BAYOU DES ALLEMANDS WATERSHED TMDL FOR BIOCHEMICAL OXYGEN-DEMANDING SUBSTANCES

SUBSEGMENT 020301

SURVEYED SEPTEMBER 9-13, 2002

REVISED TMDL REPORT

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For:
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EXECUTIVE SUMMARY

This report presents the results of calibrated dissolved oxygen (DO) modeling and total maximum daily load (TMDL) calculations for subsegment 020301 (Bayou des Allemands U.S. Highway 90 to Lake Salvador). The modeling was conducted to establish a TMDL for biochemical oxygen-demanding pollutants for the Bayou des Allemands watershed. Bayou des Allemands is located in southern Louisiana in the Barataria basin near New Orleans. The size of subsegment 020501 is approximately 90 square miles. The primary land use is freshwater marsh. No point source discharges were included in the model, but several small point source discharges within the subsegment were included in the TMDL.

Inputs for the calibration model were developed from data collected during the September 2002 intensive survey, data collected by the Louisiana Department of Environmental Quality (LDEQ) at one monitoring station in the watershed, the LDEQ Reference Stream Study, and NPDES permits and permit applications for each of the point source dischargers. A satisfactory calibration was achieved for the model. In those cases where the calibration was not as accurate, the difference was in the conservative direction. For the projection models, data were taken from current discharge permits, current applications, and ambient temperature records. The Louisiana TMDL Technical Procedures manual (dated 09/23/2003) has 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.

Subsegment 020301 was listed as impaired on both the EPA 1999 Court Ordered 303(d) list for Louisiana and the LDEQ Final 2002 303(d) list. The subsegment was found to be not supporting its designated use of fish and wildlife propagation. Bayou des Allemands was subsequently scheduled for TMDL development with other listed waters in the Barataria basin. According to the 1999 Court Ordered 303(d) list, the suspected causes of impairment included organic enrichment / low DO and nutrients; and the suspected sources were industrial point sources,
minor industrial point sources, other, sediment resuspension, and upstream sources. This TMDL addresses the organic enrichment / low DO impairment and the nutrient impairment.

Based on the results of the projection modeling, meeting the water quality standard for DO of 5.0 mg/L will require man-made nonpoint sources to be reduced by 86% for summer and 0% for winter. The no load scenarios (i.e., no reduction in natural background sources) yielded minimum DO values of 5.23 mg/L for summer and 6.28 mg/L for winter.

Nonpoint source load calculations and TMDL calculations were performed using LDEQ's standard TMDL spreadsheet. This spreadsheet calculates wasteload allocations (WLAs) for point sources, load allocations (LAs) for man-made nonpoint sources and natural nonpoint sources, and incorporates an explicit margin of safety (MOS). For this TMDL, the explicit MOS was set to 20% of the sum of the man-made nonpoint sources and the point sources. This MOS accounts for future growth as well as lack of knowledge concerning the relationship between pollutant loads and water quality. The explicit MOS is provided in addition to the implicit MOS, which is created by conservative assumptions in the modeling. A summary of the TMDL is provided in Table ES.1.

Table ES.1. TMDL for Bayou des Allemands (Sum of CBODu, NBODu, and SOD).

	Summer (May-Oct)		**Winter (Nov-Apr)**	
	Reduction	**Load (kg/day)**	**Reduction**	**Load (kg/day)**
Point Source WLA	0%	16	0%	16
Point Source Reserve MOS (20%)		4		4
Natural Nonpoint Source LA	0%	37374	0%	32756
Natural Nonpoint Source MOS (0%)		0		0
Man-made Nonpoint Source LA	86%	2251	0%	12499
Man-made Nonpoint Source MOS (20%)		563		3125
TMDL	--	40208	--	48400

This subsegment was listed as impaired due to nutrients as well as organic enrichment / low DO. This TMDL establishes load limitations for oxygen-demanding substances and goals for reduction of those pollutants. LDEQ's position, as stated in the declaratory ruling issued by Dale Givens regarding water quality criteria for nutrients (Sierra Club v. Givens, 710 So.2d 249 (La. App. 1st Cir. 1997), writ denied, 705 So.2d 1106 (La. 1998), is that when oxygen-demanding substances are controlled and limited in order to ensure that the dissolved oxygen criterion is supported, nutrients are also controlled and limited. The implementation of this TMDL through wastewater discharge permits and implementation of best management practices to control and reduce runoff of soil and oxygen-demanding pollutants from nonpoint sources in the watershed will also control and reduce the nutrient loading from those sources.

LDEQ will work with other agencies such as local Soil Conservation Districts to implement nonpoint source 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 four-year cycle. Long-term trend monitoring sites at various locations on the larger rivers and Lake Pontchartrain are sampled throughout the four-year cycle. Sampling is conducted on a monthly basis to yield approximately 12 samples per site each year the site is monitored. Sampling sites are located where they are considered to be representative of the waterbody. Under the current monitoring schedule, approximately one half of the state's waters are newly assessed for 305(b) and 303(d) listing purposes for each biennial cycle with sampling occurring statewide each year. The four-year cycle follows an initial five-year rotation which covered all basins in the state according to the TMDL priorities. 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.

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ACKNOWLEDGMENTS

This TMDL was developed by FTN Associates, Ltd. with assistance from numerous LDEQ personnel, as well as several other people. The LDEQ project manager was Emelise Cormier and the FTN project manager was Philip Massirer. The guidance and assistance from Ms. Cormier throughout this project was extremely valuable. Other LDEQ personnel that provided valuable guidance at various times were Dick Duerr and Marian Aguillard.

Several field reconnaissance trips were made by LDEQ watershed survey personnel. A reconnaissance survey was performed by Philip Massirer of FTN, Dick Duerr of LDEQ, and several LDEQ watershed survey personnel.

The intensive survey was performed by LDEQ watershed survey personnel and the laboratory analyses of water samples were performed by LDEQ laboratory personnel. Initial compilation of some of the field data was done by LDEQ watershed survey personnel.

Stage data for Bayou des Allemands were provided by Bill Hicks of the New Orleans District Corps of Engineers and by Brady Carter of the Louisiana Department of Natural Resources.

Hydraulic analysis and modeling of Bayou des Allemands was performed by several FTN personnel including Ranjit Jadhav and Surya Ravalaparthy.

The field data analysis, water quality modeling, TMDL calculations, and preparation of the report were performed by several FTN personnel including Christine Richmond, Christina Laurin, Richard Bennett, and Philip Massirer.

ABBREVIATIONS

BMP	best management practice
BOD	biochemical oxygen demand
CBODu	ultimate carbonaceous biochemical oxygen demand
CFR	Code of Federal Register
cfs	cubic feet per second
DO	dissolved oxygen
EPA	Environmental Protection Agency
FTN	FTN Associates, Ltd.
ft/sec	feet per second
$g/m^2/day$	grams per square meter per day
kg/day	kilograms per day
km	kilometer
LA	load allocation
LAC	Louisiana Administrative Code
lbs/day	pounds per day
LC	loading capacity
LDEQ	Louisiana Department of Environmental Quality
LDNR	Louisiana Department of Natural Resources
LTP	Louisiana TMDL Technical Procedures Manual
MGD	million gallons per day
NBODu	ultimate nitrogenous biochemical oxygen demand
NCM	nonconservative material
NPDES	National Pollutant Discharge Elimination System
mg/L	milligrams per liter
TMDL	total maximum daily load
USGS	United States Geological Survey
WLA	wasteload allocation

1. Introduction

This report presents a total maximum daily load (TMDL) for biochemical oxygen demanding substances for subsegment 020301 (Bayou des Allemands from US Hwy 90 to Lake Salvador). This subsegment was listed as impaired on both the 1999 Court Ordered 303(d) List for Louisiana (EPA 1999) and the Louisiana Department of Environmental Quality (LDEQ) Final 2002 303(d) List (LDEQ 2003a). On both of these 303(d) lists, organic enrichment/low dissolved oxygen (DO) and nutrients were cited as suspected causes of impairment. Therefore, development of a TMDL for biochemical oxygen demanding substances was required. A calibrated water quality model was developed and projections were simulated to quantify the load reductions which would be necessary in order for this subsegment to comply with the established water quality standards and criteria. The TMDL in this report was developed in accordance with the LDEQ TMDL Technical Procedures Manual (known as the “LTP”) (LDEQ 2003b) as well as requirements in Section 303(d) of the Federal Clean Water Act and the Environmental Protection Agency’s (EPA) regulations in 40 CFR 130.7.

2. Study Area Description

2.1 General Information

Bayou des Allemands is located in southern Louisiana in the Barataria basin, approximately 30 miles southwest of New Orleans (see Figure A1.1 in Appendix A1). It begins at the outlet of Lac Des Allemands and flows generally southeast for approximately 21 miles through two subsegments before flowing into Lake Salvador. Bayou des Allemands has a total drainage area of 759 mi^2, which includes 547 mi^2 of drainage area at the outlet of Lac des Allemands (USGS 1971). Subsegment 020301 includes Bayou des Allemands from US Highway 90 to Lake Salvador, a total of 13.5 river miles (21.8 km). The total area of subsegment 020301 is approximately 90 mi^2 (233 km^2). The predominant land use is freshwater marsh. Land use data are summarized in Table 2.1 and shown spatially on Figure A1.2 (in Appendix A1).

