TMDLS FOR DISSOLVED OXYGEN FOR CYPRESS BAYOU RESERVOIR AND BLACK BAYOU RESERVOIR, LOUISIANA (SUBSEGMENTS 100404 AND 100405)

MARCH 25, 2008

TMDLS FOR DISSOLVED OXYGEN
FOR CYPRESS BAYOU RESERVOIR AND
BLACK BAYOU RESERVOIR, LOUISIANA
(SUBSEGMENTS 100404 AND 100405)

Prepared for

USEPA Region 6
Water Quality Protection Division
Oversight and TMDL Team
1445 Ross Avenue, Suite 1200
Dallas, TX 75202-2733

Contract No. 68-C-02-108
Task Order 95

Prepared by

FTN Associates, Ltd.
3 Innwood Circle, Suite 220
Little Rock, AR 72211

FTN No. 2110-616

March 25, 2008

EXECUTIVE SUMMARY

Section 303(d) of the Federal Clean Water Act requires states to identify waterbodies that are not meeting water quality standards and to develop total maximum daily pollutant loads for those waterbodies. A total maximum daily load (TMDL) is the amount of pollutant that a waterbody can assimilate without exceeding the established water quality standard for that pollutant. Through a TMDL, pollutant loads can be distributed or allocated to point sources and nonpoint sources (nonpoint sources) discharging to the waterbody. This report presents TMDLs that have been developed for dissolved oxygen (DO) for Black Bayou Reservoir (Subsegment 100405), and Cypress Bayou Reservoir (Subsegment 100404), in the Red River basin in northwest Louisiana.

Black Bayou Reservoir Subsegment (100405) covers approximately 25 sq mi. Black Bayou Reservoir has a surface area of approximately 600 acres and Black Bayou is its only major tributary. Cypress Bayou Reservoir Subsegment (100404) covers approximately 26 sq mi of the 155 sq mi reservoir watershed. Cypress Bayou Reservoir has a surface area of approximately 3,000 acres and the majority of the inflow comes from Cypress Bayou (Subsegment 100403). The majority of the land in both subsegments is forested, however they both also have significant areas of developed land and agricultural use. Controlled releases are made from these reservoirs to supply irrigation needs withdrawn from Cypress Bayou downstream.

Subsegments 100404 and 100405 were included on the final 2004 303(d) list for Louisiana as not fully supporting their designated use of propagation of fish and wildlife and were ranked as priority No. 7 for DO TMDL development. The DO criterion specified in the Louisiana water quality standards for these subsegments is 5 mg/L year round.

Separate water quality models (LA-QUAL) were set up to simulate DO, carbonaceous biochemical oxygen demand (CBOD), ammonia nitrogen, and organic nitrogen in the two reservoirs. The models were calibrated to conditions observed during a field survey performed by FTN Associates, Ltd. (FTN) on August 31, 2005 through September 1, 2005. Depths and widths in the models were based on 1999 USGS bathymetric studies of the reservoirs. Reaeration was simulated in the model using a surface transfer coefficient based on wind speed. Decay rates for CBOD and ammonia nitrogen were set to averages of values observed during the FTN field survey. Headwater flow rates were based on flows reported for nearby Dorcheat Bayou (USGS Gage 07349795) during the FTN field survey. Headwater concentrations were based on field data collected by FTN. Model inputs for nonpoint source loads of CBOD and organic nitrogen, benthic loads of ammonia, and sediment oxygen demand were treated as calibration parameters; their values were adjusted until the model output was similar to the calibration target values.

Summer and winter projection simulations were run at critical flows and temperatures to address seasonality as required by the Clean Water Act. Reductions of existing nonpoint source loads were required for the projection simulations to show the DO criterion of 5 mg/L being maintained in the bayou. In general, the modeling in this study was consistent with guidance in the Louisiana TMDL Technical Procedures Manual (the “LTP”).

TMDLs for oxygen demanding substances (CBOD, ammonia nitrogen, organic nitrogen, and sediment oxygen demand) were calculated for summer and winter using the results of the projection simulations. The TMDL calculations included an implicit margin of safety as well as an explicit margin of safety (10% of the TMDL) and an explicit allocation for future growth (also 10% of the TMDL). The wasteload allocation (WLA) for point sources and load allocation (LA) for nonpoint sources was calculated from the loading simulated in the model. Nonpoint source load reductions of 5% in the summer and 17% in the winter were needed for the Black Bayou Reservoir projection simulations to show the DO criterion of 5.0 mg/L being maintained. Nonpoint source load reductions of 23% in the summer and 0 in the winter were needed for the Cypress Bayou Reservoir projection simulations to show the DO criterion of 5.0 mg/L being maintained. The results of the TMDL calculations for the two reservoirs for summer and winter are summarized in Tables ES.1 through ES.4.

Table ES.1. Summer DO TMDL for Subsegment 100405 (Black Bayou Reservoir).

	Oxygen Demand (kg/day) from:					Oxygen Demand (lbs/day) from:					Percent Reduction Needed
	SOD	CBODu	Organic Nitrogen	Ammonia Nitrogen	Total	SOD	CBODu	Organic Nitrogen	Ammonia Nitrogen	Total	
Point Sources											
WLA	NA	0	0	0	0	NA	0	0	0	0	0
MOS	NA	0	0	0	0	NA	0	0	0	0	NA
FG	NA	0	0	0	0	NA	0	0	0	0	NA
Nonpoint Sources											
LA	5,053.6	1,0312	590.45	0.49	15,956.47	11,141.08	22,733.8	13,01.71	1.08	35,177.6	5%
MOS	631.7	1,289	73.8	0.06	1,994.56	1,392.62	28,41.73	162.70	0.13	43,97.21	NA
FG	631.7	1,289	73.8	0.06	1,994.56	1,392.62	28,41.73	162.70	0.13	43,97.21	NA
TMDL	6,316.9	12,890.0	738.1	0.6	19,945.6	13,926.32	28,417.3	16,27.11	1.34	43,972	NA

Table ES.2. Winter DO TMDL for Subsegment 100405.

	Oxygen Demand (kg/day) from:					Oxygen Demand (lbs/day) from:					Percent Reduction Needed
	SOD	CBODu	Organic Nitrogen	Ammonia Nitrogen	Total	SOD	CBODu	Organic Nitrogen	Ammonia Nitrogen	Total	
Point Sources											
WLA	NA	0	0	0	0	NA	0	0	0	0	0
MOS	NA	0	0	0	0	NA	0	0	0	0	NA
FG	NA	0	0	0	0	NA	0	0	0	0	NA
Nonpoint Sources											
LA	1852.91	9383.20	756.89	4.75	11997.75	4084.93	20686.20	1668.64	10.47	26450.24	17.2%
MOS	231.62	1172.90	94.61	0.59	1499.72	510.63	2585.78	208.58	1.30	3306.28	NA
FG	231.62	1172.90	94.61	0.59	1499.72	510.63	2585.78	208.58	1.30	3306.28	NA
TMDL	2316.15	11729.00	946.11	5.93	14997.19	5106.18	25857.75	2085.79	13.07	33062.81	NA

Table ES.3. Summer DO TMDL for Subsegment 100404 (Cypress Bayou Reservoir).

	Oxygen Demand (kg/day) from:					Oxygen Demand (lbs/day) from:					Percent Reduction Needed
	SOD	CBODu	Organic Nitrogen	Ammonia Nitrogen	Total	SOD	CBODu	Organic Nitrogen	Ammonia Nitrogen	Total	
Point Sources											
WLA	NA	6.5	4.07	2.03	12.61	NA	14.33	8.97	4.48	27.80	0
MOS	NA	0.81	0.51	0.25	1.58	NA	1.79	1.12	0.55	3.48	NA
FG	NA	0.81	0.51	0.25	1.58	NA	1.79	1.12	0.55	3.48	NA
Nonpoint Sources											
LA	43,526.27	8,470.46	3,198.84	0.49	55,196.04	95,958.01	18,673.98	7,052.16	1.08	121,685.19	23%
MOS	5,440.78	1,058.81	399.85	0.06	6,899.51	11,994.74	2,334.25	881.51	0.13	15,210.66	NA
FG	5,440.78	1,058.81	399.85	0.06	6,899.51	11,994.74	2,334.25	881.51	0.13	15,210.66	NA
TMDL	54,407.83	10,596.20	4,003.63	3.14	69,010.83	119,947.50	23,360.38	8,826.40	6.92	152,141.28	NA

Table ES.4. Winter DO TMDL for Subsegment 100404 (Cypress Bayou Reservoir).

