BAYOU COURTABLEAU WATERSHED TMDL FOR DISSOLVED OXYGEN

SUBSEGMENT 060204

TMDL Report

Jeff Baker
William C. Berger, Jr.
Jay Carney
Karen LeBlanc

Engineering Section 2
Environmental Technology Division
Office of Environmental Assessment
Louisiana Department of Environmental Quality

January 24, 2000

EXECUTIVE SUMMARY

A TMDL for dissolved oxygen has been developed for the Bayou Courtableau Watershed based on hydrologic and water quality data available as of November, 1999. Bayou Courtableau was listed on both the 1996 and 1998 Section 303(d) Lists as not meeting the water quality standard for dissolved oxygen. Bayou Courtableau was ranked as high priority (priority 1) on both lists for development of a total maximum daily load (TMDL).

The Bayou Courtableau watershed is subsegment 060204 of the Vermilion-Teche River Basin (Basin 6). Subsegment 060204 is comprised of Bayou Courtableau and all tributaries, including Bayou Carron, Bayou Wauksha, Grand Gully, and numerous unnamed tributaries west of Bayou Teche; and Little Bayou Darbonne, Big Bayou Darbonne, 3 Diversion Canals, and numerous unnamed tributaries east of Bayou Teche. The west and east sections of Bayou Courtableau come together near Port Barre and flow into Bayou Teche.

Bayou Courtableau has been extensively hydromodified in all reaches west and east of Bayou Teche. The bayou and its tributaries are dominated by corn, soybean, and milo propagation. All of these conditions have inhibited the bayou's natural processes, including reaeration and fish propagation (Smythe and Malone, 1989a-a, 1990).

The current state standard requires a DO of 5.0 mg/L throughout the year. A UAA has been proposed changing the DO standard for Bayou Courtableau to 4.0 mg/L June-August and 5.0 mg/L September-May. Therefore, model projections were performed at those particular seasons and DO criteria. In addition, projections were performed at the current year-round DO criterion of 5.0 mg/L using a summer season of May-October and a winter season of November-April. Projections show that compliance with the current dissolved oxygen criteria will require a 30% reduction of man-made nonpoint loading year-round. In order to meet the proposed DO criteria, a 15% reduction of man-made nonpoint loading is required year-round.

Several point sources fall within the subsegment; these facilities were deemed either intermittent stormwater or minor discharges and were represented in the nonpoint loading via benthic loads. Limits for these small facilities are generally set by state policy.

West Bayou Courtableau was modeled from its headwaters with Bayou Boeuf and Bayou Cocodrie (River Kilometer 21.6) to its confluence with Bayou Teche (River Kilometer 0.00). West Bayou Courtableau was modeled because the water quality along this portion of Bayou Courtableau was not meeting the 5.0 mg/L dissolved oxygen standard at the City of Washington. East Bayou Courtableau from Bayou Teche to the West Atchafalaya Borrow Pit Canal was not modeled because of the addition of the Teche-Vermillion Fresh Water District Pumping Station. All of the flow from the eastern

section of Bayou Courtableau is influenced by the large amount of water being pumped into Bayou Courtableau from the Atchafalaya River. The water quality on East Bayou Courtableau is different from West Bayou Courtableau because it is coming from the Atchafalaya River. There are 5 pumps, each having a capacity to pump 260 cfs. The number of pumps used at any one time depends on seasonal stage elevations. Also, during drought conditions, the amount of water pumped through varies. Because of the water quality differences, the permanent man-alterations, and the unpredictable fluctuations in flow, East Bayou Courtableau was not included in this TMDL.

A survey was conducted (July 27-28, 1999) during a period of very dry weather. The Bayou Courtableau watershed was in a condition of low flow. There were no tributaries that had a velocity that could be measured with typical survey equipment. Consequently, none of the tributaries were included in the model. The nonpoint source loads included headwater loading and other nonpoint loading not associated with flow.

The various spreadsheets that were used in conjunction with the modeling program may be found in the appendices in the order in which they were used. The flow calibration was based on measurements taken during the low flow watershed survey (July 27-28, 1999), and on flows at USGS station 07382500 corresponding to the low flow watershed survey. Water quality calibration was also based on measurements taken during the survey. Projections were adjusted to meet the dissolved oxygen criteria by reducing man-made nonpoint source loads.

Land use in the Bayou Courtableau watershed is fairly homogeneous. It is 63.77 percent agriculture, principally corn, soybean, and milo farming. TMDLs have been calculated for the western portion of Bayou Courtableau and are presented in the following tables. Due to the many assumptions made while developing the model, the inherent error within the model algorithms, and the scale of a watershed-based model, the results of the model should be used only as an aid in making water quality based decisions.

Proposed Standard:	Summer season (Jun - Aug)		Winter season (Sep - May)	
	Load (lbs/day)	% of TMDL	Load (lbs/day)	% of TMDL
Headwater/Tributary Loads	6,374.1	19	7,461.2	21
Benthic Loads	27,623.9	81	27,623.9	79
Reduction of man-made nonpoint	15.0 %		15.0 %	
Nonpoint source margin of safety (MOS)	0 %		0 %	
Total maximum daily load (TMDL)	33,998	100.0	35,085	100.0

Current Standard:	Summer season (May - Oct)		Winter season (Nov - Apr)	
	Load (lbs/day)	% of TMDL	Load (lbs/day)	% of TMDL
Headwater/Tributary Loads	6,374	21	9,095	28
Benthic Loads	23,369	79	23,369	72
Reduction of man-made nonpoint	30%		30%	
Nonpoint source margin of safety (MOS)	0		0	
Total maximum daily load (TMDL)	29,743	100	32,464	100

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

Subsegment 060204
J. Baker, W.C. Berger, Jr., J. Carney, K. LeBlanc
Originated: January 24, 2000

1.0 Introduction

Bayou Courtableau, Segment 060204 of the Vermillion-Teche Basin, is listed on the 1996 and 1998 303(d) lists as being impaired due to organic enrichment/low DO and requiring the development of a total maximum daily load (TMDL) for dissolved oxygen. A calibrated water quality model for the Bayou Courtableau watershed was developed and projections were run to quantify the nonpoint source load allocations (LAs) required to meet established dissolved oxygen criteria. This report presents the model development and results.

2.0 Study Area Description

2.1 Vermilion-Teche Basin

The Vermilion-Teche River Basin lies in south-central Louisiana. The upper end of the basin lies in the central part of the state near Alexandria, and the basin extends southward to the Gulf of Mexico. The basin is bordered on the north and northeast by a low escarpment and the lower end of the Red River Basin. The Atchafalaya River Basin is to the east, and the Mermentau River Basin is to the west (LA DEQ, 1996).

2.2 Bayou Courtableau Watershed, Subsegment 060204

This area is typical of the basin and is primarily used for agriculture as documented in Table 1 (LADEQ, 1999). Segment 060204 is comprised of Bayou Courtableau as the main stem with several tributaries. The modeled portion of Bayou Courtableau receives intermittent flow from the following tributaries: Bayou Carron, Bayou Wauksha, and several unnamed tributaries.