There are no flow control structures (e.g., pumps, weirs, etc.) on Bayou Des Allemands. Bayou des Allemands is not classified as estuarine, but it is hydraulically influenced by tides due to its proximity to the Gulf of Mexico and its low gradient. Although diurnal water level fluctuations in Bayou des Allemands are usually small (< 0.2 ft), reversing flow is common except after storms when runoff from the large upstream drainage area tends to maintain a continuous flow towards the Gulf. There are no flow gages on Bayou des Allemands.

Table 2.1. Land use for subsegment 020301.

Land Use Type	Percent of Total Area
Fresh Marsh	59.4%
Wetland Forest Deciduous	12.7%
Upland Forest Deciduous	0.0%
Upland Forest Mixed	0.0%
Wetland Scrub/Shrub Deciduous	1.3%
Wetland Scrub/Shrub Evergreen	1.3%
Upland Scrub/Shrub Mixed	0.1%
Agriculture/Cropland/Grassland	10.6%
Vegetated Urban	1.3%
Nonvegetated Urban	0.0%
Wetland Barren	0.0%
Upland Barren	0.0%
Water	13.3%
TOTAL	100.0%

2.2 Water Quality Standards

The designated uses and numeric water quality standards for subsegment 020301 are listed below in Table 2.2. This subsegment has a year round DO standard of 5.0 mg/L.

Table 2.2. Water quality numeral criteria and designated uses (LDEQ 2003c).

Subsegment Number	020301
Subsegment Name	Bayou des Allemands from US Hwy 90 to Lake Salvador
Designated Uses	A, B, C, G
Criteria:	
DO	5 mg/L
Chloride	600 mg/L
Sulfate	100 mg/L
PH	6.0 – 8.5
Bacteria	see note 1 below
Temperature	32°C
TDS	1320 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 May through October; 1000 colonies / 100 mL maximum log mean and no more than 25% of samples exceeding 2000 colonies / 100 mL for November through April.

As specified in EPA's regulations at 40 CFR 130.7(b)(2), applicable water quality standards include antidegradation requirements. The LDEQ antidegradation policy (LAC 33: IX.1109.A) includes the following statements that are applicable to this TMDL: "No lowering of water quality will be allowed in waters where standards for the designated water uses are not currently being attained. ... The administrative authority will not approve any wastewater discharge or certify any activity for federal permit that would impair water quality or use of state waters." The TMDL in this report is consistent with the LDEQ antidegradation policy.

2.3 Point Sources

A total of five National Pollutant Discharge Elimination System (NPDES) permits were identified for point source discharges within subsegment 020301. Information for these point source discharges is shown in Table 2.3 and their locations are plotted on Figure A1.3 (in Appendix A1). This information was obtained by reviewing data from both the LDEQ point source database and from a point source database prepared for the Barataria and Terrebonne basins under contract to EPA Region 6. Because none of these facilities discharges directly into Bayou des Allemands, they were not included in the model.

2.4 Nonpoint Sources

Suspected nonpoint sources for subsegment 020301 have been listed in the 1999 Court Ordered 303(d) List for Louisiana (EPA 1999). These sources include sediment resuspension and upstream sources. Based on LDEQ's experience in the Barataria basin, it is suspected that there is considerable nonpoint oxygen demand in this subsegment that is natural (i.e., not induced by human activities).

2.5 Water Quality Conditions/Assessment

As mentioned in Section 1, this subsegment was listed as impaired by both EPA and LDEQ due to organic enrichment / low DO and nutrients. The suspected sources, suspected causes, and priority ranking from the EPA 303(d) list are shown in Table 2.4. The water quality data that LDEQ used to assess this subsegment and include it on the 303(d) list were ambient monitoring data collected at LDEQ station 0921 (Bayou Des Allemands 0.5 mile south of Hwy 90 bridge in Des Allemands, LA). The location of this monitoring station is shown on Figure A1.1. Data were collected at this station at approximately monthly intervals from January 2000 through December 2000. As shown in Table 2.5, nine of the twelve DO measurements (75%) were below the water quality standard of 5.0 mg/L.

It should be noted that the data for station 0921 were collected near the end of a multi-year drought in southern Louisiana. Long term data collected at station 0292 (approximately 0.6-0.7 miles upstream of station 0921) show that DO values in Bayou des Allemands were significantly lower during 2000 than during 1991-97. The data for LDEQ station 0292 are shown in Appendix A2.

Table 2.3. Information for point source discharges in subsegment 020301.

FILE NUMBER	COMPANY	FACILITY	FACILITY TYPE	LOCATION	RECEIVING WATER	EXPECTED FLOW (MGD)	BOD5 LIMIT (MG/L)	MODELING COMMENTS
LAG750349	Phat Daddy’s	Phat Daddy’s	Commercial Car Wash	"Raceland, 1556 Hwy 90 e, lot #9"	"Godchaux Canal, via local drainage"			not modeled but in tmdl
LA0003239	Raceland Raw Sugars Corporation		"Sugar Mill, Raw Sugar & Molass"	"Raceland, Hwy 3199 & Mill St"	Godchaux Canal		Average 10	not modeled but in tmdl
LAG540909	Gibbens & Lefort Inc	Presto Fuel Center LLC	Truck Stop/Convenience Store/Rrest	"Raceland, on Hwy 90 e; 3 m e of LA 1"	Godchaux Canal	0.0075	Average 30	not modeled but in tmdl
LAG530277, WG-010101	Judy's Trailer Park		"1,800 gpd Mechanical STP"	"des Allemands, Hwy 90"	Unnamed canal-Bayou des Allemands	0.0018		not modeled but in tmdl
WG110021	Somme's Lucky 7 Truck Stop	des Allemands	Service Station	des Allemands, 4298 Hwy 90				not modeled but in tmdl

Table 2.4. 303(d) listing for subsegment 020301.

Subsegment Number	Waterbody description	Suspected sources	Suspected causes	Priority ranking (1=highest)
020301	Bayou Des Allemands U.S. Hwy. 90 to Lake Salvador (Scenic)	Industrial point sources, Minor industrial point sources, Other, Sediment resuspension, Upstream sources	Organic enrichment/low DO, Turbidity, Pesticides, Nutrients, Salinity/TDS/chloride/sulfate, Oil & Grease, Suspended solids, Noxious aquatic plants	3

Table 2.5. DO data for LDEQ station 0921 (Bayou des Allemands).

Date	Time	DO (mg/L)	Meets standard?
12/6/00	0925	6.85	Yes
11/1/00	1015	4.20	No
10/4/00	1030	3.20	No
9/6/00	0845	2.86	No
8/9/00	1027	3.04	No
7/12/00	1015	4.62	No
6/7/00	1020	3.15	No
5/10/00	1027	4.17	No
4/12/00	1005	5.57	Yes
3/15/00	1130	8.60	Yes
2/9/00	1032	2.51	No
1/12/00	1015	2.90	No

2.6 Previous Studies and Data

No previous water quality studies have been identified for subsegment 020301. Hourly water surface elevation data have been collected in Bayou Des Allemands at Highway 90 (by the Corps of Engineers) and at the confluence with Company Canal (by the Louisiana Department of Natural Resources). The only historical water quality data that are known to exist are the LDEQ data mentioned in Section 2.5.

3. Field Survey

A field survey was conducted by LDEQ personnel on Bayou des Allemands during the week of September 10-17, 2002. The purpose of this intensive survey was to gather data that would be needed to set up and calibrate the water quality model. The field data that were collected included water quality samples and in situ measurements, continuous in situ monitoring, acoustic doppler flow measurements, dye studies, cross sections, and velocity measurements with drogues. Continuous in situ data (temperature, DO, pH, and specific conductivity) were taken during September 10-17 on the main stem and during September 10-12 for the tributaries. Grab samples and in situ data were collected on September 11. A map and descriptions of the field data collection sites are included in Appendix B1.

3.1 Water Quality Sampling and In Situ Data

The water quality sampling data and the in situ data collected with the water quality samples are shown in Table B2.1 (in Appendix B2). All of the instantaneous DO readings along the main stem of Bayou des Allemands were above the water quality standard of 5 mg/L. The only two instantaneous DO readings that were below 5 mg/L were at stations UCB-1 and CC-1.

Table B2.2 (also in Appendix B2) shows a comparison of data collected at BDA-2 during the survey with LDEQ historical data collected during the month of September at station 0292 (within about 0.2 km of BDA-2). This comparison shows that in general, the survey data appear to be representative of late summer conditions in Bayou des Allemands.