	Oxygen Demand (kg/day) from:					Oxygen Demand (lbs/day) from:					Percent Reduction Needed
	SOD	CBODu	Organic Nitrogen	Ammonia Nitrogen	Total	SOD	CBODu	Organic Nitrogen	Ammonia Nitrogen	Total	
Point Sources											
WLA	NA	6.50	4.07	2.03	12.61	NA	14.33	8.97	4.48	27.80	0
MOS	NA	0.81	0.51	0.25	1.58	NA	1.79	1.12	0.55	3.48	NA
FG	NA	0.81	0.51	0.25	1.58	NA	1.79	1.12	0.55	3.48	NA
Nonpoint Sources											
LA	23,098.92	11,000.06	4,168.92	4.75	38,272.67	50,923.88	24,250.73	9,190.80	10.47	84,375.93	0%
MOS	2,887.37	1,375.01	521.12	0.59	4,784.08	6,365.50	3,031.35	1,148.86	1.30	10,546.98	NA
FG	2,887.37	1,375.01	521.12	0.59	4,784.08	6,365.50	3,031.35	1,148.86	1.30	10,546.98	NA
TMDL	28,873.66	13,758.20	5,216.25	8.46	47,856.60	63,654.87	30,331.33	11,499.74	18.65	105,504.66	NA

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

LIST OF APPENDICES

LIST OF TABLES

LIST OF TABLES (CONTINUED)

1.0 INTRODUCTION

This report presents total maximum daily loads (TMDLs) for dissolved oxygen (DO) for Cypress Bayou Reservoir and Black Bayou Reservoir (Subsegments 100404 and 100405, respectively). These subsegments were cited as being impaired on the final 2004 303(d) list for Louisiana (Louisiana Department of Environmental Quality (LDEQ) 2005). The priority ranking and the suspected sources and suspected causes for impairment from the 303(d) list are presented in Table 1.1. The TMDLs in this report were developed in accordance with Section 303(d) of the Federal Clean Water Act and United States Environmental Protection Agency (USEPA) regulations at Title 40 Code of Federal Regulations (CFR) Part 130.7.

The purpose of a TMDL is to determine the pollutant loading that a waterbody can assimilate without exceeding the water quality standard for that pollutant and to establish the load reduction that is necessary to meet the standard in a waterbody. The TMDL is the sum of the wasteload allocation (WLA), the load allocation (LA), future growth (FG), and a margin of safety (MOS). The WLA is the load allocated to point sources of the pollutant of concern. The LA is the load allocated to nonpoint sources, including natural background. The FG is reserved for future increases in loads to the waterbody. The MOS is a percentage of the TMDL that accounts for any lack of knowledge concerning the relationships between pollutant loading and water quality, including uncertainty associated with model assumptions and data inadequacies.

Table 1.1. Summary of 303(d) listing for Subsegments 100404 and 100405.

Subsegment Number	Waterbody Description	Suspected Causes	Suspected Sources	Priority Ranking (1 = highest)
100404	Cypress Bayou Reservoir	Low DO	Unknown	7
100405	Black Bayou Reservoir	Low DO	Unknown	7

2.0 STUDY AREA DESCRIPTION

2.1 General Information

Cypress Bayou Reservoir and Black Bayou Reservoir Subsegments 100404 and 100405, respectively) are located in northwestern Louisiana in the Red River basin approximately 10-15 miles north of Shreveport (see Figure A.1 in Appendix A). Miscellaneous information for these reservoirs is listed in Table 2.1.

Table 2.1. Miscellaneous information for Cypress Bayou Reservoir and Black Bayou Reservoir.

	Cypress Bayou Reservoir	**Black Bayou Reservoir**
Subsegment number	100404	100405
Area of subsegment	25.7 mi^2	24.9 mi^2
Total drainage area at dam [A]	155 mi^2	24.9 mi^2
Area of lake at normal pool [B]	2,970 acres (4.64 mi^2)	600 acres (0.94 mi^2)
Normal pool elevation [C]	180 ft	185 ft
Year that dam was built	1975	1975
Original purpose of lake	Recreational uses	Recreational uses

[A] Drainage area of Cypress Bayou Reservoir is from USGS (1999a).
[B] Lake areas were calculated from bathymetric maps of each lake (USGS 1999a; USGS 1999b).
[C] Normal pool elevations were assumed to be the elevations of the spillways (USGS 1999a; USGS 1999b).

There is a control structure that could be used to transfer water between the two reservoirs by gravity flow, but it is rarely used. Water can flow out of each reservoir into Cypress Bayou whenever the water surface elevations rise above the elevations of the spillways. Controlled releases can be made from Black Bayou Reservoir at two locations; the release structure on the east side of the reservoir releases water into Cypress Bayou (the natural drainage path). Another release structure on the west side of the reservoir releases water into Flat River. Controlled releases from Cypress Bayou Reservoir can be made at one location, which drains into Cypress Bayou. Controlled releases are usually made to satisfy downstream demands for irrigation water.

Cypress Black Bayou Park and Recreation Area borders Cypress Bayou Reservoir on the west side of the reservoir.

2.2 Land Use

Land use characteristics for Subsegments 100404 and 100405 were compiled from the United States Geological Survey (USGS) 2001 National Land Cover Database (USGS 2006). These data are the most recent land use data that are currently available for this area. The spatial distribution of these land uses is shown on Figure A.2 (located in Appendix A) and land use percentages are shown in Table 2.2. These data indicate that the most common land use in these subsegments is forest.

Table 2.2. Land uses in Subsegments 100404 and 100405.

Land Use Type	Percent of Total Area	
	100404	100405
Water	17.1%	3.7%
Urban/Transportation	12.0%	8.5%
Barren	0.0%	0.0%
Forest	45.7%	56.1%
Grassland/Pasture/Hay	16.1%	20.2%
Cultivated Crops	0.0%	0.0%
Wetlands	9.1%	11.5%
TOTAL	100.0%	100.0%

2.3 Water Quality Standards

Water quality standards for Louisiana are included in the Title 33 Environmental Regulatory Code (LDEQ 2007). The designated uses for Subsegments 100404 and 100405 are primary contact recreation, secondary contact recreation, propagation of fish and wildlife, drinking water supply, and agriculture. The primary numeric criteria for the TMDLs presented in this report are the DO criterion of 5 mg/L (year round) and the temperature criterion of 32°C.

The Louisiana water quality standards also include an antidegradation policy (LAC 33:IX.1109.A). This policy states that waters exhibiting high water quality should be maintained at that high level of water quality. If this is not possible, water quality of a level that supports designated uses of the waterbody should be maintained. Changing the designated uses of a waterbody to allow a lower level of water quality can only be achieved through a use attainability study.

2.4 Point Sources

A list of point sources in selected portions of the Red River basin was developed using data from LDEQ's internal point source databases with additional information obtained from LDEQ’s Electronic Document Management System (EDMS). Based on this information, three point sources were identified within subsegments 100404 and 100405. Table 2.3 is a summary of the permit information for these three point sources. The locations of these point sources are shown on Figure A.1 in Appendix A. Both of the point sources with active permits were included in the water quality model and TMDL calculations presented later in this report.

Table 2.3. Point sources for Subsegments 100404 and 100405.

Subsegment Number	Permit Number and AI Number	Company and Facility Name	Type of Discharge	Receiving Water-body	Flow (gallons per day)	Permit Limits		Included in model?	Included in TMDL?
						Concentration and Parameter	Type		
100404	LAG530158 (AI=41198)	Cypress Black Bayou Recreation District	Sanitary waste-water	Local drainage, then into Cypress Bayou Reservoir	3,125	45 mg/L BOD5	Weekly average	yes	yes
100404	LAG560185 (AI=42002)	Eagle Water, Inc. Cypress Gardens Oxidation System	Sanitary waste-water from residences	Local drainage, then into Cypress Bayou Reservoir	30,200 expected	20 mg/L BOD5	Monthly average	yes	yes
100405	LA0111252 (AI=31146)	Calumet Lubricants Cottage Grove Tank Farm	Permit was inactivated in 2003 because the only discharge is stormwater that is not associated with industrial activity.					no	no

2.5 Nonpoint Sources

The 303(d) list did not cite any specific nonpoint sources as suspected sources of the impairments for Subsegments 100404 and 100405 (Table 1.1). Based on land use data and other information, forestry activities and cattle in pastures may contribute some oxygen demanding pollutants to these reservoirs.

