TRIBUTARIES TO BAYOU D'ARBONNE LAKE TMDL FOR BIOCHEMICAL OXYGEN-DEMANDING SUBSTANCES

SUBSEGMENTS 080603, 080609, AND 080610

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TMDL REPORT

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EXECUTIVE SUMMARY

This report presents the results of a watershed based, calibrated modeling analysis of the tributaries to Bayou D'Arbonne Lake. These tributaries are Bayou D'Arbonne (subsegment 080603), Middle Fork Bayou D'Arbonne (subsegment 080610), and Corney Bayou (subsegment 080609). The modeling was conducted to establish total maximum daily loads (TMDLs) for oxygen-demanding pollutants for the Bayou D'Arbonne Lake watershed. One model was constructed for each subsegment. The Bayou D'Arbonne model begins at Lake Claiborne, while the Middle Fork model begins in Haynesville, and the Corney Bayou model begins at Corney Lake. Each of the models extends downstream to Bayou D'Arbonne Lake. The Bayou D'Arbonne Lake watershed is located in north central Louisiana and is part of the Ouachita River basin. The drainage areas of the tributary subsegments are as follows: Bayou D'Arbonne: 265 mi^2, Middle Fork: 216 mi^2, and Corney Bayou: 163 mi^2. The area is sparsely populated outside of several small towns and land use is dominated by forest. Four wastewater treatment plants were explicitly modeled, one in the Bayou D'Arbonne model and three in the Middle Fork model.

Input data for the calibration models was developed from data collected during the July 2001 intensive survey; data collected by LDEQ and USGS at monitoring stations in the watershed; the LDEQ Reference Stream Study; DMRs, permits, and permit applications for each of the point source dischargers; USGS drainage area and low flow publications; and data garnered from several previous LDEQ studies on nonpoint source loadings. A satisfactory calibration was achieved for the main stem of each of the three models. In those cases where the calibration was not as accurate, the difference was in the conservative direction. For the projection models, data was taken from the current municipal discharge permits, current applications, and ambient temperature records. The Louisiana Total Maximum Daily Load Technical Procedures, 05/22/2001, have been followed in this study.

Modeling was limited to low flow scenarios for both the calibration and the projections since the constituent of concern was dissolved oxygen and the available data was limited to low flow conditions. The model used was LAQUAL, a modified version of QUAL-TX, which has been adapted to address specific needs of Louisiana waters.

Both LDEQ's 1998 303(d) list and EPA's 2000 Modified Court Ordered 303(d) list cited the three tributaries to Bayou D'Arbonne Lake (subsegments 080603, 080609, and 080610) as being impaired. The suspected cause was organic enrichment/low DO and the suspected sources were "natural sources" and "unknown source". These three subsegments were subsequently scheduled for TMDL development with other listed waters in the Ouachita River basin. This TMDL addresses the organic enrichment/low DO impairment.

For subsegment 080603 (Bayou D'Arbonne), the suspected causes for impairment on EPA's Modified Court Ordered 303(d) list included nutrients in addition to organic enrichment/low DO. The listing for nutrients was addressed by comparing nitrogen and phosphorus concentrations in Bayou D'Arbonne with values from reference streams and examining diurnal DO and pH data collected in Bayou D'Arbonne. This analysis indicated that Bayou D'Arbonne does not have a

problem with over-enrichment due to nutrients. Therefore, TMDLs for nitrogen and phosphorus are not needed.

A Use Attainability Analysis (UAA) was previously developed for Middle Fork by LDEQ. Based on this UAA, a new summer DO standard of 3 mg/L from July through September was proposed by LDEQ. The new DO standard has been approved by EPA but has not yet been promulgated by LDEQ. The existing DO standard for Middle Fork during other months (October through June) is 5 mg/L. The existing DO standard for Bayou D'Arbonne and Corney Bayou is 5 mg/L year round.

For Bayou D'Arbonne (subsegment 080603), the results of the projection modeling show that the existing DO standard of 5.0 mg/L can be maintained if man-made nonpoint sources are reduced by 95% in the summer and 85% in the winter. No reductions are needed for the point source loads. The only oxygen demanding point source discharge in the Bayou D'Arbonne subsegment (City of Dubach West Pond) is already discharging at advanced treatment levels and was shown to have little impact on DO in the main stem of Bayou D'Arbonne. The components of the TMDLs for Bayou D'Arbonne are shown in Table ES.1.

Table ES.1. TMDL for Bayou D'Arbonne (Sum of CBOD, Organic N, Ammonia N, and SOD).

	Summer (July-Sept)		**Winter (Oct-June)**	
	Reduction	**Load (kg/day)**	**Reduction**	**Load (kg/day)**
Point Source WLA	none	25	none	46
Point Source Reserve MOS (20%)	--	6	--	11
Natural Nonpoint Source LA	0%	401	0%	971
Natural Nonpoint Source MOS (0%)	--	0	--	0
Man-made Nonpoint Source LA	95%	13	85%	132
Man-made Nonpoint Source MOS (20%)	--	5	--	35
TMDL	--	450	--	1195

For Middle Fork (subsegment 080610), the results of the projection modeling show that meeting the existing DO standard of 5.0 mg/L during summer would require a 100% reduction in man-made nonpoint source loads plus a 40% reduction in natural nonpoint source loads. In order to meet the proposed summer DO standard of 3.0 mg/L, a 70% reduction in man-made nonpoint source loads would be required. To meet the existing winter DO standard of 5.0 mg/L, a 65% reduction in man-made nonpoint source loads would be required. For each of these scenarios, a point source load reduction was assumed for the City of Bernice and for Outfall 003 at the David Wade Correctional Center (upgrading from secondary treatment to advanced treatment). The other oxygen demanding point source discharges in the Middle Fork subsegment (City of Haynesville and Outfalls 001 and 002 at the David Wade Correctional Center) are already discharging at advanced treatment levels and have little impact on DO in the main stem of Middle Fork. The components of the TMDLs for Middle Fork are shown in Tables ES.2 and ES.3.

Table ES.2. TMDL for Middle Fork for existing DO standard (Sum of CBOD, Ammonia N, Organic N, and SOD).

	Summer (July-Sept)		**Winter (Oct-June)**	
	Reduction	**Load (kg/day)**	**Reduction**	**Load (kg/day)**
Point Source WLA	upgrade 2 facilities to advanced treatment	262	upgrade 2 facilities to advanced treatment	262
Point Source Reserve MOS (20%)	--	65	--	65
Natural Nonpoint Source LA	40%	1151	0%	1964
Natural Nonpoint Source MOS (0%)	--	0	--	0
Man-made Nonpoint Source LA	100%	0	65%	379
Man-made Nonpoint Source MOS (20%)	--	0	--	106
TMDL	--	1478	--	2776

Table ES.3. TMDL for Middle Fork for proposed summer DO standard (Sum of CBOD, Organic N, Ammonia N, and SOD).

	Summer (July-Sept)	
	Reduction	**Load (kg/day)**
Point Source WLA	Upgrade 2 facilities to advanced treatment	262
Point Source Reserve MOS (20%)	--	65
Natural Nonpoint Source LA	0%	1902
Natural Nonpoint Source MOS (0%)	--	0
Man-made Nonpoint Source LA	70%	367
Man-made Nonpoint Source MOS (20%)	--	93
TMDL	--	2689

For Corney Bayou (subsegment 080609), the results of the projection modeling show that the existing DO standard of 5.0 mg/L can be maintained during summer if man-made nonpoint sources are reduced by 75% to 100% and natural nonpoint sources are reduced by 0% to 50%. The lower percent reductions are in the downstream portion of the subsegment and the higher percent reductions are in the upper reaches. For winter, the existing DO standard of 5.0 mg/L can be maintained if man-made nonpoint sources are reduced by 60% to 80%. There were no point sources in the Corney Bayou model to be considered for load reductions. Components of the TMDLs for Corney Bayou are shown in Table ES.4.

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

Table ES.4. TMDL for Corney Bayou (Sum of CBOD, Organic N, Ammonia N, and SOD).

	Summer (July-Sept)		**Winter (Oct-June)**	
	Reduction	**Load (kg/day)**	**Reduction**	**Load (kg/day)**
Point Source WLA	None	17	None	17
Point Source Reserve MOS (20%)	--	4	--	4
Natural Nonpoint Source LA	0% - 50%	3972	0%	4066
Natural Nonpoint Source MOS (0%)	--	0	--	0
Man-made Nonpoint Source LA	75% - 100%	1524	60% - 80%	2456
Man-made Nonpoint Source MOS (20%)	--	381	--	619
TMDL	--	5898	--	7162

In accordance with Section 106 of the federal Clean Water Act and under the authority of the Louisiana Environmental Quality Act, the 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.

The LDEQ has implemented a watershed approach to surface water quality monitoring. Through this approach, the entire state is sampled over a five-year cycle with two targeted basins sampled each year. Long-term trend monitoring sites at various locations on the larger rivers and Lake Pontchartrain are sampled throughout the five-year cycle. Sampling is conducted on a monthly basis or more frequently if necessary to yield at least 12 samples per site each year. Sampling sites are located where they are considered to be representative of the waterbody. Under the current monitoring schedule, targeted basins follow the TMDL priorities. In this manner, the first TMDLs will have been implemented by the time the first priority basins will be monitored again in the second five-year cycle. This will allow the 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. The sampling schedule for the next five years is shown below.

2002 - Red and Sabine River Basins
2003 - Mermentau and Vermilion-Teche River Basins
2004 - Calcasieu and Ouachita River Basins
2005 - Barataria and Terrebonne Basins
2006 - Lake Pontchartrain Basin and Pearl River Basin
(Atchafalaya and Mississippi Rivers will be sampled continuously.)

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Daily flow data and discharge measurement data for several gages in the study area were obtained from the US Geological Survey (USGS).