3.2 Continuous Monitoring Data

Figures B3.1 through B3.46 (in Appendix B3) show plots of the continuous in situ data collected during the survey. The diurnal fluctuations of DO were typically about 1-3 mg/L at all stations except UCB-1, where the diurnal fluctuation was about 3-5 mg/L. The DO percent saturation values slightly exceeded 100% at most stations, but the values along the main stem never exceeded 120%. At UCB-1, though, the DO percent saturation ranged from about 70% to just barely above 0%. Diurnal fluctuations of pH were between 0.2 su and 0.7 su at most of the stations except BDA-2 and DP-1, where the diurnal pH fluctuations were as high as 1.5 su. For most of the stations, the greatest diurnal fluctuation of pH occurred on the same day that water quality samples were collected (September 11). The diurnal fluctuations of DO and pH and the occurrence of supersaturated DO values indicate that there is certainly some algal productivity in Bayou des Allemands.

The continuous conductivity and salinity data showed little diurnal fluctuation but generally decreased during September 10-17. The decreasing trend is consistent with the apparent flow patterns, which are discussed in Section 3.5. The continuous water level data showed diurnal variations of less than 0.1 m (0.3 ft).

3.3 BOD Time Series Analyses

Results of 60-day BOD time series analyses are shown in Appendix B4. For each sample, values of cumulative oxygen demand and NO2+NO3 concentration were obtained at selected intervals over a period of about 60 days. These data were entered into an LDEQ spreadsheet called GSBOD, which contains algorithms for fitting first order curves to the data to calculate values of ultimate carbonaceous biochemical oxygen demand (CBODu), ultimate nitrogenous biochemical oxygen demand (NBODu), decay rates for both CBODu and NBODu, and lag times for both CBODu and NBODu. The results of these analyses are shown in Appendix B4.

3.4 Cross Section Data

Cross sections were measured at a total of 10 locations along Bayou des Allemands and other adjacent canals and bayous. These cross section data are shown in Appendix B5.

3.5 Velocity and Flow Measurements

Table B6.1 (in Appendix B6) shows velocity measurements made at various sampling sites using drogues. These measurements did not show a consistent flow pattern.

Acoustic Doppler flow measurements were made on several occasions at both the northwest and southeast ends of the subsegment (BDA-1 and BDA-9) and on one occasion for Bayou Gauche (BG-3). A summary of these flow measurements is presented in Table B6.2 (in Appendix B6). These measurements show that there was a strong upstream flow (i.e., flowing away from the Gulf) on September 10 (the day before the water quality sampling). These data also show that the flow began to turn around and flow towards the Gulf during the late morning on September 11. Due to the lag time from one end of the subsegment to the other, the water at BDA-1 did not start flowing towards the Gulf until later.

A dye study was also conducted to measure velocity in Bayou des Allemands. A slug of dye was injected in Bayou des Allemands at river kilometer 10.4 (near the southeastern end of Bayou Gauche) during the morning of September 11 and four "runs" were made to locate and characterize the dye cloud at different times. Appendix B6 contains time of travel calculations (Table B6.3) and a plot of dye concentration versus distance for these four runs (Figure B6.1). The dye moved upstream (to the northwest) during the day on September 21, but the current reversed overnight and the dye was found downstream of the injection location the next day. The results of the dye study were consistent with the acoustic Doppler flow measurements discussed above. This diurnal flow reversal is assumed to be typical for Bayou des Allemands due to its proximity to the Gulf and its diurnal water level fluctuations.

4. Documentation of Calibration Model

4.1 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 hydraulic characteristics of Louisiana waterbodies and was particularly suitable for use in modeling Main Canal. 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, EPA 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, LDEQ 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 LDEQ 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 nonpoint source pollution is estimated from the difference between the calibration loads and the loads observed on reference or least impacted streams.

4.2 Input Data Documentation

Data collected during the September 2002 intensive survey (described in Section 3) were used to establish the input for the model calibration. The survey was conducted during a period that was typical of late summer conditions.

The flows in the model were determined based on acoustic Doppler flow measurements, dye study results, and selected drogue measurements. Flow calculations are discussed in Section 4.2.11. A simulation of conservative constituents (e.g., chloride and conductivity) was performed as an attempt to check the flow balance (see Section 4.3.1).

Field and laboratory water quality data were entered in a spreadsheet for ease of analysis. The Louisiana GSBOD program was applied to the BOD time series data in a separate spreadsheet as described in Section 3. The survey data were the primary source for the model input data for initial conditions, decay rates, and inflow water quality.

4.2.1 Model Schematics and Maps

A vector diagram of the modeled area is presented in Figure 4.1 and in Appendix C. The vector diagram shows the locations of survey stations, the reach design, and the locations of inflows and outflows. Because the intensive survey was conducted during a period of upstream flow, the model was set up with the upstream end at Lake Salvador and the downstream end at Highway 90. Therefore, the headwater flow in the model was the inflow from Lake Salvador and the lower boundary conditions were based on data near Highway 90. The reach design is discussed in Section 4.2.5. Maps showing the entire subsegment are included in Appendix A1.

4.2.2 Model Options, Data Type 2

Five constituents were modeled during the calibration process. These were chlorides, conductivity, dissolved oxygen (DO), CBODu, and NBODu. The chlorides and conductivity were included in the model for the purpose of checking the flow balance. NBODu was represented in the model as nonconservative material (NCM).

4.2.3 Program Constants, Data Type 3

Three program constants were specified in the model input. First, the hydraulic calculation method was specified as 2 rather than 1. Method 2 is the preferred method and allows the user to input widths and depths rather than velocities and depths. The second program constant that was specified was the NCM oxygen uptake rate, which was set to 1.0 mg of oxygen consumed per mg of NCM decayed.

The third program constant that was specified was a minimum surface transfer coefficient (K_L) for reaeration. Because Bayou des Allemands is wide enough for wind to affect reaeration, a wind-aided surface transfer coefficient was calculated using the mean daily wind speed at the New Orleans International Airport on September 11, 2002 (the day that water quality sampling occurred). This resulted in a value of 0.81 m/day for the minimum K_L. The calculations are shown in Table D.1 (in Appendix D).

4.2.4 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:

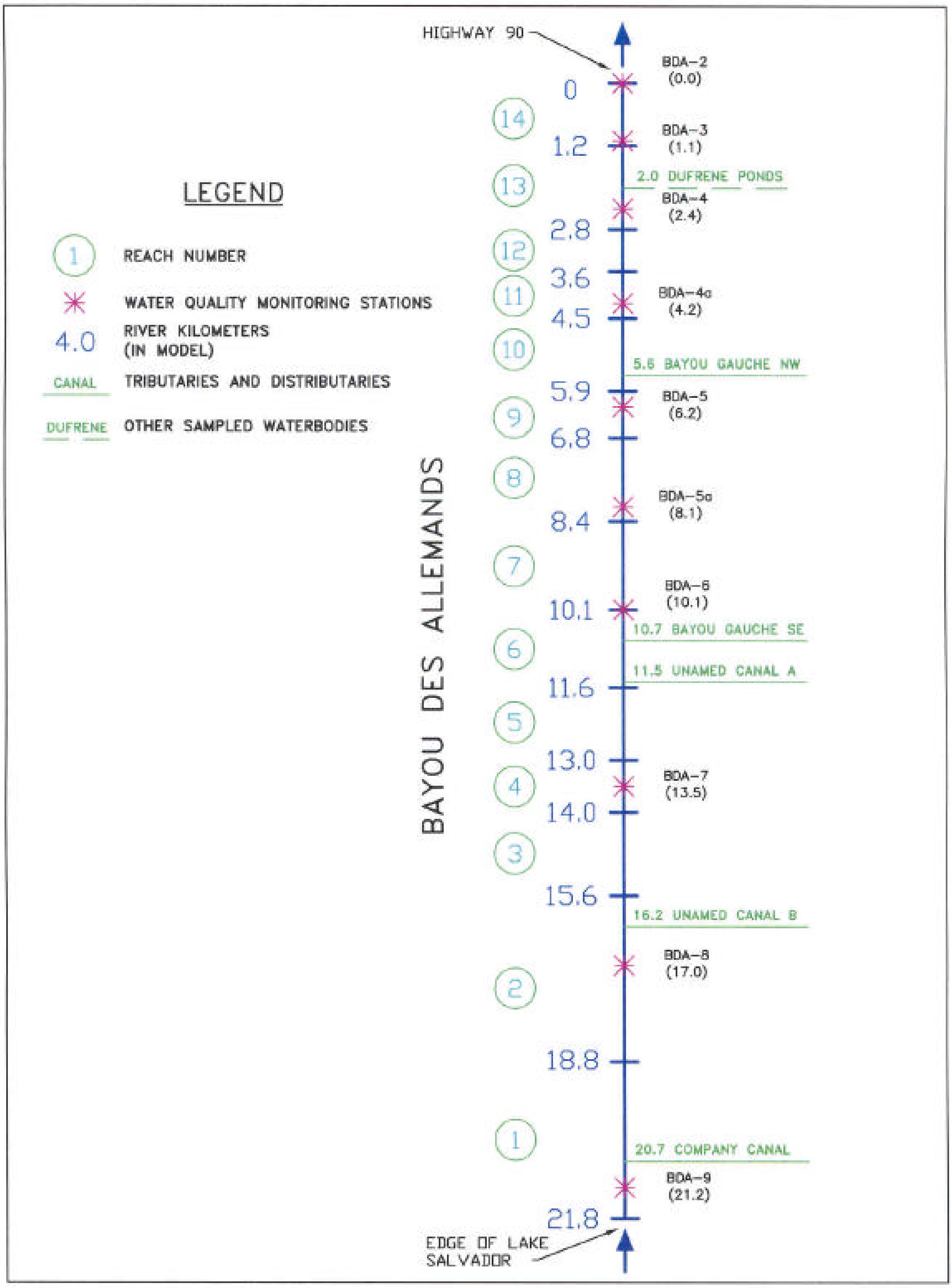

Figure 4.1. LA-QUAL vector diagram for Bayou des Allemands.