Average annual precipitation in the segment, based on the nearest Louisiana Climatic Station in Crowley, is 56.91 inches based on a 30-year record (LSU, 1999). Land use in the Vermilion-Teche Basin is largely agricultural, the primary crops being corn, soybeans, and milo. In the segment under study, agricultural uses account for 63.77% of the total segment area. Land uses in Segment 060204 are shown in Table 1 below (LA DEQ, 1999).

Table 1. Land uses in Subsegment 060204 of the Vermilion-Teche Basin

Land use	Acres	%
Urban	125	0.1
Rangeland	163	0.1
Agricultural	76,742	63.8
Forest Land	221	0.2
Water	4,775	4.0
Wetland	38,319	31.8

2.3 Water Quality Standards

Water quality standards for the State of Louisiana have been defined (LA DEQ, 1999). The standards are defined according to designated uses of the waterbodies. Both general narrative standards and numerical criteria have been defined. General standards include prevention of objectionable color, taste and odor, solids, toxics, oil and grease, foam, and nutrient conditions as well as aesthetic degradation. The numerical criteria are shown in Table 2.

Designated uses for Bayou Courtableau from its headwaters to the West Atchafalaya Borrow Pit Canal (waterbody subsegment 060204) include primary contact recreation, secondary contact recreation, and propagation of fish and wildlife.

Bayou Courtableau is listed on the 1996 and 1998 303(d) lists as a waterbody requiring a dissolved oxygen TMDL. Section 303(d) of the Clean Water Act requires the identification, listing, ranking and development of TMDLs for waters that do not meet applicable water quality standards after implementation of technology-based controls. Current dissolved oxygen criteria are shown in Table 3. Waterbodies are placed on the 303(d) list based on the comparison of data from ambient monthly samples and the criteria. Due to diurnal variations in dissolved oxygen, the time in which the assessment samples were taken was an important factor. Algae and macrophytes that produce dissolved oxygen in the water column in the presence of sunlight (photosynthesis) and utilize dissolved oxygen in the absence of sunlight (respiration) cause diurnal variations in dissolved oxygen. This process can cause the dissolved oxygen levels of the water to be depressed during the morning hours and elevated during the evening hours. Either extreme is not representative of the stream. It is uncertain if the samples that were used to assess Bayou Courtableau and place it on the 303(d) waterbody list were representative of the stream or the diurnal effects of algae and macrophytes. Instead of individual samples, time-weighted averages based on a 24-hour time period may be a better representation of the stream.

Table 2. Current Numerical Criteria for Bayou Courtableau (LA DEQ, 1999)

Parameter	Criteria
Cl, mg/L	40
SO_4, mg/L	30
pH	6.0-8.5
BAC	Primary Contact
Temperature, deg Celsius	32
TDS, mg/L	220

Table 3. Dissolved Oxygen Criteria, (mg/L)

Year-round (current standard)	5.0
June-August (proposed)	4.0
September-May (proposed)	5.0

2.4 Discharger Inventory

All of the dischargers located in this watershed are small and need not be included in a model of this scale because it is unlikely that they are having an impact on the targeted waterbody due to the small load and/or the distance from the waterbody named in the 303(d) lists. These dischargers are accounted for as nonpoint loading through the process of calibration. They fall within one of several state or regional policies that govern permit limitations. Current permit information and discharge monitoring reports were reviewed for all of these facilities.

2.5 Previous Studies and Other Data

The majority of the data used for this project was obtained during a watershed survey conducted on July 27-28, 1999. Additional cross-sections were obtained during a following survey conducted in December 1999.

Discharge data, cross-section data, field data, and lab water quality data from the watershed survey are presented in Appendix C. The Ultimate BOD plots are also in Appendix C.

3.0 Documentation of Calibration Model

3.1 Model Description and Input Data Documention

3.1.1 Program Description

The model used for this TMDL was LA-QUAL, a steady-state one-dimensional water quality model. Its history dates back to the QUAL-I model developed by the Texas Water Development Board with Frank D. Masch & Associates in 1970 and 1971. William A. White wrote the original code.

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

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

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

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

3.1.2 Model Schematic or Vector Diagram

A vector diagram of the modeled area is presented in Appendix A. The vector diagram shows the reach/element design and the locations of major tributaries. A digitized map of the stream showing river kilometers, locations of cross-sections and July, 1999 survey sampling sites is included in Appendix F.

3.1.3 Hydrology and Stream Geometry and Sources

The USGS has historical daily flow estimates for a station on Bayou Courtableau at the City of Washington. LADEQ has a monthly water quality sampling station at the City of Washington. Calibration flows were determined from flow measurements taken during the July, 1999 survey.

Data collected during an Eularian survey conducted July 27-28, 1999, was used to establish the input for the model calibration and is presented in Appendix C.

The reach and element design for the Bayou Courtableau model was made using a 0.20 km element length. The total number of reaches and elements was within the limitations of the model. “The current version is dimensioned for a maximum of 200 reaches, 100 headwaters, 300 wasteloads and 3000 elements" (LA-QUAL User's Manual). The final design incorporated 4 reaches, 1 headwater, and 108 elements. A simple spreadsheet was used to calculate the reach length, element length, and cumulative number of elements at the bottom of each reach. This spreadsheet is presented in Appendix A.

Rather than directly inputting the widths and depths of the stream, the model requires that the advective hydraulic characteristics (a modification of the Leopold Coefficients and Exponents) be entered. In reviewing the stream hydrology from the three surveys done in 1999 as well as the USGS Flow Station on Bayou Courtableau, it was determined that the waterbody's width and depth are not dependent on the flow rate. Since the depths and widths are basically consistent during critical flow periods, the model's reach coefficients and exponents were set to zero and the measured widths and depths from the three hydrologic surveys were input as the modified Leopold equation constants.

Since Bayou Courtableau is characterized by frequent flow reverses and is deep, wide and very sluggish especially at low flows, the dispersive hydraulic coefficients were used for reaches three and four. Most of the tidal dispersion was assumed to be near Bayou Teche where the flow from East Bayou Courtableau is combining with West Bayou Courtableau. During critical flow periods, the East Bayou Courtableau flow rate is the primary flow into Bayou Teche and occasionally backs up into West Bayou Courtableau.

3.1.4 Headwater

Bayous Boeuf and Cocodrie are combined to form a headwater to the model. A flow measurement was made at their confluence during the July, 1999 survey and is the headwater flow for the calibration model. The headwater water quality was taken from the July, 1999 survey. Summaries and copies of selected data are presented in Appendix C.

