BAYOU SERPENT WATERSHED TMDL
FOR BIOCHEMICAL OXYGEN-DEMANDING SUBSTANCES

SUBSEGMENT 030701

SURVEYED JULY 11-13, 2000

TMDL REPORT

By:

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EXECUTIVE SUMMARY

This report presents the results of a watershed based, calibrated modeling analysis of Bayou Serpent. The modeling was conducted to establish a TMDL for biochemical oxygen-demanding pollutants for the Bayou Serpent watershed. The model extends from the headwaters near Kinder, LA to the confluence of Bayou Serpent with the Calcasieu River northeast of Lake Charles, La. Bayou Serpent is located in south west Louisiana and its watershed includes the following tributaries: Bayou Alligator, Gum Bayou, Cow Bayou, Little Bayou, Bayou Arceneaux, and several unnamed tributaries. The watershed is 218.4 square miles in area. Bayou Serpent is in the Calcasieu River Basin and includes Water Quality Subsegment 030701. The area is sparsely populated and land use is dominated by agriculture. Only one sewage treatment facility was addressed in the TMDL effort.

Input data for the calibration model was developed from data collected during the July, 2000 intensive survey; data collected by LDEQ and USGS at monitoring stations in the watershed; the LDEQ Reference Stream Study; DMRs, permits and permit applications for each of the point source dischargers; USGS drainage area and low flow publications; and data garnered from several previous LDEQ studies on non-point source loadings. The level of uncertainty associated with this model may be high due to the drought conditions which have characterized this watershed for the past 3 years. Both the intensive survey data and much of the monitoring data used to develop this model were collected under drought conditions. A satisfactory calibration was achieved for the main stem. In those cases where the calibration was not as accurate (primarily due to rice fields discharging during the survey), the difference was in the conservative direction. For the projection models, data was taken from the current municipal discharge permits, current applications, and ambient temperature records. The Louisiana Total Maximum Daily Load Technical Procedures, 09/08/2000, have been followed in this study.

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

Bayou Serpent, Subsegment 030701, was not on any 303(d) list; however, Bayou Serpent was part of the 1999 ambient sampling monitoring program and was listed in the 2000 305(b) report. The subsegment was found to be "not supporting" its designated use of Fish and Wildlife Propagation. It was "fully supporting" all other uses. Bayou Serpent was subsequently scheduled for TMDL development with other listed waters in the Calcasieu River Basin. The suspected cause of impairment was organic enrichment/ low DO, and the suspected sources were agriculture and hydromodification. This TMDL addresses the organic enrichment/low DO impairment.

The results of the projection modeling show that the water quality standard for dissolved oxygen of 5.0 mg/l can be maintained during the summer critical season with a 90% reduction of nonpoint source pollution. The minimum DO is 5.07 mg/l at RK 1.80 to RK 2.25. Since the required percent reduction exceeds any achievable nonpoint source reduction goal, no explicit margin of safety has been included. A No Load Scenario for summer using reference stream data to estimate natural background yields a minimum DO of 2.81 mg/l with all manmade loads removed. This suggests that a more appropriate DO criterion is needed for Bayou Serpent.

Table 1. Total Maximum Daily Load (Sum of UCBOD, UNBOD, and SOD)

ALLOCATION	SUMMER		WINTER	
	% Reduction Required	(MAR-NOV) (lbs/day)	% Reduction Required	(DEC-FEB) (lbs/day)
Point Source WLA	0	35	0	35
Point Source MOS (20%)	0	9	20	9
Nonpoint Source LA	90	545	50	3471
Nonpoint Source MOS (0% Summer; 10%, Winter)	0	0	10	371
TMDL		589		3886

The results of the winter projection model show that the water quality criterion for dissolved oxygen of 5.0 mg/l can be maintained during the winter critical season with a 50% reduction in nonpoint source pollution. The minimum dissolved oxygen is 5.08 mg/l and is located at RK 0.0.

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

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

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

2001 - Lake Pontchartrain Basin and Pearl River Basin
2002 - Red and Sabine River Basins
2003 - Mermentau and Vermilion-Teche River Basins
2004 - Calcasieu and Ouachita River Basins
2005 - Barataria and Terrebonne Basins
(Atchafalaya and Mississippi Rivers will be sampled continuously.)

