FINAL

TMDLs for Dissolved Oxygen in Selected Subsegments in the Pearl River Basin, Louisiana

(090105, 090204, 090207)

Prepared for:

United States Environmental Protection Agency, Region 6
Water Quality Protection Division
Permits, Oversight, and TMDL Team
Dallas, TX

Contract No. 68-C-02-108
Task Order No. 134

Prepared by:

Tetra Tech, Inc.
10306 Eaton Place, Suite 340
Fairfax, VA 22030

March 25, 2008
Revised September 10, 2008

EXECUTIVE SUMMARY

Section 303(d) of the Clean Water Act and the U.S. Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations (at Title 40 of the *Code of Federal Regulations* [CFR] Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for impaired waterbodies. A TMDL establishes the amount of a pollutant that a waterbody can assimilate while still meeting the water quality standard for that pollutant. TMDLs provide the scientific basis for a state to establish water quality-based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of the state's water resources (USEPA 1991).

A TMDL for a given pollutant and waterbody is composed of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL must include an implicit or explicit margin of safety (MOS) to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody and may include a future growth (FG) component. The TMDL components are illustrated using the following equation:

$$TMDL = \Sigma WLAs + \Sigma LAs + MOS + FG$$

The study area for this TMDL includes three Pearl River Basin subsegments. The Pearl River flows along the border of Louisiana and Mississippi. It originates in Mississippi at the confluence of Nanawaya and Tallahaga creeks and flows southerly for almost 500 miles. It has a drainage area of almost 9,000 square miles. In the TMDL study area, the largest percentage of area is wetland, followed by forest, shrubland, and agriculture.

The Louisiana Department of Environmental Quality (LDEQ) has included three Pearl River Basin subsegments on the state's 2004 section 303(d) list of impaired waterbodies. The subsegments are listed for dissolved oxygen impairments. The impaired designated uses for the subsegments (Table ES-1) are primary and secondary contact recreation (PCR and SCR), and fish and wildlife propagation (FWP). The subsegments are either fully supporting (F) or not supporting (N).

Table ES-1. Section 303(d) listing for subsegments included in this report

Subsegment	Subsegment name	Subsegment description	Designated use		
			PCR	SCR	FWP
090105	Pearl River Navigation Canal	Pools Bluff to Lock No. 3	F	F	N
090204	Pearl River Navigation Canal	Below Lock No.3	F	F	N
090207	Middle River and West Middle River	West Pearl River to Little Lake	F	F	N

A water quality model (LA-QUAL) was set up to simulate dissolved oxygen, carbonaceous biochemical oxygen demand (CBOD), ammonia, and nitrite/nitrate. The model was calibrated using data from field work conducted in August 2006. The projection simulation was run at critical flows and temperatures to address seasonality, as the Clean Water Act requires.

Reductions of nonpoint source loads were required for the projection simulation to show the dissolved oxygen standard, 5 mg/L, being maintained. In general, the modeling in this study was consistent with guidance in the Louisiana TMDL technical procedures manual (LDEQ 2005). TMDLs for oxygen-demanding substances ($CBOD_u$, ammonia, nitrate, and sediment oxygen demand) were calculated using the results of the projection simulation.

Table ES-2 presents a summary of the TMDLs for the subsegments addressed in this report. The numeric water quality criterion that applies to the impaired subsegments and was used to calculate the total allowable pollutant loads is 5 mg/L.

In TMDL development, allowable loadings from all pollutant sources that cumulatively amount to no more than the TMDL must be established, thereby providing the basis for establishing water quality-based controls. WLAs were assigned to permitted point source discharges. The LAs include background loadings and human-induced nonpoint sources. An explicit MOS of 10 percent and an FG component of 10 percent were also included. Table ES-3 presents a summary of the reduction percentages for LAs. Reduction percentages for total oxygen demand ranged from 20 to 66 percent. There were no reductions for WLAs (ES-4).

Table ES-2. Summary of dissolved oxygen TMDLs, WLAs, LAs, MOSs, and FGs for Pearl River Basin

Subsegment	Oxygen demand (lb/d)				
090105	**SOD**	**$CBOD_u$**	**Ammonia[a]**	**Nitrate[a]**	**Total**
WLA	0.00	12.88	0.79	0.00	13.67
MOS for WLA	0.00	1.61	0.10	0.00	1.71
FG for WLA	0.00	1.61	0.10	0.00	1.71
LA	392.42	1,425.07	109.21	548.32	2,475.02
MOS for LA	49.05	178.13	13.65	68.54	309.38
FG for LA	49.05	178.13	13.65	68.54	309.38
TMDL	490.53	1,797.44	137.50	685.40	3,110.87
Subsegment	**Oxygen demand (lb/d)**				
090204	**SOD**	**$CBOD_u$**	**Ammonia[a]**	**Nitrate[a]**	**Total**
WLA	0.00	15.63	9.81	0.00	25.44
MOS for WLA	0.00	1.95	1.23	0.00	3.18
FG for WLA	0.00	1.95	1.23	0.00	3.18
LA	2,171.11	1,237.23	868.31	134.41	4,411.06
MOS for LA	271.39	154.65	108.54	16.80	551.38
FG for LA	271.39	154.65	108.54	16.80	551.38
TMDL	2,713.89	1,566.08	1,097.64	168.01	5,545.62
Subsegment	**Oxygen demand (lb/d)**				
090207	**SOD**	**$CBOD_u$**	**Ammonia[a]**	**Nitrate[a]**	**Total**
WLA	0.00	0.00	0.00	0.00	0.00
MOS for WLA	0.00	0.00	0.00	0.00	0.00
FG for WLA	0.00	0.00	0.00	0.00	0.00
LA	6,482.47	6,197.28	73.31	3,863.46	16,616.53
MOS for LA	810.31	774.66	9.16	482.93	2,077.07
FG for LA	810.31	774.66	9.16	482.93	2,077.07
TMDL	8,103.09	7,746.60	91.64	4,829.33	20,770.67

[a] Converted to oxygen demand. (concentration × 4.33 [conversion factor])

Table ES-3. Summary of reduction percentages for LAs in the Pearl River Basin

Subsegment	Percent reduction				
	SOD	$CBOD_u$	Ammonia	Nitrate	Total
090105	17.93	27.35	0.00	0.00	20.12
090204	48.43	60.10	0.00	0.00	46.95
090207	67.47	75.38	0.00	0.00	66.12

Table ES-4. Summary of WLAs for the Pearl River Basin

Sub-segment	Permit #	Outfall	Facility Name	Flow (gpd)	BOD_5 Limit (mg/L)	Ammonia Limit (mg/L)	BOD_5 (lb/d)	Ammonia (lb/d)
090105	LA0106143	001	Double D Meat Co.	5,500	--	4.0	5.60	0.18
090204	LA0055638	002	MacKenzie Co LLC	800	45	15	0.30	0.10
090204	LAG480357	001	St. Tammany Parish Government-Bush Maintenance	2,000	45	15	0.75	0.25
090204	LAG530499		Bellsouth Telecommunications J2840	5,000	45	15	1.88	0.63
090204	LAG530848	001	Highway 21 LLC	5,000	45	15	1.88	0.63
090204	LAG531949	001	Hebron Baptist Church of Bush La - Hebron B	1,800	45	15	0.68	0.23
090204	LAG541203	001	Sixth Ward Junior High School	5,240	30	10	1.31	0.44

Hurricane Katrina made landfall on Monday, August 29, 2005, as a Category 4 hurricane. The storm brought heavy winds and rain to southeast Louisiana. Floodwaters breached several levees, flooding large areas of coastal Louisiana. The hurricane caused a change in sedimentation and water quality in southern Louisiana. Several federal and state agencies, including EPA and LDEQ, are engaged in collecting environmental data and assessing the recovery of the Gulf of Mexico waters. The proposed TMDLs in this report were developed on the basis of pre- and post-hurricane conditions. Therefore, some post-hurricane conditions and other factors could delay implementation of these proposed TMDLs, render some proposed TMDLs obsolete, or require modifications of the TMDLs. Hurricane effects might be a valid justification for some TMDL modification, however, any deviation from the TMDLs should be justified using site-specific data or information.

CONTENTS

TABLES

FIGURES

APPENDICES

1 INTRODUCTION

Section 303(d) of the Clean Water Act and the U.S. Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations (at Title 40 of the *Code of Federal Regulations* [CFR] Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not supporting their designated uses, even if pollutant sources have implemented technology-based controls. A TMDL establishes the maximum allowable load (mass per unit time) of a pollutant that a waterbody is able to assimilate while still supporting its designated uses. The maximum allowable load is determined on the basis of the relationship between pollutant sources and in-stream water quality. A TMDL provides the scientific basis for a state to establish water quality-based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of the state's water resources (USEPA 1991).

Monitoring data collected by the Louisiana Department of Environmental Quality (LDEQ) indicate that observed dissolved oxygen water quality sometimes does not meet criteria for three subsegments in the Pearl River Basin. The impaired designated uses for the subsegments are primary and secondary contact recreation, and fish and wildlife propagation. The subsegments are either fully supporting (F) or not supporting (N) the designated uses. Table 1-1 presents information from Louisiana's 2004 section 303(d) list for the three subsegments. All subsegments have the suspected cause of "unknown sources," which indicates that various sources might be present but not enough data are available to identify them.

Table 1-1. Subsegments and impairments addressed in this report

Subsegment	Subsegment name	Subsegment description	Designated use		
			PCR	SCR	FWP
090105	Pearl River Navigation Canal	Pools Bluff to Lock No. 3	F	F	N
090204	Pearl River Navigation Canal	Below Lock No.3	F	F	N
090207	Middle River and West Middle River	West Pearl River to Little Lake	F	F	N

Oxygen concentrations in the water column fluctuate under natural conditions, but severe depletion usually results from human activities that introduce large quantities of biodegradable organic materials into surface waters. In polluted waters, bacterial degradation of organic materials can result in a net decline in oxygen concentrations in the water. Oxygen depletion can also result from chemical reactions that place a chemical oxygen demand on receiving waters. Other factors, such as temperature and salinity, influence the amount of oxygen dissolved in water. Prolonged hot weather decreases oxygen concentrations and can cause fish kills even in clean waters because warm water cannot hold as much oxygen as cold water (Scorecard 2005). Other factors affecting dissolved oxygen concentrations include the following (Murphy 2005):

- Volume and velocity of water flowing in the waterbody
- Climate/season
- The type and number of organisms in the waterbody
- Altitude

- Dissolved or suspended solids
- Amount of nutrients in the water
- Organic wastes
- Riparian vegetation
- Groundwater inflow

Low dissolved oxygen concentrations in streams can be linked to both natural conditions and human activities. In Louisiana, natural stream conditions like low flow, high temperature, and high organic content often result in dissolved oxygen levels already below current water quality criteria, making it difficult to develop standards for Best Management Practices (BMPs) (Mason et al. 2007). Additional data for these 303(d) listed areas are needed to determine whether the low dissolved oxygen occurs naturally or is related to human activity (is anthropogenic).

2 BACKGROUND INFORMATION

2.1 General Description

The Pearl River flows along the border of Louisiana and Mississippi. It originates in Mississippi at the confluence of Nanawaya and Tallahaga creeks and flows southerly for almost 500 miles. It has a drainage area of almost 9,000 square miles. About 50 miles above its mouth, the Pearl River splits and forms the East Pearl River and West Pearl River. Both portions flow to Lake Borgne and eventually to the Gulf of Mexico. In Louisiana the Pearl River Basin includes portions of Washington and St. Tammany parishes, as well as a small portion of Tangipahoa Parish. The watershed's U.S. Geological Survey (USGS) hydrologic unit codes are 03180004 and 03180005.

The area of interest for this TMDL consists of selected subsegments in the Pearl River and East Pearl River watersheds in Washington and St. Tammany parishes. Table 2-1 lists the parish and approximate drainage area of each subsegment, and Figures 2-1 and 2-2 shows the locations of the subsegments.