3.1.5 Water Quality Input Data and Their Sources

Water quality data collected on July 27-28, 1999 on Bayou Courtableau and its tributaries was entered in a spreadsheet for ease of analysis. The Louisiana GSBOD program was applied to the 20-day suppressed BOD data in the spreadsheet, and the ultimate BOD was computed for each sample taken. A complete listing is presented in Appendix C. The NBOD values were derived from TKN data, and the decay and settling rates were based on the Texas "Waste Load Evaluation Methodology" document for Organic Nitrogen (Org-N). This data was the primary source for the model calibration input data for initial conditions, decay rates, incremental temperature, incremental DO, headwater temperature, and headwater DO.

3.1.5.1 Temperature Correction of Kinetics, Data Type 4

The temperature values computed are used to correct the rate coefficients in the source/sink terms for the other water quality variables. These coefficients are input at 20 ^{o}C and are then corrected to temperature using the following equation:

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

Where:

X_T = the value of the coeffieicnt at the local temperatue T in degrees Celsius
X_{20} = the value of the coefficient at the standard temperature at 20 degrees Celsius
Theta = an empirical constant for each reaction coefficient
(QUAL2E Documentation and User Model, 1987)

The temperature correction factor specified in the LTP for benthal oxygen demand of 1.065 was entered in the model. In absence of specified values for data type 4, the model uses default values. A complete listing of these values can be found in the LA-QUAL for Windows User's Manual (LDEQ, 1999).

3.1.5.2 Initial Conditions, Data Type 11

The initial conditions are used to reduce the number of iterations required by the model. The values required for this model were temperature and DO by reach. The initial condition input values were determined from the July, 1999 survey stations located on Bayou Courtableau. See Appendix C for a composite of the survey water quality data.

3.1.5.3 Reaeration Rates, Data Type 12

The average depths and low velocities for Bayou Courtableau do not meet the depth and velocity limitations for the reaeration equations available. Therefore, the reaeration rates were determined through calibration.

3.1.5.4 Sediment Oxygen Demand, Data Type 12

Values of SOD from the LTP were used in several preliminary calibration runs. These values have been established for wasteload allocation modeling of short stream reaches directly below treatment plant outfalls and were not suitable for a watershed level model. SOD values were therefore achieved through calibration. The values were determined to be zero. This was probably a result of the deeper waters of Bayou Courtableau.

3.1.5.5 Carbonaceous BOD Decay and Settling Rates, Data Type 12

These rates are labeled Aerobic BOD Decay and BOD Settling in LA-Qual. The BOD decay and settling rates were taken from the Texas "Waste Load Evaluation Methodology", page D-14. The decay and settling rates used for each reach are shown in Appendix A.

3.1.5.6 Nitrogenous Decay and Settling Rates, Data Type 13

These rates are labeled NCM decay and NCM Settling in LA-QUAL. The decay and settling rates used were based on the Texas "Waste Load Evaluation Methodology" guidelines for Org-N. These rates were not modified during calibration. The Org-N decay and settling rates were used to the simulate NBOD rates because the Org-N decay rate is the limiting rate in the nitrogen cycle and is the part of NBOD that is settleable. The decay and settling rates used for each reach are shown in Appendix A.

3.1.5.7 Incremental Conditions, Data Types 16, 17, and 18

The incremental conditions are used in the calibration to represent nonpoint source loads associated with flows. Due to the extreme dry weather during the July, 1999 survey no incremental flows were detected. Therefore, it was determined that incremental flow would not be present at critical conditions and was not included in the calibration nor the projections.

3.1.5.8 Nonpoint Sources, Data Type 19

Nonpoint source loads, which are not associated with a flow, are input into this part of the model. These loads are used to simulate loads from the stream bed that have been resuspended into the water column. The values used in the model were determined via calibration. Their load equivalents in (g O_2/m^2-day) were comparable to values found in the other models recently performed on the Mermentau Basin. These nonpoint sources could include agricultural loading, industrial stormwater loading, and natural background benthic materials. The data and sources are presented in Appendix A.

3.1.5.9 Headwaters, Data Types 20, 21, and 22

The headwater values were determined from the July, 1999 survey site just below the confluence of Bayou Boeuf and Bayou Cocodrie. The data and sources are presented in Appendix A.

3.1.5.10 Wasteloads, Data Types 24, 25, and 26

The model uses wasteloads to represent treatment plant effluent or unmodeled tributaries. None of the tributaries were found to have flow and therefore, not modeled. There were no significant dischargers on the mainstem.

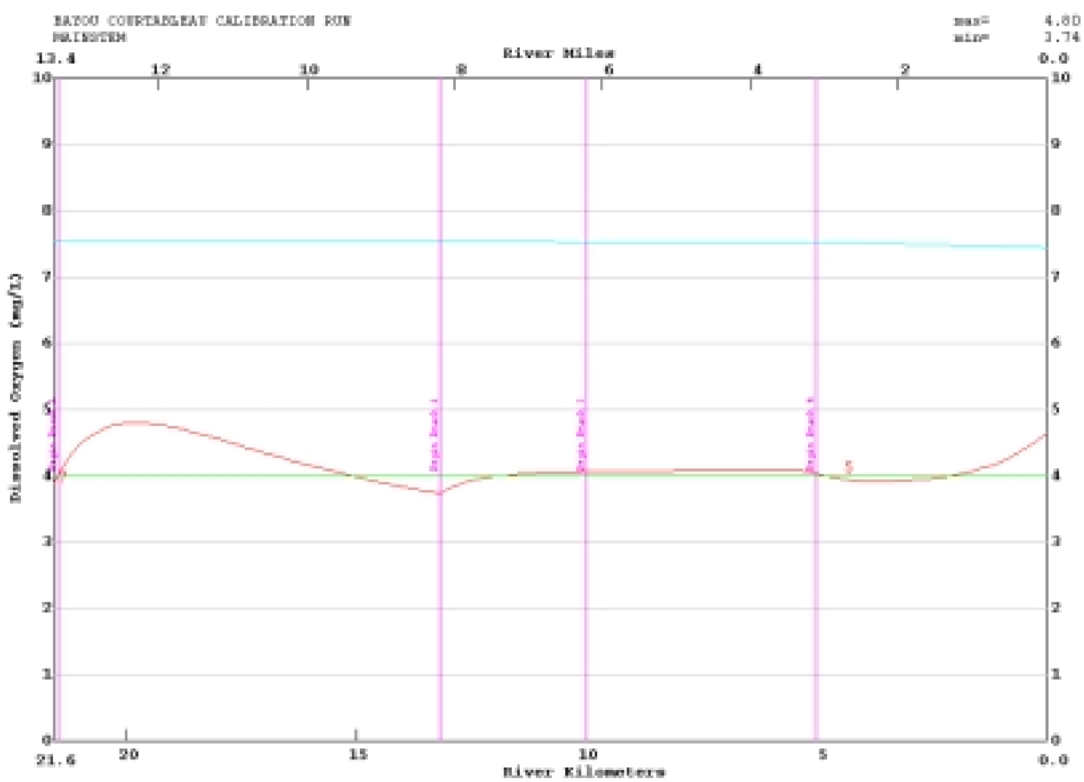
3.1.5.11 Boundary Conditions, Data Type 27

The lower boundary conditions were assumed to be equivalent to the measurements taken at the July, 1999 survey station located at the confluence of Bayou Teche with Bayou Courtableau. This station was near the location of the model boundary.