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TABLE OF CONTENTS

ACKNOWLEDGMENTS v

1. Introduction 1

2. Study Area Description 1

2.1 General Information 1
2.2 Water Quality Standards 2
2.3 Wastewater Discharges 3
2.4 Water Quality Conditions/Assessment 4
2.5 Prior Studies 4

3. Documentation of Calibration Model 6

3.1 Program Description 6
3.2 Input Data Documentation 8
3.2.1 Model Schematics and Maps 8
3.2.2 Model Options, Data Type 2 9
3.2.3 Temperature Correction of Kinetics, Data Type 4 9
3.2.4 Reach Identification Data, Data Type 8 9
3.2.5 Advective Hydraulic Coefficients, Data Type 9 10
3.2.6 Initial Conditions, Data Type 11 11
3.2.7 Reaeration Rates, Data Type 12 11
3.2.8 SOD and CBOD Decay Rates, Data Type 12 11
3.2.9 Nitrogen Coefficients, Data Type 13 12
3.2.10 Nonpoint Source Loads, Data Type 19 12
3.2.11 Headwaters, Data Types 20 and 21 12
3.2.12 Wasteloads, Data Types 24 and 25 13
3.3 Model Discussion and Results 13

4. Water Quality Projections 14

4.1 Critical Conditions, Seasonality and Margin of Safety 14
4.2 Input Data Documentation 15
4.2.1 Model Options, Data Type 2 15
4.2.2 Temperature Correction of Kinetics, Data Type 4 15
4.2.3 Reach Identification Data, Data Type 8 16
4.2.4 Advective Hydraulic Coefficients, Data Type 9 16
4.2.5 Initial Conditions, Data Type 11 16
4.2.6 Reaeration Rates and Decay Rates, Data Types 12 and 13 16
4.2.7 Sediment Oxygen Demand and Nonpoint Sources, Data Types 12 and 19 16
4.2.8 Headwaters and Wasteloads, Data Types 20, 21, 24 and 25 17
4.3 Model Discussion and Results 18
4.3.1 No Point Source, No Nonpoint Source, and No Load Scenarios 18
4.3.2 Summer and Winter Projections 19
4.4 Calculated TMDL, WLAs, and LAs 20
4.4.1 Outline of TMDL Calculations 20
4.4.2 Results of TMDL Calculations 22
4.5 Nutrient Analysis 23

4.5.1 Nitrogen and Phosphorus Data 23
4.5.2 Diurnal DO and pH Data 24
4.5.3 Conclusions 24
5. Sensitivity Analyses 24
6. Conclusions 27
7. References 29
8. Appendices 30

LIST OF TABLES

Table ES.1. TMDL for Bayou D'Arbonne (Sum of CBOD, Organic N, Ammonia N, and SOD) ii
Table ES.2. TMDL for Middle Fork for existing DO standard (Sum of CBOD, Ammonia N, Organic N, and SOD) iii
Table ES.3. TMDL for Middle Fork for proposed summer DO standard (Sum of CBOD, Organic N, Ammonia N, and SOD) iii
Table ES.4. TMDL for Corney Bayou (Sum of CBOD, Organic N, Ammonia N, and SOD)..... iv
Table 2.1. Land use by subsegment based on GAP data (USGS 1998) 2
Table 2.2 Water quality numeral criteria and designated uses 3
Table 2.3. Summary of 303(d) listing for the 3 subsegments in the study area (EPA 2000) 4
Table 4.1. Model inputs for no point source, no nonpoint source, and no load scenarios..... 18
Table 4.2. Predicted DO for no point source, no nonpoint source, and no load scenarios 18
Table 4.3. Summary of nonpoint source load reductions required to meet DO standards 19
Table 4.4. TMDL for Bayou D'Arbonne (Sum of CBOD, Organic N, Ammonia N, and SOD) 22
Table 4.5. TMDL for Middle Fork (Sum of CBOD, Organic N, Ammonia N, and SOD) 22
Table 4.6. TMDL for Corney Bayou (Sum of CBOD, Organic N, Ammonia N, and SOD) 23
Table 5.1. Summary of Calibration Model Sensitivity Analysis for Bayou D'Arbonne..... 25
Table 5.2. Summary of Calibration Model Sensitivity Analysis for Middle Fork 26
Table 5.3. Summary of Calibration Model Sensitivity Analysis for Corney Bayou 27

1. Introduction

The tributaries to Bayou D'Arbonne Lake consist of three subsegments: Bayou D'Arbonne (080603), Corney Bayou (080609), and Middle Fork Bayou D'Arbonne (080610). All three of these subsegments were listed on both the 1998 303(d) list (LDEQ 1998) and the EPA Modified Court Ordered 303(d) list (EPA 2000) as being impaired due to organic enrichment/low DO. Therefore, development of Total Maximum Daily Loads (TMDLs) for biochemical oxygen demanding substances was required. For each subsegment, a calibrated water quality model was developed and projections were simulated to quantify the point source and nonpoint source waste load reductions which would be necessary in order for the subsegments to comply with established water quality standards and criteria. This report presents the results of that analysis.

2. Study Area Description

2.1 General Information

The Bayou D'Arbonne system is located in northern Louisiana in the Ouachita River basin (see map in Appendix A1). The components of the Bayou D'Arbonne system that are the focus of this project are:

- Bayou D'Arbonne – from Lake Claiborne to Bayou D'Arbonne Lake (080603)
- Corney Bayou – from Corney Lake to Bayou D'Arbonne Lake (080609)
- Middle Fork Bayou D'Arbonne – from origin to Bayou D'Arbonne Lake (080610)

These streams are in an area that is predominantly forested (65% – 75% of the watershed). The land uses for each subsegment are summarized in Table 2.1.

Two of the streams have dams at the upstream end of the study area. One of those streams is Bayou D'Arbonne, which was dammed near the town of Homer in 1966 to form Lake Claiborne. The primary outflow from Lake Claiborne is uncontrolled flow over a circular weir (a "morning glory" outlet structure). There is no minimum flow structure or outlet to release water when the pool elevation falls below the invert of the weir. However, the channel of Bayou D'Arbonne below the dam always has at least standing water, possibly due to seepage (LDOTD 2001). Lake Claiborne is owned by the State of Louisiana (COE 2001).

The other stream with a dam at the upstream end of the study area is Corney Bayou, which was dammed near the town of Lillie in 1937 to form Corney Lake. The primary outflow from Corney Lake is uncontrolled flow over a long weir at the dam. The dam contains two gates whose purpose is to drain the lake in order to control aquatic vegetation. These gates have never been used and there are no other structures for maintaining flow through the dam should the water level fall below the invert of the spillway (NRCS 2001). Corney Lake is owned by the U.S. Forest Service (COE 2001).

Table 2.1. Land use by subsegment based on GAP data (USGS 1998).

Land Use Type	Percent of Total Area		
	Subsegment 080603	**Subsegment 080609**	**Subsegment 080610**
Fresh Marsh	0.0%	0.0%	0.0%
Saline Marsh	0.0%	0.0%	0.0%
Wetland Forest	14.3%	14.6%	14.9%
Upland Forest	52.3%	53.7%	59.5%
Wetland Scrub/Shrub	0.3%	0.7%	0.3%
Upland Scrub/Shrub	21.0%	18.0%	17.2%
Agriculture	9.7%	10.2%	6.3%
Urban	0.0%	0.0%	0.0%
Barren	0.0%	0.0%	0.0%
Water	2.4%	2.8%	1.7%
TOTAL	100.0%	100.0%	100.0%

Downstream of these 2 lakes, Bayou D'Arbonne and Corney Bayou are both low gradient streams that flow through mostly forested areas towards Bayou D'Arbonne Lake. The drainage area of Bayou D'Arbonne as it enters Bayou D'Arbonne Lake is approximately 464 square miles (mi^2) (USGS 1971); approximately 265 mi^2 of that drainage area is within subsegment 080603. The drainage area of Corney Bayou as it enters Bayou D'Arbonne Lake is approximately 722 mi^2 (USGS 1971); approximately 163 mi^2 of that drainage area is within subsegment 080609.

The third primary stream in the study area is Middle Fork Bayou D'Arbonne. This stream originates near Haynesville and flows through mostly forested areas towards Bayou D'Arbonne Lake. The drainage area of Middle Fork Bayou D'Arbonne as it enters Bayou D'Arbonne Lake is approximately 216 mi^2 (USGS 1971). Middle Fork Bayou D'Arbonne has no impoundments along the main stem and it is listed as an LDEQ reference stream (Smythe 1999).

2.2 Water Quality Standards

The designated uses and numeric water quality standards for each subsegment within the study area are listed below in Table 2.2. All 3 subsegments currently have a year round DO standard of 5.0 mg/L, but LDEQ has proposed seasonal DO standards for Middle Fork Bayou D'Arbonne (LDEQ 2001a) based on a Use Attainability Analysis (UAA) for DO (LDEQ 2000a). The proposed standards have been approved by EPA but have not yet been promulgated.

Table 2.2. Water quality numeral criteria and designated uses (LDEQ 2000b).

Subsegment Number	080603	080609	080610
Waterbody Description	Bayou D'Arbonne – from Lake Claiborne to Bayou D'Arbonne Lake	Corney Bayou – from Corney Lake to Bayou D'Arbonne Lake	Middle Fork Bayou D'Arbonne – from origin to Bayou D'Arbonne Lake
Designated Uses	ABC	ABCG	ABCG
Criteria:			
DO (existing)	5 mg/L (year round)	5 mg/L (year round)	5 mg/L (year round)
DO (proposed)	N/A	N/A	5 mg/L (Oct – Jun) 3 mg/L (Jul – Sep)
Chloride	50 mg/L	160 mg/L	50 mg/L
Sulfate	15 mg/L	25 mg/L	15 mg/L
pH	6.0 – 8.5	6.0 – 8.5	6.0 – 8.5
Bacteria	Note 1	Note 1	Note 1
Temperature	32 °C	32 °C	32 °C
TDS	200 mg/L	300 mg/L	200 mg/L

USES: A – primary contact recreation; B – secondary contact recreation; C – propagation of fish and wildlife; D – drinking water supply; E – oyster propagation; F – agriculture; G – outstanding natural resource water; L – limited aquatic life and wildlife use.

Note 1 – 200 colonies/100 mL maximum log mean and no more than 25% of samples exceeding 400 colonies/100 mL for the period May through October; 1,000 colonies/100mL maximum log mean and no more than 25% of samples exceeding 2,000 colonies/100mL for the period November through April.