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

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 (20 degrees Celsius)
Theta = an empirical constant for each reaction coefficient

In the absence of specified values for data type 4, the model uses default values. The default theta values include 1.047 for CBOD decay, 1.070 for nonconservative material (NBOD) decay, and 1.065 for SOD. All three of these default values were consistent with the LTP (LDEQ 2003b), so no values were explicitly specified in data type 4.

4.2.5 Reach Identification Data, Data Type 8

The model includes Bayou des Allemands starting at Lake Salvador and extending northwest to Highway 90. As mentioned in Section 4.2.1, the model was oriented with the upstream end closes to the Gulf because the flow was away from the Gulf for the calibration scenario. No branches were modeled. A vector diagram of the model is shown in Appendix C.

The system being modeled was divided into a total of 14 reaches based on changes in width and depth. The element size was 0.10 km throughout the model. The widths and depths are discussed in Section 4.2.6.

4.2.6 Hydraulic Coefficients, Data Types 9 and 10

The hydraulics were specified in the model input for the LA-QUAL model using the power functions (width = a * Q^b + c and depth = d * Q^e + f). Values specified in the model for these power functions are shown in Table D.2 in Appendix D. Based on the low gradient of streams in this subsegment and hydraulic conditions during the intensive field survey, it was assumed that changes in the stream flow rate between the calibration and projection simulations would create only negligible changes in depths and widths. Therefore, the coefficients and exponents (a, b, d, and e) were set to zero and the constants (c and f) were set based on the widths measured from aerial imagery (DOQQs) and depths from measured cross sections. Plots of modeled and observed depths and widths for Bayou des Allemands are shown in Appendix E.

Because Bayou des Allemands is tidally influenced and typically exhibits reversing flows (as discussed in Section 3.5), dispersion was specified in the model. The dispersion coefficient for each reach was set to 10 m^2/sec based on experience in other waterbodies in the Barataria basin (FTN 2004a, FTN 2004b, FTN 2004c). The model calibration results were not sensitive to the dispersion coefficient due to the relatively strong advection for the calibration scenario.

4.2.7 Initial Conditions, Data Type 11

The initial conditions were used to specify the temperature and salinity for each reach and reduce the number of iterations required by the model for constituents being simulated. The values used for this model were temperature, salinity, DO, and chlorophyll by reach. The input values came from the survey station(s) located closest to the reach or from an average of samples taken from stations located within the reach. For DO, the initial values were set to the calibration targets. The model inputs and data sources for the initial conditions are shown in Table D.3 in Appendix D.

Initial concentrations of chlorophyll were not originally specified in the model but were added during calibration in order to improve the match between predicted and observed DO.

4.2.8 Reaeration Rates, Data Type 12

For reaeration, the Louisiana equation (option 15) was used. Although it was developed for streams that are shallower than Bayou des Allemands, the Louisiana equation was used because it provided a better calibration for DO than other equations and it yielded reaeration coefficients that appeared reasonable. Based on the width of Bayou des Allemands, the model was allowed to calcuate wind-aided reaeration using the minimum surface transfer coefficient specified in Data Type 3 (see Section 4.2.6). However, for most reaches, the reaeration coefficients from the Louisiana equation were slightly higher than reaeration coefficients based on wind. Therefore, the wind had no effect on reaeration for most reaches. The model inputs for reaeration are shown in Table D.4 in Appendix D.

4.2.9 SOD, Data Type 12

The SOD values were achieved through calibration and ranged from 3.25 g/m^2/day to 0.20 g/m^2/day in Bayou des Allemands, with the highest values near the southeast end of Bayou des Allemands. The SOD values used in the model are shown in Table D.5 in Appendix D. Results of the water quality calibration are discussed in Section 4.3.2.

4.2.10 CBODu and NBODu Rates, Data Types 12 and 15

The CBODu and NBODu decay rates used in the model were based on values calculated by the LDEQ spreadsheet GSBOD for each station. For all reaches in the model, the CBODu and NBODu decay rates were set to the average of the decay rates calculated for sampling stations along the main stem (decay rates at each sampling station are shown in Table B4.1 in Appendix B4).

CBODu and NBODu settling rates were not used in the model because there was no information suggesting that simulating CBODu or NBODu settling was necessary. There were no point source discharges or other inflows that are known to be high in particulate CBODu or NBODu. The effects of settled CBODu and NBODu on DO are already implicitly included in the SOD.

4.2.11 Flow Calculations

To apply a steady state water quality model (LA-QUAL) on a tidally influenced stream with flow reversals, the flows used in the model should be tidally averaged values rather than instantaneous values. The approach that was initially attempted for determining tidally averaged flows for each of the boundaries in the LA-QUAL model was to perform a dynamic hydraulic simulation of Bayou des Allemands using the Corps of Engineers Unsteady flow NETwork model (UNET). However, a satisfactory calibration was not achieved due to a lack of accurate water surface elevation data at the boundaries in the UNET model.

Because hydraulic modeling results were not available, average flows for Bayou des Allemands during the intensive survey were estimated using acoustic Doppler flow measurements and velocity measurements from drogues. First, the total inflow and outflow to the subsegment were calculated by averaging the flows measured at BDA-1 and BDA-9 from 4:00 pm on September 10 to 4:00 pm on September 11 (the day of the sampling). Next, inflows and outflows for side channels were estimated using an acoustic Doppler flow measurement for Bayou Gauche and drogue velocities and measured cross sections for Unnamed Canal A, Unnamed Canal B, and Company Canal. For Bayou Gauche, the flow was assumed to be the same at both ends (i.e., the flow leaving the northwest end of Bayou Gauche was assumed to be the same magnitude as the measured flow entering the southeast end). After these calculations were performed, the sum of the outflows was greater than the sum of the inflows. Therefore, the amount of inflow needed to balance the flows was represented in the model as incremental inflow. Incremental inflow was assumed to enter Bayou des Allemands at a constant flow per unit length of stream. The flow calculations are shown in Appendix F.

4.2.12 Incremental Inflow, Data Types 16, 17, and 18

The flow rates for incremental inflow were calculated as described in Section 4.2.11. The values used for model inputs for the incremental inflows are shown in Table D.6 in Appendix D.

For the conservative materials (conductivity and chloride), the incremental inflow concentrations were initially set based on measured values in several tributaries. However, using these values in the model did not provide a good match between predicted and observed concentrations. Because there was considered to be more uncertainty in the incremental inflow concentrations than in the flow calculations, it was decided to adjust the incremental inflow concentrations to improve the match between predicted and observed values of chloride and conductivity.

For the other parameters (DO, CBODu, and NBODu), incremental inflow concentrations were estimated based on best professional judgement and typical concentrations in the stream.

4.2.13 Nonpoint Source Loads, Data Type 19

Nonpoint source loads which were 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, CBODu loads, and NBODu loads. These loads were used as calibration parameters and adjusted to get the model to match observed data. The values used for the model input data for nonpoint source loads are shown in Table D.5 in Appendix D.

4.2.14 Headwaters, Data Types 20, 21, and 22

As mentioned previously, the headwater in the model represented the inflow from Lake Salvador. The headwater flow rate was calculated based on acoustic Doppler flow measurements at BDA-9 as described in Section 4.2.11. The water quality for the headwaters was based on averages of observed data at stations

LS-1 and BDA-9. The values used for model inputs for the headwater are shown in Table D.7 in Appendix D.

The DO value for the headwater was an average of daily average DO values for LS-1 and BDA-9. Because continuous monitoring data were not available for LS-1, the daily average DO at that station was estimated using continuous monitoring data at BDA-9. The ratio of the instantaneous DO to daily average DO at BDA-9 was calculated for 15 minute intervals throughout the day. Then the instantaneous DO at LS-1 was divided by the ratio corresponding to the measurement time at BDA-9 (see calculations in Appendix G2).

4.2.15 Wasteloads, Data Types 24 and 25

No point source discharges were simulated in the model because the existing point sources are small and distant from the modeled waterbody. Five tributaries and distributaries were specified as wasteloads in the model. The flow rates for these tributaries and distributaries were calculated as described in Section 4.2.11. Three of these were outflows rather than inflows, so water quality inputs were needed for only two tributaries (Unnamed Canal B and Bayou Gauche at northwest end). Water quality inputs for these inflows were based on observed data for stations UCB-1 and BG-2. The values used for model inputs for the wasteloads are shown in Table D.8 in Appendix D.