3.2 Model Discussion and Results

The calibration model input and output is presented in Appendix A. The overlay plotting option was used to determine if calibration had been achieved. A plot of the dissolved oxygen concentration versus river kilometer is presented in Figure 1.

Figure 1. Calibration Model--Dissolved Oxygen versus River Kilometer



West Bayou Courtableau main stem extends from the confluence of Bayou Boeuf and Bayou Cocodrie to the confluence with Bayou Teche and is represented by Reaches 1 - 4. The model simulates the measured values of DO adequately at the one meter depth. The survey data shows that in July 1999, the current DO standard of 5.0 mg/L was not being met on the modeled portion of Bayou Courtableau. The calibration model went through the measured survey data values using reasonable model input values and was determined to be a reasonable calibration.

4.0 Water Quality Projections

The traditional summer and winter projections loading scenarios were performed for both the current DO standard as well as the proposed standard. These scenarios were:

a. Summer Projection Scenario – Reduced man-made nonpoint loads at summer season critical conditions.
b. Winter Projection Scenario – Reduced man-made nonpoint loads at winter season critical conditions.

It was not necessary to run the no load scenario because there were no point source dischargers located on this stream. The DO criteria in both the current and proposed standards were achieved with less than 100% reduction.

4.1 Critical Conditions

4.1.1 Seasonality and Margin of Safety

The Clean Water Act requires the consideration of seasonal variation of conditions affecting the constituent of concern, and the inclusion of a margin of safety (MOS) in the development of a TMDL. For the Bayou Courtableau TMDL, LDEQ has employed an analysis of its long-term ambient data to determine critical seasonal conditions and used a combination of implied and explicit margins of safety.

Critical conditions for dissolved oxygen were determined for the Mermentau Basin using long-term water quality data from six stations on the LDEQ Ambient Monitoring Network and the Louisiana Office of State Climatology water budget. Graphical and regression techniques were used to evaluate the temperature and dissolved oxygen data from the Ambient Network and the run-off determined from the water budget. Since nonpoint loading is conveyed by run-off, this seemed 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 nonpoint 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 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.

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

LDEQ simulated critical summer conditions in the Bayou Courtableau dissolved oxygen TMDL projection modeling by using the annual 7Q10 flow or 0.1 cfs, whichever is higher, for all headwaters, and 90th percentile temperature for the summer season. Incremental flow was assumed to be zero; model loading was from headwater loading; and benthal loading as sediment oxygen demand and resuspension of NBOD and CBOD. LDEQ simulated critical winter conditions by using the lowest of the monthly 7Q10 flow published for the winter months or 1 cfs, whichever was higher, for all headwaters, and 90th percentile temperature for the season. Again, incremental flow was assumed to be zero. Several point sources fall within the subsegment; these facilities were deemed either intermittent stormwater or minor discharges and were represented in the nonpoint loading as benthic loads.

In reality, the highest temperatures occur in July-August, and the lowest stream flows occur in October-November. The combination of these conditions plus the impact of other conservative assumptions regarding rates and loadings yields an implied margin of safety, which is estimated to be in excess of 10%.

4.1.2 Hydrology and Stream Geometry and Sources

The headwater flows used in all the projection scenarios were based on the critical 7Q10 flows from the USGS station at Washington. All incremental flows were assumed to be zero during critical flow periods. This assumption was based on the survey data taken at near critical conditions.

Rather than directly inputting the widths and depths of the stream, the model requires that the advective hydraulic characteristics (a modification of the Leopold Coefficients and Exponents) be entered. In reviewing the stream hydrology from the three surveys done in 1999 as well as the USGS Flow Station on Bayou Courtableau, it was determined that the waterbody’s width and depth are not dependent on the flow rate at critical conditions.

Since the depths and width are basically consistent during critical flow periods, the model's reach coefficients and exponents were set to zero and the measured widths and depths from the three hydrologic surveys were input as the modified Leopold equation constants.

Since Bayou Courtableau is characterized by flow reversals and is deep, wide and very sluggish especially at low flows, the dispersive hydraulic coefficients were used in reaches three and four. Most of the tidal dispersion was assumed to be near Bayou Teche where the flow from East Bayou Courtableau is combining with West Bayou Courtableau. During critical flow periods, the East Bayou Courtableau flow rate is the primary flow into Bayou Teche and occasionally backs up into West Bayou Courtableau.

4.1.3 Water Quality Input Data and Their Sources

The initial conditions temperatures were set to the 90th percentile critical season temperature in accordance with the LTP. Critical temperatures for each season were determined from the temperature data collected by LADEQ as part of its historical and current ambient monitoring strategy. The 90th percentile temperature for each season was computed for LADEQ water quality ambient station #0102 on Bayou Courtableau at Washington, LA from 1988 to 1997. This represents ten years of record. The temperature analysis spreadsheet is shown in Appendix B. The dissolved oxygen values for the initial conditions were set at 90% of the DO saturation at the 90th percentile temperature for the season.

The CBOD decay and settling rates as well as the NBOD decay and settling rates, were held constant at the calibration rates. The reaeration rates determined from calibration were used in the projections. The data and calculations are shown in Appendix B.

The incremental conditions are normally used in the calibration to represent nonpoint source loads associated with flows. For the projection and scenario runs, the incremental flows were set to zero to emulate the critical conditions for dissolved oxygen. Any small flows, such as individual sewage package plants are assumed to be susceptible to evaporation or groundwater recharge.

The headwater UCBOD and UNBOD used in all the projection scenarios were taken from the July 1999 survey data. The temperature used was the 90th percentile critical season temperature determined from the LADEQ ambient monitoring station on Bayou Courtableau at the City of Washington (Site # 0102). The DO was 90% of the DO saturation at the 90th percentile temperature for the season determined from the same site. The period of record used was 1988-1997.

The lower boundary conditions were set to the 90th percentile critical season temperature in accordance with the LTP. Critical temperatures for each season were determined from the temperature data collected by LADEQ as part of its historical and current ambient monitoring strategy. The 90th percentile temperature for each critical season was computed for LADEQ water quality ambient station on Bayou Courtableau east of Port Barre (Site #0101). The period of record used was 1985-1990. Only 5 years was used because of the significant changes taking place in this waterbody as of 1984 when the pumping station was added upstream of the confluence of Bayou Courtableau and Bayou Teche. No data was available after 1990 for this station. The temperature spreadsheets are shown in Appendix D.

4.1.3.1 Sediment Oxygen Demand, Data Type 12

In the summer, and winter projections, the man-made SOD was set to zero as per calibration.