2.3 Wastewater Discharges

Lists of NPDES permits that were identified in or near each subsegment in the study area are included in Appendix A2. These permits were identified primarily from information provided by LDEQ as well as from EPA's Permit Compliance System (PCS). Information concerning permit parameters and design flow in Appendix A2 was obtained by reviewing copies of NPDES applications and permits obtained from the LDEQ file room.

The City of Haynesville WWTP is the only significant oxygen demanding point source that discharges directly into the 303(d) waterbodies (i.e., Bayou D'Arbonne, Corney Bayou, and Middle Fork Bayou D'Arbonne). Several other significant oxygen demanding point sources discharge into tributaries of the 303(d) waterbodies; these discharges and their respective receiving streams are listed below:

- David Wade Correctional Center (unnamed trib. to Tiger Cr. to Middle Fork B. D'Arbonne)
- Bernice WWTP (Bull Creek to Middle Fork Bayou D'Arbonne)
- Dubach WWTP - West Pond (Autrey Creek to Bayou D'Arbonne)

The locations of these discharges are shown on the map in Appendix A1. Relevant information on these discharges is listed in Appendix A2.

2.4 Water Quality Conditions/Assessment

As shown in Table 2.3, all 3 of the subsegments in the study area were included on EPA's Modified Court Ordered 303(d) list for Louisiana. These subsegments were also included in the 1998 303(d) list developed by LDEQ. The streams were listed for organic enrichment/low DO due to measured DO values below the standard. There are 7 LDEQ water quality monitoring stations within these 3 subsegments (see list of stations in Section 2.5). At all 7 stations, the percentage of DO values below the 5 mg/L standard was 10% or more during 1995–99.

Table 2.3. Summary of 303(d) listing for the 3 subsegments in the study area (EPA 2000).

Subsegment Number	Waterbody Name	Suspected Sources	Suspected Causes	Priority Ranking (1=highest)
080603	Bayou D'Arbonne	Other Natural sources Unknown source	Organic enrichment/low DO Lead Nutrients* Suspended solids* Other inorganics*	2
080609	Corney Bayou	Other Natural sources Unknown source	Organic enrichment/low DO Lead Suspended solids* Salinity/TDS/chlorides/sulfates*	2
080610	Middle Fork Bayou D'Arbonne	Other Natural sources Unknown source	Organic enrichment/low DO Pathogen indicators Lead Salinity/TDS/chlorides/sulfates* Turbidity*	2

* Not included in the 1998 303(d) list.

2.5 Prior Studies

Existing water quality data collected in the 3 subsegments in the study area include the following:

1. Monthly to bi-monthly data collected by LDEQ for "Little Corney Bayou East of Lillie" (station 0015) for February 1965 to May 1998. This station is located at the State Hwy 15 bridge, 1.4 miles east of Lillie, 1.7 miles west of Spearsville.

2. Monthly to bi-monthly data collected by LDEQ for "Corney Bayou near Lillie" (station 0068) for January 1965 to May 1998. This station is located at the US Hwy 167 bridge, 3.0 miles south of Lillie, 4.5 miles north of Bernice.

3. Monthly to bi-monthly data collected by LDEQ for "Bayou D'Arbonne near Dubach" (station 0073) for February 1965 to May 1998. This station is located at the US Hwy 167 bridge, 1.5 miles south of Dubach.

4. Bi-monthly data collected by LDEQ for "Middle Fork Bayou D'Arbonne West of Farmerville" (station 0325) for January 1991 to May 1998. This station is located at the US Hwy 167 bridge, 3.9 miles south of Bernice.

5. Monthly data collected by LDEQ for "Bayou D'Arbonne East of Dubach" (station 0779) for January to December 1999. This station is located at the State Hwy 151 bridge east of Dubach.

6. Monthly data collected by LDEQ for "Corney Bayou East of Bernice" (station 0784) for January to December 1999. This station is at the State Hwy 550 bridge east of Bernice.

7. Monthly data collected by LDEQ for "Middle Fork Bayou D'Arbonne northeast of Dubach" (station 0785) for January to December 1999. This station is at the State Hwy 823 bridge northeast of Dubach.

Existing water quality data collected in subsegments near the study area include the following:

1. Monthly data collected by LDEQ for "Lake Claiborne at Spillway" (station 0778) for January to December 1999. This station is located at the Lake Claiborne spillway just off State Hwy 518, in the Lake Claiborne subsegment (080602).

2. Monthly data collected by LDEQ for "Corney Lake at Spillway" (station 0783) for January to December 1999. This station is at the spillway at the south end of Corney Lake, in the Corney Lake subsegment (080608).

Historical stream flow data within the study area include the following:

1. Daily flow data collected by the USGS for "Bayou D'Arbonne near Dubach" (gage 07365000) for October 1940 to December 1968. This station is located at the US Hwy 167 bridge, 1.5 miles south of Dubach.

2. Daily flow data collected by the USGS for "Middle Fork Bayou D'Arbonne near Bernice" (gage 07365500) for October 1940 to September 1970. This station is located at the US Hwy 167 bridge, 4 miles south of Bernice.

3. Daily flow data collected by the USGS for "Corney Bayou near Lillie" (gage 07366000) for October 1940 to September 1957. This station is located at the US Hwy 167 bridge, 3 miles south of Lillie.

4. Daily flow data collected by the USGS for "Little Corney Bayou near Lillie" (gage 07366200) for October 1955 to present. This station is located at the State Hwy 15 bridge, 1.4 miles east of Lillie.

Relevant studies for waterbodies in or near the study area include the following:

1. A National Eutrophication Survey (NES) study was performed on Bayou D'Arbonne Lake (EPA 1977). This study included one year of monthly sampling for major tributaries to Bayou D'Arbonne Lake.

2. A wasteload allocation for total phosphorus was performed for the discharge from the City of Farmerville Wastewater Treatment Plant (WWTP) into Bayou D'Arbonne Lake (Limno-Tech 1984).

3. A reference stream survey was conducted for Middle Fork Bayou D'Arbonne on August 14-16, 1995 (Smythe 1996). The report includes background information as well as one cross section and a set of water quality data (both in situ and laboratory analyses) for one location (near the State Hwy 2 bridge).

4. Reference stream modeling was performed for Middle Fork Bayou D'Arbonne (Smythe 1997). The report includes a LIMNOSS model that was calibrated to the reference stream survey data at one location.

3. Documentation of Calibration Model

3.1 Program Description

"Simulation models are used extensively in water quality planning and pollution control. Models are applied to answer a variety of questions, support watershed planning and analysis and develop total maximum daily loads (TMDLs).... Receiving water models simulate the movement and transformation of pollutants through lakes, streams, rivers, estuaries, or near shore ocean areas. Receiving water models are used to examine the interactions between loadings and response, evaluate loading capacities (LCs), and test various loading scenarios.... A fundamental concept for the analysis of receiving waterbody response to point and nonpoint source inputs is the principle of mass balance (or continuity). Receiving water models typically develop a mass balance for one or more constituents, taking into account three factors: transport through the system, reactions within the system, and inputs into the system." (EPA841-B-97-006, pp. 1-30)

The model used for this TMDL was LA-QUAL, a steady-state one-dimensional water quality model. LA-QUAL has the mechanisms for incorporating dams and weirs in the analysis and was particularly suitable for use in modeling the tributaries of Bayou D'Arbonne Lake. LA-QUAL history dates back to the QUAL-I model developed by the Texas Water Development Board with Frank D. Masch & Associates in 1970 and 1971. William A. White wrote the original code.

In June, 1972, the United States Environmental Protection Agency awarded Water Resources Engineers, Inc. (now Camp Dresser & McKee) a contract to modify QUAL-I for application to the Chattahoochee-Flint River, the Upper Mississippi River, the Iowa-Cedar River, and the Santee River. The modified version of QUAL-I was known as QUAL-II.

Over the next three years, several versions of the model evolved in response to specific client needs. In March, 1976, the Southeast Michigan Council of Governments (SEMCOG) contracted with Water Resources Engineers, Inc. to make further modifications and to combine the best features of the existing versions of QUAL-II into a single model. That became known as the QUAL-II/SEMCOG version.

Between 1978 and 1984, Bruce L. Wiland with the Texas Department of Water Resources modified QUAL-II for application to the Houston Ship Channel estuarine system. Numerous modifications were made to enable modeling this very large and complex system including the addition of tidal dispersion, lower boundary conditions, nitrification inhibition, sensitivity analysis capability, branching tributaries, and various input/output changes. This model became known as QUAL-TX and was subsequently applied to streams throughout the State of Texas.

In 1999, the Louisiana Department of Environmental Quality and Wiland Consulting, Inc. developed LA-QUAL based on QUAL-TX Version 3.4. The program was converted from a DOS-based program to a Windows-based program with a graphical interface and enhanced graphic output. Other program modifications specific to the needs of Louisiana and the Louisiana DEQ were also made. LA-QUAL is a user-oriented model and is intended to provide the basis for evaluating total maximum daily loads in the State of Louisiana.

The development of a TMDL for dissolved oxygen generally occurs in 3 stages. Stage 1 encompasses the data collection activities. These activities may include gathering such information as stream cross-sections, stream flow, stream water chemistry, stream temperature and dissolved oxygen and various locations on the stream, location of the stream centerline and the boundaries of the watershed which drains into the stream, and other physical and chemical factors which are associated with the stream. Additional data gathering activities include gathering all available information on each facility which discharges pollutants in to the stream, gathering all available stream water quality chemistry and flow data from other agencies and groups, gathering population statistics for the watershed to assist in developing projections of future loadings to the water body, land use and crop rotation data where available, and any other information which may have some bearing on the quality of the waters within the watershed. During Stage 1, any data available from reference or least impacted streams which can be used to gauge the relative health of the watershed is also collected.