Table 2-1. Parish and drainage area for each listed subsegment in the Pearl River Basin

Subsegment number	Subsegment name	Parish	Subsegment area (acres)
090105	Pearl River Navigation Canal	Washington	8,108
090204	Pearl River Navigation Canal	St. Tammany	26,386
090207	Middle River and West Middle River	St. Tammany	18,185

2.2 Land Use

Land use data were obtained from the 2001 USGS National Land Cover Dataset (NLCD; Table 2-2 and Figure 2-3). The predominant land use in the impaired subsegments is wetland. The percentage of wetlands in the watersheds ranges from 30 percent to 97 percent, followed by forest, shrubland, and agriculture. There is very little developed land in any of the three subsegments. Subsegments 090105 and 090204 have large areas of forest and woody wetland. Subsegment 090207 is almost entirely wetland and open water. It has only just over 1 percent developed area, which consists of highways.

Table 2-2. Land use percentages for each listed subsegment in the Pearl River Basin

Sub-segment	Open water	Developed	Barren land	Forest	Grass/ shrub	Pasture/ hay	Cultivated crops	Woody wetland	Emergent herbaceous wetland
090105	2.60	6.83	0.09	22.56	15.31	12.76	2.42	36.04	1.40
090204	2.27	5.14	0.07	33.17	19.79	5.37	3.81	29.88	0.51
090207	6.30	1.07	0.02	0.02	0.00	0.00	0.00	63.07	29.52

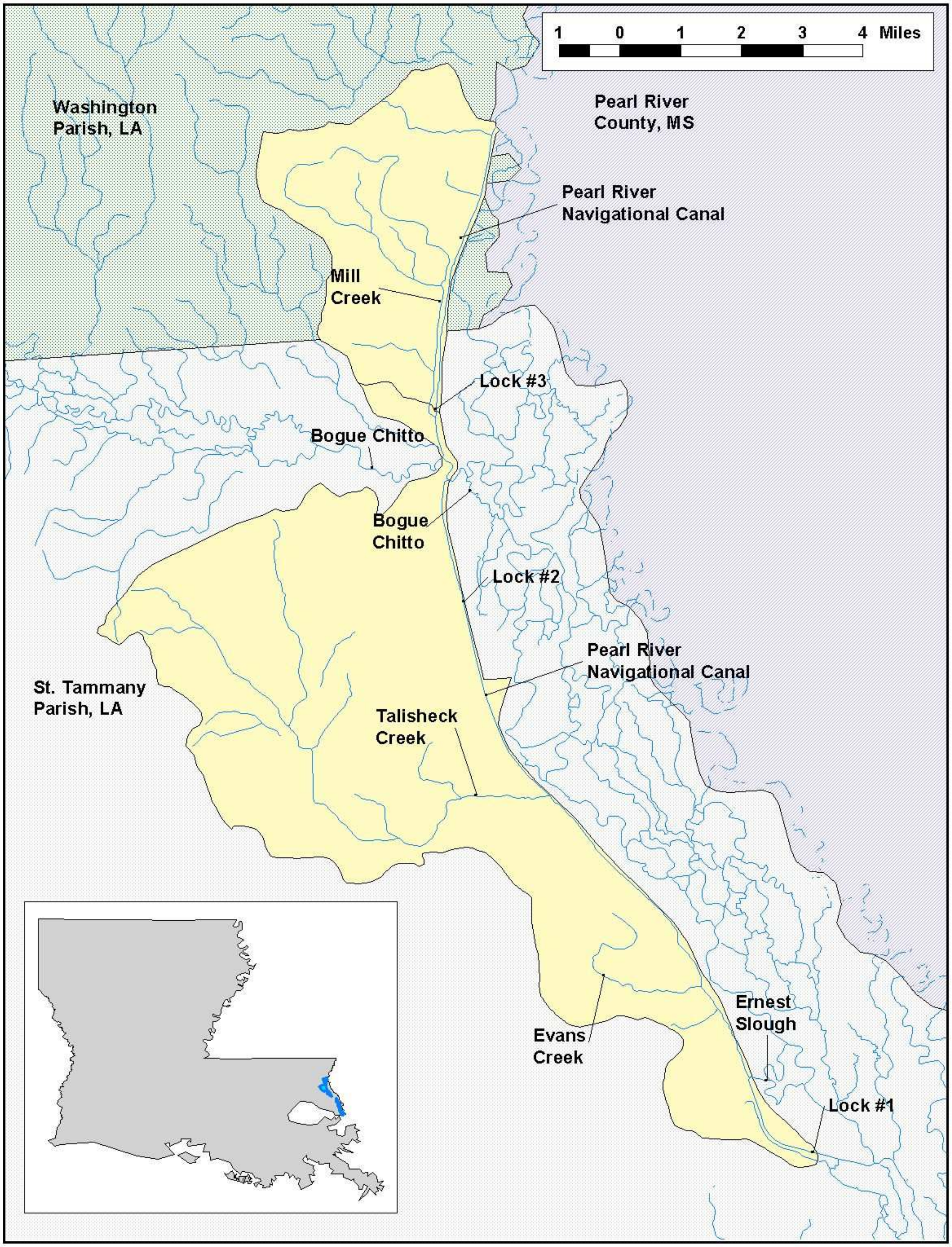

Figure 2-1. Locations of the northern Pearl River Basin subsegments.

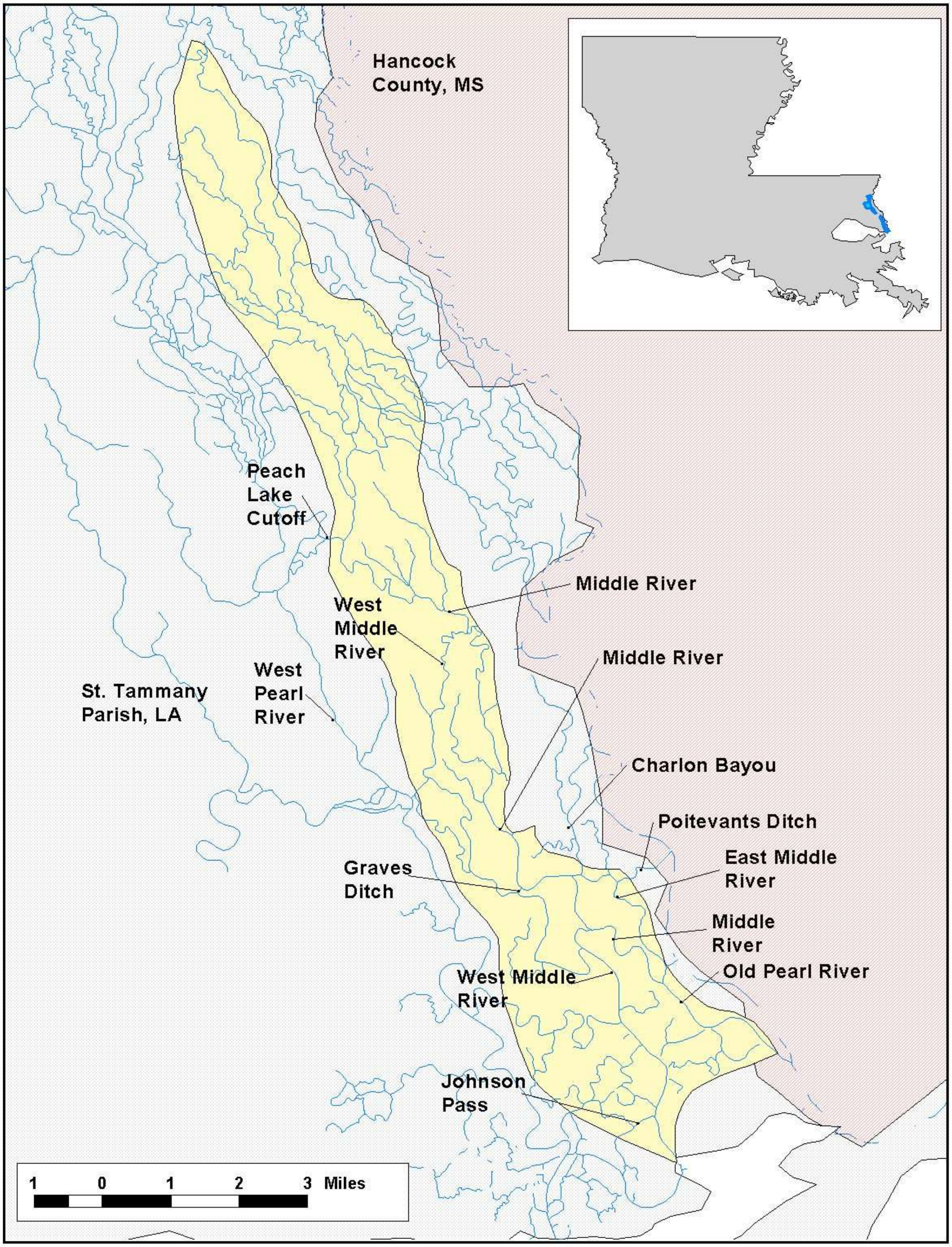

Figure 2-2. Locations of southern Pearl River Basin subsegment.

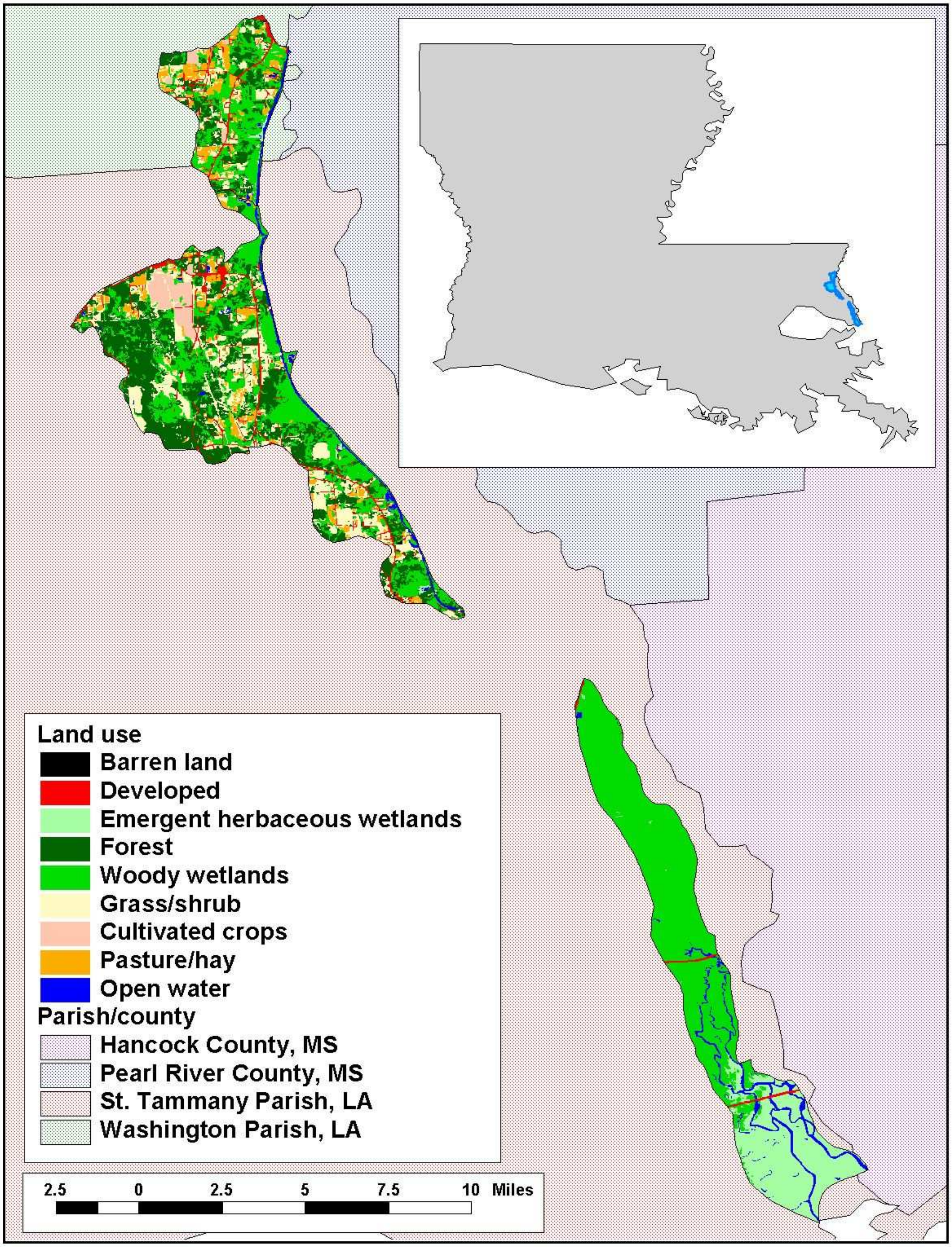

Figure 2-3. Land use in the Pearl River Basin subsegments.