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1. Introduction

Bayou Serpent, Subsegment 030701, was not on any 303(d) list; however, Bayou Serpent was part of the 1999 ambient sampling monitoring program and was listed in the 2000 305(b) report. The subsegment was found to be "not supporting" its designated use of Fish and Wildlife Propagation. It was "fully supporting" all other uses. Bayou Serpent was subsequently scheduled for TMDL development with other listed waters in the Calcasieu River Basin. The suspected causes of impairment were organic enrichment/ low DO, and the suspected sources were agriculture and hydromodification. This TMDL addresses the organic enrichment/low DO impairment.

A calibrated water quality model for the entire watershed was developed and projections were modeled to quantify the point source and non-point source waste load reductions which would be necessary in order for Bayou Serpent to comply with its established water quality standards and criteria. The level of uncertainty associated with this model is very high due to the drought conditions which have characterized this watershed for the past 3 years. Both the intensive survey data and much of the monitoring data used to develop this model were collected under drought conditions. This report presents the results of that analysis.

2. Study Area Description

2.1 General Information

Water quality subsegment 030701 is part of the Calcasieu River Basin. "The Calcasieu Basin is located in southwestern Louisiana and is positioned in a north-south direction. The drainage area of the Calcasieu Basin comprises approximately 3,910 square miles. Headwaters of the Calcasieu River are in the hills west of Alexandria. The river flows south for about 160 miles to the Gulf of Mexico; the mouth of the river is about 30 miles east of the Texas - Louisiana state line. The landscape in this basin varies from pine forested hills in the upper end to brackish and salt marshes in the lower reach around Calcasieu Lake."(LDEQ, 1993) Bayou Serpent enters the Calcasieu River upstream from the salt water barrier on the river which prevents salt water encroachment in the upper reaches. The subsegment is located in the parishes of Allen, Jefferson Davis, and Calcasieu and has a drainage area of 130,501 acres (203.9 square miles). In mapping the subsegment for modeling, the watershed boundary was refined and resulted in a drainage area of 218.4 square miles to Bayou Serpent. The bayou flows generally from the northeast to the southwest within a limited forested/scrub stream corridor. Bayou Serpent has been heavily dredged and has little canopy over most of its length. Much of the area is given over to rice farming. Because of its relatively low relief and the influence of the saltwater barrier, the region is characterized by poor drainage and frequent backwater effects from the River. A vector diagram showing the model layout and the survey stations is presented in Figure 1. A map of the study area is presented in Figure 2. The land use in the watershed is vividly depicted on the GAP map in Appendix H and summarized in Table 2.