Another potential nonpoint source of oxygen demanding pollutants to the reservoirs is the numerous homes along the shorelines of both reservoirs. Some of the homes are connected to the Eagle Water wastewater treatment plant, but other homes use either a septic system or an onsite treatment system that consists of a small tank, aerator, and either a sprinkler system or field lines on the homeowner's land. Only a few homes have septic tanks because most homes have soils that are not suitable for septic tanks due to poor percolation. Neither the onsite treatment systems nor the septic tanks have direct discharges to the reservoirs (Bossier Parish Health Unit 2007).

The magnitude of individual nonpoint sources is not computed here because these TMDLs focus on total nonpoint source loading. Individual sources should be quantified by state or local agencies during development of an implementation plan.

2.6 Historical Data Summary

The two LDEQ routine ambient monitoring stations in these subsegments are Station 1181 (Cypress Bayou Reservoir southeast of Benton, Louisiana) and Station 1182 (Black Bayou Reservoir at Linton Road, southeast of Benton, Louisiana). The locations of these monitoring stations are shown on Figure A.1 in Appendix A. The DO data from these two monitoring stations are summarized in Table 2.4 and the individual data are listed in Tables B.1 and B.2 in Appendix B. The percentage of DO values below the 5 mg/L criterion was 23% for Station 1181 and 17% for Station 1182. These percentages are slightly higher than the allowable percentage of DO violations in USEPA's guidance for assessment procedures (10%; USEPA 2002).

Table 2.4. Summary of LDEQ DO data for Subsegments 100404 and 100405.

Station	Waterbody	Period of Record	Total Number of Values	Min. (mg/L)	Average (mg/L)	Median (mg/L)	Max. (mg/L)	Number of Values Below Criterion	Percent of Values Below Criterion
1181	Cypress Bayou Reservoir	Jan – Dec 2002 and Jan 2007	13	4.4	7.5	8.2	9.9	3	23%
1182	Black Bayou Reservoir	Jan – Dec 2002	12	4.3	7.4	7.0	10.0	2	17%

2.7 Previous Studies

The two previous studies that were found for Subsegments 100404 and 100405 were bathymetric surveys of Cypress Bayou Reservoir (USGS 1999a) and Black Bayou Reservoir (USGS 1999b). These studies produced bathymetric maps with depth contours showing maximum depths slightly over 20 ft for each reservoir. Each study also included a few measurements of DO and other in situ parameters.

The DO data showed stratification occurring at depths of 12 through 18 ft for Cypress Bayou Reservoir and 10 through 14 ft for Black Bayou Reservoir. DO values near the surface were 4.9 to 5.3 mg/L for Cypress Bayou Reservoir and 3.5 to 4.3 mg/L for Black Bayou Reservoir. DO values near the bottom were less than 0.5 mg/L for Cypress Bayou Reservoir and less than 1.0 mg/L for Black Bayou Reservoir.

3.0 FTN FIELD DATA

FTN conducted a field survey for 14 subsegments in the Red River and Sabine River basins during August 31 through September 9, 2005. Low flow conditions existed throughout the survey area during this time. The survey was conducted after Hurricane Katrina and before Hurricane Rita. Hurricane Katrina did not cause any noticeable impacts on water quality in the survey area.

The field survey included water quality sampling and corresponding in situ measurements at various locations; measurements of flow, depth, and width at several locations; and continuous in situ monitoring at several locations. The water quality samples were analyzed for 20-day carbonaceous biochemical oxygen demand (CBOD) time series, total Kjeldahl nitrogen (TKN), ammonia nitrogen, nitrate+nitrite nitrogen, total phosphorus, chlorophyll *a*, total organic carbon (TOC), and total suspended solids (TSS). A list of the survey sites and the type of data collected at each site is presented in Table C.1 (in Appendix C). The in situ measurements and water quality sampling results are summarized in Tables C.2 and C.3, respectively. The calculations of CBOD decay rates and ultimate CBOD (CBODu) concentrations from the time series data are shown in Table C.4.

For Subsegments 100404 and 100405, data were collected at two stations in each subsegment. The locations of these stations are shown on Figure A.1 in Appendix A. The data for each subsegment are summarized in Tables 3.1 and 3.2. The only DO measurement below the 5 mg/L criterion was a value of 1.0 mg/L, which was measured in Black Bayou upstream of the reservoir.

Table 3.1. FTN field data collected for Subsegment 100404.

	Station 100404-A (Cypress Bayou Reservoir at Highway 162)	**Station 1181 (Cypress Bayou Reservoir)**
Date and time of sample / measurements	9/01/05 11:20 AM	9/01/05 10:44 AM
Depth (m) of sample / measurements	--	0.46
Water temperature (°C)	30.4	30.8
DO (mg/L)	6.1	7.3
Conductivity (µmhos/cm)	51	54
pH (su)	7.0	7.3
TSS (mg/L)	--	7.7
TKN (mg/L)	--	1.8
Total phosphorus (mg/L)	--	0.045
TOC (mg/L)	--	9.1
Chlorophyll *a* (µg/L)	--	35
Ammonia nitrogen (mg/L)	--	0.24
Nitrate+nitrite nitrogen (mg/L)	--	<0.05
CBOD on day 2 of analysis (mg/L)	--	<2.0
CBOD on day 5 of analysis (mg/L)	--	3.3
CBOD on day 9 of analysis (mg/L)	--	5.0
CBOD on day 14 of analysis (mg/L)	--	5.3
CBOD on day 20 of analysis (mg/L)	--	5.2
Ultimate CBOD (mg/L; calculated)	--	5.49
CBOD decay rate (1/day; calculated)	--	0.22
Flow (cfs)	--	--

Table 3.2. FTN field data collected for Subsegment 100405.

	Station 100405-A (Black Bayou at Highway 162)	**Station 1182 (Black Bayou Reservoir)**
Date and time of sample / measurements	9/01/05 11:45 AM	9/01/05 10:20 AM
Depth (m) of sample / measurements	mid-depth	0.77
Water temperature (°C)	24.9	29.8
DO (mg/L)	1.0	5.5
Conductivity (µmhos/cm)	440	75
pH (su)	6.9	7.2
TSS (mg/L)	8.4	8.0
TKN (mg/L)	2.4	1.9
Total phosphorus (mg/L)	0.082	0.061
TOC (mg/L)	12	10
Chlorophyll *a* (µg/L)	<20	51
Ammonia nitrogen (mg/L)	0.56	0.14
Nitrate+nitrite nitrogen (mg/L)	<0.05	<0.05
CBOD on day 2 of analysis (mg/L)	<2.0	2.9
CBOD on day 5 of analysis (mg/L)	<2.0	4.8
CBOD on day 9 of analysis (mg/L)	3.3	6.7
CBOD on day 14 of analysis (mg/L)	5.1	8.1
CBOD on day 20 of analysis (mg/L)	6.9	12.0
Ultimate CBOD (mg/L; calculated)	12.47	15.61
CBOD decay rate (1/day; calculated)	0.05	0.06
Flow (cfs)	too low to measure	--

4.0 CALIBRATION OF WATER QUALITY MODEL

4.1 Model Setup

In order to evaluate the linkage between pollutant sources and water quality, a computer simulation model was used. The model used for these TMDLs was Version 8.11 of LA-QUAL (Wiland and LeBlanc 2007), which was selected because it includes the relevant physical, chemical, and biological processes and it has been used successfully in the past for other TMDLs in Louisiana. The LA-QUAL model was set up to simulate organic nitrogen, ammonia nitrogen, ultimate carbonaceous biochemical oxygen demand (CBODu), and DO.

Figures D.1 and D.2 in Appendix D show the model reach/element design and the location of the modeled inflows for the Cypress Bayou Reservoir model and the Black Bayou Reservoir model. Each reservoir was modeled separately because the structure that allows water to be transferred from Black Bayou Reservoir to Cypress Bayou Reservoir is rarely used (see Section 2.1). Each model was divided into four reaches to represent varying depths and widths along the length of each reservoir. All reaches were divided into smaller elements to take into account variation in water quality along their length.

4.2 Calibration Period and Calibration Targets

The two conditions that usually characterize critical periods for DO are high temperatures and low flows. High temperatures decrease DO saturation values and increase rates for oxygen demanding processes (CBOD decay, nitrification, and sediment oxygen demand (SOD)). In most systems, low flow causes low reaeration rates. The purpose of selecting a critical period for calibration is so that the model will be calibrated as accurately as possible for making projection simulations for critical conditions.

The two data sets that were considered for model calibration were the FTN field survey (September 1, 2005) and the LDEQ routine monitoring data at Stations 1181 and 1182 (approximately monthly during 2002). The FTN field survey was chosen for the calibration period for both models because the survey was conducted during hot, dry conditions, field data were collected at multiple locations within each subsegment, and the FTN field survey included measurements that were not available for the LDEQ routine ambient monitoring data (e.g., CBOD values).