2.3 Hydrologic Setting

The USGS online hydrology database (NWISWeb) does not contain any stations with flow data in the subsegments that are impaired for dissolved oxygen.

The subsegments in this TMDL do not have typical flow patterns. Subsegments 090105 and 090204 are the Pearl River Navigational Canal (PRNC), and subsegment 090207 is the Middle and West Middle rivers.

2.3.1 Pearl River Navigational Canal

The PRNC runs just over 30 kilometers through two subsegments. The subsegments were once part of a canal and lock system, which is no longer operational. The system has three locks. The northernmost lock, Lock 3, acts as the boundary between the two subsegments. The PRNC is a dredged channel that has a fairly uniform depth and width.[1] It is assumed to have a constant water elevation based on shoreline vegetation and fixed-location docks.[2] Most of its shoreline is bounded by levees and piled soils from when the canal was initially dredged.

Even though the locks are no longer operational, small gaps in the gates permit a limited amount of flow though the locks. The northern section of the PRNC is connected to the Pearl River, near Pools Bluff, Louisiana, through only a small channel, through which small boats can pass. However, little flow enters the canal, except during flood conditions.[2]

The canal does not have any major tributaries. Duck Pond, at the northern portion of the canal, is a backwater pond, and no flow enters the canal from the pond.[1] Mill Creek drains portions of subsegment 090105, but the flow from the creek enters a lake and does not enter the canal.[1]

Subsegment 090204 has more tributaries; however, most of them have little associated flow. Evans Creek has negligible flow; Talisheek Creek flows into a swamp, from which a negligible flow enters the PRNC.[1] In addition to these tributaries, there is a spillway from the PRNC to Ernest Slough. This spillway operates mainly during high-flow conditions and is mostly for erosion control.[1]

The major tributary to the PRNC is Bogue Chitto. Bogue Chitto enters the PRNC in subsegment 090204 and exits the canal shortly after entering. Most of the water entering the canal from Bogue Chitto exits the canal with Bogue Chitto.[1] A large amount of sediment has accumulated in the PRNC upstream of its confluence with Bogue Chitto.[2] This sediment bar forms a barrier similar to the one between the Pearl River and the PRNC; like that barrier, it has a narrow channel cutout through which boats can navigate.[2]

The PRNC eventually enters the West Pearl River, shortly before Holmes Bayou enters into the West River.

[1] David Ogé, Louisiana Department of Environmental Quality (Southeast Regional Office), personal communication, February 8, 2007.
[2] Nathan Siria, field sampler for FTN Associates, personal communication, February 9, 2007.

2.3.2 Middle and West Middle Rivers

The Middle and West Middle rivers partly originate in the West Pearl River. The West Pearl River is connected to the Middle River though Peach Lake Cutoff. Only a small amount of flow enters the Middle River during low flows, but a significant amount enters during high flows.[3] Just south of Route 10, the Middle River splits into the Middle and West Middle rivers. A recent field study found that 60 percent of the flow goes to the West Middle River (FTN Associates 2006). The two rivers are connected at Graves Ditch and through several small, unnamed channels. Very little flow goes through Graves Ditch at low flow, and most of the flow is tidally influenced.[3]

During the course of the Middle and West Middle rivers, numerous small bayous and sloughs are connected to the rivers. Many of these bayous and sloughs have become blocked with sediment bars over the years, and flow occurs only during high-flow periods.[3] Most of the flow in the subsegment is tidally influenced, except during winter high flows, when there is significant rain upstream of the subsegment.[3]

The Middle West River flows from its split with the Middle River south to the East Mouth of the West Pearl River. During its course, it connects with several bayous and sloughs, including Mill Bayou, Upper Black Bayou, Lower Black Bayou, and Grassy Bayou. Some flow from the river flows into Johnson Pass, which also discharges into the East Mouth. The East Mouth then joins Little Lake.

The flow pattern of the Middle River is slightly more complicated than that of the West Middle River. After splitting with the West Middle River, the Middle River is joined by Steamboat Bayou and Morgan Bayou. The river then splits into the Middle River and the East Middle River, which later combine after flows from Chalon Bayou and Poitevants Ditch enter the East Middle River. Chalon Bayou and Poitevants Ditch connect the East Middle River with the main stem of the Pearl River. The Middle River and the East Middle River combine to form the Old Pearl River, which joins with the Pearl River and flows to Lake Borgne.

2.4 Designated Uses and Water Quality Criteria

Louisiana’s 2004 section 303(d) list indicates that the three listed subsegments—all assigned a use of primary or secondary contact recreation, or fish and wildlife propagation—do not meet applicable water quality standards because of unknown sources. Primary contact recreation involves any recreational or other water contact involving full-body exposure to water and a considerable probability of ingesting water. Examples are swimming and water skiing. Secondary contact recreation involves activities like fishing, wading, or boating, where water contact is accidental or incidental and there is a minimal chance of ingesting appreciable amounts of water. Fish and wildlife propagation includes the use of water for aquatic habitat, food, resting, reproduction, cover, or travel corridors for any indigenous wildlife and aquatic life species associated with the aquatic environment.

[3] David Ogé, Louisiana Department of Environmental Quality (Southeast Regional Office), personal communication, February 28, 2007.

The assessment methodology presented in LDEQ's 305(b) report (LDEQ 2004) specifies that primary contact recreation, secondary contact recreation, and fish and wildlife propagation uses are to be fully supported. The state minimum criterion for the subsegments in this TMDL is 0.5 ppm (5 mg/L).

The Louisiana water quality standards also include an antidegradation policy (*Louisiana Administrative Code* [LAC] Title 33, Part IX, Section 1109.A), which states that state waters exhibiting high water quality should be maintained at that high level of water quality. If that is not possible, water quality of a level that supports the designated uses of the waterbody should be maintained. The designated uses of a waterbody may be changed to allow a lower level of water quality only through a use attainability study.

2.5 Identification of Sources

2.5.1 Point Sources

LDEQ stores permit information using internal databases. A list of permits in the Pearl River Basin was obtained from LDEQ using its TEMPO and PTS databases. Information on point source discharges to the listed subsegments was obtained from the Electronic Document Management System (EDMS) database at LDEQ. Data were pulled from these databases and analyzed for the TMDLs. Each facility was evaluated based on its discharges and the relevant subsegment's 303(d) listing to determine whether the facility would be used in developing the TMDLs. The evaluation yielded seven point source discharges (Table 2-3) that could affect dissolved oxygen levels. Of these, only two were used directly in the model, on the basis of distance to the main model channel. None of the facilities' discharge permits specify dissolved oxygen.

Table 2-3. Point source discharge information for the Pearl River Basin

NPDES permit number	Outfall	Facility name	Receiving water body	Flow (gpd)	BOD_5 limit (mg/L)	Ammonia limit (mg/L)	Used in model?
Subsegment 090105							
LA0106143	001	Double D Meat Co.	ditch – PRNC	5,500 (design)	11.2 lb/d (daily); 5.6 lb/d (monthly)	8 (daily); 4 (monthly)	No – Does not discharge to main channel.
Subsegment 090204							
LA0055638	001	MacKenzie Co LLC	Talisheek Creek – PRNC	3,645 (average)	--	10 (daily)	No – Does not discharge to main channel.
	002			800 (design)	45 (daily)	--	
	003			1,080 (average)	--	10 (daily)	
LAG480357	001	St. Tammany Parish Government – Bush Maintenance	Talisheek Creek – PRNC	2,000 (design)	45 (weekly)	--	No – Does not discharge to main channel.
	002			200 (average)	--	--	
LAG530499		Bellsouth Telecommun-ications J2840	ditch – Little Brushy Branch	5,000 (max)	45 (weekly)	--	No – Does not discharge to main channel.

Table 2-3. (continued)

NPDES permit number	Outfall	Facility name	Receiving water body	Flow (gpd)	BOD_5 limit (mg/L)	Ammonia limit (mg/L)	Used in model?
LAG530848	001	Highway 21 LLC	Waterhole Branch	5,000 (max)	45 (weekly)	--	No – Does not discharge to main channel.
LAG531949	001	Hebron Baptist Church of Bush, LA	ditch – Little Brushy Branch – PRNC	1,800 (design); 2,500 (max)	45 (weekly)	--	Yes
LAG541203	001	Sixth Ward Junior High School	ditch – PRNC	5,240 (design); 10,000 (max)	45 (weekly); 30 (monthly)	--	Yes

2.5.2 Nonpoint Sources

Louisiana's section 303(d) list does not identify the suspected cause of the dissolved oxygen impairment in the subsegments of the Pearl River Basin. The source is listed as *unknown*. In addition to natural wetlands, land uses in the subsegment include pasture, urban land, and row crops. These land uses could also introduce nutrients and oxygen demand to the subsegment.

3 CHARACTERIZATION OF EXISTING WATER QUALITY

3.1 Water Quality Data

Water quality data were obtained from LDEQ's routine ambient water quality monitoring program (Figures 3-1 and 3-2). Appendix A includes summaries of the data for the 303(d) listed constituents, along with additional constituents used in the TMDL development process. Dissolved oxygen data were available for each of the three listed subsegments, each with 17 or 18 monitoring events. In addition, nutrient data are summarized because they were also used in developing the dissolved oxygen TMDLs. Appendix B contains the field notes.

Water quality monitoring data for each listed subsegment were obtained from LDEQ (Table 3-1). Tables 3-1 through 3-6 provide a summary of the LDEQ water quality data available for three stations in three subsegments (Figure 3-1). The stations had between 14 and 18 data points. Dissolved oxygen concentrations are lower in the summer and early fall months.

Table 3-1. Summary of dissolved oxygen data for the Pearl River Basin

Sub-segment	Station	Station name	Period of record	No. of obs.	DO minimum (mg/L)	DO maximum (mg/L)	DO average (mg/L)
090105	1118	Pearl River Navigation Canal at Lock 3, Louisiana	1/16/2001–6/21/2006	18	3.02	9.17	6.00
090204	1053	Pearl River Navigation Canal at Lock 1	1/2/2001–6/27/2006	18	2.58	10.01	6.63
090207	1055	Middle Pearl River at Hwy 90	1/2/2001–5/22/2006	17	3.95	10.73	6.79

Table 3-2. Summary of total organic carbon data for the Pearl River Basin

Subsegment	Station	Station name	Period of record	No. of obs.	TOC minimum (mg/L)	TOC maximum (mg/L)	TOC average (mg/L)
090105	1118	Pearl River Navigation Canal at Lock 3, Louisiana	1/16/2001–3/29/2006	16	3.10	15.60	9.83
090204	1053	Pearl River Navigation Canal at Lock 1	1/2/2001–3/21/2006	14	5.50	34.60	11.82
090207	1055	Middle Pearl River at Hwy 90	1/2/2001–3/28/2006	15	6.90	12.60	8.76

Table 3-3. Summary of nitrite+nitrate data for the Pearl River Basin

Subsegment	Station	Station name	Period of record	No. of obs.	Total NO_2+NO_3 minimum (mg/L)	Total NO_2+NO_3 maximum (mg/L)	Total NO_2+NO_3 average (mg/L)
090105	1118	Pearl River Navigation Canal at Lock 3, Louisiana	1/16/2001–3/29/2006	16	0.05	0.18	0.09
090204	1053	Pearl River Navigation Canal at Lock 1	1/2/2001–3/21/2006	14	0.05	0.12	0.06
090207	1055	Middle Pearl River at Hwy 90	1/2/2001–3/28/2006	15	0.05	0.23	0.12

Table 3-4. Summary of ammonia data for the Pearl River Basin

Subsegment	Station	Station name	Period of record	No. of obs.	Ammonia minimum (mg/L)	Ammonia maximum (mg/L)	Ammonia average (mg/L)
090105	1118	Pearl River Navigation Canal at Lock 3, Louisiana	1/16/2001–3/29/2006	16	0.10	0.28	0.12
090204	1053	Pearl River Navigation Canal at Lock 1	1/2/2001–3/21/2006	14	0.10	0.56	0.14
090207	1055	Middle Pearl River at Hwy 90	1/2/2001–3/28/2006	15	0.10	0.56	0.14