Figure 1. Vector Diagram

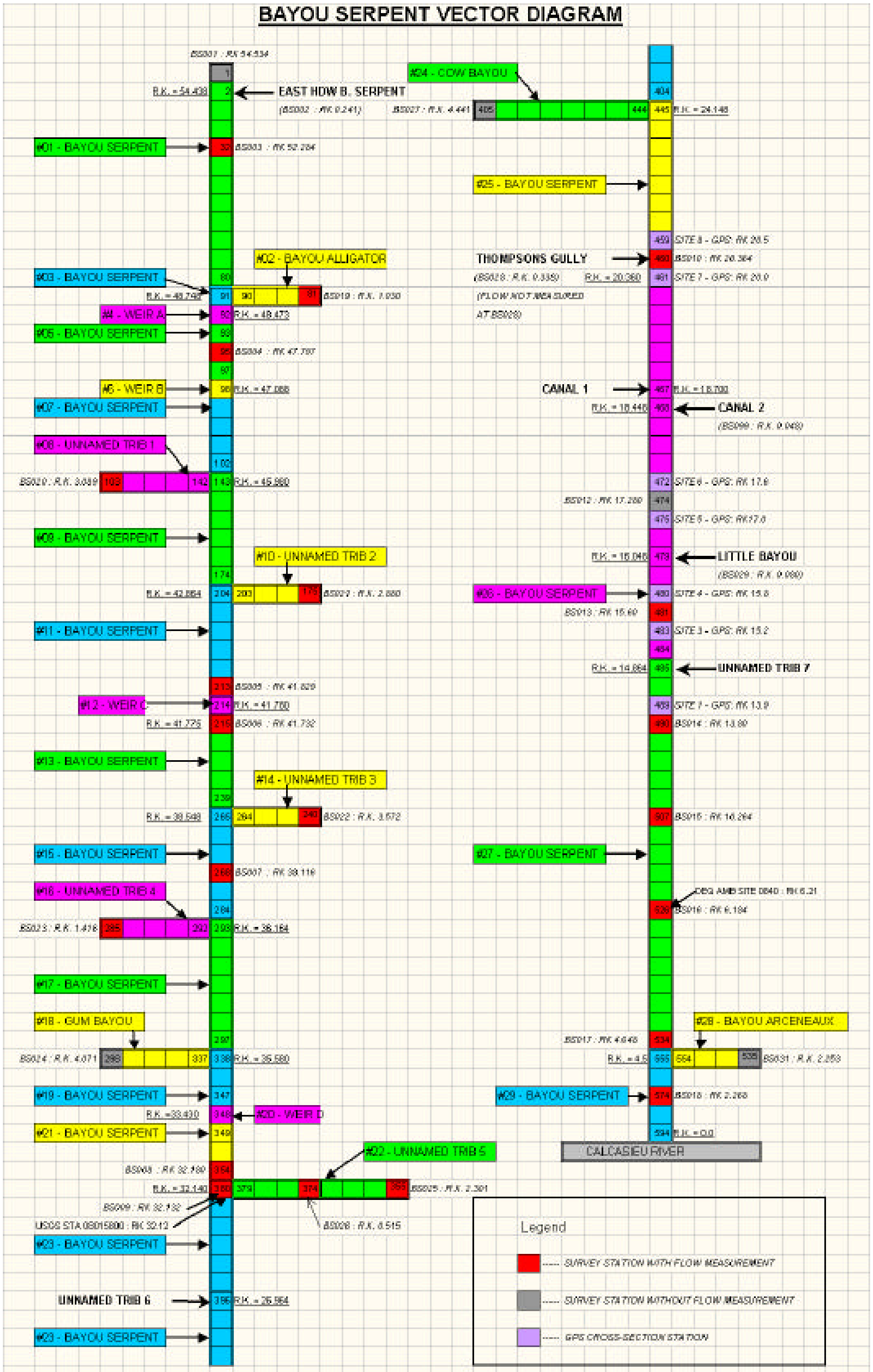


Figure 2. Map of Study Area

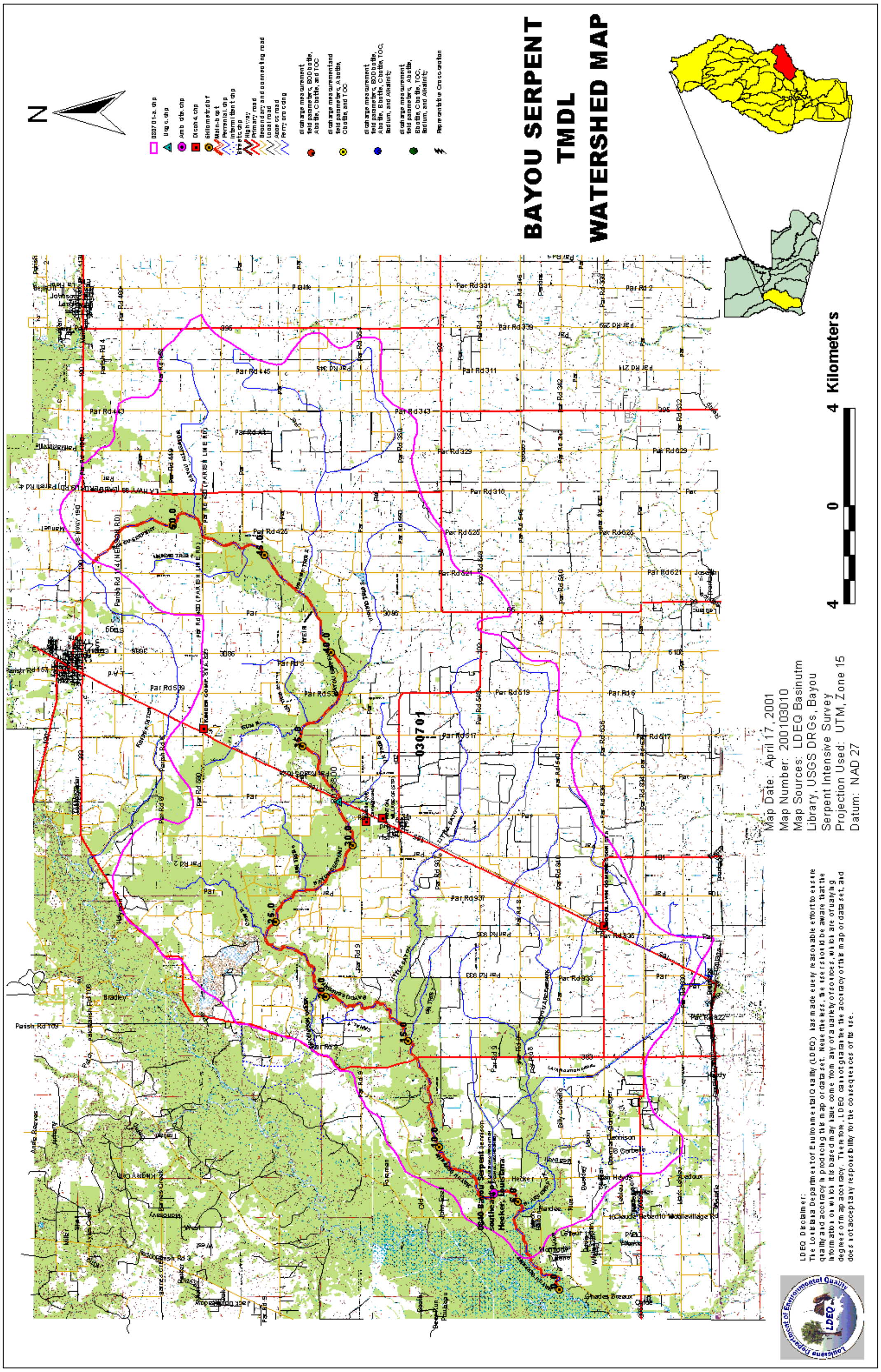


Table 2. Land Uses in Segment 030701

LAND USE	ACRES	PERCENT
Agricultural land	100364.38	76.91
Barren	22.06	0.02
Forest land	16237.03	12.44
Rangeland	4993.05	3.83
Urban or built-up	938.86	0.72
Water	2565.76	1.97
Wetland	5380.10	4.12
Total	130501.24	100.00

The model extends from the headwaters near Kinder, LA to the confluence of Bayou Serpent with the Calcasieu River northeast of Lake Charles, La. Bayou Serpent's watershed includes the following tributaries: Bayou Alligator, Gum Bayou, Cow Bayou, Little Bayou, Bayou Arceneaux, and several unnamed tributaries. Bayou Serpent is in the Calcasieu River Basin and includes Water Quality Subsegment 030701. The area is sparsely populated. One sewage treatment facility was addressed in the TMDL effort. Maps of the study area are presented in Appendix H.

2.2 Water Quality Standards

The Water Quality criteria and designated uses for Bayou Serpent watershed are shown in Table 3.

A Use Attainability Analysis (UAA) was completed for the Calcasieu River Basin establishing seasonal dissolved oxygen criteria of 5 mg/L November through April and 3.5 mg/L May through October. UAAs have also been established for several tributaries to the Calcasieu which are comparable to Bayou Serpent, most notably English Bayou (Subsegment 030702). Seasonal criteria for these tributaries is 5 mg/L December through February and 3.0 mg/L March through November. Unfortunately, Bayou Serpent was not included in any of these UAAs. It should be noted that modeling results show that a 3.0 mg/l DO criterion cannot be met in Bayou Serpent under natural summer conditions. Bayou Serpent has been heavily dredged and has numerous weirs. The practical use of the water is as a conveyance for agricultural and stormwater run-off and a source of irrigation water.