Stage 2 involves organizing all of this data into one or more useable forms from which the input data required by the model can be obtained or derived. Water quality samples, field measurements, and historical data must be analyzed and statistically evaluated in order to determine a set of conditions which have actually been measured in the watershed. The findings are then input to the model. Best professional judgment is used to determine initial estimates for parameters which were not or could not be measured in the field. These estimated variables are adjusted in sequential runs of the model until the model reproduces the field conditions which were measured. In other words, the model produces a value of the dissolved oxygen, temperature, or other parameter which matches the measured value within an acceptable margin of error at the locations along the stream where the measurements were actually made. When this happens, the model is said to be calibrated to the actual stream conditions. At this point, the model should confirm that there is an impairment and give some indications of the causes of the

impairment. If a second set of measurements is available for slightly different conditions, the calibrated model is run with these conditions to see if the calibration holds for both sets of data. When this happens, the model is said to be verified.

Stage 3 covers the projection modeling which results in the TMDL. The critical conditions of flow and temperature are determined for the waterbody and the maximum pollutant discharge conditions from the point sources are determined. These conditions are then substituted into the model along with any related condition changes which are required to perform worst case scenario predictions. At this point, the loadings from the point and nonpoint sources (increased by an acceptable margin of safety) are run at various levels and distributions until the model output shows that dissolved oxygen criteria are achieved. It is critical that a balanced distribution of the point and nonpoint source loads be made in order to predict any success in future achievement of water quality standards. At the end of Stage 3, a TMDL is produced which shows the point source permit limits and the amount of reduction in man-made nonpoint source pollution which must be achieved to attain water quality standards. The man-made portion of the NPS pollution is estimated from the difference between the calibration loads and the loads observed on reference or least impacted streams.

3.2 Input Data Documentation

Data collected during an intensive survey conducted from July 16-20, 2001 was used to establish the input for the model calibration and is presented in Appendix B. This survey was conducted during a period of low flows and warm temperatures.

For each subsegment, the flow in each reach, headwater, and unmodeled tributary was determined based on the survey discharge measurements. A flow balance using conservative constituents (e.g., chloride, conductivity, or TDS) could not be performed for several reasons. In some places where two inflows were being combined (e.g. at the confluence of a tributary and the main stem), the concentrations of the conservative constituents were similar between the two inflows. In other places along the main stem, there were increases or decreases in concentrations of the conservative constituents that were apparently due to influences not represented in the model (e.g., natural groundwater concentrations, influences from oil and gas activity, etc.). Best professional judgment was used to determine where similar stream concepts could be used.

Field and laboratory water quality data were entered in a spreadsheet for ease of analysis. The Louisiana GSBOD program was applied to the BOD data in a separate spreadsheet and values of ultimate CBOD, CBOD decay rate, and CBOD lag were computed for each sample. This data was the primary source for the model input data for initial conditions, decay rates, and inflow water quality. Reference stream data was also used in developing the input data set.

3.2.1 Model Schematics and Maps

A vector diagram of each modeled area is presented in Appendix C. The vector diagrams shows the locations of survey stations, the reach design, and the locations of tributaries contributing flow but not modeled. The reach design is discussed in Section 3.2.4. Each subsegment was simulated as a separate model.

3.2.2 Model Options, Data Type 2

Seven constituents were modeled. These were chlorides, conductivity, dissolved oxygen (DO), ultimate carbonaceous biochemical oxygen demand (CBODu), ammonia nitrogen, organic nitrogen, and nitrate+nitrite nitrogen. The chlorides and conductivity were included in the model as an attempt to check the flow balance, although that was unsuccessful as mentioned above.

3.2.3 Temperature Correction of Kinetics, Data Type 4

The temperature values in the model are used to correct the rate coefficients in the source/sink terms for the other water quality variables. These coefficients are input at 20°C and are then corrected to the stream temperatures using the following equation:

$$X_T = X_{20} * \text{Theta}^{(T-20)}$$

where:

X_T = the value of the coefficient at the local temperature T in degrees Celsius
X_{20} = the value of the coefficient at the standard temperature at 20 degrees Celsius
Theta = an empirical constant for each reaction coefficient

The only value that was explicitly specified in data type 4 was the theta value for nitrification (1.07). For temperature correction of other kinetic rates, the model used default values. A complete listing of the default values can be found in the LA-QUAL for Windows User's Manual (Wiland and LeBlanc 2001).

3.2.4 Reach Identification Data, Data Type 8

The reach/element design for each of the three models is described below. Each subsegment was simulated as a separate model. In general, each subsegment was divided into separate reaches based on changes in widths and/or depths as measured in the intensive survey. For the lower three reaches in Corney Bayou, the reach boundaries were set based on changes in width shown on the USGS 7.5 minute topographic maps.

The Bayou D'Arbonne model extends from the upper end of subsegment 080603 (outflow from Lake Claiborne dam) to the lower end of subsegment 080603 (near Bayou D'Arbonne Lake). The stream was divided into four reaches. The element sizes were 0.38 – 0.49 km. The inflows from significant tributaries draining into the main stem (Sugar Creek, Big Creek, Autrey Creek, and Cypress Creek) were modeled as wasteloads. For the calibration, no tributaries were modeled as branches. Although there are point source discharges on Autrey Creek (City of Dubach and Dubach Gas Company), the model was extended up into Autrey Creek only for the projection scenarios, not for the calibration. The model was not calibrated along Autrey Creek because these point sources are small and have minimal impact on DO in the main stem of Bayou D'Arbonne. Based on guidance in Section 3.1.5 of the LTP, having an uncalibrated model for this tributary is appropriate based on the sizes of the point source discharges.

The Middle Fork model extends from the Haynesville WWTP discharge to the lower end of subsegment 080610 (near Bayou D'Arbonne Lake). The stream was divided into six reaches. The element sizes were 0.30 – 0.49 km. The inflows from significant tributaries draining into the main stem (Tiger Creek and Bull Creek) were modeled as wasteloads. For the calibration, no tributaries were modeled as branches. Although there are point source discharges on Tiger Creek (David Wade Correctional Center) and Bull Creek (City of Bernice), the model was extended up into Tiger Creek and Bull Creek only for the projection scenarios, not for the calibration. The model was not calibrated along Tiger Creek and Bull Creek because these point sources are small and have minimal impact on DO in the main stem of Middle Fork. Based on guidance in Section 3.1.5 of the LTP, having an uncalibrated model for these tributaries is appropriate based on the sizes of the point source discharges.

The Corney Bayou model extends from the upper end of subsegment 080609 (outflow from Corney Lake dam) to the lower end of subsegment 080609 (near Bayou D'Arbonne Lake). The stream was divided into five reaches. The element sizes were 0.23 – 0.44 km. The inflow from one significant tributary draining into the main stem (Little Corney Bayou) was modeled as a wasteload. For both the calibration and projection scenarios, no tributaries were modeled as branches. The only oxygen demanding point source discharge in this subsegment (Town of Junction City) is located far from the main stem. Desktop modeling for this discharge shows a complete recovery of water quality prior to reaching the main stem (Appendix D).

3.2.5 Advective Hydraulic Coefficients, Data Type 9

Rather than directly inputting the widths and depths of the stream, the model requires entry of the advective hydraulic characteristics. The hydraulics were specified in the input for the LA-QUAL model using the power functions (width = a * Q^b + c and depth = d * Q^e + f). Figures in Appendix E show the predicted and measured depths and widths for each model.

The lower three reaches of Corney Bayou were simulated with constant widths and depths because the water level in those reaches under low flow conditions appears to be controlled by backwater from Bayou D'Arbonne Lake (based on field observations and the USGS 7.5 minute topographic maps). Because the widths and depths are independent of flow for these reaches, the coefficients and exponents (a, b, d, and e) were set to zero and the constants (c and f) were set equal to the estimated widths and depths. The average widths for these reaches were estimated by measuring the surface areas from the topographic maps and dividing by the reach lengths. The depths for these reaches were based on average depths measured during the survey.

For Bayou D'Arbonne, Middle Fork, and the upper two reaches of Corney Bayou, the widths and depths were specified as a function of flow. The exponents (b and e) for these reaches were estimated based on regressions of width vs. flow and depth vs. flow from USGS discharge measurements. For each of the three subsegments, there was a discontinued USGS flow gage on the main stem; however, the USGS discharge measurement data were not available for any of those gages. Therefore, discharge measurement data for Little Corney Bayou near Lillie (gage number 07366200) were obtained and analyzed. These data and the regression plots are shown in Appendix F. The constants (c and f) were assumed to be zero for the regressions and also for the model input. If nonzero constants were developed in the regression using Little Corney

Bayou data, those constants would probably not be appropriate for characterizing other streams. The coefficients (a and d) were adjusted for each reach until the predicted widths and depths were similar to the target widths and depths (which were based on field measurements). The model input values for the calibration are summarized in Appendix G.

3.2.6 Initial Conditions, Data Type 11

The initial conditions are used to specify the temperature for each reach and reduce the number of iterations required by the model for constituents being simulated. The values required for these models were temperature, DO, ammonia nitrogen, and nitrate+nitrite nitrogen by reach. The input values came from the survey station located closest to the reach or from an average of samples taken from stations located within the reach. The input data and sources are shown in Appendix G.

3.2.7 Reaeration Rates, Data Type 12

For the lower three reaches of Corney Bayou, reaeration was specified in the model using a surface transfer coefficient (K2 = a/d). This option was selected because these three reaches resemble a lake more than a free-flowing stream. Because those three reaches are wide, the reaeration was assumed to be affected by wind. A wind-aided surface transfer coefficient was calculated using the daily average wind speed for July 17, 2001 at the Monroe Regional Airport. The wind speed was corrected to a height of 0.1 m and then used to calculate a surface transfer coefficient of 0.86 m/day. These calculations are shown in Appendix G.

For the upper two reaches of Corney Bayou, reaeration was specified in the model using the Texas equation. The Louisiana equation was considered, but that equation yielded a reaeration coefficient at 20°C that exceeded 10.0/day. Calibrating the DO with such a high reaeration coefficient would have required the use of unreasonably high SOD values. The Texas equation yielded a more conservative value that provided a more reasonable calibration for DO.

For Bayou D'Arbonne and Middle Fork, reaeration was specified in the model using the Louisiana equation. This equation was developed for streams in Louisiana and has been successfully used for other Louisiana TMDLs in the past. Also, the depths and velocities measured during the intensive survey were generally within the range of values for which the equation was developed (LDEQ 2001b).

