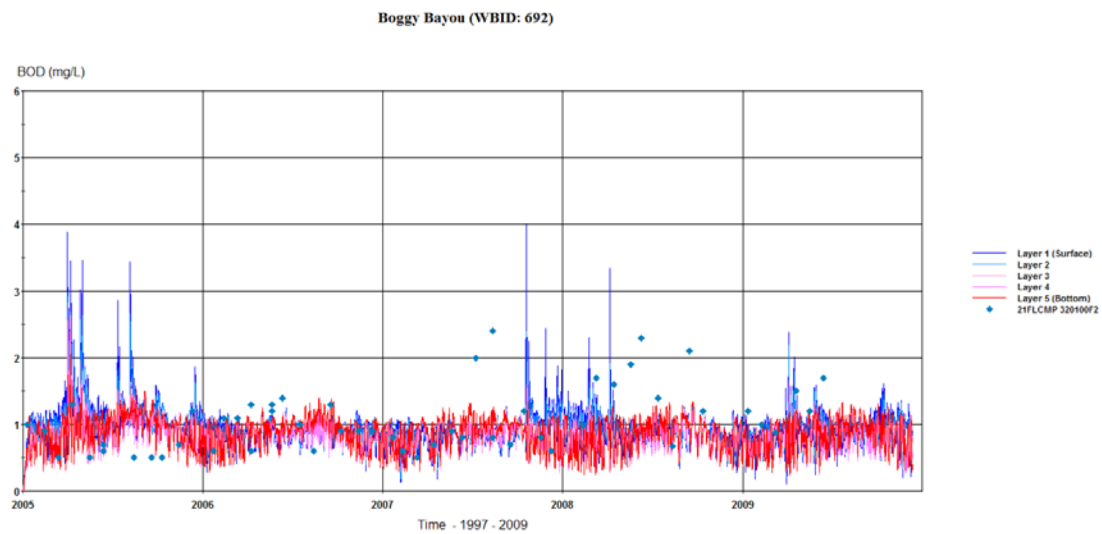

Figure 9 WASP Calibration for BOD in Boggy Bayou

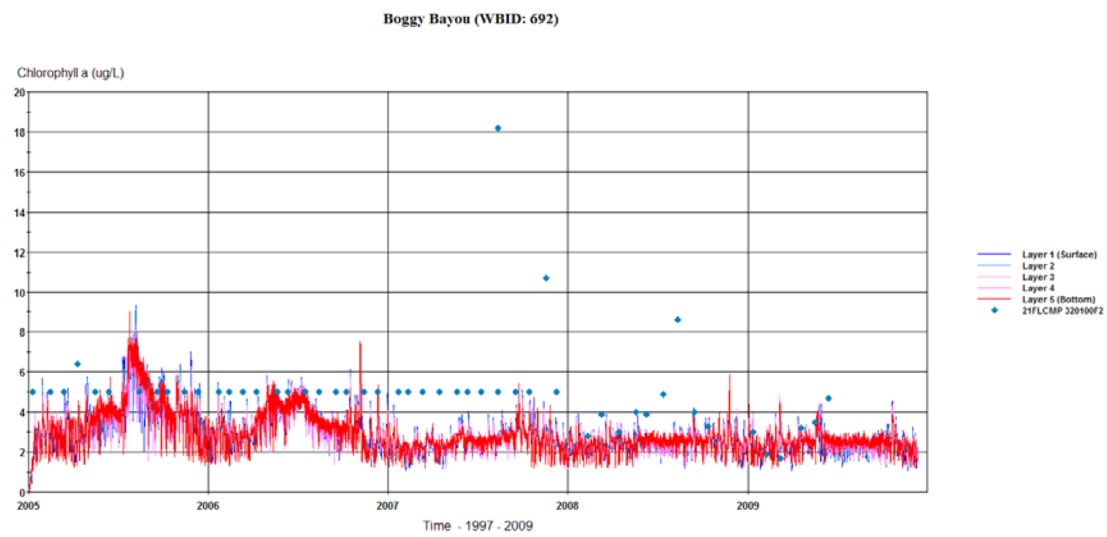

Figure 10 WASP Calibration for Chlorophyll a in Boggy Bayou

4. Modeling Scenarios

Using the calibrated watershed and water quality models, up to two potential modeling scenarios will be developed. The first scenario will be to predict water quality conditions under a natural condition (remove point sources and returning landuses back to upland forests and wetlands). A second scenario will be developed if water quality standards can be met under natural conditions (balanced flora and fauna, dissolved oxygen greater than 5 mg/L); loads would be reduced from the current conditions until standards are met (balanced flora and fauna, dissolved oxygen greater than 5 mg/L)

4.1. Boggy Bayou Watershed Natural Condition Analysis

Boggy Bayou sub basins and upstream landuses were changed from impacted lands to upland forest and wetlands landuses. LSPC was then used to simulate the natural condition nutrient loads (Table 8) which were inputted in to WASP model. Other than the nutrient load reductions the SOD rate was reduced to reflect the reduced loadings. Table 6 provides the annual average model predictions for total nitrogen, total phosphorus, and dissolved oxygen.

Table 6 Annual Average Loadings for Natural Condition

	Natural Condition	
Constituent	WLA (kg/yr)	LA (kg/yr)
Total Nitrogen	NA	3,681
Total Phosphorus	NA	227
BOD	NA	11,764

Table 7 presents the predicted annual average concentrations under natural conditions. Without the impacts of anthropogenic sources the dissolved oxygen concentration in the Boggy Bayou still would not achieve the dissolved oxygen standard of 5 mg/l.

Table 7 Natural Condition Annual Average Model Predictions

Constituent	Natural Condition
Total Nitrogen (mg/L)	0.25
Total Phosphorus (mg/L)	0.02
BOD (mg/L)	0.87
DO (mg/L)	5.84
Chlorophyll a (ug/L)	2.86

4.2. TMDL Load Reductions

Because water quality standards cannot be met under natural conditions no other scenarios were conducted. The TMDL will be set to the natural conditions.

5. TMDL Determination

The TMDL load reduction was determined by reducing the current conditions to the natural conditions. The annual average loadings are given in Table 8 along with the prescribed load reductions.

Table 8 TMDL Determination

	Current Condition		TMDL Condition		MS4	LA
Constituent	WLA (kg/yr)	LA (kg/yr)	WLA (kg/yr)	LA (kg/yr)	% Reduction	% Reduction
Total Nitrogen	NA	6,088	NA	3,681	40%	40%
Total Phosphorus	NA	362	NA	227	37%	37%
BOD	NA	15,052	NA	11,764	22%	22%