4.1.3.2 Nonpoint Sources, Data Type 19

The resuspended man-made CBOD and NBOD loading was reduced by 30% (current DO criteria) and 15% (proposed DO criteria) in both the summer and winter projection scenarios. These reductions were determined using the calibrated values for Nonpoint CBOD & NBOD and the total benthic natural loading of 2.0 gm O2/m2/day. A percentage of each loading component was calculated by comparison to the total calibration benthic value. The natural benthic value was subtracted from the total calibration benthic load to determine the man-made benthic loading value. These percentages were then applied to the 70% (current DO criteria) and 85% (proposed DO criteria) of man-made loading value, and the CBOD and NBOD loading portions of the reduced man-made benthic loading were determined by adding the CBOD and NBOD portions of the man-made benthic loading to the CBOD and NBOD portions, respectfully, of the background benthic loading. These calculations are shown in Appendix B. The value and sources of CBOD and NBOD for each projection run are presented in Appendix B.

4.1.3.3 Wasteloads, Data Types 24, 25, and 26

There were no wasteloads entered into the model.

4.2 Projection Model Discussion and Results

The projection model inputs and output data sets are presented in Appendix B.

4.2.1 Summer Projections

Summer projections were run for both the current standard of 5.0 mg/L May-October and the proposed standard of 4.0 mg/L June-August. In order to meet the 5.0 mg/L standard, a 30% reduction of man-made nonpoint sources is necessary. As shown in the output graph, the bayou meets the dissolved oxygen criterion. The minimum DO on the main stem is 5.06 mg/L from RK 2.2 to 2.6. A graph of the dissolved oxygen concentration versus river kilometer for the summer projection is presented in Figure 2.

In order to meet the 4.0 mg/L standard, a 15% reduction of man-made nonpoint sources is necessary. As shown in the output graph, the bayou meeets the dissolved oxygen criterion. The minimum DO on the main stem is 4.55 mg/L from RK 2.0 to 2.2. A graph of the dissolved oxygen concentration versus river kilometer for the summer projection is presented in Figure 3.

Figure 2. Summer Projection Model--Dissolved Oxygen versus River Kilometer

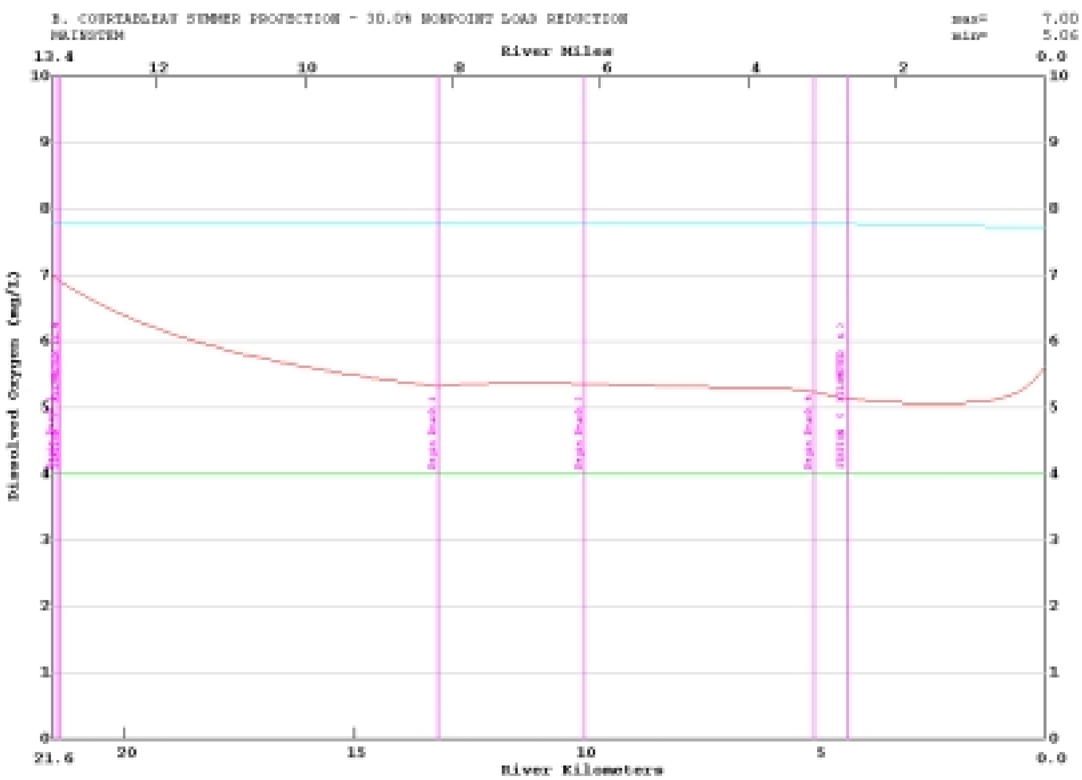
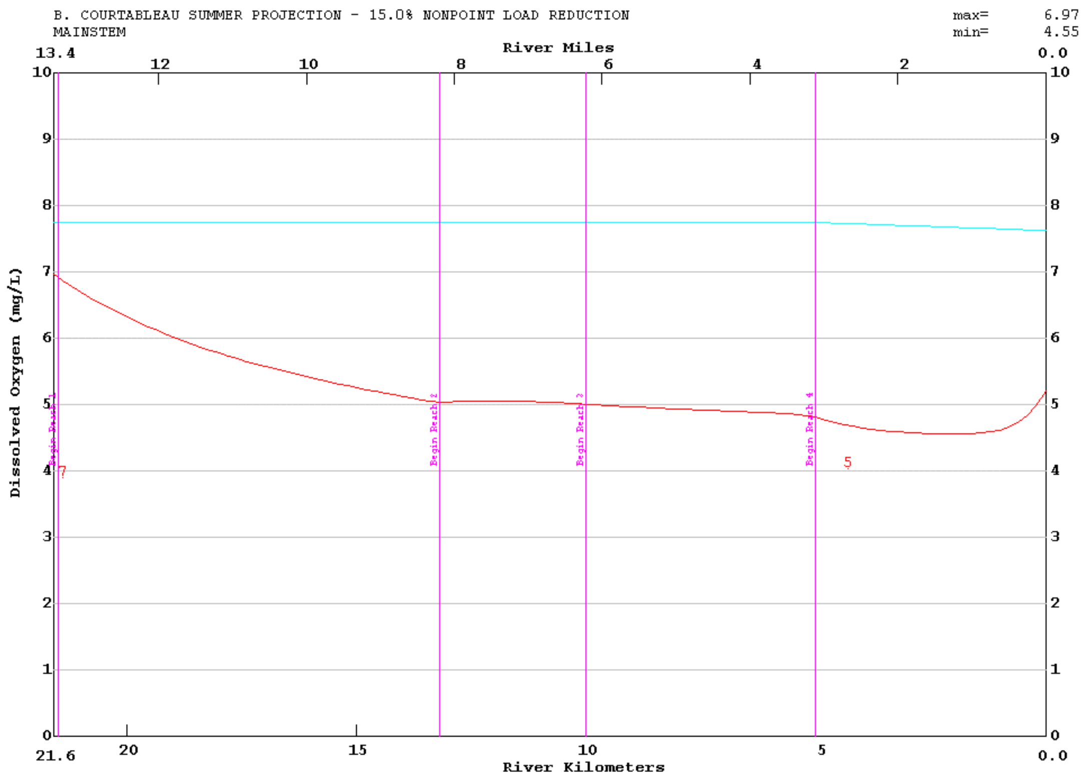