4.2.16 Lower Boundary Conditions

Since dispersion was explicitly specified in the model, lower boundary conditions were required. The lower boundary conditions were based on water quality data from station BDA-1 where data were available, with some data from station BDA-2 as needed. The DO is an estimated daily DO calculated using the instantaneous value from BDA-1 and continuous data from BDA-2 in the same way as described for the headwater (see Section 4.2.14). The values used for model inputs for the lower boundary conditions are shown in Table D.9 in Appendix D.

4.3 Model Discussion and Results

4.3.1 Simulation of Chloride and Conductivity

Before calibrating the water quality, the model predictions for chloride and conductivity were examined as an attempt to evaluate the flow balance. Because there was large uncertainty about incremental inflow water quality, the flow balance could not be confirmed using the chloride and simulations. As discussed in Section 4.2.12, the chloride and conductivity concentrations for the incremental inflow were adjusted during calibration. Plots of predicted and observed chloride and conductivity for Bayou des Allemands are shown in Appendix H.

4.3.2 Water Quality Calibration Results

Plots of predicted and observed values of CBODu, NBODu, and DO for Bayou des Allemands are shown in Appendix I. A plot of predicted and observed DO is also shown in Figure 4.2. A printout of the tabular model output is included in Appendix J.

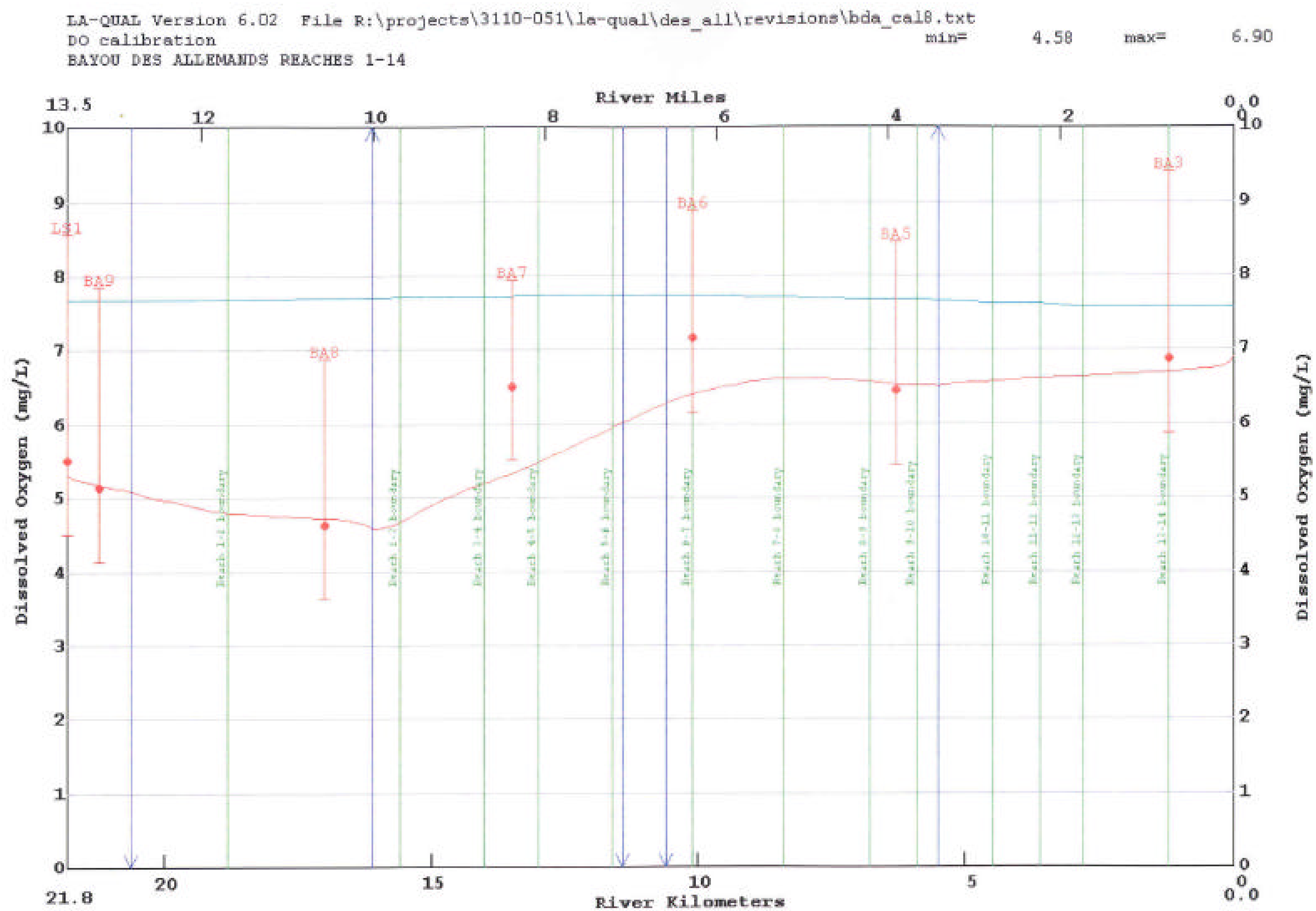

Figure 4.2. Predicted and observed DO for Bayou des Allemands calibration model.

The predicted values of CBODu and NBODu were close to the observed values except for slight underpredictions in the middle of the system (i.e., BDA-7 and BDA-6) and overpredictions both upstream and downstream of there (i.e., BDA-8 and BDA-5). Large gradients were difficult to simulate with the model due to the relatively short residence time in the bayou.

According to recent LDEQ policy, the DO calibration target at each station was set as shown below based on the diurnal DO fluctuations from the continuous monitoring data:

Diurnal DO fluctuation < 2 mg/L:	daily average DO
Diurnal DO fluctuation 2-9 mg/L:	1 mg/L above daily minimum DO

The diurnal DO fluctuations were determined from continuous monitoring data collected on the day of the water quality sampling (September 11). For stations without continuous monitoring data, daily minimum DO values in a similar manner to the way that daily average DO values were estimated (see Section 4.2.14). The calculations for daily minimum DO values are shown in Appendix G1.

The predicted DO values were similar to the observed values except for BDA-6 and BDA-7, where the predicted values were significantly lower than the observed values. Chlorophyll was specified in the initial conditions to improve the DO calibration, but the predicted DO values were still low at BDA-6 and BDA-7. The model calibration was considered acceptable because the model accurately predicted the minimum DO.

5. Water Quality Projections

Since the calibrated model indicated that the DO criterion was not being met in Bayou des Allemands, no-load scenarios were performed in addition to the traditional summer and winter projections.

5.1 Critical Conditions, Seasonality and Margin of Safety

The Clean Water Act requires the consideration of the seasonal variation of the conditions affecting the constituent of concern, and the inclusion of a margin of safety (MOS) in the development of a TMDL.

Critical conditions for dissolved oxygen were determined by calculating 90th percentile temperatures for each season for Bayou des Allemands using long term water quality data from the LDEQ Ambient Monitoring Network. The 90th percentile temperatures were calculated using recorded values from station 0292 ("Bayou des Allemands at Des Allemands, LA"). These calculations are shown in Appendix K.

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 critical low flows, and the 90th percentile temperature. Incremental flow was assumed to be zero; model loading was from perennial tributaries, sediment oxygen demand, and resuspension of sediments.

In reality, the highest temperatures occur in July-August, lowest stream flows may occur in other months, and the maximum nonpoint source loading 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.

5.2 Input Data Documentation

The values and sources of the input data used for the summer projection, summer no-load, winter projection, and winter no-load scenarios are shown in Appendix L. Except as mentioned below, the projection inputs were unchanged from the calibration.

5.2.1 Program Constants, Data Type 3

For the projections, the minimum surface transfer coefficient for reaeration (K_L) was calculated based on long term average wind speeds rather than the wind speed during the intensive survey. Long term average wind speeds for each month of the year for New Orleans were examined and the lowest values within each season (summer and winter) were used to calculate the minimum K_L values. These calculations are shown in Appendix M.

5.2.2 Initial Conditions, Data Type 11

The initial temperatures were set to the 90^{th} percentile temperature for each season in accordance with the LTP. The initial DO, chlorophyll, and salinity values were unchanged from the calibration.

5.2.3 SOD and Nonpoint Sources, Data Types 12 and 19

The nonpoint source values were calculated for each projection scenario using a load equivalent spreadsheet. An analysis was made of the calibration nonpoint source and SOD loads in terms of total loading in units of $g O_2/m^2$/day and compared to the reference stream loads in the same terms (which accounted for the width differences between the reference and the modeled streams). Calibration values were used where they were smaller than reference stream values. The same spreadsheet also calculated load reductions for the tributary inflows.