3.2.8 SOD and CBOD Decay Rates, Data Type 12

For all three models, the SOD values were achieved through calibration. Except for the lower three reaches of Corney Bayou, the values used for calibration ranged from 0.20 to 4.75 $g/m^2/day$. SOD values of zero were used for the lower three reaches of Corney Bayou because the predicted DO could not be increased enough to match the observed value. Although the SOD in the stream is not actually zero, these three reaches still have oxygen demand from NPS (mass loads of CBODu and organic nitrogen in data type 19). The model input values for each reach are shown in Appendix G.

The CBOD decay rate was set to 0.26/day for all three models. This value was the average of the bottle rates from the five samples for which the measured BOD was greater than detection limit for several readings (BD-9, CB-1, CB-4, MF-4, and MF-5).

3.2.9 Nitrogen Coefficients, Data Type 13

The nitrogen coefficients that were required for this model were organic nitrogen decay rates, ammonia nitrogen decay rates (nitrification rates), and benthic ammonia source rates. The decay rates for organic nitrogen and ammonia nitrogen were set based on values used in previous models for LDEQ that simulated organic nitrogen and ammonia nitrogen explicitly (FTN 2000a; FTN 2000b; FTN 2000c). The benthic ammonia source rates were treated as calibration parameters. They were set to zero because the decay of organic nitrogen generated enough ammonia to cause the predicted ammonia concentrations to equal or exceed the observed values. The model input values used for each reach are shown in Appendix G.

3.2.10 Nonpoint Source Loads, Data Type 19

Nonpoint source loads which are not associated with a flow are input into this part of the model. These loads can be most easily understood as resuspended load from the bottom sediments and are modeled as SOD, CBOD and organic nitrogen loads. These loads were used as calibration parameters, and adjusted to get the models to match observed data. Generally, calibration started with loads set to LDEQ reference stream values for Middle Fork Bayou D'Arbonne and Meridian Creek, and then adjusted as needed. In general, the total NPS loads required to calibrate the models exceeded the reference stream loads. The manmade portion of the NPS loading is the difference between the calibration load and the reference stream load where the calibration load is higher. The model input data and sources are presented in Appendix G.

3.2.11 Headwaters, Data Types 20 and 21

The headwater for the Bayou D'Arbonne model was the outflow from the Lake Claiborne dam. The observed flow and water quality for station BD-1 (located just downstream of the Lake Claiborne spillway) were used as model input values for the headwater.

For the Middle Fork model, the observed flow and water quality for station MF-1 (located just upstream of the City of Haynesville WWTP discharge) were used as model input values for the headwater.

The headwater for the Corney Bayou model was the outflow from the Corney Lake dam. The observed flow at station CB-2 and the observed water quality at station CB-1 were used as model input values for the headwater. Station CB-1 was located on the downstream side of the Corney Lake dam and station CB-2 was located approximately 8 km downstream of CB-1. A flow measurement was not taken at station CB-1 because the stream was wide and braided at that location. Based on observations during the field survey and evaluation of drainage areas for the two stations, it was considered reasonable to assume that the flow at station CB-2 would be similar to the flow at the headwater (station CB-1).

3.2.12 Wasteloads, Data Types 24 and 25

For the Bayou D'Arbonne calibration, inflows from significant tributaries (Sugar Creek, Big Creek, Autrey Creek, and Cypress Creek) were modeled as wasteloads. As discussed in Section 3.2.4, no tributaries were modeled as branches for the calibration. The flow rates and water quality for the tributary inflows were set to measured data from stations SC-1, BiC-1, AC-2, and CC-1. Sampling station AC-2 is downstream from the point source discharges on Autrey Creek; it represents the combined loading from the point source discharges plus the upstream flow in Autrey Creek. Model input values are shown in Appendix G.

For the Middle Fork calibration, wasteloads were used to simulate inflows from significant tributaries (Tiger Creek and Bull Creek) and one point source discharging directly into the main stem (City of Haynesville). As discussed in Section 3.2.4, no tributaries were modeled as branches for the calibration. The flow rates and water quality for the wasteloads were set to measured data from stations TC-1, BuC-2, and HAYN. Sampling stations TC-1 and BuC-2 are downstream from the point source discharges on Tiger Creek and Bull Creek; they represent the combined loading from the point source discharges plus the upstream flow in those tributaries.

For Corney Bayou, inflow from one significant tributary (Little Corney Bayou) was modeled as a wasteload. As discussed in Section 3.2.4, no tributaries were modeled as branches. The flow rates and water quality for the tributary inflow were set to measured data from station LC-1.

3.3 Model Discussion and Results

The calibration output for each of the three models is presented in Appendix H. Plots of the predicted and observed concentrations of CBODu, organic nitrogen, ammonia nitrogen, and DO are presented in Appendix I.

For the Bayou D'Arbonne model, the CBODu and organic nitrogen calibrated well. The model slightly overpredicted ammonia nitrogen, even though the benthic ammonia source rates were set to zero in all reaches. Therefore, the predicted ammonia nitrogen values could not be reduced further without changing the organic nitrogen decay rate. The DO calibrated well except for the lower end, where the observed DO values were 6-7 mg/L (80-90% saturation) and the predicted values were around 4 mg/L. It is possible that photosynthesis from algae caused the measured DO values to be higher at these stations than for the other parts of the stream. Even if the SOD was reduced to zero in the last reach, the predicted DO would increase by only several tenths of a mg/L.

For the Middle Fork model, the CBODu calibrated well. The model did not quite match the observed value at MF-4, but the model did reproduce the overall pattern of observed CBODu values. The organic nitrogen calibrated well. The model overpredicted ammonia nitrogen at several stations (MF-4, MF-7, MF-9, and MF-10) but underpredicted ammonia nitrogen at MF-5. The benthic ammonia source rates were set to zero in all reaches. The DO calibrated well at all stations except MF-3.

For the Corney Bayou model, the CBODu and organic nitrogen both calibrated well except for overpredicting the concentrations at station CB-2. For both CBODu and organic nitrogen, the mass loads in data type 19 were set to zero, so the predicted concentrations at CB-2 could not be decreased further without increasing the decay rates. The model overpredicted ammonia nitrogen, even though the benthic ammonia source rates were set to zero in all reaches. Therefore, the predicted ammonia nitrogen values could not be reduced further without decreasing the organic nitrogen decay rate (which would have caused the organic nitrogen calibration to look worse). The DO calibrated well except for the lower end, where the observed DO value at CB-5 was 7.2 mg/L (99% saturation) and the predicted values were around 3 mg/L. It is possible that photosynthesis from algae caused the measured DO values to be higher at this station than for the other parts of the stream. Because the SOD values for the last 3 reaches of Corney Bayou were set to zero, the predicted DO values could not be increased further without altering the reaeration rate (which was calculated based on wind-aided reaeration).

4. Water Quality Projections

Since the calibrated model indicated that the DO criteria were not being met in Bayou D'Arbonne, Middle Fork, and Corney Bayou, no-load summer scenarios were performed in addition to the traditional summer and winter projections for all three subsegments.

4.1 Critical Conditions, Seasonality and Margin of Safety

The Clean Water Act requires the consideration of seasonal variation of conditions affecting the constituent of concern, and the inclusion of a margin of safety (MOS) in the development of a TMDL. For the tributaries to Bayou D'Arbonne Lake TMDL, an analysis of LDEQ ambient data has been employed to determine critical seasonal conditions and an appropriate margin of safety.

Critical conditions for dissolved oxygen were determined using long term water quality data from Bayou D'Arbonne, Middle Fork, and Corney Bayou on the LDEQ Ambient Monitoring Network. The 90th percentile temperature for each season and the corresponding 90% of saturation DO were determined. Ambient temperature data, critical temperature and DO saturation determinations are shown in Appendix J. Graphical and regression analysis techniques have been used by LDEQ historically to evaluate the temperature and dissolved oxygen data from the Ambient Monitoring Network and run-off determinations from the Louisiana Office of Climatology water budget. Since nonpoint loading is conveyed by run-off, this was a reasonable correlation to use. Temperature is strongly inversely proportional to dissolved oxygen and moderately inversely proportional to run-off. Dissolved oxygen and run-off are also moderately directly proportional. The analysis concluded that the critical conditions for stream dissolved oxygen concentrations were those of negligible nonpoint run-off and low stream flow combined with high stream temperature.

When the rainfall run-off (and non-point loading) and stream flow are high, turbulence is higher due to the higher flow and the temperature is lowered by the run-off. In addition, run-off 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. Reaeration rates and DO saturation 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 dissolved oxygen but not necessarily periods of high BOD decay.

This phenomenon is interpreted in TMDL modeling by assuming that nonpoint loading associated with flows into the stream are responsible for the benthic blanket which accumulates on the stream bottom and that the accumulated benthic blanket of the stream, expressed as SOD and/or resuspended BOD in the calibration model, has reached steady state or normal conditions over the long term and that short term additions to the blanket are off set by short term losses. This accumulated loading has its greatest impact on the stream during periods of higher temperature and lower flow. The manmade portion of the NPS loading is the difference between the calibration load and the reference stream load where the calibration load is higher. The only mechanism for changing this normal benthic blanket condition is to implement best management practices and reduce the amount of nonpoint source loading entering the stream and feeding the benthic blanket.

Critical season conditions were simulated in the dissolved oxygen TMDL projection modeling by using the default flows from the Louisiana Technical Procedures Manual (LTP), and the 90th percentile temperature. Incremental flow was assumed to be zero; model loading was from point sources, perennial tributaries, sediment oxygen demand, and resuspension of sediments.

In reality, the highest temperatures occur in July-August, the lowest stream flows occur in October-November, and the maximum point source discharge occurs following a significant rainfall, i.e., high-flow conditions. The summer projection model is established as if all these conditions happened at the same time. The winter projection model accounts for the seasonal differences in flows and BMP efficiencies. Other conservative assumptions regarding rates and loadings are also made during the modeling process. In addition to the conservative measures, an explicit MOS of 20% was used for all man-made loads to account for future growth, safety, model uncertainty and data inadequacies.