Table 3-5. Summary of total organic nitrogen data for the Pearl River Basin

Subsegment	Station	Station name	Period of record	No. of obs.	TKN minimum (mg/L)	TKN maximum (mg/L)	TKN average (mg/L)
090105	1118	Pearl River Navigation Canal at Lock 3, Louisiana	1/16/2001–3/29/2006	16	0.21	1.04	0.58
090204	1053	Pearl River Navigation Canal at Lock 1	1/2/2001–3/21/2006	14	0.31	0.73	0.54
090207	1055	Middle Pearl River at Hwy 90	1/2/2001–3/28/2006	15	0.10	1.50	0.69

Table 3-6. Summary of total phosphorus data for the Pearl River Basin

Subsegment	Station	Station name	Period of record	No. of obs.	Total phos. minimum (mg/L)	Total phos. maximum (mg/L)	Total phos. average (mg/L)
090105	1118	Pearl River Navigation Canal at Lock 3, Louisiana	1/16/2001–3/29/2006	16	0.05	0.12	0.08
090204	1053	Pearl River Navigation Canal at Lock 1	1/2/2001–3/21/2006	14	0.05	0.08	0.06
090207	1055	Middle Pearl River at Hwy 90	1/2/2001–3/28/2006	15	0.05	0.21	0.11

Additional environmental data were obtained from a recent monitoring event, conducted August 14, 2006, though August 18, 2006. Water quality data were collected at 18 locations for total phosphorus, chlorophyll a, 25-day carbonaceous biochemical oxygen demand (CBOD), ammonia, total Kjeldahl nitrogen (TKN), nitrate plus nitrite nitrogen, and total organic carbon (TOC). In addition, these 18 locations, along with 14 other locations, were monitored for in situ measurements of temperature, dissolved oxygen, pH, and conductivity; 3 of the locations were continuously monitored in situ for 24 to 48 hours.

The results of the data compilation and review include the following:

- In situ data collected throughout each subsegment
- Continuous in situ data
- Laboratory analyses of water samples

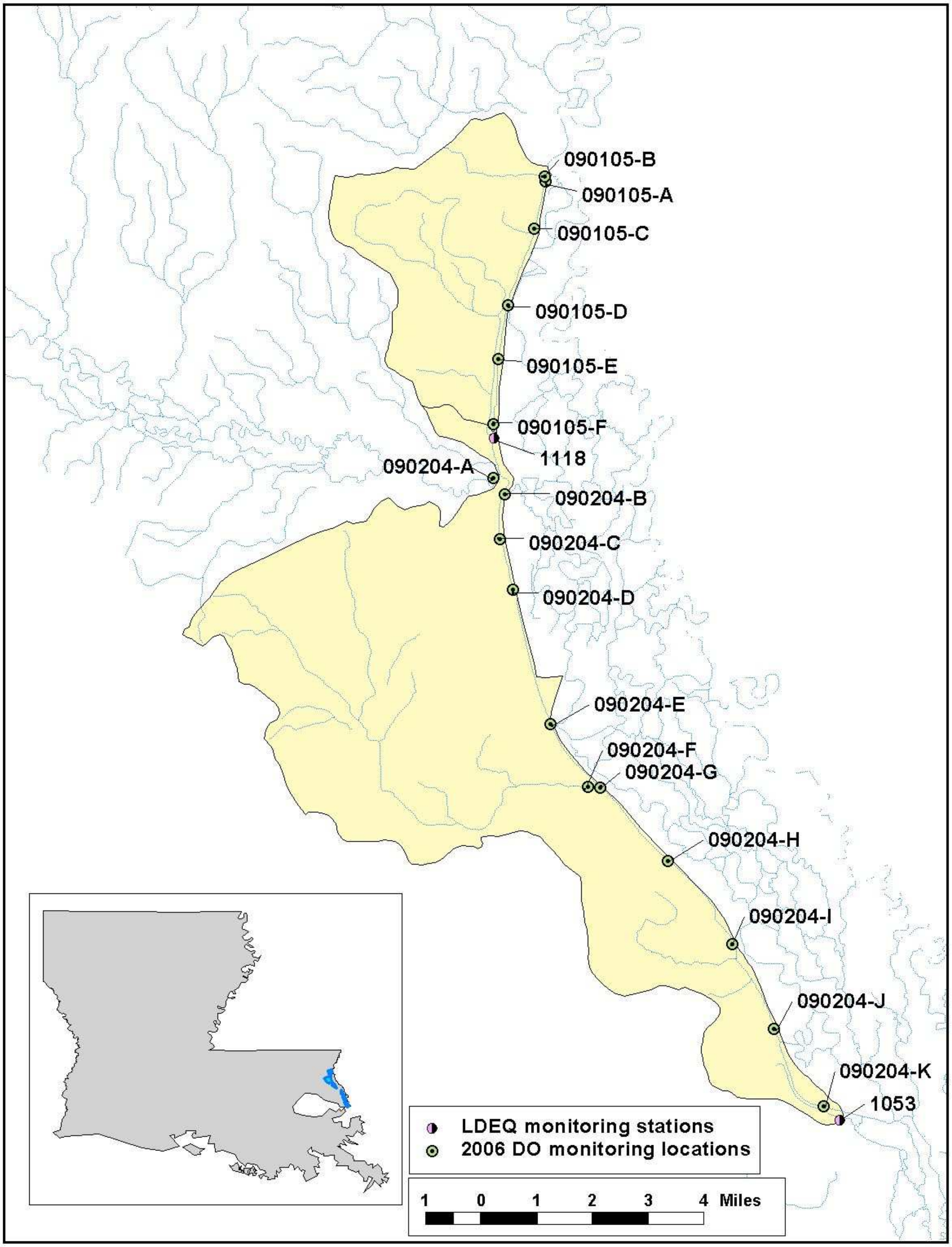

Figure 3-1. Locations of monitoring stations in the northern Pearl River Basin.

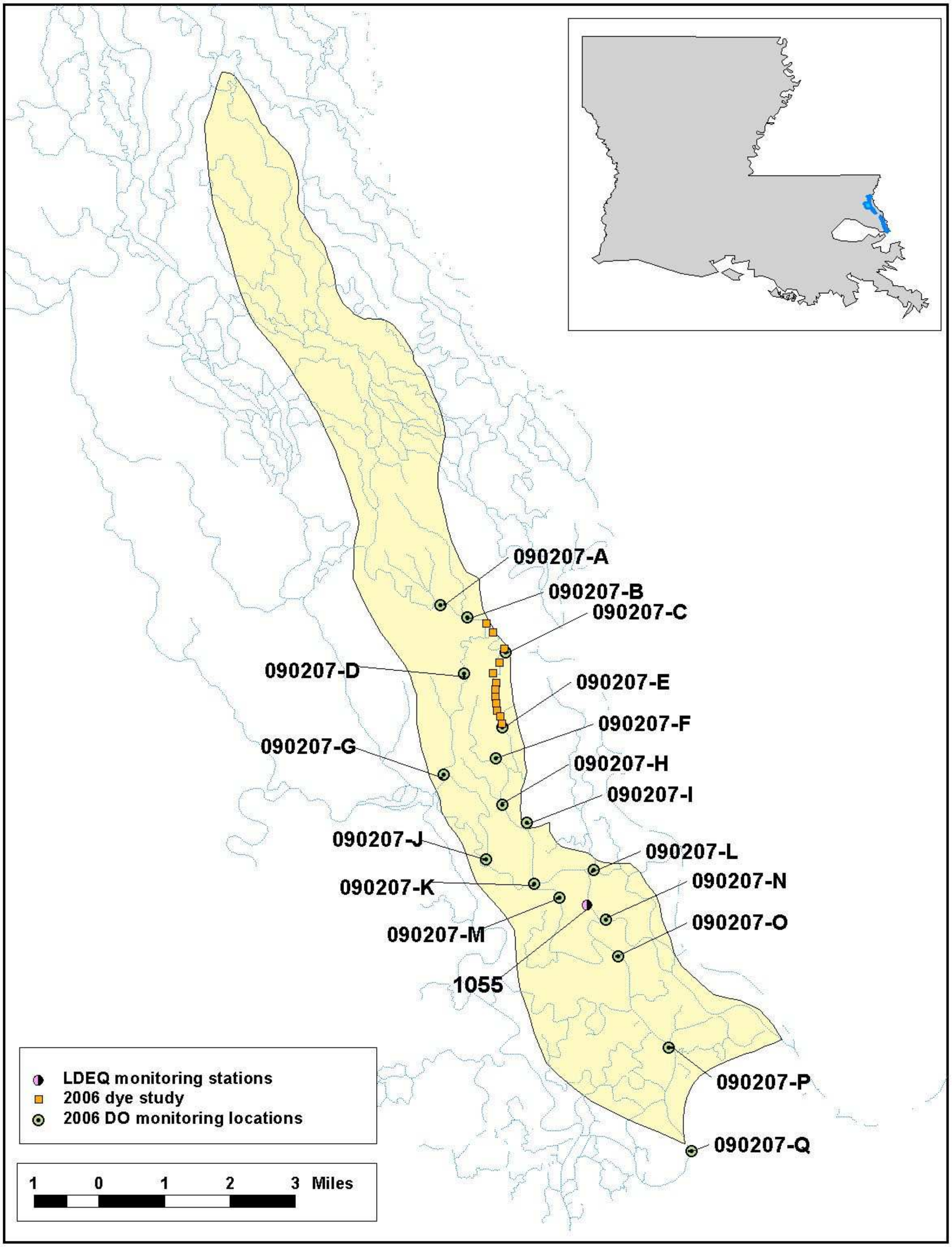

Figure 3-2. Locations of monitoring stations in the southern Pearl River Basin.

- Continuous water level data
- Cross section and flow data from the acoustic Doppler current profiler (ADCP)
- Dye study data (time of travel).

These data were collected during an intensive 4-day field survey in August 2006. There were no large storms or other atypical weather during or immediately prior to the field survey (FTN Associates 2006).

3.1.1 In Situ Data

The in situ measurements of water temperature, dissolved oxygen, specific conductivity, and pH are presented in Appendix A (Table A-1). These data were collected at 16 stations in the PRNC system (subsegments 090105 and 090204) and 16 stations in the Middle River/West Middle River system (subsegment 090207). At the a depth of 3 feet, the only two stations in the PRNC system that had dissolved oxygen values below the water quality standard of 5.0 mg/L were 090105-C (main stem) and 090204-F (stagnant embayment at confluence with Talisheek Creek). For the Middle River/West Middle River system, all the dissolved oxygen values at 3 feet were below the water quality standard of 5.0 mg/L except at station 090207-Q (at the entrance to Little Lake).

3.1.2 Continuous In Situ Monitoring

Continuous in situ data were collected at two stations in the PRNC system and two stations in the Middle River/West Middle River system. Each continuous monitor recorded measurements of pH, temperature, specific conductivity, and dissolved oxygen at 30-minute intervals. Data for the northern part of the PRNC (station 090105-D) show there was minimal diurnal variation in temperature, specific conductivity, and pH (Figures A-1 through A-4 in Appendix A). The dissolved oxygen varied from 3.8 mg/L to 6.3 mg/L (Figure 3-3). Data for the southern part of the PRNC (station 090204-E) show there was minimal diurnal variation in temperature, specific conductivity, and pH (Figures A-5 through A-8 in Appendix A). The dissolved oxygen varied from 5.6 mg/L to 7.0 mg/L (Figure 3-4).

Data for the Middle River at Interstate 10 (station 090207-B) show the following results (Figures A-9 through A-12 in Appendix A). The temperature varied from 29.5 °C to 32.0 °C. The conductivity showed minimal diurnal fluctuation even though the tides have a significant impact on diurnal fluctuations of water levels at this station. The dissolved oxygen varied from less than 3 mg/L to afternoon peaks of 4.5 mg/L to 4.9 mg/L (Figure 3-5). All the continuous dissolved oxygen values at this station were below the water quality standard of 5.0 mg/L. The pH and dissolved oxygen data at this station indicate relatively low algal productivity.