LDEQ has collected and measured the CBOD and NBOD oxygen demand loading components for a number of years. These loads have been found in all streams including the non-impacted reference streams. It is LDEQ’s opinion that much of this loading is attributable to runoff loads which are flushed into the stream during runoff events, and subsequently settle to the bottom in the slow moving streams. These benthic loads decay and breakdown during the year, becoming easily resuspended into the water column during the high temperature season. This season has historically been identified as the critical dissolved oxygen season.

LDEQ simulates part of the nonpoint source oxygen demand loading as resuspended benthic load and SOD. The calibrated nonpoint loads (CBODu, NBODu, and SOD) are summed to produce the total calibrated benthic load. The total calibrated benthic load is then reduced by the total background benthic load (determined from LDEQ's reference stream research) to determine the total manmade benthic loading. The manmade portion is then reduced incrementally on a percentage basis to determine the necessary percentage reduction of manmade loading required to meet the water body's dissolved oxygen criteria. These reductions are applied uniformly to all reaches sharing similar hydrology and land uses.

Following the same protocol as the point source discharges, the total reduced manmade benthic load is adjusted for the margin of safety by dividing the value by one minus the margin of safety. This adjusted load is added back to the total background benthic value to obtain the total projection model benthic load. This total projection benthic load is then broken out into its components of SOD, resuspended CBOD, and resuspended NBOD by multiplying the total projection benthic load by the ratio of each calibrated component to the total calibrated benthic load.

LDEQ has found variations in the breakdown of the individual CBOD and NBOD components. While the total BOD is reliable, the carbonaceous and nitrogenous component allocation is subject to the type of test method. In the past, LDEQ used a method which suppressed the nitrogenous component to obtain the carbonaceous component value, which was then subtracted from the total measured BOD to determine the nitrogenous value. The suppressant in this method was only reliable for twenty days thus leading to the assumption that the majority of the carbonaceous loading was depleted within that period of time. The test results supported this assumption. Recently the suppressant started failing around day seven and the manufacturer of the suppressant will only guarantee its potency for a five day period. LDEQ felt a five day test would not adequately depict the water quality of streams and began a search for a new test method. The research found a new proposed method for testing long term BODs in Standard Methods.

This proposed method is a sixty day test which measures the incremental total BOD of the sample while at the same time measuring the increase in nitrite/nitrate in the sample. This increase in nitrite/nitrate allows LDEQ to calculate the incremental nitrogenous portion by multiplying the increase by 4.57 to determine the NBOD daily readings. These NBOD daily readings are then subtracted from the daily readings for total BOD to determine the CBOD daily values. A curve fit algorithm is then applied to the daily component readings to obtain the estimated ultimate values of each component as well as the decay rate and lag times of the first order equations.

LDEQ has implemented the new test method over the last several survey seasons. The results obtained using the new method showed that a portion of the CBOD first order equation does begin to level off prior to the twentieth day; however a secondary CBOD component begins to use dissolved oxygen sometime between day ten and day twenty-five. This secondary CBOD component was not being assessed as CBOD using the previous method but was being included in the NBOD load. Thus the CBOD and NBOD component loading used in the reference stream studies is not consistent with the results using the new proposed sixty day method and the individual values should not be used to determine background values for samples processed using the new test method. However, the sum of CBOD and NBOD should be about the same for both new and old test methods. For this reason, background values in this model are based on the sum of reference stream benthic loads.

LDEQ's reference stream data were examined to identify reference streams that might be applicable for estimating background loads for Bayou des Allemands. Although none of the reference streams is located in or near the Barataria basin, four reference streams were identified as having some characteristics (i.e., sediment type and velocity) similar to Bayou des Allemands. The nonpoint source loads estimated by LDEQ for these four reference streams are shown in Table 5.1 below. All of the reference streams were shallower than Bayou des Allemands, but the four shown in Table 5.1 are the deepest LDEQ reference streams. Based on previous experience with DO TMDLs in Louisiana, the total nonpoint source loads for Saline Bayou and Beaucoup Bayou (3.9 to 4.0 g/m^2/day) seemed unreasonably high as estimates of background loading for Bayou des Allemands. Therefore, the background load for Bayou des Allemands was set to 2.0 g/m^2/day based on the estimated loads for Big Roaring Bayou and Indian Bayou.

Table 5.1. Data from selected LDEQ reference streams (Smythe 1999).

	Big Roaring Bayou	Indian Bayou	Beaucoup Bayou	Saline Bayou Site 2-3
Sediment type	silt	silt	silt	silt
Velocity during survey (m/sec)	0.00	0.00	0.00	0.23
Depth during survey (m)	1.08	0.64	0.67	0.93
NPS CBODu load (g/m^2/day)	0.688	0.218	0.169	0.531
NPS NBODu load (g/m^2/day)	0.095	0.090	0.498	1.637
SOD at 20°C (g/m^2/day)	1.45	1.52	4.20	2.25
Temperature during survey (°C)	20.15	20.82	16.45	16.11
SOD at stream temp. (g/m^2/day)	1.46	1.60	3.36	1.76
Total NPS load (g/m^2/day)	2.24	1.91	4.03	3.93
CBODu concentration (mg/L)	3.48	2.94	2.72	1.60
NBODu concentration (mg/L)	5.41	7.26	5.80	3.70

Background concentrations of CBODu and NBODu for the tributaries were also estimated based on LDEQ's reference stream data. Concentrations of CBODu and NBODu in these four reference streams are shown in Table 5.1. The concentrations for Saline Bayou appeared to be inconsistent with the values for the other three streams. Therefore, the background concentrations for tributary inflows to Bayou des Allemands were based on values for Big Roaring Bayou, Indian Bayou, and Beaucoup Bayou. Based on data for these three streams, a concentration of 9 mg/L of total BODu (i.e., sum of CBODu and NBODu) was selected as the background value. However, the LDEQ TMDL spreadsheet requires individual concentration of CBODu and NBODu. Therefore, the background concentration of 9 mg/L BODu was divided between CBODu and NBODu based on the ratio of CBODu to NBODu for each inflow in calibration. When the total of CBODu and NBODu in the calibration was less than 9 mg/L, the calibration values were used as background values.

5.2.4 Headwaters, Data types 21, 22, and 23

As discussed in Section 7.1, critical hydrologic conditions for most streams are characterized by low flows. Guidance in the LTP specifies the 7Q10 or 0.1 cfs (whichever is greater) as the critical low flow for summer conditions; however, the LTP also states that for certain situations, "more appropriate critical conditions may be selected, and must be technically justified in the TMDL report." A 7Q10 value can not be calculated for Bayou des Allemands because it has frequent flow reversals due to tidal influences. Also, 0.1 cfs is not a realistic value for flow in a large stream such as Bayou des Allemands.

For tidal channels with flows greater than 100 cfs, the LDEQ water quality standards specify a critical flow that is calculated as "1/3 of the average or typical flow over one tidal cycle irrespective of flow direction" (LAC 33:IX.1115.C.7). Therefore, the critical flow for the projection simulation in this report was calculated as 1/3 of the average tidal flow using data from the intensive survey on Bayou des Allemands during September 2002 . Absolute values of the flow were averaged over a 72 hour period and then divided by 3 to obtain a critical flow value of 26.8 m^3/sec, which was input to the model as the headwater flow rate. These calculations are shown in Appendix N.

Although the LTP allows the DO concentration for the headwater inflow to be set to 90% saturation at the critical temperature, it was decided to be more conservative and use the percent saturation from the calibration model (which was lower than 90%). Headwater concentrations for other parameters were kept at the calibration values.

5.2.5 Wasteloads, Data Types 24, 25, and 26

All the tributaries were eliminated except Bayou Gauche. The outflow rate for Bayou Gauche was set equal to 23% of the headwater flow. This is the percentage of the flow that split off from Bayou des Allemands and entered Bayou Gauche during the intensive survey. It was assumed that the water that left Bayou des Allemands through Bayou Gauche returned to Bayou des Allemands (i.e. the sole source of water in Bayou Gauche was from Bayou des Allemands). Tributary concentrations of CBODu and NBODu were set based on background concentrations and percent reduction calculations in the spreadsheets as discussed in Section 5.2.3.

5.2.6 Lower Boundary Conditions, Data Type 27

For the projections, the temperature for the lower boundary was set to the 90th percentile temperature and the DO was set to 90% saturation (slightly lower than in the calibration). Values for other parameters were unchanged from the calibration.

5.3 Model Discussion and Results

5.3.1 No-Load Scenarios

The summer and winter no-load scenarios were run to predict DO concentrations with no man-made sources under critical conditions. Printouts of the spreadsheets with nonpoint source load calculations for these scenarios are presented in Appendix O. Graphs of the predicted DO and printouts of the tabular output are presented in Appendix P.

The minimum predicted DO values from the no-load scenarios were 5.23 mg/L for summer and 6.28 mg/L for winter. In other words, these simulations showed that complete elimination of man-made sources would result in DO values meeting the current standard during summer and above the standard during winter.