The calibration targets (i.e., the concentrations to which the model was calibrated) for each parameter were set equal to the concentrations measured during the field survey with the exception of DO, which was set equal to the estimated daily minimum DO plus 1 mg/L. Continuous in situ data were not available at the four field survey sites in Subsegments 100404 and 100405; therefore, a minimum daily DO was estimated at each site by assuming that the ratio of instantaneous DO to daily minimum DO at any given time was the same at these four sites as it was at the nearest site with continuous in situ data (Station 272 – Flat River near Taylortown). Estimated daily minimum DO values for the monitoring sites in Subsegments 100404 and 100405 were calculated as the instantaneous DO measurement divided by the ratio of instantaneous DO to daily minimum DO that was calculated for Station 272 at the same time that the instantaneous value was measured. These calculations are shown in Table C.5 and the results are summarized in Table 4.1. The Station 100405-A data were not included in these calculations because that station represented boundary conditions (headwater) rather than a calibration target within the simulated waterbody.

Table 4.1. Summary of values used to develop DO calibration targets.

Station	Date	Time	Instantaneous DO (mg/L)	Ratio of instantaneous DO to daily minimum DO	Estimated daily minimum DO (mg/L)	Calibration target (mg/L)
100404-A	9/01/05	11:20	6.1	2.29	2.7	3.7
1181	9/01/05	10:44	7.3	2.00	3.7	4.7
1182	9/01/05	10:20	5.5	1.67	3.3	4.3

4.3 Program Constants (Data Type 3)

A value was input to replace the LA-QUAL default value for net oxygen production per unit of chlorophyll *a*. The default value (0.05 mg oxygen / µg chlorophyll *a* / day) was replaced because the chlorophyll specified in the initial conditions was contributing an unreasonably large amount of oxygen to the reservoirs in the preliminary simulations. Calculations of oxygen production from photosynthesis and oxygen consumption from respiration were developed in a spreadsheet for a 24-hour period during the calibration period (shown in Appendix E). The calculations assumed a steady state concentration of algae; the increases in algal biomass due to growth were equal to the decreases in algal biomass due to respiration and settling over a 24-hour period. The net rate of oxygen added to the system from the combination of photosynthesis and respiration over a 24-hour period was calculated to be 0.026 mg oxygen / µg chlorophyll *a* / day. This value was input to the model in Data Type 3.

Another model parameter that was specified in Data Type 3 was the effective BOD due to algae. The default value of this parameter (zero) was overridden because preliminary model simulations indicated that a large amount of the CBODu came from algae. The LA-QUAL User's Manual (Wiland and LeBlanc 2007) recommends a range of values from 0.10 to 0.25 mg/L of BOD per µg/L of chlorophyll *a* for this parameter. The value used in both models was 0.10 mg/L of BOD per µg/L of chlorophyll *a*, which was within the range of values in the User's Manual and within the range of values used by LDEQ in other approved TMDLs.

4.4 Temperature Correction of Kinetics (Data Type 4)

The temperature correction factors used in the model were consistent with the Louisiana Technical Procedures Manual (the "LTP"; LDEQ 2006). These correction factors were:

- Correction for BOD decay: 1.047 (value in LTP is same as model default)
- Correction for SOD: 1.065 (value in LTP is same as model default)
- Correction for ammonia N decay: 1.070 (specified in Data Group 4)
- Correction for organic N decay: 1.020 (not specified in LTP; model default used)

4.5 Hydraulics (Data Type 9)

The widths and depths were specified in the LA-QUAL model using the power functions (width = $a * Q^b + c$ and depth = $d * Q^e + f$). The width and depth of each reach for a given model were calculated based on the bathymetric maps discussed in Section 2.7 (USGS 1999a; USGS 1999b). The bathymetric contours were digitized and used to calculate volumes and surface areas at each depth contour. The average width for each reach was calculated as the surface area divided by the reach length. The average depth for each reach was calculated as the volume divided by the surface area. Because the widths and depths in these reservoirs do not fluctuate as a function of the flow rate through the reservoir, the depths and widths were entered in each model as constants. The values that were used as inputs to each model for length, width, and depth of each reach are listed in Table 4.2.

Table 4.2. Model calibration input values for reach length, width, and depth.

Waterbody	Reach	Length (km)	Width (m)	Depth (m)
Black Bayou Reservoir	1	2.0	209	0.366
	2	2.0	295	1.883
	3	1.7	351	3.076
	4	2.0	420	3.606
Cypress Bayou Reservoir	1	3.0	1,173	1.357
	2	2.7	1,339	2.689
	3	1.6	1,097	2.542
	4	2.8	1,122	3.846

4.6 Initial Conditions (Data Type 11)

Because temperature is not being simulated in the model, the temperature for each reach was specified in the initial conditions for LA-QUAL based on temperatures measured during the FTN field survey. Values for chlorophyll *a* were also specified in the initial conditions because observations and data from the FTN field survey indicated that both reservoirs have a significant amount of algae. The chlorophyll *a* values were set to observed values from the FTN field study. Initial concentrations of DO and ammonia nitrogen were set equal to the calibration targets and measured values, respectively; values for these two parameters are used by the model only as starting points for its iterative solution technique. The values used as model inputs are shown in Table 4.3.

For other constituents not being simulated, the initial concentrations were set to zero. Otherwise the model would have assumed a fixed concentration of those constituents and the model would have included effects of the unmodeled constituents on the modeled constituents.

Table 4.3. Model input values for initial conditions (Data Type 11).

Waterbody	Parameter	Reaches	Value used in model	Data Source / Comment
Black Bayou Reservoir	Temperature	1-4	29.8°C	FTN measured value at Station 1182
	DO	1-4	4.3 mg/L	Calibration target for Station 1182
	Ammonia N	1-4	0.14 mg/L	FTN measured value at Station 1182
	Chlorophyll *a*	1-4	51 µg/L	FTN measured value at Station 1182
Cypress Bayou Reservoir	Temperature	1-4	30.6°C	Average of FTN measured values at Stations 100404-A and 1181
	DO	1	3.7 mg/L	Calibration target for Station 100404-A
		2,3	4.2 mg/L	Average of values for reaches 1 and 4
		4	4.7 mg/L	Calibration target for Station 1181
	Ammonia N	1-4	0.24 mg/L	FTN measured value at Station 1181
	Chlorophyll *a*	1-4	35 µg/L	FTN measured value at Station 1181

4.7 Water Quality Kinetics (Data Types 12 and 13)

Kinetic rates used in LA-QUAL include reaeration rates, CBOD decay rates, nitrification rates, and mineralization rates (organic nitrogen decay).

For reaeration, a surface transfer coefficient (option 20) was specified because reaeration in both reservoirs is controlled by wind rather than by velocity of flowing water. The surface transfer coefficient was calculated using the daily average wind speed for the calibration period (September 1, 2005) from the Shreveport Regional Airport, which is about 15 to 20 miles south-southwest of the reservoirs. The daily average wind speed was 5.0 knots (5.75 miles per hour; NCDC 2007) and the resulting surface transfer coefficient was 0.97 m/day. This value was used in both models. The calculations for the surface transfer coefficient are shown in Appendix F.

The CBOD decay rate for both models was set to 0.14/day, which was the average of the laboratory CBOD decay rates from samples collected at stations 1181 and 1182 during the FTN field survey (0.06/day and 0.22/day; Tables 3.1 and 3.2). The difference between the two individual decay rates was assumed to be due to analytical variability rather than real differences in the composition of CBOD in each lake.

The nitrification rate for both models was set to 0.08/day, which was the average of 36 nitrogenous BOD (NBOD) decay rates measured by LDEQ in forested subsegments in the Ouachita River and Calcasieu River basins (shown in Table B.3 in Appendix B).

The mineralization rates (organic nitrogen decay) in the model were set to 0.02/day for both models. This value was similar to the values shown in the "Rates, Constants, and Kinetics" publication (USEPA 1985) for dissolved organic nitrogen being transformed to ammonia nitrogen.

4.8 Nonpoint Source Loads (Data Type 19)

The nonpoint sources loads that are specified in the model can be most easily understood as resuspended load from the bottom sediments and are modeled as SOD, benthic ammonia source rates, CBOD loads, and organic nitrogen loads. The SOD (specified in data type 12), the benthic ammonia source rates (specified in data type 13), and the mass loads of organic nitrogen and CBODu (specified in data type 19) were all treated as calibration parameters; their values were adjusted until the model output was similar to the calibration target values. The values used as model input are shown in Table 4.4. No benthic ammonia source was included in the models because the predicted ammonia nitrogen values were slightly higher than the calibration targets even without the benthic source.