4.2 Input Data Documentation

The values and sources of the input data used for the summer and winter projection runs are shown in Appendices K, L, and M for Bayou D'Arbonne, Middle Fork, and Corney Bayou, respectively.

4.2.1 Model Options, Data Type 2

The constituents modeled in the projection simulations were the same as in the calibration simulations.

4.2.2 Temperature Correction of Kinetics, Data Type 4

The temperature correction factors specified in the LTP were used in the projection models. These were the same values that were used in the calibration models.

4.2.3 Reach Identification Data, Data Type 8

For Corney Bayou, the reach/element design from the calibration was used in the projection modeling.

In the projection modeling for Bayou D'Arbonne, Autrey Creek was added to the model as an uncalibrated branch in order to include the point source discharge from the City of Dubach WWTP. The Autrey Creek reach had a length of 3.5 km and an element size of 0.14 km. The projection modeling for the main stem of Bayou D'Arbonne included the same reach design as the calibration.

In the projection modeling for Middle Fork, Tiger Creek and Bull Creek were added to the model as uncalibrated branches in order to include point source discharges from the Wade Correctional Center and the Bernice WWTP, respectively. The Tiger Creek branch had a length of 4.83 km and an element size of 0.19 km. The Bull Creek branch had a length of 8.05 km and an element size of 0.16 km. The projection modeling for the main stem of Middle Fork included the same reach design as the calibration.

4.2.4 Advective Hydraulic Coefficients, Data Type 9

For the main stem of each model, the stream cross-sections were automatically adjusted for the projection flows by the models through the use of the coefficients, exponents, and constants established during the calibration. For the branches that were added to the projection models (Autrey Creek, Tiger Creek, and Bull Creek), the coefficients for the width and depth power functions were calculated by using the same exponents and constants as for the main stem reaches and then back-calculating the coefficients that would yield the widths and depths that were measured during the survey.

4.2.5 Initial Conditions, Data Type 11

The initial conditions were set to the 90th percentile critical season temperature in accordance with the LTP. The dissolved oxygen values for the initial conditions were set at the applicable stream criteria. All other values were set to the average of the measured values within the reach.

4.2.6 Reaeration Rates and Decay Rates, Data Types 12 and 13

The reaeration rate equations and CBOD and nitrogen decay rates were not changed from the calibration for any of the main stem reaches, For each branch that was added to the projection models (Autrey Creek, Tiger Creek, and Bull Creek), the reaeration equation and decay rates were set to the same values as used in the main stem within that subsegment.

4.2.7 Sediment Oxygen Demand and Nonpoint Sources, Data Types 12 and 19

Data from reference stream models for Middle Fork and Meridian Creek (Smythe 1999) were used to determine natural or background SOD and NPS loadings for the projection model. Meridian Creek was chosen because it is located in the same ecoregion and in close proximity to

the study area and it was surveyed during high temperatures. The LDEQ template spreadsheet for TMDL calculations was used to determine nonpoint loads for natural conditions and for each of the projection simulations. Using the SOD and the CBOD and NBOD loads from the reference stream models, a total benthic load was calculated for each stream (1.85 g/m^2/day for Middle Fork and 1.00 g/m^2/day for Meridian Creek). These two values were averaged to obtain the total natural benthic load used in the projection models (1.43 g/m^2/day). Using the ratios established during the calibration, the natural benthic load was divided into SOD, CBOD, and organic nitrogen components. For the no-load and no-nonpoint source scenarios, the model inputs for SOD and loads of CBOD and organic nitrogen were set equal to the calculated natural values. For the other projections, model inputs for SOD and loads of CBOD and organic nitrogen were set to values calculated in the LDEQ spreadsheet based on user-specified percent reductions of manmade nonpoint sources.

For all three branches that were added to the projection models (Autrey Creek, Tiger Creek, and Bull Creek), the SOD and the loads of CBOD and organic nitrogen were calculated using the LDEQ spreadsheet. In this spreadsheet, the "calibration" values for these three branches were set to the same values per unit area as reach 1 of the Middle Fork model. Then the spreadsheet applied the user-specified percent reduction of manmade nonpoint sources for each branch. Reach 1 of the Middle Fork model was chosen as the basis of the "calibration" values because its channel size and drainage area were similar to the three branches and it receives effluent from a point source discharge (like all three branches).

4.2.8 Headwaters and Wasteloads, Data Types 20, 21, 24 and 25

Each of the three subsegments has a discontinued USGS gaging station that is located on the main stem of the stream and has a long period of record of daily flow data (see list of flow gages in Section 2.5). The published 7Q10 for each of these three gages is zero (Lee 2000). Therefore, the flow rate for each headwater and unmodeled tributary was set to 0.1 cfs (0.003 m^3/sec) for summer and 1.0 cfs (0.03 m^3/sec) for winter as specified in the LTP. Flows for point source wasteloads were set to 125% of the design or expected flow.

The 90th percentile temperatures were used for all headwaters and wasteloads. The DO for headwaters and unmodeled tributaries was set to 90% saturation as specified in the LTP. A DO value of 5.0 mg/L was used for all point source wasteloads because they were all being modeled at advanced treatment levels (i.e., BOD_5 = 10 mg/L) during the summer.

For Bayou D'Arbonne and Middle Fork, permit limits and the LTP were used to establish point source concentrations of CBODu, ammonia nitrogen, and organic nitrogen for the projection runs. As discussed in Section 3.2.4, there were no point sources having a significant effect on dissolved oxygen in Corney Bayou; therefore, no point sources were explicitly modeled for Corney Bayou.

4.3 Model Discussion and Results

4.3.1 No Point Source, No Nonpoint Source, and No Load Scenarios

The no point source, no nonpoint source, and no load scenarios were run to examine the relative impacts of point sources versus nonpoint sources. All three scenarios were run under critical conditions (i.e., 7Q10 flows and 90th percentile seasonal temperatures). The point source and nonpoint source inputs were specified as summarized in Table 4.1. The model output for these scenarios is presented in Appendices N, O, and P for Bayou D'Arbonne, Middle Fork, and Corney Bayou, respectively. The predicted minimum DO values for these scenarios are listed in Table 4.2.

Each of these scenarios was run for both summer and winter conditions. For all three subsegments, summer was defined as July through September because that is the period for which the proposed DO standard of 3.0 mg/L will become effective for Middle Fork. Winter was defined as the remaining months of the year (October through June).

Table 4.1. Model inputs for no point source, no nonpoint source, and no load scenarios.

	No Point Source	**No Nonpoint Source**	**No Load**
SOD	Same as calibration	Natural conditions*	Natural conditions*
CBODu and organic nitrogen mass loads	Same as calibration	Natural conditions*	Natural conditions*
Headwater and unmodeled tributary concentrations	Same as calibration	Natural conditions*	Natural conditions*
Point source discharges	Zero	Expected flows and current permit limits	Zero

*Natural conditions = complete elimination of man-made nonpoint sources.

Table 4.2. Predicted DO for no point source, no nonpoint source, and no load scenarios.

	Season	**Predicted Minimum DO (mg/L)**		
		No Point Source	**No Nonpoint Source**	**No Load**
Bayou D'Arbonne	Summer	1.67	5.10	5.24
	Winter	4.06	6.47	6.53
Middle Fork	Summer	1.38	4.04	5.21
	Winter	2.41	6.04	6.73
Corney Bayou	Summer	0.68	same as no load	2.46
	Winter	1.66	same as no load	6.29

For Bayou D'Arbonne, the impact of man-made nonpoint sources on the in-stream DO can be seen by comparing the predicted minimum DO values between the no point source and no load

scenarios. The difference in predicted minimum DO between these two scenarios is approximately 3.6 mg/L for summer and 2.5 mg/L for winter. The impact of point sources can be seen by comparing the no nonpoint source and no load scenarios; the difference in predicted minimum DO between these two scenarios is approximately 0.1 mg/L for both summer and winter. These comparisons shows that point sources have much less impact on DO in Bayou D'Arbonne than man-made nonpoint sources do.

To examine the impact of man-made nonpoint sources on the DO in Middle Fork, the results from the no point source and no load scenarios were compared. The difference in predicted minimum DO between these two scenarios was approximately 3.8 mg/L for summer and 4.3 mg/L for winter. To examine the impact of point sources, the differences in predicted minimum DO values between the no point source and no load scenarios were evaluated and found to be approximately 1.2 mg/L for summer and 0.7 mg/L for winter. These comparisons show that the point sources have much less impact on DO in Middle Fork than the man-made nonpoint sources do.

Because no point sources were included in the Corney Bayou model, the no nonpoint source scenario was identical to the no load scenario. The comparison between the no point source and no load scenarios showed that man-made nonpoint sources have a significant impact on DO in Corney Bayou.

4.3.2 Summer and Winter Projections

Printouts of the tabular output for the summer and winter projections are presented in Appendices Q, R, and S for Bayou D'Arbonne, Middle Fork, and Corney Bayou, respectively. Graphs of the predicted DO for the summer and winter projections are shown in Appendix T. Table 4.3 summarizes the nonpoint source load reductions that would be required to meet the DO standards in each stream.

Table 4.3. Summary of nonpoint source load reductions required to meet DO standards.

	Summer (July-Sept)		**Winter (Oct-June)**	
	Man-made NPS	**Natural NPS**	**Man-made NPS**	**Natural NPS**
Bayou D'Arbonne	95%	0%	85%	0%
Middle Fork (existing standard)	100%	40%	65%	0%
Middle Fork (proposed standard)	70%	0%	NA	NA
Corney Bayou (reaches 1-2)	100%	50%	80%	0%
Corney Bayou (reaches 3-5)	75%	0%	60%	0%

For Bayou D'Arbonne, the summer and winter projection runs showed that man-made nonpoint source loads would need to be reduced by 95% in summer and 85% in winter in order for the stream to meet the existing year round DO standard of 5.0 mg/L. These reductions yielded

predicted minimum DO values of 5.0 mg/L in the summer and 5.0 mg/L in the winter. The point source load in the Bayou D'Arbonne model (City of Dubach West Pond) was not reduced in these projections because the facility is already discharging at advanced treatment levels (i.e., BOD5 = 10 mg/L) and additional treatment of the effluent would have little effect on the amount of nonpoint source reductions needed.