Data for the West Middle River at Highway 90 (station 090207-M) show the following results (Figures A-13 through A-16 in Appendix A). The conductivity varied from 6,000 µmhos in the afternoon to 700 µmhos the next morning. The timing of the fluctuations was unexpected. Normally, the higher conductivity values would be expected to occur near the time of the maximum water level (i.e., near the end of the incoming tide) and the lower conductivity values would be expected to occur near the time of the minimum water level (i.e., near the end of the outgoing tide). The data at station 090207-M, though, did not follow the expected pattern. The

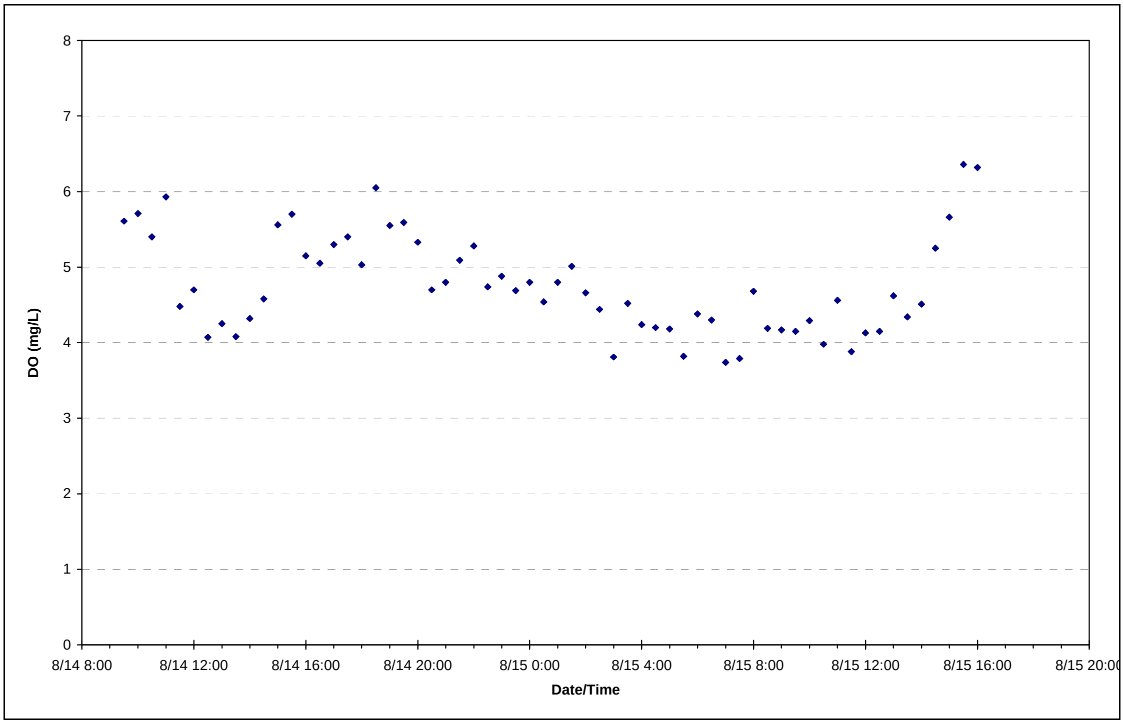

Figure 3-3 Continuous dissolved oxygen for PRNC at station 090105-D.

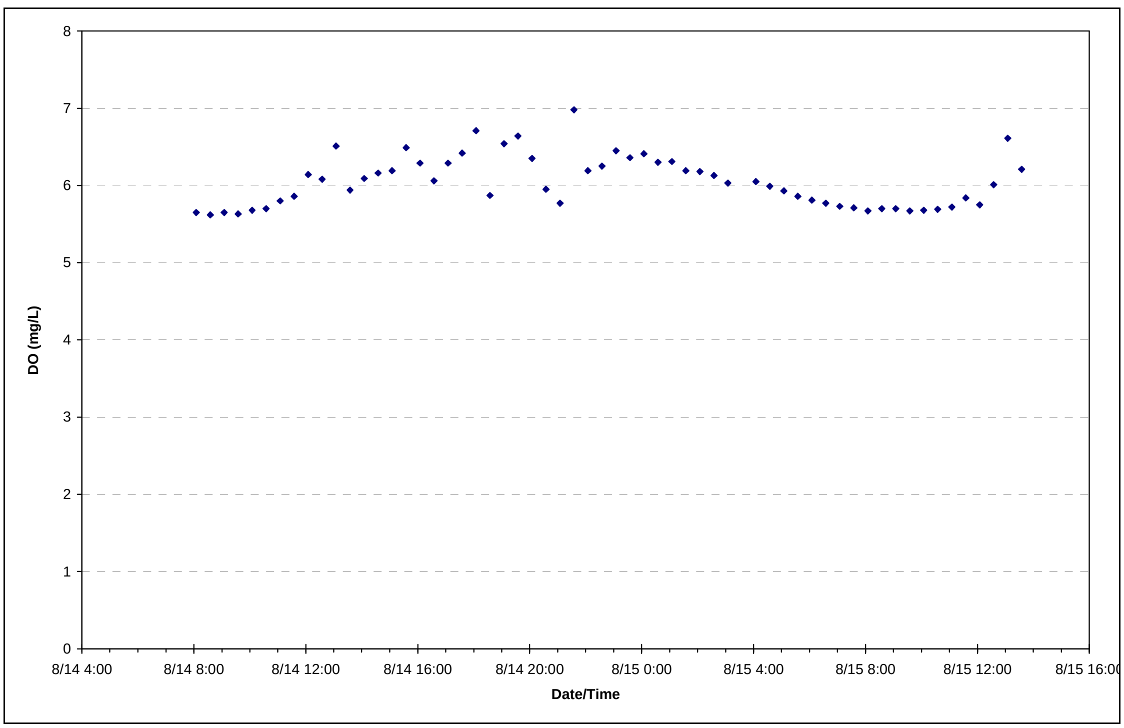

Figure 3-4 Continuous dissolved oxygen for PRNC at station 090204-E.

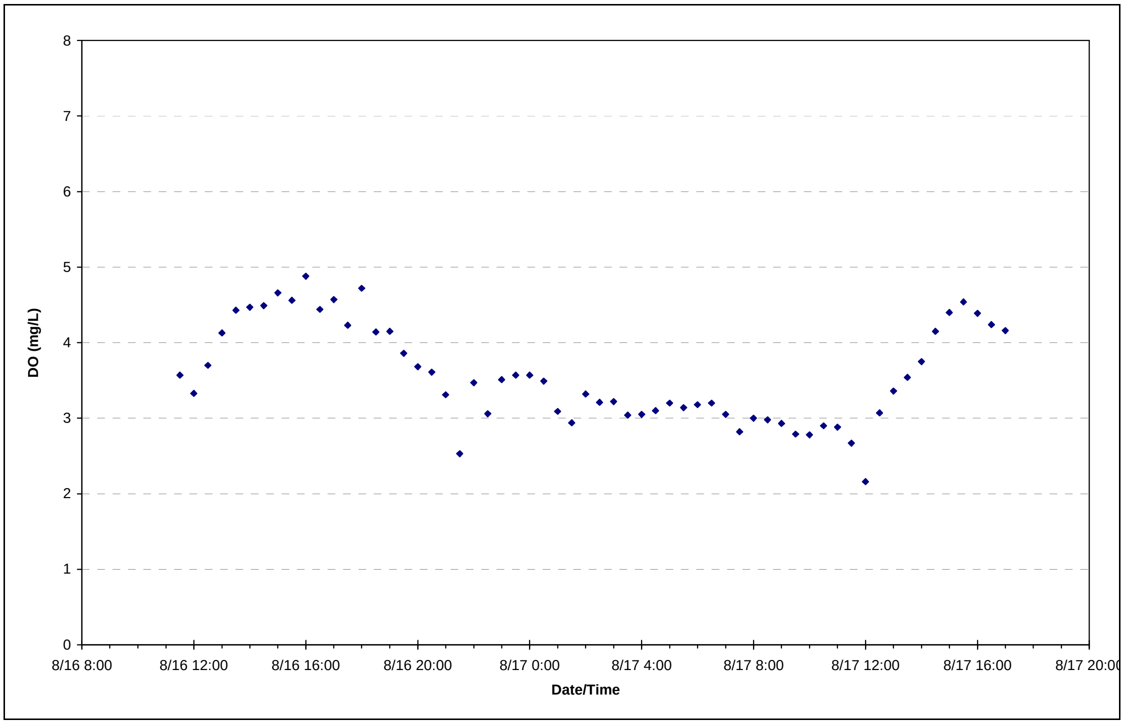

Figure 3-5 Continuous dissolved oxygen for Middle River at station 090207-B.

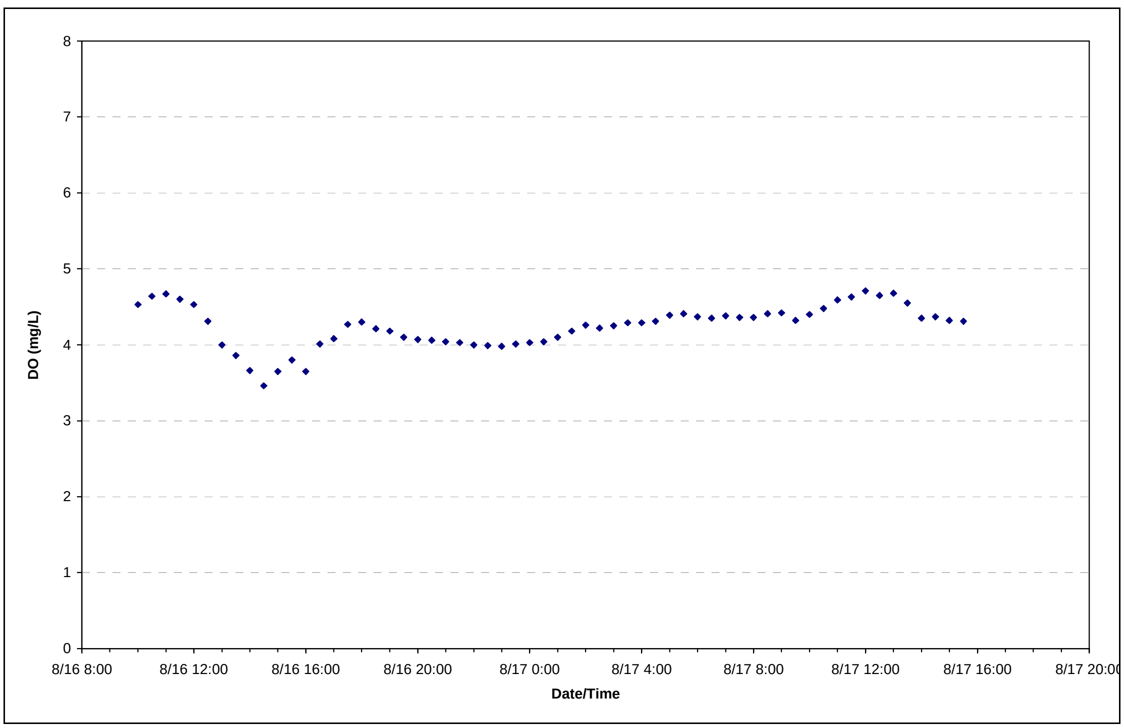

Figure 3-6 Continuous dissolved oxygen for West Middle River at station 090207-M.

highest conductivity value occurred near the middle of the outgoing tide and the lowest conductivity value occurred just after the end of the incoming tide. One possible explanation for this would be fluctuations in the vertical distribution of conductivity at station 090207-M. The in situ data in Appendix A (Table A-1) show that the conductivity values at station 090207-M were 2,130 μmhos at a depth of 3 feet and 20,130 μmhos at depth of 20 feet. The peak conductivity measured by the continuous recorder might have been due to a mixing phenomenon, which could have been caused by wind or boat traffic. The pH and dissolved oxygen data for station 090207-M show minimal diurnal fluctuations. All the continuous dissolved oxygen values at this station were below the water quality standard of 5.0 mg/L (Figure 3-6). The pH and dissolved oxygen data at station 090207-M indicate low algal productivity.