Figure 3. Summer Projection Model--Dissolved Oxygen versus River Kilometer



4.2.2 Winter Projection

Winter projections were run at both the current and proposed standards. The current standard is 5.0 mg/L November-April, and the proposed standard is 5.0 mg/L September-May. In order to meet the November-April standard, a 30% reduction of man-made nonpoint sources is required. As shown in the output graph, the bayou meets the DO criterion. The minimum DO on the main stem is 6.51 mg/L from RK 1.4 to 2.2. A graph of the dissolved oxygen concentration versus river kilometer is presented in Figure 4.

In order to meet the September-May criterion, a 15% reduction of man-made nonpoint sources is necessary. As shown in the output graph, the bayou meets the DO criterion. The minimum DO on the main stem is 5.09 mg/L from RK 1.2 to 1.0. A graph of the dissolved oxygen concentration versus river kilometer is presented in Figure 5.

Figure 4. Winter Projection Model--Dissolved Oxygen versus River Kilometer

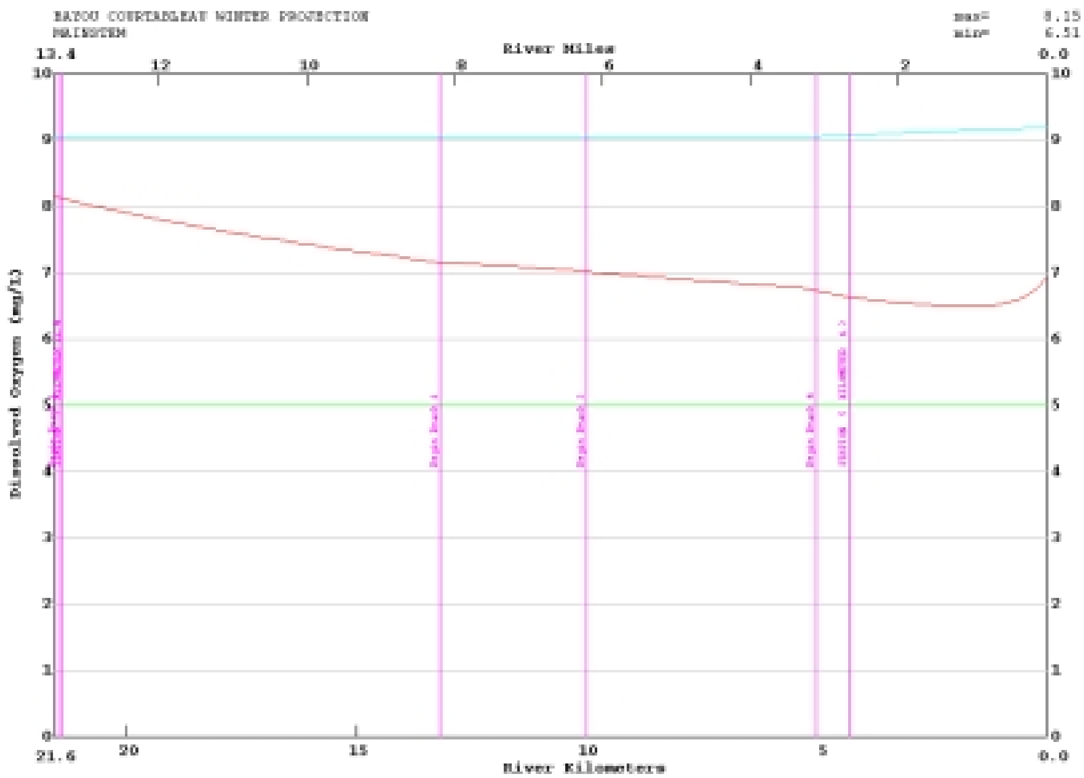
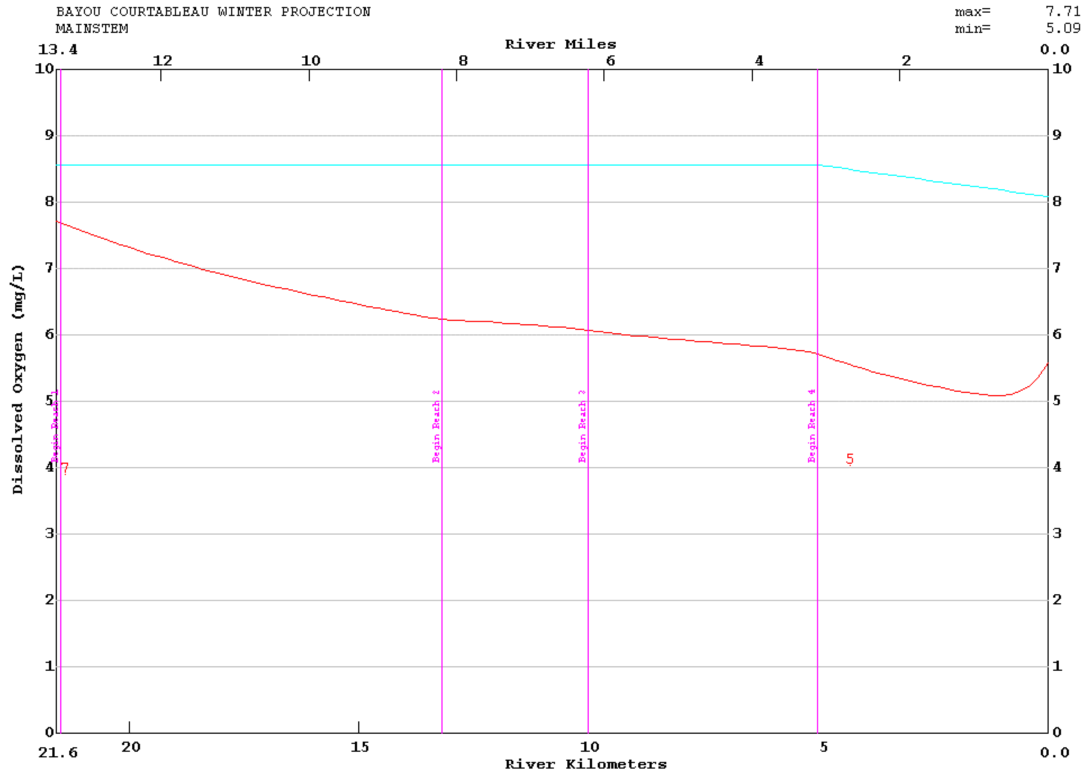


Figure 5. Winter Projection Model--Dissolved Oxygen versus River Kilometer



4.3 Calculated TMDLs, WLAs and LAs

TMDLs have been calculated for the summer and winter projection runs. They are presented in Appendix E. The winter TMDL is in this case greater than the summer TMDL because of the higher flow rate of the headwater. A summary of the loads is presented in Tables 4 and 5.