For Middle Fork, the summer projection runs showed that reductions of 100% of man-made nonpoint source loads and 40% of natural nonpoint source loads would be needed in order for the stream to meet the existing DO standard of 5.0 mg/L during the summer. The predicted minimum DO from this simulation was 5.0 mg/L (which occurred in reach 2). The winter projection run showed that a 65% reduction in man-made nonpoint source loads would be needed to maintain the existing DO standard of 5.0 mg/L. With this reduction, the winter projection run yielded a predicted minimum DO of 5.1 mg/L. For both of these scenarios, it was assumed that the City of Bernice and Outfall 003 at the David Wade Correctional Center would be upgraded from secondary treatment (i.e. BOD5 = 30 mg/L) to advanced treatment (i.e., BOD5 = 10 mg/L). The other oxygen demanding point source discharges in the Middle Fork subsegment (City of Haynesville and the Outfalls 001 and 002 at the David Wade Correctional Center) are already discharging at advanced treatment levels and have little impact on DO in the main stem of Middle Fork.

To meet the proposed summer DO standard of 3.0 mg/L in Middle Fork, man-made nonpoint source loads would need to be reduced by 70%. This reduction yielded a predicted minimum DO of 3.2 mg/L. The same point source upgrades that were described in the previous paragraph were also assumed for this simulation.

For Corney Bayou, reaches 1 and 2 were evaluated separately from reaches 3, 4, and 5 because of significant hydrologic/hydraulic differences. To meet the existing DO standard of 5.0 mg/L during summer, reductions of 100% of man-made nonpoint sources and 50% of natural nonpoint sources were required in reaches 1 and 2 and a reduction of 75% of man-made nonpoint sources was required in reaches 3, 4, and 5. For winter, man-made nonpoint sources would need to be reduced by 80% in reaches 1 and 2 and 60% in reaches 3, 4, and 5. The predicted minimum DO was 5.0 mg/L in both the summer and winter simulations. There were no point sources in the Corney Bayou model to be considered for load reductions.

4.4 Calculated TMDL, WLAs, and LAs

4.4.1 Outline of TMDL Calculations

An outline of the TMDL calculations is provided below to assist in understanding the TMDL calculations, which are shown in Appendices U, V, and W for Bayou D'Arbonne, Middle Fork, and Corney Bayou, respectively. Slight variances may occur based on individual cases. All of the TMDLs were calculated using the LDEQ TMDL spreadsheet.

A) The natural background benthic loading was estimated from resuspension nonpoint CBOD and nitrogenous biochemical oxygen demand (NBOD), and SOD load data. Because the LDEQ TMDL spreadsheet was set up for NBOD, the organic nitrogen and ammonia nitrogen

components in the model were added together and then multiplied by 4.33 to obtain NBOD values for input to the spreadsheet.

B) The calibration man-made benthic loading was determined as follows:

- Calibration resuspension and SOD loads were summed for each reach as gm O_2/m^2-day to get the calibration benthic loading.

- The natural background benthic loading was subtracted from the calibration benthic loading to obtain the man-made calibration benthic loading.

C) Projection benthic loads are determined by trial and error during the modeling process using a uniform percent reduction for resuspension and SOD. When modeled, point sources are reduced as necessary to subsequently more stringent levels of treatment consistent with the size of the treatment facility as much as possible. Point source design flows are increased to obtain an explicit MOS of 20%. Headwater and tributary concentrations of CBOD, organic nitrogen, ammonia nitrogen, and DO range from reference stream levels to calibration levels based on the character of the headwater. Where headwaters and tributaries exhibit man-made pollutant loads in excess of reference stream values, the loadings are reduced by the same uniform percent reduction as the benthic loads.

- The projection benthic loading at 20^oC is calculated as the sum of the projection resuspension and SOD components expressed as gm O_2/m^2-day.

- The natural background benthic load is subtracted from the projection benthic load to obtain the man-made projection benthic load for each reach.

- The percent reduction of man-made loads for each reach is determined from the difference between the projected man-made nonpoint load and the man-made nonpoint load found during calibration.

- The projection loads are also computed in units of lb/d and kg/d for each reach.

D) The total stream loading capacity at critical water temperature is calculated as the sum of:

- Headwater and tributary CBOD and NBOD loading in lb/d and kg/d.

- The natural and man-made projection benthic loading for all reaches of the stream is converted to the loading at critical temperature and summed in lb/d and kg/d.

- Point source CBOD and NBOD loading in lb/d and kg/d.

- The margin of safety in lb/d and kg/d.

4.4.2 Results of TMDL Calculations

The TMDLs for the biochemical oxygen demanding constituents (CBOD, ammonia nitrogen, organic nitrogen, and SOD) were calculated for the summer and winter critical seasons. For each subsegment, the TMDLs were set equal to the total stream loading capacity. Printouts of the TMDL spreadsheets are presented in Appendices U, V, and W for Bayou D'Arbonne, Middle Fork, and Corney Bayou, respectively. Summaries of the loads are presented in Tables 4.4 through 4.6.

In each of these TMDLs, 20% of the total point source load and 20% of the man-made nonpoint source load was designated as an explicit margin of safety (MOS). For natural nonpoint sources, no explicit margin of safety was used. The implicit margin of safety in these TMDLs is discussed in Section 4.1.

Table 4.4. TMDL for Bayou D'Arbonne (Sum of CBOD, Organic N, Ammonia N, and SOD).

	Load (kg/day) for:	
	Summer (July-Sept)	**Winter (Oct-June)**
Point Source WLA	25	46
Point Source Reserve MOS	6	11
Natural Nonpoint Source LA	401	971
Natural Nonpoint Source MOS	0	0
Man-made Nonpoint Source LA	13	132
Man-made Nonpoint Source MOS	5	35
TMDL	450	1195

Table 4.5. TMDL for Middle Fork (Sum of CBOD, Organic N, Ammonia N, and SOD).

	Load (kg/day) for:		
	Summer (July-Sept)		**Winter (Oct-June)**
	Proposed Standard	**Existing Standard**	
Point Source WLA	262	262	262
Point Source Reserve MOS	65	65	65
Natural Nonpoint Source LA	1902	1151	1964
Natural Nonpoint Source MOS	0	0	0
Man-made Nonpoint Source LA	367	0	379
Man-made Nonpoint Source MOS	93	0	106
TMDL	2689	1478	2776

Table 4.6. TMDL for Corney Bayou (Sum of CBOD, Organic N, Ammonia N, and SOD).

	Load (kg/day) for:	
	Summer (July-Sept)	**Winter (Oct-June)**
Point Source WLA	17	17
Point Source Reserve MOS	4	4
Natural Nonpoint Source LA	3972	4066
Natural Nonpoint Source MOS	0	0
Man-made Nonpoint Source LA	1524	2456
Man-made Nonpoint Source MOS	381	619
TMDL	5898	7162

4.5 Nutrient Analysis

For subsegment 080603 (Bayou D'Arbonne), the suspected causes for impairment on EPA's Modified Court Ordered 303(d) list included nutrients in addition to organic enrichment/low DO. The listing for nutrients was addressed by comparing nitrogen and phosphorus concentrations in Bayou D'Arbonne with values from reference streams and examining diurnal DO and pH data collected in Bayou

4.5.1 Nitrogen and Phosphorus Data

Measured concentrations of nitrogen and phosphorus for Bayou D'Arbonne were compared with values from LDEQ reference streams in the South Central Plain Ecoregion (SCPE; the ecoregion in which Bayou D'Arbonne is located). The reference stream data consisted of 11 samples collected on streams throughout the SCPE (Smythe 1999). These data are shown in Table X.1 (located in Appendix X). The data for Bayou D'Arbonne consisted of three data sets:

- LDEQ ambient monitoring data for station 0073 (Bayou D'Arbonne near Dubach)
- LDEQ ambient monitoring data for station 0779 (Bayou D'Arbonne east of Dubach)
- Data from the FTN intensive survey on July 18, 2001 (9 stations)

The LDEQ ambient monitoring data for Bayou D'Arbonne were downloaded from the LDEQ web site (www.deq.state.la.us/surveillance/wqdata/wqnsites.stm) and are shown in Tables X.2 and X.3. The FTN intensive survey data (shown in Table X.4) were collected at 9 stations on Bayou D'Arbonne within subsegment 080603.

Concentrations of total nitrogen and total phosphorus were compared by calculating selected statistics (minimum, 25th percentile, median, 75th percentile, and maximum) for each data set. These statistics are shown in tabular form in Table X.5 and graphically in Figures X.1 and X.2. Visual comparisons of the statistics for each data set show that the concentrations of total nitrogen and total phosphorus are similar between Bayou D'Arbonne and the reference streams.

4.5.2 Diurnal DO and pH Data

During the FTN intensive survey, measurements of temperature, DO, pH, and conductivity were made every 15 minutes over a 24 hour period in Bayou D'Arbonne at station BD-7 (at Highway 167). These data are shown in tabular form in Table X.6 and graphically in Figures X.3 and X.4. The purpose of examining these data is to see if the DO and pH data show any indications of significant photosynthesis by algae or macrophytes (which would be an indication of possible impairment due to nutrients). A stream that is impaired by nutrients would be expected to exhibit large fluctuations in DO and pH between late afternoon and early morning, with the late afternoon DO values likely exceeding 100% saturation.

For the Bayou D'Arbonne data, the difference in DO values between late afternoon and early morning was only about 0.5-0.6 mg/L. The fluctuation in pH values during the 24 hour period was only 0.05 su. All of the DO saturation values were 64% or less. Therefore, these DO and pH data do not show any indications of significant photosynthesis by algae or macrophytes.

4.5.3 Conclusions

Based on the analyses above of nitrogen and phosphorus data and diurnal measurements of DO and pH, Bayou D'Arbonne does not have a problem with over-enrichment due to nutrients. Therefore, TMDLs for nitrogen and phosphorus are not needed. This subsegment (080603) should be removed from the 303(d) list for nutrients.