Table 4.4. Nonpoint source loads for model calibration.

Waterbody	Reach	SOD ($g/m^2/day$)	Benthic Ammonia Source ($g/m^2/day$)	CBODu Load (kg/day)	Organic Nitrogen Load (kg/day)
Black Bayou Reservoir	1	1.50	0	345	6.5
	2	1.50	0	2570	47
	3	1.35	0	4250	78
	4	1.40	0	7000	127
Cypress Bayou Reservoir	1	2.90	0	2,150	184
	2	3.10	0	4,300	378
	3	2.90	0	2,000	172
	4	3.40	0	5,300	465

4.9 Headwater Flow Rates (Data Type 20)

Headwater inflow rates were specified for each model Table 4.5. The inflow rates for Black Bayou Bayou Reservoir and Cypress Bayou Reservoir were estimated by multiplying the estimated headwater drainage area (24 mi^2 and 132 mi^2 respectively) by an estimated average flow per unit area for the basin. The flow had to be estimated since the flow gage for Cypress Bayou near Benton (USGS 07349795) was discontinued in 1986 and there was no flow gage on Black Bayou. The average flow per unit area was calculated by taking the flow measured on September 1, 2005 at Bayou Dorcheat near Springhill, LA (USGS 07348700), dividing it by the drainage area of the gage, and multiplying the result by the ratio of the historical average flow at Bayou Dorcheat near Springhill to the average flow at Cypress Bayou near Benton (USGS 07349795). These calculations are included in Appendix G.

4.10 Headwater Water Quality (Data Types 21)

Concentrations of DO, CBODu, organic nitrogen, and ammonia nitrogen were specified in the model for the headwater flows (Table 4.5). Water quality for both headwaters was set to the concentrations measured at 100405-A, Black Bayou upstream of the reservoir. Station 100405-A was used for both lakes since there was no other headwater water quality data for either Cypress Bayou Reservoir or Black Bayou Reservoir, and the watersheds are similar in land use and topography.

Table 4.5. Headwater inputs (Data Types 20 and 21) for Black Bayou and Cypress Bayou Reservoir.

Name of inflow	Parameter name	Value used in model	Data Source / Comment
Cypress Bayou Reservoir	Flow rate	0.00221 m^3/sec	Average flow per unit area times area of upstream Subsegment (100403)
Black Bayou Reservoir	Flow rate	0.01215 m^3/sec	Average flow per unit area times area of subsegment
These parameters apply to both models.	DO	1.0 mg/L	Values measured at 100405-A during FTN intensive survey.
	CBODu	13.1 mg/L	
	Organic N	1.84 mg/L	
	Ammonia N	0.56 mg/L	

4.11 Point Source Inputs (Data Types 24 and 25)

Two NPDES permitted dischargers were included in the Cypress Bayou Reservoir model. There were no modeled point sources in the Black Bayou Reservoir model. The point source flows and water quality concentrations were set to their average effluent concentrations based on DMRs for September and August. The nitrogen load was assumed to be half of the BOD load, with 2/3 of the nitrogen assumed to be ammonia and 1/3 assumed to be organic based on the LTP and assuming mechanical treatment plant. The values used in the calibration models are shown in Table 4.6.

Table 4.6. Wasteload inputs (Data Types 24 and 25) for Cypress Bayou Reservoir Model.

Name of Point Source	Parameter name	Value used in model	Data Source / Comment
Eagle Water Inc. (LA560185)	Flow rate	0.0014 m^3/sec	Average of monthly flows for August and September from DMRs.
	DO	5.0	From LTP, based on assumption of advanced treatment.
	CBODu	12.9 mg/L	Average of BOD5 values from August and September DMRs time 2.3.
	Organic N	4.3 mg/L	One third of total nitrogen concentration of 6.45 mg/L (based on advanced treatment) Half of ammonia nitrogen (from LTP).
	Ammonia N	2.15 mg/L	Two thirds of total nitrogen concentration of 6.45 mg/L (based on advanced treatment) Half of ammonia nitrogen (from LTP).
Cypress Black Bayou Recreation District (LAG530158)	Flow rate	0	No discharge reported on DMR for calibration period.
	DO	0	
	CBODu	0	
	Organic N	0	
	Ammonia N	0	

4.12 Model Results for Calibration

Plots of predicted and observed water quality for the calibrations are presented in Appendix H (Black Lake Reservoir) and Appendix I (Cypress Bayou Reservoir) along with printouts of the LA-QUAL output files. The calibrations were considered to be acceptable based on the amount of data that were available.

5.0 WATER QUALITY MODEL PROJECTION

USEPA's regulations at 40 CFR 130.7 require the determination of TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. Therefore, the calibrated models were used to project water quality for critical conditions. The identification of critical conditions and the model input data used for critical conditions are discussed below.

5.1 Identification of Critical Conditions

Section 303(d) of the Federal Clean Water Act and USEPA's regulations at 40 CFR 130.7 both require the consideration of seasonal variation of conditions affecting the constituent of concern and the inclusion of a MOS in the development of a TMDL. For the TMDLs in this report, analyses of LDEQ long-term ambient data were used to determine critical seasonal conditions. A combination of implicit and explicit MOS was used in developing the projection model.

Critical conditions for DO have been determined for Louisiana waterbodies in previous TMDL studies. The analyses concluded that the critical conditions for stream DO concentrations occur during periods with negligible nonpoint runoff, low stream flow, and high stream temperature.

When the rainfall runoff (and nonpoint loading) and stream flow are high, turbulence is higher due to the higher flow and the stream temperature is lowered by the cooler precipitation and runoff. In addition, runoff coefficients are higher in cooler weather due to reduced evaporation and evapotranspiration, so that the high flow periods of the year tend to be the cooler periods. DO saturation values are; of course, much higher when water temperatures are cooler, but BOD decay rates are much lower. For these reasons, periods of high loading are periods of higher reaeration and DO but not necessarily periods of high BOD decay.

LDEQ interprets this phenomenon in its TMDL modeling by assuming that the annual nonpoint loading, rather than loading for any particular day, is responsible for the accumulated benthic blanket of the stream, which is, in turn, expressed as SOD and/or resuspended BOD in the model. This accumulated loading has its greatest impact on the stream during periods of higher temperature and lower flow.

According to the LTP, critical summer conditions in DO TMDL projection modeling are simulated by using the annual 7Q10 flow or 0.1 cfs, whichever is higher, for all headwaters, and 90^{th} percentile temperature for the summer season. Critical winter conditions in DO TMDL projection modeling are simulated by setting the headwater flows to either the winter 7Q10 flow or 1.0 cfs, whichever is higher, and by using the 90^{th} percentile temperature for the winter season. Model loading is from perennial tributaries, point sources, SOD, and resuspension of sediments.

In reality, the highest temperatures occur in July through August and the lowest stream flows occur in October through November. The combination of these conditions plus the impact of other conservative assumptions regarding rates and loadings yields an implicit MOS that is not quantified. Over and above this implicit MOS, explicit MOS of 10% for nonpoint sources, and 20% for point sources were incorporated into the TMDLs in this report to account for model uncertainty.

5.2 Temperature Inputs

The LTP (LDEQ 2001) specified that the critical temperature should be determined by calculating the 90^{th} percentile seasonal temperature for the waterbody being modeled. The LDEQ water quality monitoring stations on Black and Cypress reservoirs are not long term stations, so they do not have enough data to estimate long term 90^{th} percentile seasonal temperatures. There is an LDEQ station on nearby Lake Bistineau with a long term temperature record (Station 0275). Therefore, data from Lake Bistineau were used to estimate 90^{th} percentile temperatures for Black and Cypress reservoirs. The long term water temperature data collected by LDEQ at Station 0275 on Lake Bistineau are summarized in Table J.1 in Appendix J. Calculations for 90th percentile temperatures were developed for this station for each season (summer and winter). These calculations are shown in Table J.2. These calculations resulted in 90^{th} percentile temperatures of 31.2°C for summer and 19.3°C for winter (see Table J.2). These temperatures were adjusted based on differences between seasonal average temperatures taken at

Black and Cypress reservoirs (Stations 1182 and 1181 respectively) and Lake Bistineau (Station 0275) during their overlapping period of record (2002). These calculations are shown in Tables J.3 and J.4 in Appendix J. The 90th percentile temperatures used as model inputs for the Black Bayou Reservoir projection simulations were 30.2°C for summer and 16.5°C for winter. The 90th percentile temperatures used as model inputs for the Cypress Bayou Reservoir projection simulations were 30.2ºC for summer and 15.9ºC for winter. These values were specified in Data Type 11.