Table 4. Seasonal Total Maximum Daily Load Summaries—Proposed Criteria

ALLOCATION	SUMMER (JUN-AUG) DO criterion=4.0 mg/L (lbs/day)	WINTER (SEP-MAY) DO criterion=5.0 mg/L (lbs/day)
Point Source WLA	0	0
Point Source Reserve MOS	0	0
Natural/Manmade Nonpoint Source LA	27,623.9	27,623.9
Headwater/Tributary Source LA	6,374.1	7,461.2
TMDL = WLA + LA + MOS	33,998.0	35,085.1

Table 5. Seasonal Total Maximum Daily Load Summaries—Current Criteria

ALLOCATION	SUMMER (MAY-OCT) DO criterion=5.0 mg/L (lbs/day)	WINTER (NOV-APR) DO criterion=5.0 mg/L (lbs/day)
Point Source WLA	0	0
Point Source Reserve MOS	0	0
Natural/Manmade Nonpoint Source LA	23,369	23,369
Headwater/Tributary Source LA	6,374	9,095
TMDL = WLA + LA + MOS	29,743	32,464

4.3.1 Outline of TMDL calculations

An outline of the TMDL calculations is provided to assist in understanding the calculations in the Appendices. Slight variances may occur based on individual cases.

- The natural background benthic loading was estimated from reference stream NBOD, CBOD, and SOD data.
- The calibration anthropogenic (man-made) benthic loading was determined as follows:
  - Calibration nonpoint CBOD and NBOD (resuspension), and SOD were summed for each reach as gm O_2/m^2-day to get the total calibration benthic loading.
  - The natural background benthic loading was subtracted from the total calibration benthic loading to get the total anthropogenic (man-made) calibration benthic loading.
- Projection runs were made with:
  - Point sources represented at 125% of design flow (based on Department of Health design criteria) to provide an explicit 20% margin of safety for point source loading.
  - Headwater flows at seasonal 7Q10 or 0.1(summer)/1.0(winter) cfs, whichever was greater.
  - Headwater concentrations of CBOD, NBOD, and DO at calibration levels.
- For each reach, the nonpoint CBOD and NBOD (resuspension) were adjusted to bring the projected in-stream dissolved oxygen in compliance with criteria. No additional explicit margin of safety was employed for nonpoint loading. The loading capacity and percent reduction of nonpoint were calculated as follows:
  - The total projection benthic loading at 20^{o}C was calculated as the sum of projection NBOD, CBOD, and SOD expressed as gm O_2/m^2-day.

  - The natural background benthic loading was subtracted from the total projection benthic loading to get the total anthropogenic (man-made) projection benthic loading.
  - The total anthropogenic projection benthic loading was subtracted from the total calibration anthropogenic benthic loading and that number divided by the total calibration anthropogenic benthic loading to obtain the percent reduction of nonpoint loading needed to achieve the in-stream dissolved oxygen criteria.
- ➢ The total projection benthic loading for each reach was calculated as follows:
  - The projection SOD at 20^{o}C was adjusted to stream critical temperature.
  - The projection CBOD, NBOD, and SOD were summed to get the total benthic loading at critical stream temperature in lb/d for each reach.
- ➢ The total stream loading capacity at critical stream temperature was calculated as the sum of:
  - Headwater CBOD and NBOD loading in lb/d.
  - Projection benthic loading for all reaches of the stream in lb/d.
  - Total point source CBOD and NBOD loading in lb/d.
  - The facility margin of safety.

The TMDL for the Bayou Courtableau watershed was set equal to the total stream loading capacity.

5.0 Sensitivity Analyses

All modeling studies necessarily involve uncertainty and some degree of approximation. It is therefore of value to consider the sensitivity of the model output to changes in model coefficients, and in the hypothesized relationships among the parameters of the model. The 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. The sensitivity of the model's minimum DO to these parameters is presented in Table 6. Parameters were varied by +/- 30%, except temperature, which was adjusted +/- 2 degrees Centigrade. The calibration minimum DO was 3.74 mg/L.

Table 6. Summary of Calibration Model Sensitivity Analysis

	Positive Changes in parameter			**Negative Changes in parameter**		
Parameter	% change	Minimum DO (mg/l)	Percentage Difference	% change	Minimum DO (mg/l)	Percentage Difference
Reaeration	30.0%	4.3	**15.0%**	-30.0%	2.20	**-41.2%**
Velocity	30.0%	2.85	**-23.8%**	-30.0%	4.23	**13.1%**
Depth	30.0%	4.20	**12.3%**	-30.0%	2.73	**-27.0%**
BOD Decay	30.0%	3.26	**-12.8%**	-30.0%	4.18	**11.8%**
Initial Temperature	2 deg C	3.47	**-7.2%**	-2 deg C	4.03	**7.8%**
Headwater DO	30.0%	3.74	**0.0%**	-30.0%	3.16	**-15.5%**
Baseflow	30.0%	3.90	**4.3%**	-30.0%	3.45	**-7.8%**
Headwater Flow	30.0%	3.90	**4.3%**	-30.0%	3.45	**-7.8%**
BOD Settling	30.0%	3.88	**3.7%**	-30.0%	3.59	**-4.0%**
Headwater BOD	30.0%	3.62	**-3.2%**	-30.0%	3.16	**3.2%**
Headwater NCM (NBOD)	30.0%	3.69	**-1.3%**	-30.0%	3.78	**1.1%**
NCM (NBOD) Settling Rate	30.0%	3.76	**0.5%**	-30.0%	3.71	**-0.8%**

As shown in the summary table, reaeration is the parameter to which DO is most sensitive (15.0%-41.2%). The other parameters creating major variations in the minimum DO values are Velocity (13.1%-23.8%), CBOD Decay Rate (11.8%-12.8%), Headwater DO (0%-15.5%), and Depth (12.3%-27.0%). Initial Temperature, Baseflow, Headwater Flow, Headwater CBOD, and CBOD Settling are moderately sensitive with variations ranging from 3.2% to 7.8%. The model is not overly sensitive to tidal range. The Depth sensitivity could be affected by its relationship to the Velocity.

6.0 Conclusions

The results of the summer projections show that the water quality standard for dissolved oxygen for Bayou Courtableau (WQ Subsegment 060204) of the proposed 4.0 mg/L can be maintained during the summer critical season. This can be accomplished with the imposition of a 15% reduction of man-made nonpoint sources. The current summer DO criterion of 5.0 mg/L can be met with a 30% reduction of man-made nonpoint sources.