3.1.3 Sample Data

Data from laboratory analyses of water samples are presented in Appendix A (Table A-2). Samples were collected at nine stations in the PRNC system and nine stations in the Middle River/West Middle River system. Three samples were collected as quality assurance/quality control (QA/QC) duplicates.

In general, the measured concentrations were reasonable and within expected ranges of values for waterbodies in southern Louisiana. The CBOD values, however, were lower than expected. At the end of the 25-day CBOD time series analysis, all the CBOD values were less than 5 mg/L and seven of them were below the detection level of 2 mg/L. Although the 25-day CBOD values are expected to be somewhat lower than ultimate CBOD values, this comparison suggests that further investigation is needed to determine appropriate CBOD values for model calibration.

3.1.4 Continuous Water Levels

Water levels were recorded at 15-minute intervals at three stations in the Middle River/West Middle River system. The data show a diurnal water level fluctuation of about 2 feet at all three stations. The diurnal fluctuation at the northernmost station (090207-B) was expected to be significantly smaller and slightly delayed compared to the diurnal fluctuations at the two southern stations (090207-M and 090207-Q); however, all three showed nearly the same magnitude and timing of fluctuations.

3.1.5 Flow Measurements

Acoustic Doppler Data

An acoustic Doppler current profiler (ADCP) instrument was used to measure cross-sectional widths, depths, and flows at 14 stations in the PRNC system and 15 stations in the Middle River/ West Middle River system.

In subsegment 090105 (the portion of the PRNC north of Lock 3), only about 4–5 cfs of water was flowing, based on the flow measurements at 090105-B and 090105-F. The measured inflow from the Bogue Chitto River (station 090204-A; south of Lock 3) was 625 cfs, which was similar to the provisional mean daily flow of 641 cfs that had been reported for the USGS flow gauge on the Bogue Chitto River a few miles upstream of station 090204-A. Most of the inflow from the Bogue Chitto River flows out of the PRNC near station 090204-B, where the Bogue Chitto River continues flowing eastward. There was no accessible location for measuring the amount of water flowing eastward out of the PRNC into Bogue Chitto River because of a weir along the eastern edge of the PRNC where the Bogue Chitto River flows eastward.

South of the Bogue Chitto River confluence, about 60 to 70 cfs was flowing south in the PRNC, on the basis of the flow measurements at stations 090204-D, 090204-G, and 090204-K. The water level was at least 10 feet higher on the upstream side of Lock 1 than on the downstream side, and water was leaking through the gates at Lock 1. There is a spillway along the eastern side of the PRNC about 0.5 mile downstream (south) of station 090204-J. A small amount of flow was leaving the PRNC at that location, but the flow could not be measured.

In the Middle River/West Middle River system, the diurnal flow reversals did not allow a flow balance to be established using only the ADCP flows. One of the purposes of the ADCP flow measurements for this system was to estimate how flow splits at the confluence of the West Middle River and Middle River just south of Interstate 10. Flow measurements at stations 090207-C and 090207-D show that 60 percent of the flow moving south at this confluence flows to the West Middle River (715 cfs) and 40 percent flows to the Middle River (527 cfs). The measured inflows to the Middle River at stations 090207-F and 090207-I (606 cfs and 750 cfs) show that significant amounts of flow are exchanged between the main stem and numerous side channels. The flows measured at stations 090207-N and 090207-O were unexpected because the water at station 090207-N was flowing inland and the water at station 090207-O was flowing toward the Gulf of Mexico, even though the measurements at both stations were taken within a period of about 50 minutes. The difference in direction might be partly due to the fact that measurements at both stations were taken near the time at which high tide occurred.

Dye Study

A dye study was conducted to measure tidally averaged velocity in the Middle River/West Middle River system. The measured velocity was needed to estimate tidally averaged flow.

A slug of dye was injected in the Middle River between the Interstate 10 bridge and the Middle River/West Middle River split. The dye was injected at 4:50 p.m. on August 16, 2006. Based on tide predictions obtained before the field study, the dye was expected to move north during the evening and overnight and then return southward to the vicinity of the injection location during the next day. Dye concentrations in the river were measured after an elapsed time of approximately 25 hours, and the center of the mass of the dye slug was 3,288 meters downstream of the injection point. This resulted in an average velocity of 0.12 ft/s over a full tidal cycle.

The average velocity was used to estimate a tidally averaged flow for the Middle River/West Middle River system. The average of the cross-sectional areas at stations 090207-C and 090207-E (958 ft^2) was multiplied by the average velocity (0.12 ft/s) to obtain a tidally averaged flow rate of 115 cfs in the Middle River. The tidally averaged flow in the West Middle River was then estimated by assuming that the ratio of tidally averaged flows for the Middle River and West Middle River is the same as the ratio of the ADCP flows at stations 090207-C and 090207-D (527 cfs and 715 cfs, respectively). This calculation yielded a tidally averaged flow rate of 155 cfs for the West Middle River, which resulted in a tidally averaged flow rate of 270 cfs for both the Middle River and West Middle River combined.

A dye study was not conducted in the PRNC system because there are no diurnal fluctuations in flows due to tides. The acoustic Doppler flow measurements are sufficient for developing a flow balance in the PRNC system.

3.1.6 Additional Data

Data searches of additional databases were conducted. The USGS water quality database had data for some stations in the TMDL areas, but the data were older than 1996 or were not for the parameters of interest. A search of STORET returned only data supplied by LDEQ. Therefore, only data obtained from LDEQ were used in developing these TMDLs.

3.2 Comparison of Observed Data to Criteria

Water quality monitoring data for each listed subsegment were obtained from LDEQ (Table 3-1). Table 3-7 provides a summary of the LDEQ dissolved oxygen data compared to criteria. All three stations had dissolved oxygen observations below the water quality criterion of 5 mg/L.

Table 3-7. Summary of dissolved oxygen data for the Pearl River Basin

Sub-segment	Station	Period of record	No. of obs.	Minimum (mg/L)	Maximum (mg/L)	Average (mg/L)	No. of obs. < 5.0 mg/L	Percent samples < 5 mg/L
090105	1118	1/16/2001–6/21/2006	18	3.02	9.17	6.00	6	33
6090204	1053	1/2/2001–6/27/2006	18	2.58	10.01	6.63	4	22
090207	1055	1/2/2001–5/22/2006	17	3.95	10.73	6.79	2	12

4 WATER QUALITY MODEL SETUP AND CALIBRATION

4.1 Model Setup

LA-QUAL (Version 8.00) was chosen to simulate dissolved oxygen in the TMDL subsegments. LA-QUAL is a steady-state model that was developed by LDEQ based on the QUAL-TX (Version 3.4) model. Several modifications were made to the QUAL-TX model, including the addition of new aeration equations that better represent conditions in Louisiana.

LA-QUAL evaluates the relationships between pollutant sources and water quality. Model configuration involved setting up the model segments, setting initial conditions, boundary conditions, and hydraulic and kinetic parameters. This section describes key components of the model by their associated data type, which are groupings of model parameters.

A separate model and segmentation were used for each subsegment. Only the main stem of the systems was explicitly simulated and thus segmented for modeling purposes. Segmentation refers to separating a waterbody into smaller computational units. Segmentation occurred around major hydrological features, such as tributaries. Tributaries were represented through boundary condition designation. Appendix C contains diagrams of the model segmentations and stream kilometers.

4.2 Calibration Period

The calibration period was selected to coincide with the intensive field monitoring that had occurred in August 2006. The data used for calibration are the averages of the samples taken during the measurement period from August 14 through August 16, 2006. These dates were selected for calibration because they were the only dates for which data were available. This period is considered the critical period because high temperatures decrease dissolved oxygen saturation values and increase rates for oxygen-demanding processes, such as BOD decay, nitrification, and SOD. In addition, lower flow rates do not cause strong reaeration, so the exchange of oxygen between air and water is low.

4.3 Model Options (Data Type 2)

Data type 2 is used to identify the constituents being modeled to achieve calibration—for this TMDL, dissolved oxygen, BOD, and a nitrogen series (ammonia, and nitrate+nitrite).

4.4 Program Constants (Data Type 3)

LA-QUAL is programmed with certain default program constants. Data type 3 is used to override the default constants and is optional; that is, values need to be entered only if values other than the default values are desired. Table 4-1 lists the constants that were changed from their default values. Default values were used for all other program constants. Refer to the LA-QUAL user manual for descriptions of the constants and their default values (Wiland Consulting 2005).

4.5 Temperature Correction of Kinetics (Data Type 4)

Data type 4 contains factors that are used for temperature correction in rate equations. The temperature correction factors used in the model were consistent with the *Standard Operating*

Table 4-1. Program constants used for modeling TMDL subsegments

Program constant	090105	090204	090207	Default
Maximum iteration limit	5,000	5,000	5,000	100
Hydraulic calculation method	2	2	2	1
Non-conservative material (NCM) oxygen uptake rate	1.0	1.0	1.0	0.0
Inhibition control value	3.0	3.0	3.0	4
K_2 (reparation rate) maximum	25.0	25.0	25.0	10.0
Dispersion equation	--	--	2	1
Tide height	--	--	0.6	0.0

Procedure for Louisiana TMDL Technical Procedures (LTP) when these factors were available (LDEQ 2005). The correction factors were:

- Correction for BOD decay: 1.047 (LTP and model default)
- Correction for SOD: 1.065 (LTP and model default)
- Correction for ammonia N decay: 1.083 (model default)
- Correction for organic N decay: 1.020 (model default)
- Correction for reaeration: 1.024 (LTP and model default)

4.6 Hydraulics and Dispersion (Data Types 9 and 10)

These data types describe the hydraulic and dispersion characteristics of the model reaches. Typically dispersion is used only in tidal environments, such as subsegment 090207.

The stream hydraulics were specified in the input file for the model using the following power functions:

$$width = a \times Q^b + c$$
$$depth = d \times Q^e + f$$

where:

a = width coefficient = 0.0
b = width exponent = 0.0
c = width constant = average width of segment
d = depth coefficient = 0.0
e = depth exponent = 0.0
f = depth constant = average depth of segment

The hydraulic data type also contains information on slope and Manning's "n." For these models, the slope was set to 0.0001 and Manning's "n" was set to 0.025 for all segments. The average width and depth for each segment were derived from observed measurements in August 2006; they are shown in Table 4-2.

The dispersion data type was used only for subsegment 090207, where tidal fluctuations occur. For all segments the tidal range was 1.0. Tidal dispersion is calculated from the following:

$$E = aD^b \times Q^c V_T^{\,d}$$

where:

a = dispersion coefficient = 1.0
b = dispersion exponent = 0.0
c = dispersion exponent = 0.0

d = dispersion exponent = 0.0
D = depth
Q = flow
V_T = tidal velocity

Table 4-2. Average channel widths and depths for each model segment

Model reach	090105		090204		090207	
	Width (m)	Depth (m)	Width (m)	Depth (m)	Width (m)	Depth (m)
1	44.70	0.99	55.1	2.21	52.60	1.71
2	44.70	0.99	55.1	2.21	45.20	4.92
3	44.70	0.99	55.1	2.21	63.00	2.48
4	44.70	0.99	59.3	2.11	103.50	4.05
5	43.75	1.18	62.9	1.91	116.50	5.47
6	62.75	2.07	62.9	1.91	116.50	5.47
7	82.70	2.77	69.5	3.75	116.50	5.47
8	67.70	2.29	49.6	1.64	224.75	6.65
9	58.90	2.08	98.1	2.25	224.75	6.65
10	65.10	2.34	98.1	2.25	260.20	4.33
11	--	--	98.1	2.25	236.94	5.70
12	--	--	58.9	1.81	236.94	5.70
13	--	--	85.7	2.26	236.94	5.70
14	--	--	--	--	110.00	5.70
15	--	--	--	--	110.00	5.70
16	--	--	--	--	110.00	5.70

4.7 Initial Conditions (Data Type 11)

Initial conditions were set for temperature, dissolved oxygen, ammonia, nitrate+nitrite nitrogen, total phosphorus, and chlorophyll a using observed water quality data observed data for all three subsegments. For subsegments 090105 and 090207, the remaining parameters were set to constants; for subsegment 090204, these parameters varied with the model reach on the basis of observed data. Because LAQUAL is a steady-state model, the initial conditions affect only the number of iterations to reach steady-state conditions. Setting initial conditions on the basis of observed data reduces the amount of iterations the model must perform to reach steady-state.