5.3.2 Summer and Winter Projections

The summer and winter projection simulations were run to determine the allowable loadings and percent reductions for Bayou des Allemands that would result in the existing DO standard being maintained. Printouts of the spreadsheets with nonpoint source load calculations for these scenarios are presented in Appendix Q. Graphs of the predicted DO and printouts of the tabular output for these scenarios are presented in Appendix R. Graphs of the predicted DO are also shown in Figures 5.1 and 5.2.

As shown in Table 5.2, the load reductions that were required for the model to show the DO standard being met with no background reductions and no reductions needed at all in the winter projection. For each scenario, a uniform percent reduction was applied to all reaches in the model.

Table 5.2. Summary of nonpoint source load reductions required to meet the DO standard.

	Man-made nonpoint sources	**Background nonpoint sources**
Summer (May – October)	86%	0%
Winter (November – April)	0%	0%

5.4 Calculated TMDL, WLAs, and LAs

5.4.1 Outline of TMDL Calculations

An outline of the TMDL calculations is provided below to assist in understanding the TMDL calculations, which are shown in Appendix Q. Slight variances may occur based on individual cases. All of the TMDL calculations were done using the LDEQ TMDL spreadsheet.

A) The natural background benthic loading was estimated from reference stream resuspension (nonpoint CBOD and NBODu) and SOD load data.

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

- Calibration resuspension and SOD loads were summed for each reach as g/m^2/day of oxygen demand 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. Point source design flows are increased to obtain an explicit MOS of 20%. Headwater and tributary concentrations of CBODu, NBODu, and DO range from reference stream levels to calibration levels based on the percent reductions. 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.

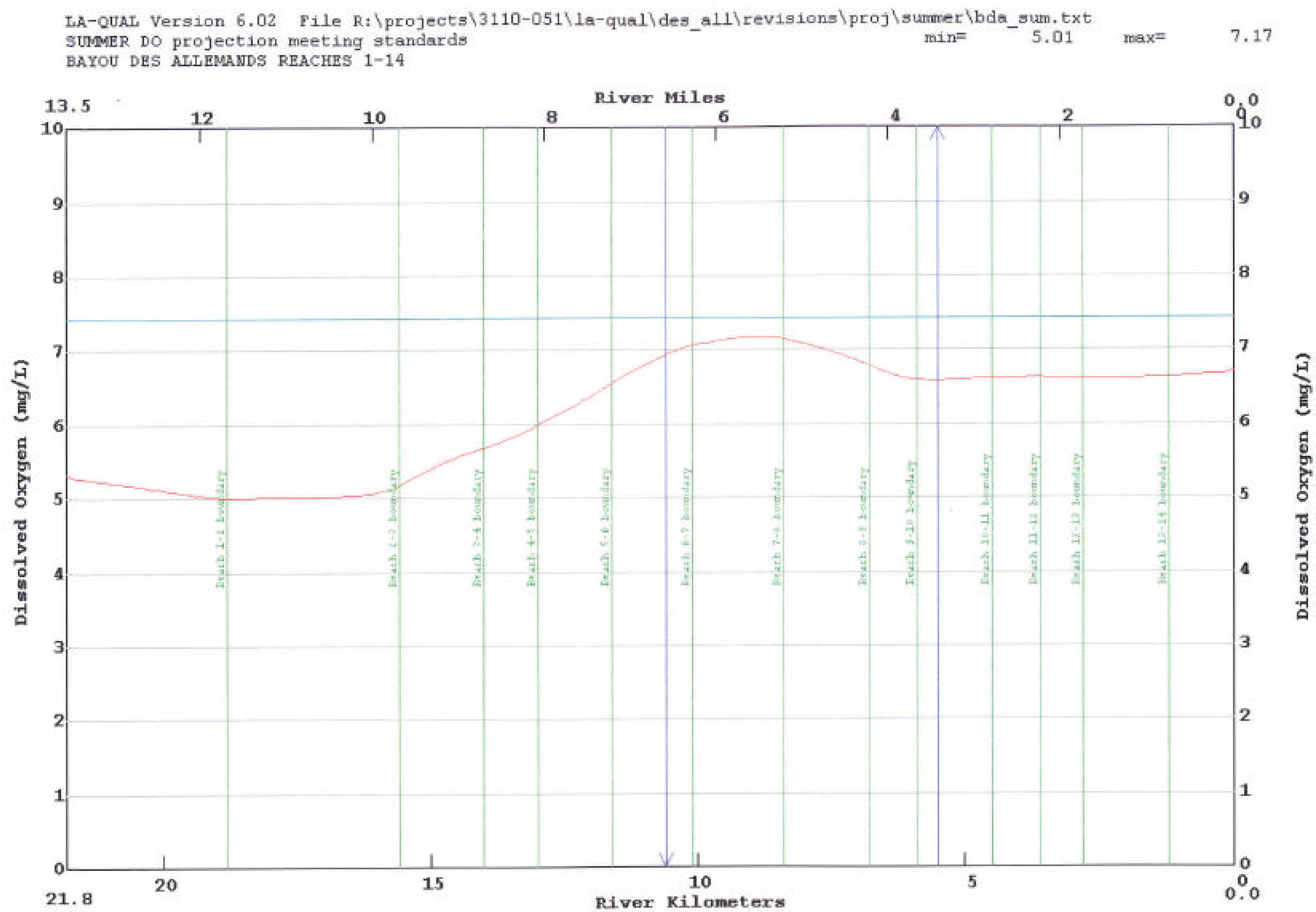

Figure 5.1. Predicted DO for Bayou des Allemands summer projection.

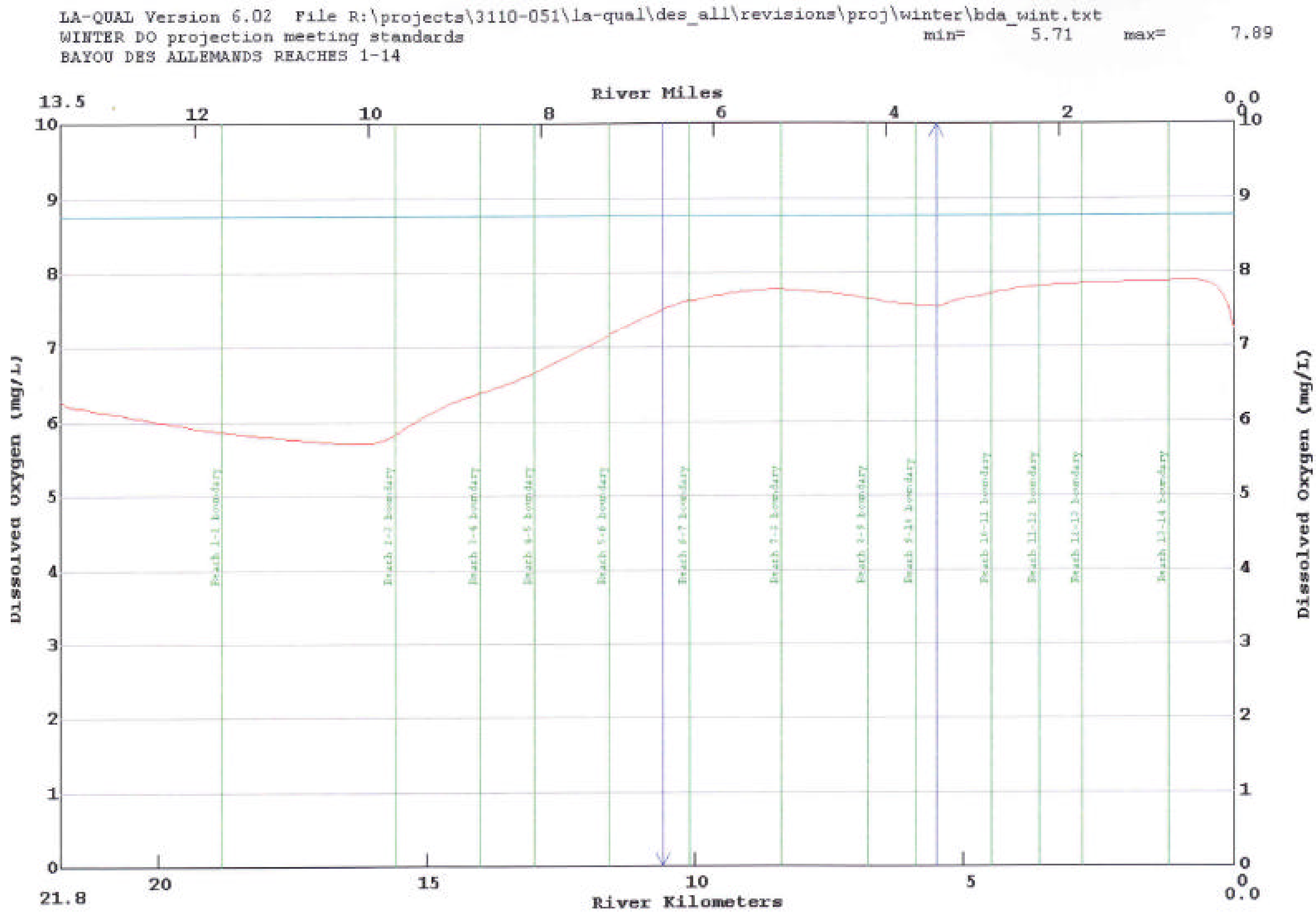

Figure 5.2. Predicted DO for Bayou des Allemands winter projection.