Table 3. Water Quality Numerical Criteria and Designated Uses

Subsegment	030701
Stream Description	Bayou Serpent –Headwaters to Calcasieu R.
Designated Uses	A B C F
Criteria:	
Cl	250
SO_4	75
DO	5
pH	6.0 – 8.5
BAC	Note 1
EC	32
TDS	300

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

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

2.3 Wastewater Discharges

The discharger inventory for the Bayou Serpent watershed was reviewed. There are only 4 dischargers listed in the LDEQ Permit Tracking System. These facilities were evaluated based on the volume of their discharge, their location with respect to the listed waterbody, any water quality data which demonstrated their impact or lack of impact, whether or not the NPS contribution included any small facilities, and best professional judgment. Only the Village of Fenton was considered to have any ability to impact the target reaches. The Village of Fenton discharges to an unnamed ditch which flows 1.68 miles to Little Bayou thence 5.35 miles to Bayou Serpent. An uncalibrated model was performed for the receiving stream for the Village of Fenton STP: the Unnamed Ditch to Little Bayou to Bayou Serpent. The uncalibrated model showed that Fenton has no impact on either Little Bayou or Bayou Serpent. The results of the uncalibrated model were entered in the summer projection model for Bayou Serpent. The list of facilities and the modeling decision for each is shown below in Table 4.