5.3 Headwater Inputs

The inputs for the headwaters for the projection simulations were based on guidance in the LTP. As specified in the LTP, the DO concentrations for the headwater inflows were set to 90% saturation at the critical temperature. Headwater concentrations for other parameters were set to calibration values. Headwater flows for the summer projection were set to either the 7Q10 flow or 0.1 cfs, whichever was greater, and for the winter projection were set to either the 7Q10 flow or 1.0 cfs, whichever was greater.

7Q10 flows were estimated for the headwaters. A basin 7Q10 flow per square mile was used to estimate the headwaters 7Q10 inflows. The basin 7Q10 flow per square mile was estimated by dividing the annual and December through February 7Q10 flows reported for USGS Gage 07349795 (Cypress Bayou above Benton, LA), by the drainage area of the gage. The annual 7Q10 for this gage was reported as zero. Therefore, the headwater flows for the summer projections were set to 0.1 cfs. The December through February 7Q10 reported for this gage was 0.72 cfs. The winter headwater 7Q10 flows estimated from this reported value were less than 1.0 cfs, so the winter projection headwater flows were set to 1.0 cfs for both Black Bayou and Cypress Bayou Reservoirs. These calculations are included in Appendix K.

5.4 Point Source Inputs

The point source flows for the Cypress Bayou Reservoir projection simulations were set to 1.25 times the design flows to allow for an MOS (Table 5.1). CBODu concentrations for the point sources were set to 2.3 times the CBOD5 permit limits. The other water quality for the wasteloads were set based on the BOD5 permit limit for the facilities, using LTP guidance (Table 5.1). The same values were used for both the summer and winter projections.

Table 5.1. Wasteload inputs (Data types 24 and 25) for Cypress Bayou Reservoir Model.

Name of Point Source	Parameter name	Value used in model	Data Source / Comment
Eagle Water Inc. (LA560185)	Flow rate	0.0016 m^3/sec	1.25 times expected flow (30,200 gpd)
	DO	5.0 mg/L	From LTP, based on assumption of advanced treatment
	CBODu	46 mg/L	2.3 times 20 mg/L BOD5 permit limit
	Organic N	6.67 mg/L	From LTP, one third of total nitrogen concentration of 10 mg/L (based on advanced treatment)
	Ammonia N	3.33 mg/L	From LTP, two thirds of total nitrogen concentration of 10 mg/L (based on advanced treatment)
Cypress Black Bayou Recreation District (LAG530158)	Flow rate	0.00017 m^3/sec	1.25 times design flow (3,125 gpd)
	DO	2.0 mg/L	From LTP, based on assumption of secondary treatment
	CBODu	103 mg/L	2.3 times 45 mg/L BOD5 permit limit
	Organic N	15 mg/L	From LTP, one third of total nitrogen concentration of 22.5 mg/L (based on secondary treatment)
	Ammonia N	7.5 mg/L	From LTP, two thirds of total nitrogen concentration of 22.5 mg/L (based on secondary treatment)

5.5 Nonpoint Source Loads

Because most of the initial projection simulations were showing low DO values, the nonpoint sources loadings were reduced until all of the predicted DO values were equal to or greater than the water quality criterion of 5.0 mg/L. The same percent reduction was applied to the SOD and nonpoint sources mass loads of CBODu and organic nitrogen. SOD was not reduced below 0.5 g/m^2/day. The values used as model input in the projection simulations are shown in Table 5.2.

Table 5.2. Nonpoint source loads for projection models.

Waterbody	Season	Reach	SOD ($g/m^2/day$)	Benthic Ammonia Source ($g/m^2/day$)	CBODu Load (kg/day)	Organic Nitrogen Load (kg/day)
Black Bayou Reservoir	Summer	1	1.43	0	321	4
		2	1.43	0	2343	30
		3	1.28	0	3865	51
		4	1.33	0	6361	85
	Winter	1	1.24	0	286	5
		2	1.24	0	2128	39
		3	1.12	0	3519	65
		4	1.16	0	5796	105
Cypress Bayou Reservoir	Summer	1	2.23	0	1656	142
		2	2.39	0	3311	291
		3	2.23	0	1540	132
		4	2.62	0	4081	358
	Winter	1	2.90	0	2150	184
		2	3.10	0	4300	378
		3	2.90	0	2000	172
		4	3.40	0	5300	465

5.6 Other Inputs

The only model inputs that were changed from the calibration to the projection simulation were the inputs discussed above in Sections 5.2 through 5.5. Other model inputs (e.g., hydraulic coefficients, decay rates, reaeration equations, etc.) were unchanged from the calibration simulation.

5.7 Model Results for Projection

Plots of predicted water quality for the projection and printouts of the LA-Qual output files for Black Bayou Reservoir are presented in Appendix L (summer projection) and Appendix M (winter projection). Projection model outputs for Cypress Bayou Reservoir are presented in Appendix N (summer projection) and Appendix O (winter projection).

Oxygen demanding load reductions were required to meet the DO standard. An nonpoint sources load reduction of approximately 5% was required to bring the summer predicted DO values for Black Bayou Reservoir to at least 5.0 mg/L, and a 17.2% reduction was required to bring winter predicted DO values to at least 5.0 mg/L. For Cypress Bayou Reservoir, a nonpoint source reduction of approximately 23% was required to bring the summer predicted DO values to at least 5.0 mg/L. However, winter predicted values were greater than 5.0 mg/L with no nonpoint source reduction. The percentage reductions for nonpoint sources loads represent a percentage of the entire nonpoint sources loading, not a percentage of the manmade nonpoint sources loading. The nonpoint sources loads in this report were not divided between natural and manmade because it would be difficult to estimate natural nonpoint sources loads for the study area. No reductions were made to the point source loads to Cypress Bayou Reservoir in the projections.

6.0 TMDL CALCULATIONS

6.1 DO TMDL

TMDLs for DO have been calculated for Black Bayou and Cypress Bayou Reservoir subsegments based on the results of the projection simulations. The DO TMDL is presented as oxygen demand from CBODu, organic nitrogen, ammonia nitrogen, and SOD. Summaries of the loads for the subsegments are presented in Tables 6.1 through 6.5.

The TMDL calculations were performed using a FORTRAN program that was written by FTN personnel. This program reads two files; one is the LA-QUAL output file from the projection simulation and the other is a small file with miscellaneous information needed for the TMDL calculations (shown in Appendix P). The outputs from the program are shown in Appendix Q and the source code for the program is shown in Appendix R.

The oxygen demand from organic nitrogen and ammonia nitrogen was calculated as 4.33 times the nitrogen loads (assuming that all organic nitrogen is eventually converted to ammonia). The value of 4.33 is the same ratio of oxygen demand to nitrogen that is used by the LA-QUAL model. For the SOD loads, a temperature correction factor was included in the calculations (in order to be consistent with LDEQ procedures).

Table 6.1. Summer DO TMDL for Subsegment 100405 (Black Bayou Reservoir).

	Oxygen Demand (kg/day) from:					Oxygen Demand (lbs/day) from:					Percent Reduction Needed
	SOD	CBODu	Organic Nitrogen	Ammonia Nitrogen	Total	SOD	CBODu	Organic Nitrogen	Ammonia Nitrogen	Total	
Point Sources											
WLA	NA	0	0	0	0	NA	0	0	0	0	0
MOS	NA	0	0	0	0	NA	0	0	0	0	NA
FG	NA	0	0	0	0	NA	0	0	0	0	NA
Nonpoint Sources											
LA	5,053.6	1,0312	590.45	0.49	15,956.47	11,141.08	22,733.8	1,301.71	1.08	35,177.6	5%
MOS	631.7	1289	73.8	0.06	1,994.56	1,392.62	2,841.73	162.70	0.13	4,397.21	NA
FG	631.7	1289	73.8	0.06	1,994.56	1,392.62	2,841.73	162.70	0.13	4,397.21	NA
TMDL	6316.9	12,890.0	738.1	0.6	1,9945.6	13,926.32	2,8417.3	1,627.11	1.34	4,3972	NA

Table 6.2. Winter DO TMDL for Subsegment 100405 (Black Bayou Reservoir).