The results of the winter projection model show that the water quality criterion for dissolved oxygen for Bayou Courtableau of 5.0 mg/L can be maintained during the winter critical season. To achieve the proposed standard, a 15% reduction of man-made nonpoint sources is required. To meet the current 5.0 mg/L standard, a 30% reduction of man-made nonpoint sources is necessary.

The modeling which has been conducted for this TMDL is very conservative. One of the major factors this model was sensitive to was velocity, which is directly related to the flows in the model.

Continued monitoring is recommended to see how well the nonpoint reductions improve the dissolved oxygen values. Additional modeling may be required if the improvements do not meet expectations.

The LDEQ has implemented a watershed approach to surface water quality monitoring. Through this approach, the entire state is sampled over a five-year cycle with two targeted basins sampled each year. Long-term trend monitoring sites at various locations on the larger rivers and Lake Pontchartrain are sampled throughout the five-year cycle. Sampling is conducted on a monthly basis or more frequently if necessary to yield at least 12 samples per site each year. Sampling sites are located where they are considered to be representative of the waterbody. Under the current monitoring schedule, targeted basins follow the TMDL priorities. In this manner, the first TMDLs will have been implemented by the time the first priority basins will be monitored again in the second five-year cycle. This will allow the LDEQ to determine whether there has been any improvement in water quality following implementation of the TMDLs. As the monitoring results are evaluated at the end of each year, waterbodies may be added to or removed from the 303(d) list. The sampling schedule for the first five-year cycle is shown below.

1998 - Mermentau and Vermilion-Teche River Basins
1999 - Calcasieu and Ouachita River Basins
2000 - Barataria and Terrebonne Basins
2001 - Lake Pontchartrain Basin and Pearl River Basin
2002 - Red and Sabine River Basins

(Atchafalaya and Mississippi Rivers will be sampled continuously.)
Mermentau and Vermilion-Teche Basins will be sampled again in 2003.

7.0 List of References

Duerr, R.K., J. Carney, and W.C. Berger. March 26, 1999. "Bayou Plaquemine Brule Watershed TMDL for Dissolved Oxygen Including Eight Point Source Wasteload Allocations and a Watershed Nonpoint Source Load Allocation," Louisiana Department of Environmental Quality, Watershed Support Division, Water Quality Modeling Section.

Forbes, Max J., Jr. 1980. "Low-Flow Characteristics of Louisiana Streams," Baton Rouge. LA: United States Department of the Interior and Louisiana Department of Transportation and Development, Office of Public Works, Technical Report No. 22.

GIS Center. 1999. "Bayou Courtableau Drainage Area Land Use," Map date: 12/7/99. Map Number : 1999-01-347. USGS La. GAP data (based on 1992-3 TM imagery). Louisiana Department of Environmental Quality.

GIS Center. 1999. "Bayou Courtableau Drainage Area Satellite Imagery." Map date: 12/7/99. Map number: 1999-01-348. SPOT-TM merged satellite imagery. Louisiana Department of Environmental Quality.

Greenberg, Arnold E., Lenore S. Clesceri, and Andrew D. Eaton. Standard Methods For the Examination of Water and Wastewater, 18th Edition. 1992. American Public Health Association, American Water Works Association, and Water Environment Federation.

LA DEQ Ambient Network Database

LA DEQ Assessment Network Database

Lee, Fred N., and Duane Everette. "A Compilation of 7 Day, 10-Year Discharges for 363 Louisiana Streamflow Sites," Baton Rouge, LA: Prepared for the Louisiana Department of Environmental Quality, Water Pollution Control Division, Engineering Section.

Lee, Fred N., Duane Everette, and Max Forbes. March 31, 1997. "Lowflow Statistics from the USGS Database Through 1993," Baton Rouge, LA: Prepared for the Louisiana Department of Environmental Quality, Water Pollution Control Division, Engineering Section. pp. 103-104, 106.

Leopold, Luna B., and Thomas Maddock, Jr. 1953. "The Hydraulic Geometry of Stream Channels and Some Physiographic Implications," Washington, D.C.: United States Government Printing Office. Professional Paper No. 252.

Louisiana Department of Environmental Quality. 1987. "Basin/Segment Boundaries and Inventories," State of Louisiana, Water Quality Management Plan Vol. 4. LA DEQ Office of Water Resources, Baton Rouge, LA.

Louisiana Department of Environmental Quality. 1990. "Nonpoint Source Assessment Report," State of Louisiana Water Quality Management Plan: Vol. 6, Part A, LA DEQ Office of Water Resources, Baton Rouge, Louisiana.

Louisiana Department of Environmental Quality. 1990. "Water Quality Inventory," State of Louisiana Water Quality Management Plan, Volume 5, Part B. LA DEQ Office of Water Resources, Water Quality Management Division, Baton Rouge, Louisiana.

Louisiana Department of Environmental Quality. 1996. "Water Quality Inventory," State of Louisiana Water Quality Management Plan, Volume 5, Part B. LA DEQ Office of Water Resources, Water Quality Management Division, Baton Rouge, Louisiana, p. A-32.

Louisiana Department of Environmental Quality. 1999. Environmental Regulatory Code: Part IX. "Water Quality Regulations". Baton Rouge, LA: LA DEQ Office of Water Resources, Water Quality Management Division. p. 179.

Louisiana State University. 1999. State Office of Climatology.

Permit Files

Permit Tracking System (PTS)

Smythe, E.D. 1999. "Overview of the 1995 and 1996 Reference Streams," June 28, 1999. prepared for the Louisiana Department of Environmental Quality, Office of Environmental Assessment, Environmental Technology Division, Engineering 2 Section.

USGS Discharge Database

Waldon, Michael G., Ph.D., "Louisiana Total Maximum Daily Load Technical Procedures, 1994," CLIWS-WQR 91.10. March, 1999 (revised). Center of Louisiana Inland Water Studies (CLIWS), Department of Civil Engineering, University of Southwestern Louisiana, for the LA Department of Environmental Quality, Office of Water Resources, Water Pollution Control Division, Engineering Section.

Water Quality Evaluation Commission, November. 1990. "Wasteload Evaluation Methodology," Austin, TX: Water Quality Standards and Evaluation Commission, Texas Water Commission.

Wiland, Bruce, P.E. 1998. "LA-QUAL User's Manual, Version 1.00." Updated June 19, 1999. Wiland Consulting Inc., Austin, TX, for the Louisiana Department of Environmental Quality, Watershed Support Division, Engineering Section.

Appendix A

Calibration Model Development

Appendix B

Projection Model Development

Appendix C

Survey Data Measurements and Analysis Results

Appendix D

Historical and Ambient Data

Appendix E

Recommended TMDL

Appendix F

Maps and Diagrams