Table 4. Discharger Inventory for Subsegment 030701

FACILITY	FILE_NUM	Out-fall No.	OUTFALL DESCRIPTION	FAC_TYPE	REC_WATER	EXPECTED FLOW, GPD	BOD, mg/L	TSS, mg/L	MODELING COMMENTS
KINDER COMP. STA. 823	LA 0045918	1	storm water runoff, treated sanitary from 101, equipment washwater, condensed water from air compressor system, and building floor drainage	NATURAL GAS COMPRESSOR STATION	UNNAMED DITCHES - GUM BAYOU-SERPENT BAYOU				No Impact - Not modeled
KINDER COMP. STA. 823	LA 0045918	101	sanitary sewage	NATURAL GAS COMPRESSOR STATION	UNNAMED DITCHES - GUM BAYOU-SERPENT BAYOU	480	45	45	expected flow is from new app; permit has 400 gpd; No Impact - Not modeled
FENTON, VILLAGE OF (STP)	LAG 560102	1	sanitary sewage	45,000 GPD EXT. AIR T.P.	DITCH-LITTLE BAYOU-BAYOU SERPENT	36000	20	20	Class III permit for Q< 50,000; App indicates a design flow of 36,000 gpd; DMRs indicate wide variation from month to month; need uncalibrated model
Mobile City Campground	LAG 540826	1	sanitary sewage	CAMPGROUND/ STP	LOCAL-BAYOU SERPEANT	6250	30	30	Class II permit for Q< 25,000; App indicates a design flow of 6,250 gpd based on 125 campsites; discontinuous flow, seasonal, ditch dry during recon; No Impact - Not modeled
WOODLAWN COMPRESSOR STA	LA 0111881	1	storm water runoff	NAT GAS COMPRESSOR STA	BAYOU ARCENEAUX				No Impact - Not modeled
WOODLAWN COMPRESSOR STA	LA 0111881	2	sanitary sewage	NAT GAS COMPRESSOR STA	BAYOU ARCENEAUX	500			No Impact - Not modeled

FACILITY	FILE_NUM	Out-fall No.	OUTFALL DESCRIPTION	FAC_TYPE	REC_WATER	EXPECTED FLOW, GPD	BOD, mg/L	TSS, mg/L	MODELING COMMENTS
WOODLAWN COMPRESSOR STA	LA 0111881	3	storm water runoff	NAT GAS COMPRESSOR STA	BAYOU ARCENEAUX				No Impact - Not modeled
RICE ACRES WELL PIPELINE	LAR 10B045	1	unknown	CONST SWGP	LITTLE BAYOU				Construction activities storm water only; potential for discharge is "unlikely";
IOWA GAS PLT	LA 0093921	1	sanitary sewage	NATURAL GAS PROCESSING	UNNAMED DITCH - LOUISIANA IRRIGATION CANAL - BAYOU ARCENEAUX - CALCASIEU RIVER	1080	45	45	Zero discharge system was installed but there are bypasses which can be used to divert any overflow to the stream. Discharges to English Bayou, not Bayou Serpent

2.4 Water Quality Conditions/Assessment

Subsegment 030701, Bayou Serpent from the headwaters to the Calcasieu River, is not supporting its designated use of fish and wildlife propagation according to the 2000 305(b) Water Quality assessment for Louisiana. Suspected pollutants are Organic Enrichment/Low DO from agriculture and hydromodification. Bayou Serpent, Subsegment 030701, was not on any 303(d) list; however, Bayou Serpent was part of the 1999 ambient sampling monitoring program. Bayou Serpent was subsequently scheduled for TMDL development with other listed waters in the Calcasieu River Basin.

2.5 Prior Studies

There have been no prior TMDL related studies on Bayou Serpent.