	Oxygen Demand (kg/day) from:					Oxygen Demand (lbs/day) from:					Percent Reduction Needed
	SOD	CBODu	Organic Nitrogen	Ammonia Nitrogen	Total	SOD	CBODu	Organic Nitrogen	Ammonia Nitrogen	Total	
Point Sources											
WLA	NA	0	0	0	0	NA	0	0	0	0	0
MOS	NA	0	0	0	0	NA	0	0	0	0	NA
FG	NA	0	0	0	0	NA	0	0	0	0	NA
Nonpoint Sources											
LA	1,852.91	9,383.20	756.89	4.75	11,997.75	4,084.93	20,686.20	1,668.64	10.47	26,450.24	17.2%
MOS	231.62	1,172.90	94.61	0.59	1,499.72	510.63	2,585.78	208.58	1.30	3,306.28	NA
FG	231.62	1,172.90	94.61	0.59	1,499.72	510.63	2,585.78	208.58	1.30	3,306.28	NA
TMDL	2,316.15	11,729.00	946.11	5.93	14,997.19	5,106.18	25,857.75	2,085.79	13.07	33,062.81	NA

Table 6.3. Summer DO TMDL for Subsegment 100404 (Cypress Bayou Reservoir).

	Oxygen Demand (kg/day) from:					**Oxygen Demand (lbs/day) from:**					**Percent Reduction Needed**
	SOD	**CBODu**	**Organic Nitrogen**	**Ammonia Nitrogen**	**Total**	**SOD**	**CBODu**	**Organic Nitrogen**	**Ammonia Nitrogen**	**Total**	
Point Sources											
WLA	NA	6.5	4.07	2.03	12.61	NA	14.33	8.97	4.48	27.80	0
MOS	NA	0.81	0.51	0.25	1.58	NA	1.79	1.12	0.55	3.48	NA
FG	NA	0.81	0.51	0.25	1.58	NA	1.79	1.12	0.55	3.48	NA
Nonpoint Sources											
LA	43,526.27	8,470.46	3,198.84	0.49	55,196.04	95,958.01	18,673.98	7,052.16	1.08	121,685.19	23%
MOS	5,440.78	1,058.81	399.85	0.06	6,899.51	11,994.74	2,334.25	881.51	0.13	15,210.66	NA
FG	5,440.78	1,058.81	399.85	0.06	6,899.51	11,994.74	2,334.25	881.51	0.13	15,210.66	NA
TMDL	54,407.83	10,596.20	4,003.63	3.14	69,010.83	119,947.50	23,360.38	8,826.40	6.92	152,141.28	NA

Table 6.4. Winter DO TMDL for Subsegment 100404 (Cypress Bayou Reservoir).

	Oxygen Demand (kg/day) from:					**Oxygen Demand (lbs/day) from:**					**Percent Reduction Needed**
	SOD	**CBODu**	**Organic Nitrogen**	**Ammonia Nitrogen**	**Total**	**SOD**	**CBODu**	**Organic Nitrogen**	**Ammonia Nitrogen**	**Total**	
Point Sources											
WLA	NA	6.50	4.07	2.03	12.61	NA	14.33	8.97	4.48	27.80	0
MOS	NA	0.81	0.51	0.25	1.58	NA	1.79	1.12	0.55	3.48	NA
FG	NA	0.81	0.51	0.25	1.58	NA	1.79	1.12	0.55	3.48	NA
Nonpoint Sources											
LA	23,098.92	11,000.06	4,168.92	4.75	38,272.67	50,923.88	24,250.73	9,190.80	10.47	84,375.93	0%
MOS	2,887.37	1,375.01	521.12	0.59	4,784.08	6,365.50	3,031.35	1,148.86	1.30	10,546.98	NA
FG	2,887.37	1,375.01	521.12	0.59	4,784.08	6,365.50	3,031.35	1,148.86	1.30	10,546.98	NA
TMDL	2,8873.66	13,758.20	5,216.25	8.46	47,856.60	6,3654.87	30,331.33	11,499.74	18.65	105,504.66	NA

Table 6.5. Flows, concentrations, and loads for point sources included in Subsegment 100404 DO TMDL.

Subsegment Number	NPDES Number	Name of discharger	Flow rate (gallons per day)	Concentrations			Loads*		
				BOD5 or CBOD5 (mg/L)	Ammonia nitrogen (mg/L)	Organic nitrogen (mg/L)	BOD5 or CBOD5 (lbs/day)	Ammonia nitrogen (lbs/day)	Organic nitrogen (lbs/day)
100404	LAG530158	C and B Rec. District	3,125	103.5	7.50	15.00	1.52	0.11	0.22
100404	LAG560185	Eagle Water Inc.	30,200	46.0	3.33	6.67	6.60	0.48	0.96
100404 Total Loads:							8.12	0.59	1.18

*Loads of organic nitrogen and ammonia nitrogen in this table represent loads of nitrogen, not oxygen demand.

6.2 Ammonia Toxicity Calculations

Although Subsegments 100405 and 100404 are not on the 303(d) List for ammonia, the ammonia concentrations predicted by the projection models were checked to make sure that they did not exceed USEPA criteria for ammonia toxicity (USEPA 1999). The USEPA criteria are dependent on temperature and pH. The water temperatures used to calculate the ammonia toxicity criterion were the critical temperatures used in the projection simulations. For pH, the seasonal averages of LDEQ monitoring data for the subsegments were used (data from Stations 1181 and 1182). None of the instream ammonia nitrogen concentrations predicted by the LA-QUAL projection models for Subsegments 100405 and 100404 were above the criteria. This indicates that the ammonia nitrogen loadings that will maintain the DO standard are low enough that the USEPA ammonia toxicity criteria will not be exceeded under critical conditions. The ammonia toxicity calculations are shown in Appendix S.

6.3 Summary of Nonpoint Source Reductions

In summary, the projection modeling used to develop the TMDLs above showed that nonpoint sources loads to Black Bayou Reservoir needed to be reduced by 5 to 17% and nonpoint sources loads to Cypress Bayou Reservoir need to be reduced by 0 to 23% to maintain the DO criterion in the reservoirs.

6.4 Seasonal Variation

As discussed in Section 4.1, critical conditions for DO in Louisiana waterbodies have been determined to be when there is negligible nonpoint runoff and low stream flow combined with high water temperatures. In addition, the model accounts for loadings that occur at higher flows by modeling sediment oxygen demand. Oxygen demanding pollutants that enter the waterbodies during higher flows settle to the bottom and then exert the greatest oxygen demand during the high temperature seasons.

6.5 Margin of Safety

The MOS accounts for any lack of knowledge or uncertainty concerning the relationship between load allocations and water quality. As discussed in Section 4.1, the highest temperatures occur in July through August, the lowest stream flows occur in October through November. The combination of these conditions, in addition to other conservative assumptions regarding rates and loadings, yields an implicit MOS, which is not quantified. In addition to the implicit MOS, the TMDL in this report includes an explicit MOS of 10% for nonpoint source loads and an explicit MOS of 20% for point source loads.

7.0 SENSITIVITY ANALYSES

All modeling studies necessarily involve uncertainty and some degree of approximation. Therefore, it is of value to consider the sensitivity of the model output to changes in model coefficients, and in the hypothesized relationships among the parameters of the model. The sensitivity analyses were performed by allowing the LA-QUAL model to vary one input parameter at a time while holding all other parameters to their original value. The calibration simulation was used as the baseline for the sensitivity analysis. The percent change of the model minimum DO projections resulting from the change to each parameter is presented in Table 7.1 (Black Bayou Reservoir) and Table 7.2 (Cypress Bayou Reservoir). Each parameter was varied by ±30%, except for temperature, which was varied ±2ºC. Values reported in Tables 7.1 and 7.2 are sorted by percentage variation of minimum DO from largest percentage variation to smallest.

Table 7.1. Summary of results of sensitivity analyses for Subsegment 100405.

Input Parameter	Parameter Change	Predicted Minimum DO (mg/L)	Percent Change in Predicted DO (%)
Baseline	--	4.07	N/A
Non-Point Source CBOD	+30	1.96	-52%
Waterbody Depth	-30	2.14	-47%
Waterbody Reaeration	-30	2.57	-37%
Non-Point Source CBOD	-30	5.25	+29%
Waterbody Depth	+30	5.22	+28%
Waterbody Reaeration	+30	4.88	+20%
Benthal Demand	+30	3.40	-16%
Benthal Demand	-30	4.74	+16%
Initial Temperature	+2 deg C	4.25	+4%
Non-Point Source Organic N	+30	3.90	-4%
Non-Point Source Organic N	-30	4.24	4%
Initial Temperature	-2 deg C	3.91	-4%
Ammonia Decay Rate	-30	4.07	0%
CBOD Aerobic Decay Rate	-30	4.07	0%
Headwater Ammonia	-30	4.07	0%
Headwater CBOD	-30	4.07	0%
Headwater Flow	-30	4.07	0%
Headwater Organic Nitrogen	-30	4.07	0%
Organic Nitrogen Decay Rate	-30	4.07	0%

Table 7.2. Summary of results of sensitivity analyses for Subsegment 100404.