- The projection benthic loading at 20°C is calculated as the sum of the projection resuspension and SOD components expressed as g/m^2/day of oxygen demand. 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 lbs/day and kg/day for each reach.

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

- Headwater and tributary CBODu and NBODu loading in lbs/day and kg/day.
- 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 lbs/day and kg/day.
- Point source CBODu and NBODu loading in lbs/day and kg/day.
- The margin of safety in lbs/day and kg/day.

5.4.2 Results of TMDL Calculations

The TMDL for the biochemical oxygen demanding constituents (CBODu, NBODu, and SOD) was calculated for the summer and winter critical seasons. Printouts of the TMDL spreadsheets are presented in Appendix Q. A summary of the loads is presented in Table 5.3.

The nonconservative behavior of dissolved oxygen allows many small or remote point source dischargers to be assimilated by their receiving waterbodies before they reach the modeled waterbody. These dischargers are said to have very little to no impact on the modeled waterbody and therefore, they are not included in the model and are not subject to any reductions based on this TMDL. These facilities are permitted in accordance with state regulation and policies that provide adequate protective controls. New similarly insignificant point sources will continue to be issued permits in this manner. Significant existing point source dischargers are either included in the model or are determined to be insignificant by other modeling. New significant point source dischargers would have to be evaluated individually to determine what impact they have on the impaired waterbody and the appropriate controls.

The point source wasteload allocation (WLA) includes loads from all permitted point sources within the subsegment that are known to discharge oxygen demanding effluent. For this subsegment, none of the point sources were included in the model because they are small and far away from the modeled waterbodies. Their loads were accounted for in the model by calibration as part of the boundary conditions or nonpoint source loading.

The LDEQ TMDL spreadsheet applies a user-specified explicit MOS to the point source loads and to the man-made nonpoint source loads (i.e., all man-made sources). The explicit MOS that was specified in the spreadsheet was 20%. This TMDL required a complete elimination of the man-made nonpoint source loads, thereby eliminating the need for an explicit MOS for that portion of the load.

It should be noted that the 20% explicit MOS used for the point sources accounts for future growth as well as uncertainties associated with the modeling process. The TMDL also includes an implicit MOS created by conservative assumptions in the modeling (see Section 5.1).

Table 5.3. TMDL for subsegment 020301 (sum of CBODu, NBODu, and SOD).

	Load (kg/day) for:	
	Summer (May-Oct)	**Winter (Nov-Apr)**
Point Source WLA	16	16
Point Source Reserve MOS	4	4
Natural Nonpoint Source LA	37374	32756
Man-made Nonpoint Source LA	2251	12499
Man-made Nonpoint Source MOS	563	3125
TMDL	40208	48400

6. Sensitivity Analysis

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 LA-QUAL 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 value. Thus the sensitivity of each parameter is reviewed separately. A sensitivity analysis was performed on the calibration scenario. Parameters were varied by +/- 30%, except temperature, which was adjusted +/- 2 degrees Centigrade. The results of the sensitivity analysis are summarized in Table 6.1.

The model was most sensitive to headwater DO, benthal demand (SOD), and reaeration. The model output was least sensitive to dispersion (due to the relatively strong advection) and lower boundary conditions (because the minimum DO was near the upstream end).

Table 6.1. Summary of calibration model sensitivity analysis.

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
Headwater DO	-30%	3.76	-17.9%	30%	5.10	11.4%
Benthal Demand	-30%	5.12	11.9%	30%	4.04	-11.9%
Stream Reaeration	-30%	4.06	-11.4%	30%	4.99	9.0%
Headwater Flow	-30%	4.15	-9.5%	30%	4.87	6.3%
Stream Velocity	-30%	4.17	-8.9%	30%	4.84	5.7%
Initial Temperature	-2^{o}C	4.90	6.9%	2^{o}C	4.24	-7.4%
Stream Depth	-30%	4.90	6.9%	30%	4.39	-4.1%
Incremental DO	-30%	4.46	-2.6%	30%	4.7	2.6%
BOD Decay Rate	-30%	4.66	1.7%	30%	4.5	-1.7%
Headwater CBOD	-30%	4.65	1.5%	30%	4.51	-1.5%
Wasteload Flow	-30%	4.64	1.4%	30%	4.52	-1.4%
Wasteload DO	-30%	4.52	-1.2%	30%	4.64	1.2%
Incremental Inflow	-30%	4.53	-1	30%	4.62	1.0%
NBOD Decay	-30%	4.61	0.7%	30%	4.55	-0.6%
Headwater NBOD	-30%	4.61	0.6%	30%	4.55	-0.6%
Incremental CBOD	-30%	4.59	0.1%	30%	4.57	-0.1%
Incremental NBOD	-30%	4.58	0.1%	30%	4.58	-0.1%
Wasteload CBOD	-30%	4.58	0%	30%	4.58	0.0%
Wasteload NBOD	-30%	4.58	0%	30%	4.58	0.0%
Lower Boundary DO	-30%	4.58	0%	30%	4.58	0.0%
Lower Boundary NBOD	-30%	4.58	0%	30%	4.58	0.0%
Lower Boundary CBOD	-30%	4.58	0%	30%	4.58	0.0%
Stream Dispersion	-30%	4.58	0%	30%	4.58	0.0%

7. Conclusions

The percent reductions of man-made nonpoint sources that are required by this TMDL to maintain a minimum DO of 5.0 mg/L under critical conditions are 86% for summer and 0% for winter.

This subsegment was listed as impaired due to nutrients as well as organic enrichment / low DO. This TMDL establishes load limitations for oxygen-demanding substances and goals for reduction of those pollutants. LDEQ's position, as stated in the declaratory ruling issued by Dale Givens regarding water quality criteria for nutrients (Sierra Club v. Givens, 710 So.2d 249 (La. App. 1st Cir. 1997), writ denied, 705 So.2d 1106 (La. 1998), is that when oxygen-demanding substances are controlled and limited in order to ensure that the dissolved oxygen criterion is supported, nutrients are also controlled and limited. The implementation of this TMDL through wastewater discharge permits and implementation of best management practices to control and reduce runoff of soil and oxygen-demanding pollutants from nonpoint sources in the watershed will also control and reduce the nutrient loading from those sources.

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 nonpoint source 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 four-year cycle. Long-term trend monitoring sites at various locations on the larger rivers and Lake Pontchartrain are sampled throughout the four-year cycle. Sampling is conducted on a monthly basis to yield approximately 12 samples per site each year the site is monitored. Sampling sites are located where they are considered to be representative of the waterbody. Under the current monitoring schedule, approximately one half of the state's waters are newly assessed for 305(b) and 303(d) listing purposes for each biennial cycle with sampling occurring statewide each year. The four-year cycle follows an initial five-year rotation which covered all basins in the state according to the TMDL priorities. 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.

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8. References

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

EPA. 1999. Louisiana's 1999 Court Ordered Section 303(d) List. Downloaded from LDEQ website (www.deq.state.la.us/technology/tmdl/303dlist.pdf).

FTN 2004a. Bayou Segnette TMDL for Biochemical Oxygen Remanding Substances. Report prepared for LDEQ by FTN Associates. Final report dated April 9, 2004.

FTN 2004b. Bayou Verret, Bayou Chevreuil, Bayou Citamon, and Grand Bayou TMDL for Biochemical Oxygen-Demanding substances. Report prepared for LDEQ by FTN Associates. Draft report March 4, 2004.

FTN 2004c. Bayou Boeuf, Halpin Canal, Theriot Canal, and Lake Boeuf TMDLs for Biochemcial Oxygen demanding substances. Prepared for LDEQ by FTN Associates. Draft report dated March 4, 2004

LDEQ 2003a. Louisiana Final 2002 303(d) List. Dated August 20, 2003. Downloaded from LDEQ website (http://www.deq.state.la.us/technology/tmdl/303dlist-2002-final.pdf).

LDEQ. 2003b. Louisiana TMDL Technical Procedures Manual. Revised by R.K. Duerr and M.U. Aguillard. Engineering Group 2, Louisiana Department of Environmental Quality, Baton Rouge, LA: September 22, 2003.

LDEQ. 2003c. Environment Regulatory Code. Part IX. Water Quality Regulations. Chapter 11. Surface Water Quality Standards. § 1123. Numerical Criteria and Designated Uses. Printed from LDEQ website (www.deq.state.la.us/planning/regs/title33/33v09.pdf).

Smythe, E. deEtte. 1999. Overview of the 1995 and 1996 Reference Streams. Prepared for Louisiana Department of Environmental Quality, Baton Rouge, LA: June 28, 1999.

Wiland, B. L. and K. LeBlanc. 2002. LA-QUAL for Windows User's Manual, Model Version 6.02, Manual Revision H. Wiland Consulting, Inc. and Louisiana Department of Environmental Quality. June 25, 2002.