5. Sensitivity Analyses

All modeling studies necessarily involve uncertainty and some degree of approximation. It is therefore 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 LAQUAL model allows multiple parameters to be varied with a single run. The model adjusts each parameter up or down by the percentage given in the input set. The rest of the parameters listed in the sensitivity section are held at their original projection value. Thus the sensitivity of each parameter is reviewed separately. A sensitivity analysis was performed on the calibration scenario for each subsegment. Parameters were varied by +/- 30%, except temperature, which was adjusted +/- 2 degrees Centigrade. The results of the sensitivity analyses are summarized in Tables 5.1 through 5.3.

For Bayou D'Arbonne, the model was most sensitive to stream reaeration, benthal demand, initial temperature, stream depth, and stream velocity. For Middle Fork, the model was most sensitive to benthal demand, stream reaeration, and initial temperature. For Corney Bayou, the model appeared to be sensitive only to a decrease in stream reaeration (see Table 5.3). However, these results are misleading because the minimum DO was occurring at the very upstream end of the model due to the low headwater DO concentration. For comparison purposes, a second sensitivity run was performed for Corney Bayou using a headwater DO concentration of 5.0 mg/L. For this run, the model was most sensitive to stream reaeration and benthal demand and slightly sensitive to initial temperature, stream velocity and stream depth.

Table 5.1. Summary of Calibration Model Sensitivity Analysis for Bayou D'Arbonne.

Parameter	**Negative Parameter Changes**			**Positive Parameter Changes**		
	Parameter Change	**Minimum DO (mg/L)**	**Percentage Difference in DO**	**Parameter Change**	**Minimum DO (mg/L)**	**Percentage Difference in DO**
Stream Reaeration	-30%	1.78	-42.1%	+30%	4.14	34.8%
Benthal Demand	-30%	3.83	24.4%	+30%	1.93	-37.4%
Initial Temperature	-2°C	3.75	21.9%	+2°C	2.38	-22.7%
Stream Depth	-30%	3.73	21.3%	+30%	2.63	-14.6%
Stream Velocity	-30%	2.53	-17.8%	+30%	2.88	-6.4%
Headwater Flow	-30%	3.02	-1.8%	+30%	3.12	1.3%
Headwater BOD	-30%	3.11	1.2%	+30%	3.04	-1.2%
BOD Decay Rate	-30%	3.11	1.1%	+30%	3.05	-0.7%
Headwater DO	-30%	3.06	-0.5%	+30%	3.08	0.3%
Ammonia Decay Rate	-30%	3.08	0.2%	+30%	3.07	-0.2%
Organic N Decay Rate	-30%	3.08	0.1%	+30%	3.07	-0.1%
Headwater Organic N	-30%	3.08	0.1%	+30%	3.07	-0.1%
Stream Dispersion	-30%	3.07	0.0%	+30%	3.07	0.0%
Wasteload Flow	-30%	3.07	0.0%	+30%	3.07	0.0%
Wasteload DO	-30%	3.07	0.0%	+30%	3.07	0.0%
Wasteload BOD	-30%	3.07	0.0%	+30%	3.07	0.0%
Wasteload Organic N	-30%	3.07	0.0%	+30%	3.07	0.0%
Wasteload Ammonia N	-30%	3.07	0.0%	+30%	3.07	0.0%

Table 5.2. Summary of Calibration Model Sensitivity Analysis for Middle Fork.

Parameter	**Negative Parameter Changes**			**Positive Parameter Changes**		
	Parameter Change	**Minimum DO (mg/L)**	**Percentage Difference in DO**	**Parameter Change**	**Minimum DO (mg/L)**	**Percentage Difference in DO**
Benthal Demand	-30%	1.91	31.8%	+30%	1.16	-19.4%
Stream Reaeration	-30%	1.06	-26.6%	+30%	1.79	23.8%
Initial Temperature	-2°C	1.61	11.5%	+2°C	1.29	-10.4%
Stream Depth	-30%	1.54	6.4%	+30%	1.39	-3.6%
Stream Velocity	-30%	1.39	-3.7%	+30%	1.50	3.6%
Wasteload Flow	-30%	1.43	-0.8%	+30%	1.45	0.5%
Wasteload Organic N	-30%	1.45	0.2%	+30%	1.44	-0.2%
Ammonia Decay Rate	-30%	1.45	0.2%	+30%	1.44	-0.1%
Organic N Decay Rate	-30%	1.45	0.1%	+30%	1.44	-0.1%
Wasteload DO	-30%	1.45	0.1%	+30%	1.45	0.1%
Wasteload BOD	-30%	1.45	0.1%	+30%	1.44	-0.1%
BOD Decay Rate	-30%	1.45	0.1%	+30%	1.45	0.0%
Stream Dispersion	-30%	1.45	0.0%	+30%	1.45	0.0%
Headwater Flow	-30%	1.45	0.0%	+30%	1.45	0.0%
Wasteload Ammonia N	-30%	1.45	0.0%	+30%	1.45	0.0%
Headwater DO	-30%	1.45	0.0%	+30%	1.45	0.0%
Headwater BOD	-30%	1.45	0.0%	+30%	1.45	0.0%
Headwater Organic N	-30%	1.45	0.0%	+30%	1.45	0.0%

Table 5.3. Summary of Calibration Model Sensitivity Analysis for Corney Bayou.

Parameter	Negative Parameter Changes			Positive Parameter Changes		
	Parameter Change	Minimum DO (mg/L)	Percentage Difference in DO	Parameter Change	Minimum DO (mg/L)	Percentage Difference in DO
Stream Reaeration	-30%	0.77	-35.8%	+30%	1.20	0.0%
Stream Velocity	-30%	1.20	0.0%	+30%	1.20	0.0%
Stream Depth	-30%	1.20	0.0%	+30%	1.20	0.0%
Stream Dispersion	-30%	1.20	0.0%	+30%	1.20	0.0%
BOD Decay Rate	-30%	1.20	0.0%	+30%	1.20	0.0%
Organic N Decay Rate	-30%	1.20	0.0%	+30%	1.20	0.0%
Ammonia Decay Rate	-30%	1.20	0.0%	+30%	1.20	0.0%
Benthal Demand	-30%	1.20	0.0%	+30%	1.20	0.0%
Initial Temperature	-2°C	1.20	0.0%	+2°C	1.20	0.0%
Headwater Flow	-30%	1.20	0.0%	+30%	1.20	0.0%
Wasteload Flow	-30%	1.20	0.0%	+30%	1.20	0.0%
Wasteload DO	-30%	1.20	0.0%	+30%	1.20	0.0%
Wasteload BOD	-30%	1.20	0.0%	+30%	1.20	0.0%
Wasteload Ammonia N	-30%	1.20	0.0%	+30%	1.20	0.0%
Wasteload Organic N	-30%	1.20	0.0%	+30%	1.20	0.0%
Headwater DO	-30%	1.20	0.0%	+30%	1.20	0.0%
Headwater BOD	-30%	1.20	0.0%	+30%	1.20	0.0%
Headwater Organic N	-30%	1.20	0.0%	+30%	1.20	0.0%

6. Conclusions

For Bayou D'Arbonne, the TMDL requires that man-made nonpoint source loads be reduced by 95% in the summer and 85% in the winter. No reductions are needed for the point source loads. The only oxygen demanding point source discharge in the Bayou D'Arbonne subsegment (City of Dubach West Pond) is already discharging at advanced treatment levels and was shown to have little impact on DO in the main stem of Bayou D'Arbonne (see Section 4.3.1).

For Middle Fork to meet the current DO standard of 5.0 mg/L during the summer, the TMDL requires a 100% reduction in man-made nonpoint source loads for all reaches plus a 40% reduction in natural nonpoint source loads. In order to meet the proposed (but not yet promulgated) summer DO standard of 3.0 mg/L, a 70% reduction in man-made nonpoint source loads is required. To meet the winter DO standard of 5.0 mg/L, a 65% reduction in man-made nonpoint source loads is required. For each of these scenarios, a point source load reduction was assumed for the City of Bernice and for Outfall 003 at the David Wade Correctional Center (upgrading from secondary treatment to advanced treatment). The other oxygen demanding point source discharges in the Middle Fork subsegment (City of Haynesville and the Outfalls 001 and 002 at the David Wade Correctional Center) are already discharging at advanced treatment levels and have little impact on DO in the main stem of Middle Fork.

For Corney Bayou, different nonpoint source load reductions were considered for the upper and lower reaches because of their hydrologic/hydraulic differences. For the upper two reaches, the TMDL requires a 100% reduction in man-made nonpoint source loads plus a 50% reduction in natural nonpoint source loads in order to meet the DO standard in the summer. For winter, an 80% reduction in man-made nonpoint sources is required to meet the DO standard. For the lower three reaches, the TMDL requires that man-made nonpoint source loads be reduced by 75% in the summer and 60% in the winter.

This TMDL has been developed to be consistent with the State antidegradation policy (LAC 33:IX.1109.A).

LDEQ will work with other agencies such as local Soil Conservation Districts to implement agricultural best management practices in the watershed through the 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, the 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.

The LDEQ has implemented a watershed approach to surface water quality monitoring. Through this approach, the entire state is sampled over a five-year cycle with two targeted basins sampled each year. Long-term trend monitoring sites at various locations on the larger rivers and Lake Pontchartrain are sampled throughout the five-year cycle. Sampling is conducted on a monthly basis or more frequently if necessary to yield at least 12 samples per site each year. Sampling sites are located where they are considered to be representative of the waterbody. Under the current monitoring schedule, targeted basins follow the TMDL priorities. In this manner, the first TMDLs will have been implemented by the time the first priority basins will be monitored again in the second five-year cycle. This will allow the 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. The sampling schedule for the next five years is shown below.

2002 - Red and Sabine River Basins
2003 - Mermentau and Vermilion-Teche River Basins
2004 - Calcasieu and Ouachita River Basins
2005 - Barataria and Terrebonne Basins
2006 - Lake Pontchartrain Basin and Pearl River Basin
(Atchafalaya and Mississippi Rivers will be sampled continuously.)

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8. Appendices

See Attached Appendices A1 - X.