Input Parameter	Parameter Change	Predicted Minimum DO (mg/L)	Percent Change in Predicted DO (%)
Baseline	--	3.59	N/A
Waterbody Reaeration	-30	1.99	-45%
Benthal Demand	-30	5.02	+40%
Benthal Demand	+30	2.16	-40%
Waterbody Reaeration	+30	4.48	+25%
Initial Temperature	+2 deg C	3.01	-16%
Initial Temperature	-2 deg C	4.15	+16%
Waterbody Depth	+30	4.08	+14%
Waterbody Depth	-30	3.11	-13%
Nonpoint Source CBOD	-30	3.74	+4%
Nonpoint Source CBOD	+30	3.44	-4%
Nonpoint Source Organic N	-30	3.63	+1%
Nonpoint Source Organic N	+30	3.55	-1%
Headwater Flow	+30	3.56	-0.8%
Headwater CBOD	-30	3.61	+0.6%
Headwater Flow	-30	3.61	+0.6%
Headwater CBOD	+30	3.57	-0.6%
Headwater Organic Nitrogen	+30	3.57	-0.6%
Headwater Organic Nitrogen	-30	3.60	+0.3%
Organic Nitrogen Decay Rate	-30	3.60	+0.3%
CBOD Aerobic Decay Rate	+30	3.58	-0.3%
Headwater Ammonia	+30	3.58	-0.3%
Organic Nitrogen Decay Rate	+30	3.58	-0.3%
Ammonia Decay Rate	-30	3.59	0%
CBOD Aerobic Decay Rate	-30	3.59	0%
Headwater Ammonia	-30	3.59	0%
Wasteload Ammonia	-30	3.59	0%
Wasteload CBOD	-30	3.59	0%
Wasteload DO	-30	3.59	0%

8.0 OTHER RELEVANT INFORMATION

These TMDLs have been developed to be consistent with the state anti-degradation policy (LAC 33:IX.1109.A).

This TMDL report does not include an implementation plan. Implementation plans are not required for TMDLs under current federal regulations. Implementation plans can be developed most effectively and efficiently on the state and local level.

LDEQ will work with other agencies such as local Soil Conservation Districts to implement nonpoint source best management practices (BMPs) in the watershed through the Section 319 programs. LDEQ will also continue to monitor the waters to determine whether standards are being attained.

In accordance with Section 106 of the Federal Clean Water Act, and under the authority of the Louisiana Environmental Quality Act, LDEQ has established a comprehensive program for monitoring the quality of the state's surface waters. The LDEQ Surveillance Section collects surface water samples at various locations, utilizing appropriate sampling methods and procedures for ensuring the quality of the data collected. The objectives of the surface water monitoring program are to determine the quality of the state's surface waters, to develop a long-term data base for water quality trend analysis, and to monitor the effectiveness of pollution controls. The data obtained through the surface water monitoring program is used to develop the state's biennial 305(b) report (Water Quality Inventory) and the 303(d) list of impaired waters. This information is also utilized in establishing priorities for the LDEQ nonpoint source program.

LDEQ has implemented a watershed approach to surface water quality monitoring. Through this approach, the entire state is sampled over a 4-year cycle. Long-term trend monitoring sites at various locations on the larger rivers and Lake Pontchartrain are sampled throughout the 4-year cycle. Sampling is conducted on a monthly basis to yield approximately 12 samples per site each year the site is monitored. Sampling sites are located where they are considered to be representative of the waterbody. Under the current monitoring schedule, approximately one half of the state's waters are newly assessed for each 305(b) and 303(d) listing biennial cycle, with sampling occurring statewide each year. The 4-year cycle follows an initial 5-year rotation that covered all basins in the state according to the TMDL priorities. This will allow LDEQ to determine whether there has been any improvement in water quality following implementation of the TMDLs. As the monitoring results are evaluated at the end of each year, waterbodies may be added to or removed from the 303(d) list.

9.0 PUBLIC PARTICIPATION

Federal regulations require USEPA to notify the public and seek comment concerning TMDLs it prepares. The TMDLs in this report were developed under contract to USEPA, and USEPA held a public review period seeking comments, information, and data from the public and any other interested parties. The notice for the public review period was published in the Federal Register on October 25, 2007, and the review period closed on November 26, 2007.

Comments were received from LDEQ. These comments were used to revise this TMDL report. The comments and responses to these TMDLs are included in a separate document that includes comments on similar TMDLs with the same public review period.

USEPA will submit the final version of these TMDLs to LDEQ for implementation and incorporation into LDEQ's current water quality management plan.

10.0 REFERENCES

Bossier Parish Health Unit. 2007. Phone conversation with Kelly Herrick, Bossier Parish Health Unit, Bossier City, Louisiana. May 11, 2007.

LDEQ. 2005. Louisiana 2004 303(d) List of Impaired Water Bodies: Including EPA's Additions. Downloaded from Louisiana Department of Environmental Quality web site (www.deq.louisiana.gov/portal/Portals/0/planning/04 IR1-FINAL-Appendix H-Cat 5 303d List with EPA - August 17 2005.xls)

LDEQ. 2006. Louisiana Total Maximum Daily Load Technical Procedures. Revision 10. Prepared by Office of Environmental Assessment, Louisiana Department of Environmental Quality. Dated August 10, 2006. Downloaded from LDEQ web site (www.deq.louisiana.gov/portal/Portals/0/planning/LTP_sop_1727_r10-081006.pdf).

LDEQ. 2007. Title 33 Environmental Quality, Part IX Water Quality, Subpart 1 Water Pollution Control, Chapter 11 Surface Water Quality Standards. Including amendments through 5/20/07. Downloaded from Louisiana Department of Environmental Quality web site (www.deq.louisiana.gov/portal/Portals/0/planning/regs/title33/33v09.pdf)

NCDC. 2007. Daily wind speed data for Shreveport Regional Airport, LA. Downloaded from National Climatic Data Center web site (http://cdo.ncdc.noaa.gov/pls/plclimprod/poemain.accessrouter?datasetabbv=SOD).

USEPA. 1985. Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling (Second Edition). Written by G.L. Bowie et. al. EPA/600/3-85/040. U.S. Environmental Protection Agency, Environmental Research Laboratory, Athens, GA.

USEPA. 1999. 1999 Update of Ambient Water Quality Criteria for Ammonia. EPA-822-R-99-014. U.S. Environmental Protection Agency, Office of Water. December 1999. Downloaded from USEPA web site (www.epa.gov/ost/standards/ammonia/99update.pdf).

USEPA. 2002. Consolidated Assessment and Listing Methodology – Toward a Compendium of Best Practices. Prepared by U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds. July 2002. Downloaded from USEPA web site (www.epa.gov/owow/monitoring/calm.html).

USGS. 1999a. Bathymetric Survey and Physical and Chemical-Related Properties of Cypress Bayou Reservoir, Louisiana, October 1997 and August and September 1998. Water Resources Investigations Report 99-4255. Prepared by P.A. Ensminger. Downloaded from U.S. Geological Survey web site (http://la.water.usgs.gov/pdfs/cypress.pdf).

USGS. 1999b. Bathymetric Survey and Physical and Chemical-Related Properties of Black Bayou Reservoir, Louisiana, September and October 1997. Water Resources Investigations Report 99-4293. Prepared by P.A. Ensminger. Downloaded from U.S. Geological Survey web site (http://la.water.usgs.gov/pdfs/black.pdf).

USGS. 2003. Low-Flow Characteristics of Louisiana Streams. Water Resources Technical Report No. 70. Prepared by P.A. Ensminger and L.S. Wright, U.S. Geological Survey, Baton Rouge, LA.

USGS. 2006. National Land Cover Database 2001 (NLCD 2001). Downloaded from U.S. Geological Survey web site (www.mrlc.gov/mrlc2k_nlcd.asp).

Wiland, B.L., and K. LeBlanc. 2007. LA-QUAL for Windows User's Manual. Prepared by Wiland Consulting, Inc. with revisions by K. LeBlanc, Louisiana Department of Environmental Quality. Model Version 8.11, Manual Revision M. August 22, 2007. Downloaded from LDEQ web site (www.deq.louisiana.gov/portal/Portals/0/planning/laqual.zip).