Salinity, phosphorus, phytoplankton, and macrophytes were the parameters not simulated in the model. Their initial conditions were set to zero so that the model would not assume a fixed concentration and include their effects.

4.8 Water Quality Kinetics (Data Types 12 and 13)

Several kinetic rates were used in the model, including reaeration, SOD, CBOD decay, nitrification, and mineralization (organic nitrogen decay) rates. Data types 12 and 13 focus on different rates used by the model. Data type 12 is needed only if BOD or dissolved oxygen is being simulated, and data type 13 is needed only if nitrogen or phosphorus is being simulated. For this TMDL, both data types were included.

The model calculates the reaeration rate by using one of a standard set of equations. For this TMDL, the O'Conner-Dobbins equation was used. This equation is applicable to moderately deep to deep channels (1 ft to 30 ft with flow between 0.5 ft/s and 12.2 ft/d). The equation is

$$K_2 = \frac{3.932 \times V^{0.969}}{D^{1.5}}$$

where:

V = stream velocity (meters per second)
D = stream depth (meters)

The input files that list these values are provided in Appendix D. Table 4-3 summarizes these rates. The CBOD decay rate varied per subsegment and was computed from the measured $CBOD_3$, $CBOD_5$, $CBOD_{12}$, $CBOD_{20}$, and $CBOD_{25}$ data. The SOD was calibrated in the model and varied per subsegment reach. SOD was calibrated after the CBOD levels were finalized. The SOD rates changed iteratively until modeled dissolved oxygen concentrations agreed well with measured water column dissolved oxygen concentrations.

Table 4-3. Water quality kinetics rates

Program constant	090105	090204	090207
Background SOD (g/m^2/d)	0.15–1.0	0–3.2	0.1–4.0
BOD #1 decay rate (aerobic) (1/d)	0.065–0.072	0.06	0.04
BOD #1 settling rate (m/d)	0.01	0.01	0.01
Settled BOD #1 conversion to SOD	1.0	1.0	1.0
Anaerobic BOD #1 decay rate (1/d)	0.001	0.001	0.001
Ammonia nitrogen oxidation rate (1/d)	0.1	0.1	0.1

4.9 Incremental Data (Data Types 16, 17, and 18)

These data types include information on inflows and outflows from the model reaches. For this TMDL incremental information was included for flow, temperature, dissolved oxygen, BOD, organic nitrogen, ammonia, and nitrate/nitrite. Appendix D contains the input files with these values. Incremental flow was determined from flow measurements obtained during the August 2006 monitoring. As stated in Section 2.3, most tributary flows are negligible.

4.10 Nonpoint Source Loads (Data Type 19)

This data type accounts for nonpoint source loads not associated with incremental and tributary flows. Because of the lack of available information, this data type was kept blank. SOD, from data type 12, is influenced by nonpoint source loads from sediment entering the waterbody system.

4.11 Headwater Flow, Water Quality, and Junction Data (Data Types 20, 21, 22, and 23)

These data types account for flow and water quality from upstream of the modeled subsegment. For each modeled subsegment, only one headwater was represented in the model; therefore, data type 23 (Junction Data) was left blank.

Headwater flow data were derived from ADCP flow measurements. In general, the flow measured at the most upstream station was taken as the headwater flow. Water quality data (mainly CBOD and dissolved oxygen) were estimated from the monitoring data at the most upstream stations.

4.12 Wasteload Flow and Water Quality Data (Data Types 24, 25, and 26)

These data types account for flow and water quality from point sources discharging into the listed waterbodies. Only subsegment 090204 contained point sources. Subsegment 090207 did not contain any permitted facilities discharging to the modeled segments. Subsegment 090105 contained discharge from the Double D Meat Company (LA0106143); however, the flow was discharged to an unnamed ditch that flowed approximately 1.3 miles to the PRNC. It was assumed that the oxygen demand of this discharge would significantly change during the course of its flow to the PRNC, and therefore it was not included in the model.

Subsegment 090204 contains two modeled point sources: 6th Ward Junior High School (LAG541203) and the Hebron Baptist Church (LAG531949). The flow for these point sources was taken from their permitted flow. The BOD_5 concentration in the effluent was estimated using the Discharge Monitoring Report data for station LAG541203. The estimated BOD_5 was also assigned to LAG531949. Permitted BOD_5 discharge limits were converted to ultimate CBOD using a conversion factor of 2.3. For ammonia, the available data for all the point sources were averaged and the average ammonia was assigned to these two point sources.

4.13 Lower Boundary Condition (Data Type 27)

Data type 27 is required only if the model contains high dispersion in the most downstream reach. All of subsegment 090207 is tidally influenced, and the dispersion is weak based on the longitudinal profile of dissolved oxygen and CBOD data. The impacts of lower boundary conditions are not significant. The final values of boundary dissolved oxygen and CBOD were taken as similar to the average of the measured dissolved oxygen and CBOD inside subsegment 090207.

4.14 Calibration and Model Results

Model calibration entailed calibrating using ammonia, CBOD, and SOD concentrations. The ammonia loads were first adjusted so predicted ammonia concentrations would match observed concentrations. Ammonia was calibrated first because impact from ammonia on dissolved oxygen is minimal. In addition, dissolved oxygen is not low enough to impact ammonia nitrification. After ammonia was calibrated the CBOD loads were adjusted until the predicted CBOD concentrations were similar to the observed concentrations. Finally, SOD was adjusted until the predicted dissolved oxygen concentrations were similar to the observed concentrations.

Plots of observed and calibration water quality are presented in Appendix E. Table 4-4 lists the oxygen demand loadings for existing conditions. Overall, the model did well in predicting the observed values for temperature, ammonia, BOD, and dissolved oxygen, and the model was considered adequately calibrated based on the data available.

Table 4-4. Existing oxygen demand

Subsegment	Oxygen demand (lb/d)				
	SOD	$CBOD_u$	Ammonia	Nitrate	Total
090105	597.67	2,551.19	145.27	725.50	4,019.63
090204	4,316.87	3,960.56	1,200.56	190.92	9,668.91
090207	24,908.93	32,908.63	273.97	5,011.66	63,103.19

5 WATER QUALITY MODEL PROJECTION

EPA'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. The calibrated model was used to project water quality for critical conditions. Two scenarios were run for the critical conditions: baseline and TMDL. The model was run for baseline conditions, which used the same water quality and model parameters as the calibration model; however the flow and temperature were changed to critical conditions and effluent water quality from permitted dischargers were changed to permit limits. The TMDL model run was the same as the baseline run, however, pollutant loadings were reduced so that dissolved oxygen met criteria at all locations. The identification of critical conditions and the model input data used for critical conditions are discussed in this section. Appendix F contains the baseline output files and Appendix G contains the TMDL output files. The output files include the input parameters.

5.1 Identification of Critical Conditions

The LDEQ LTP defines critical conditions in terms of flow and temperature. Critical flow conditions are simulated by using the annual 7Q10 flow or 0.1 cubic feet per second (cfs), whichever is greater. Since subsegment 090207 is tidally influenced, one-third the average or typical flow averaged over one tidal cycle was used as the critical flow as per the LTP.
In addition, all point sources are assumed to be discharging at design capacity and at their permit limits. The LTP specifies that the critical temperature should be determined by calculating the 90th percentile seasonal temperature for the waterbody being modeled, if data are available. Otherwise 30 degrees Celsius (ºC) was used.

Ambient water quality data from LDEQ show that low dissolved oxygen concentrations occur during the summer months. (See Appendix A for data plots.)

5.2 Temperature Inputs

The critical temperatures for the headwaters were based on the 90th percentile temperature of LDEQ ambient monitoring in the representative subsegment. A critical temperature of 30 °C was used for incremental and wasteload inputs. Because these subsegments have a year-round standard for dissolved oxygen, a winter projection simulation was not performed. The most critical time of year for meeting a constant dissolved oxygen standard is the period of high temperatures and low flows.

5.3 Headwater and Tributary Inputs

The inputs for the headwater and tributaries for the projection simulation were based on guidance in the LTP. According to the LTP, the critical flow rates for summer should be set to either the 7Q10 flow or 0.1 cfs, whichever is higher. Because 7Q10 values for the waterbodies are not available, the headwater and tributary flows used in calibrating the model were set to 0.1 cfs. It was assumed that during critical times, there might not be headwater flow for 7 days, making the 7Q10 equal to 0 cfs, so 0.1 cfs would be used. Dissolved oxygen from headwater and tributaries were set to the water quality criteria 5 mg/L. CBOD from headwater and tributaries were reduced until modeled dissolved oxygen met the criteria. The ammonia levels were low from both the headwaters and tributaries. Therefore, the ammonia inputs were not changed from calibration.

5.4 Point Source Inputs

Input point sources were kept at the same flow as the calibration inputs. Ammonia levels were changed from observed or assumed concentrations to proposed concentrations. The ammonia concentrations were assumed to be one-third the amount of the oxygen demand. These assumptions are consistent with information presented in the LTP. If necessary, input concentrations were reduced to keep the dissolved oxygen concentration above 5 mg/L. The flows from the point sources were very low compared to the flows in the segments and did not impact the dissolved oxygen significantly.

5.5 Downstream Values

Modeling parameters for downstream boundary conditions were the same as the calibration parameters except for temperature and dissolved oxygen. The temperature was set to the critical condition. The dissolved oxygen value was set to the water quality standard of 5.0 mg/L.

5.6 Baseline Model Results

Baseline line conditions were ran under critical temperature and water flow conditions for calibrated parameters and water quality values. Plots of baseline water quality are presented in Appendix H. Table 5-1 presents the baseline oxygen demand for each subsegment.

Table 5-1. Baseline oxygen demand

Subsegment	Oxygen demand (lb/d)				
	SOD	$CBOD_u$	Ammonia	Nitrate	Total
090105	597.67	2,474.03	137.50	685.40	3,894.61
090204	5,262.44	3,924.80	1,097.64	168.01	10,452.89
090207	24,908.93	31,470.77	91.64	4,829.33	61,300.68

5.7 Model Results for Projection

Several steps were used to develop the reduction percentages for oxygen demand. The TMDL was calculated by first iteratively reducing SOD. After meeting the dissolved oxygen criteria by reducing SOD, the CBOD reduction rate was calculated by the SOD/CBOD relationship ($SOD=a\times\sqrt{CBOD}$). Slight adjustments were made to the SOD reduction rate and an updated CBOD reduction rate was calculated. This process was repeated until the optimal reduction rates were determined.

To meet the dissolved oxygen standard of 5.0 mg/L, oxygen demand needs to be reduced between 20 and 66 percent. This percentage reduction for nonpoint source loads represents a percentage of the entire nonpoint source loading, not a percentage of the manmade nonpoint source loading from baseline conditions. The nonpoint source loads in this report were not divided between natural and man-made because it would be difficult to estimate natural nonpoint source loads. Plots of TMDL water quality are presented in Appendix I.

6 TMDL DEVELOPMENT

A TMDL is the total amount of a pollutant that can be assimilated by the receiving waterbody while still achieving water quality standards. In TMDL development, allowable loadings from all pollutant sources that cumulatively amount to no more than the TMDL must be established, thereby providing the basis for establishing water quality-based controls.

A TMDL for a given pollutant and waterbody is composed of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL must include an implicit or explicit margin of safety (MOS) to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody and may include a future growth (FG) component. The TMDL components are illustrated using the following equation:

$$TMDL = \Sigma WLAs + \Sigma LAs + MOS + FG$$

6.1 TMDL Analytical Approach

A TMDL for dissolved oxygen has been calculated for the Pearl River Basin subsegments based on the results of the projection simulation. The dissolved oxygen TMDL is presented as oxygen demand from $CBOD_u$, ammonia, nitrate, and SOD. A summary of the loads is presented in Table 6-1. The TMDL calculations are included in Appendix J.

6.2 TMDLs

Table 6-1 presents the TMDLs and allocations for the subsegments in this report. Appendix J contains the TMDL calculations. Table 6-2 presents a summary of the percent reductions for LAs.. The reduction percentages for total oxygen demand ranged from 20 to 66 percent. Reductions from point source discharges are not required as a result of this TMDL.

The WLA portion of the TMDL equation is the total loading of a pollutant that is assigned to point sources (Table 6-3). WLAs include loads from all permitted facilities in the subsegment, including those not included in the model. No municipal separate storm sewer systems (MS4s) were identified. The WLAs are based on the available flow levels and limits. When permit limits were not available, BOD_5 limits were obtained from the Louisiana general permit for facilities with similar discharge volumes and ammonia concentrations were determined using the method outlined in the LTP. Facilities were assumed to have secondary treatment in mechanical plants.

The LA is the portion of the TMDL assigned to nonpoint sources such as natural background loadings. For this TMDL, the LA was calculated by subtracting the WLA, MOS, and FG from the total TMDL allocation. LAs were not allocated to separate nonpoint sources because of the lack of available source characterization data.

Both section 303(d) of the Clean Water Act and the regulations at 40 CFR 130.7 require that TMDLs include an MOS to account for uncertainty in available data or in the actual effect that controls will have on the loading reductions and receiving water quality. The MOS may be expressed explicitly as unallocated assimilative capacity or implicitly using conservative assumptions in establishing the TMDL. In addition to the MOS, an FG component may be added to account specifically for future growth in the TMDL area.

Table 6-1. Summary of dissolved oxygen TMDLs, WLAs, LAs, MOSs, and FGs for the Pearl River Basin

Subsegment	Oxygen demand (lb/d)				
090105	**SOD**	**$CBOD_u$**	**Ammonia[a]**	**Nitrate[a]**	**Total**
WLA	0.00	12.88	0.79	0.00	13.67
MOS for WLA	0.00	1.61	0.10	0.00	1.71
FG for WLA	0.00	1.61	0.10	0.00	1.71
LA	392.42	1,425.07	109.21	548.32	2,475.02
MOS for LA	49.05	178.13	13.65	68.54	309.38
FG for LA	49.05	178.13	13.65	68.54	309.38
TMDL	490.53	1,797.44	137.50	685.40	3,110.87
Subsegment	**Oxygen demand (lb/d)**				
090204	**SOD**	**$CBOD_u$**	**Ammonia[a]**	**Nitrate[a]**	**Total**
WLA	0.00	15.63	9.81	0.00	25.44
MOS for WLA	0.00	1.95	1.23	0.00	3.18
FG for WLA	0.00	1.95	1.23	0.00	3.18
LA	2,171.11	1,237.23	868.31	134.41	4,411.06
MOS for LA	271.39	154.65	108.54	16.80	551.38
FG for LA	271.39	154.65	108.54	16.80	551.38
TMDL	2,713.89	1,566.08	1,097.64	168.01	5,545.62
Subsegment	**Oxygen demand (lb/d)**				
090207	**SOD**	**$CBOD_u$**	**Ammonia[a]**	**Nitrate[a]**	**Total**
WLA	0.00	0.00	0.00	0.00	0.00
MOS for WLA	0.00	0.00	0.00	0.00	0.00
FG for WLA	0.00	0.00	0.00	0.00	0.00
LA	6,482.47	6,197.28	73.31	3,863.46	16,616.53
MOS for LA	810.31	774.66	9.16	482.93	2,077.07
FG for LA	810.31	774.66	9.16	482.93	2,077.07
TMDL	8,103.09	7,746.60	91.64	4,829.33	20,770.67

[a] Converted to oxygen demand. (concentration × 4.33 [conversion factor])

Table 6-2. Summary of percent reductions for LAs in the Pearl River Basin

Subsegment	Percent reduction				
	SOD	**$CBOD_u$**	**Ammonia**	**Nitrate**	**Total**
090105	17.93	27.35	0.00	0.00	20.12
090204	48.43	60.10	0.00	0.00	46.95
090207	67.47	75.38	0.00	0.00	66.12

There are two ways to incorporate the MOS (USEPA 1991). One way is to implicitly incorporate it by using conservative model assumptions to develop allocations, including the following:

- *Using slightly higher water temperatures than the suggested water temperature.* If dissolved oxygen meets the criteria with higher water temperature, it will meet the criteria with lower water temperature when other factors remain unchanged.

- *Using dissolved oxygen water quality criteria for model inflows.* Dissolved oxygen from headwaters and tributaries was set to the water quality criterion, which is lower than the 90 percent saturation level of dissolved oxygen at 30 ºC.

Table 6-3. Summary of WLAs for the Pearl River Basin

Sub-segment	Permit #	Outfall	Facility Name	Flow (gpd)	BOD_5 Limit (mg/L)	Ammonia Limit (mg/L)	BOD_5 (lb/d)	Ammonia (lb/d)
090105	LA0106143	001	Double D Meat Co.	5,500	--	4.0	5.60	0.18
090204	LA0055638	002	MacKenzie Co LLC	800	45	15	0.30	0.10
090204	LAG480357	001	St. Tammany Parish Government-Bush Maintenance	2,000	45	15	0.75	0.25
090204	LAG530499		Bellsouth Telecommunications J2840	5,000	45	15	1.88	0.63
090204	LAG530848	001	Highway 21 LLC	5,000	45	15	1.88	0.63
090204	LAG531949	001	Hebron Baptist Church of Bush La - Hebron B	1,800	45	15	0.68	0.23
090204	LAG541203	001	Sixth Ward Junior High School	5,240	30	10	1.31	0.44

The other way is to explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations. For this analysis, the MOS is explicit: 10 percent of each targeted TMDL was reserved as the MOS to account for any uncertainty in the TMDL. Using 10 percent of the TMDL load provides an additional level of protection to the designated uses of the subsegments of concern. The MOSs for the subsegments are listed in Table 6-1.

The MOS is an allocation for scientific uncertainly, while the FG is an allocation for growth. Ten percent of the load was allocated for future growth in the area covered by the TMDL. This growth includes future urban development, including point sources, MS4 areas, agriculture, and other nonpoint sources. The FG could also be used for sources not accounted for or unknown and therefore not otherwise included in the TMDL. The FGs for the subsegments are listed in Table 6-1.

6.3 Seasonal Variation

Critical conditions for dissolved oxygen have been determined to be the following: negligible nonpoint runoff and low stream flow combined with high water temperatures. Oxygen-demanding substances can enter a water system during higher flows and settle to the bottom, where they exert a large oxygen demand during the high-temperature/low-flow seasons. Water temperature is one of the leading factors that affect dissolved oxygen in the three segments. High water temperatures lower the dissolved oxygen saturation concentration, decreasing the amount of dissolved oxygen that the stream can contain. In addition, high temperature increases CBOD decay and SOD. Therefore, it is most important to develop a TMDL to address the high-water-temperature conditions. Ambient water quality data from LDEQ show that low dissolved oxygen concentrations occur during the summer months. (See Appendix A for data plots.)

6.4 Sensitivity Analysis

A sensitivity analysis was performed on the model parameters using the sensitivity function built into LA-QUAL. LA-QUAL automatically changed the requested parameters by a set amount while keeping all other parameters constant. The calibration scenario was used as the baseline for the sensitivity analysis. For the sensitivity analysis, all parameters were varied by ±30 percent. The results for dissolved oxygen and $CBOD_u$ are shown in Table 6-4. Result plots are shown in Appendix K. Changes to the stream reaeration, stream velocity, and background SOD had the largest influence on dissolved oxygen levels. Stream dispersion had no effect on dissolved oxygen.

Table 6-4. Results of sensitivity analysis

		090105			090204			090207		
		-30%	base	+30%	-30%	base	+30%	-30%	base	+30%
$CBOD_u$ (mg/L)	BOD aerobic decay rate	3.45	2.98	2.32	0.09	0.06	0.04	1.47	1.44	1.42
	BOD settling rate	3.01	2.98	2.94	0.07	0.06	0.04	1.46	1.44	1.43
	Stream dispersion	2.98	2.98	2.98	0.06	0.06	0.06	1.44	1.44	1.45
	Stream reaeration	2.98	2.98	2.98	0.06	0.06	0.06	1.44	1.44	1.44
	Background SOD	2.98	2.98	2.98	0.06	0.06	0.06	1.44	1.44	1.44
	Steam velocity	2.04	2.98	3.39	0.02	0.06	0.10	1.40	1.44	1.47
DO (mg/L)	BOD aerobic decay rate	3.74	3.58	3.43	3.54	3.47	3.42	2.50	2.41	2.27
	BOD settling rate	3.59	3.58	3.57	3.51	3.47	3.43	2.47	2.41	2.36
	Stream dispersion	3.58	3.58	3.58	3.47	3.47	3.47	2.41	2.41	2.41
	Stream reaeration	3.00	3.58	4.01	2.84	3.47	3.94	1.48	2.41	2.50
	Background SOD	3.66	3.58	3.50	4.56	3.47	2.38	2.50	2.41	1.60
	Stream velocity	3.93	3.58	3.35	2.86	3.47	3.92	2.16	2.41	2.50

6.7 Ammonia Toxicity Analysis

An analysis was performed on the model input and modeled results to determine whether the modeled ammonia concentrations exceeded USEPA criteria for ammonia toxicity (USEPA 1999). The USEPA criteria are dependent on temperature and pH. Temperature was taken from the model output. Because pH is not included in the model, it was obtained from levels observed during the August 2006 monitoring event. The resulting criteria ranged from 0.81 to 2.82 milligrams of nitrogen per liter. The predicted ammonia concentrations ranged from 0.00 to 0.34 milligrams of nitrogen per liter. These concentrations were below the USEPA ammonia toxicity criteria and show that the criteria will not be exceeded during critical conditions. The ammonia toxicity calculations are included in Appendix L.

7 FUTURE ACTIVITIES

7.1 TMDL Implementation Strategies

Reasonable assurance is needed that the water quality criterion will be attained. WLAs will be implemented through Louisiana Pollutant Discharge Elimination System (LPDES) permit procedures. Part of the LAs might be implemented through the LDEQ 305(b) program and set priorities for the section 319 program. BMPs from the implementation plan will be implemented throughout the subsegment. This approach will reduce the loadings and improve dissolved oxygen levels in the subsegment and subsequent downstream subsegments.

Hurricane Katrina made landfall on Monday, August 29, 2005, as a Category 4 hurricane. The storm brought heavy winds and rain to southeast Louisiana. Floodwaters breached several levees, flooding large areas of coastal Louisiana. The hurricane caused a change in sedimentation and water quality in southern Louisiana. Several federal and state agencies, including USEPA and LDEQ, are engaged in collecting environmental data and assessing the recovery of the Gulf of Mexico waters. The proposed TMDLs in this report were developed on the basis of pre- and post-hurricane conditions. Therefore, some post-hurricane conditions and other factors could delay implementation of these proposed TMDLs, render some proposed TMDLs obsolete, or require modifications of the TMDLs. Hurricane effects might be a valid justification for some TMDL modification; however, any deviation from the TMDLs should be justified using site-specific data or information.

7.2 Environmental Monitoring Activities

LDEQ uses funds provided under section 106 of the Clean Water Act and under the authority of the Louisiana Environmental Quality Act to run a program for monitoring the quality of the state’s surface waters. The LDEQ Surveillance Section collects surface water samples at various locations, using appropriate sampling methods and procedures to ensure 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 database for water quality trend analysis, and to monitor the effectiveness of pollution controls. The data obtained through the surface water monitoring program are used to develop the state’s biennial section 305(b) report (*Water Quality Inventory*) and section 303(d) list of impaired waters.

LDEQ has implemented a watershed approach to surface water quality monitoring. Through the approach, the entire state is sampled on 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 monthly to yield approximately 12 samples per site during each year the site is monitored. Sampling sites are located where they are considered representative of the waterbody. Under the current monitoring schedule, approximately one-half of the state’s waters are newly assessed for section 305(b) and section 303(d) listing purposes during each 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. Monitoring will allow LDEQ to determine whether there has been any improvement in water quality following TMDL implementation. As the monitoring results are evaluated at the end of each year, waterbodies might be added to or removed from the section 303(d) list of impaired waterbodies.

8 PUBLIC PARTICIPATION

Federal regulations require USEPA to notify the public and seek comments concerning TMDLs that the Agency prepares. These TMDLs 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 February 1, 2008, and the review period closed on March 3, 2008.

Comments were received from LDEQ and revisions to this TMDL document were made as necessary. Comments are included in Appendix M of this document and include comments on similar TMDLs with the same public review period.

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

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