3. Documentation of Calibration Model

3.1 Program Description

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

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

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

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

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

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

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

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

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

3.2 Input Data Documentation

Data collected during an intensive survey conducted from July 11-13, 2000, was used to establish the input for the model calibration and is presented in Appendix F. Since this survey was conducted during the third year of a severe drought for South Louisiana, some measurements may be representative of conditions which are exempt from meeting the regulatory standards. For this reason, the TMDL which results from this modeling analysis may be more conservative than necessary.

The flow in each reach, headwater, and unmodeled tributary was determined based on the survey discharge measurements, the flow balance at selected sampling stations, the drainage area associated with each flow, and a determination of appropriate incremental nonpoint source flowrates in terms of cms/mile. Best professional judgment was used to determine where similar streams concepts could be used. Flow determinations are presented in Appendix C2.

Field and laboratory water quality data were entered in a spreadsheet for ease of analysis. The Louisiana GSBOD program was applied to the BOD data in a separate spreadsheet and values were computed for each sample taken of ultimate CBOD, CBOD decay rate, CBOD Lag, ultimate NBOD, NBOD decay rate, NBOD lag and ratios of ultimate to 5 day values of CBOD and NBOD. This data was the primary source for the model input data for initial conditions; decay rates; incremental temperature, DO, and NBOD; headwater temperature and DO; and, wasteload data. Two other sources of data also figured prominently in developing the input data set: reference stream data and previous determinations of nonpoint source loadings for several heavily impacted streams. As shown in Figure 2, the DO during the time of the survey was not meeting standards above 3 of the weirs and in the lower 15 kilometers to the junction with the Calcasieu River.

3.2.1 Model Schematics and Maps

A vector diagram of the modeled area is presented in Appendix H. The vector diagram shows the locations of survey stations, the reach/element design, the locations of modeled tributaries and the locations of tributaries contributing flow but not modeled. An ARCVIEW map of the stream and subsegment showing river kilometers, survey stations, drainage area boundaries and other points of interest is also included in Appendix H. A drainage area diagram showing the incremental drainage areas contributing to each headwater, reach and station is also presented in Appendix H.

3.2.2 Model Options, Data Type 2

Five constituents were modeled during the calibration process. These were chlorides, conductivity, dissolved oxygen, carbonaceous biochemical oxygen demand, and nitrogenous biochemical oxygen demand. Chlorophyll A was not modeled since the sampling results showed such small quantities, and the continuous monitors did not show the typical diurnal swings indicative of an algae bloom. Therefore algae was not considered to be a problem in this watershed. When chlorides failed to calibrate, an anion-cation balance was attempted but could not be achieved. A review of the data showed that field conductivity was probably more reliable as a conservative constituent for this watershed.

3.2.3 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:

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

Where:

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

In the 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, 2001).

3.2.4 Reach Identification Data, Data Type 8

Using the survey stations where discharge measurements were made and the ARCVIEW mapping as guides, the reaches and elements were established. During the calibration process, several adjustments were made in order to better delineate the stream characteristics and conditions and achieve better calibration results. The resulting design incorporated 29 reaches, 10 headwaters, 7 wasteloads (unmodeled tributaries), and 594 elements. A simple spreadsheet was used to calculate the reach length, element length and cumulative number of elements at the bottom of each reach. The locations of each survey station and unmodeled tributary were fed into a related spread sheet and the element number for each of these locations was determined. These spreadsheets are presented in Appendix C1. The reach and element design is shown on the vector diagram.

3.2.5 Advective Hydraulic Coefficients, Data Type 9

Rather than directly inputting the widths and depths of the stream, the model requires entry of the advective hydraulic characteristics (Modified Leopold Coefficients, Exponents, and Constants, Waldon, 2001). The USGS provided LDEQ with 18 discharge measurements made at the USGS site near Fenton at Highway 165 between 1959 and 1978. These measurements were entered into the LDEQ spreadsheet used to determine modified Leopold exponents, coefficients and constants. The ten USGS measurements made during the historical low flow months of late September through early December supplemented by the much higher measurements made at BS008, BS009 and BS010 on July 12, 2000 produced an acceptable set of curves for predicting flows from depth and velocity. Low flows measured during other times of the year could reflect irrigation withdrawals rather than actual low flow conditions. The rice fields were discharging rather than withdrawing during the 2000 survey. Bayou Serpent also has four weir structures which complicated the hydraulic analysis. The exponents, coefficients and constants determined for the USGS station were applied to the main stem from Unnamed Trib 4 to Thompson's Gully. The depth, width and velocity exponents from this station were applied to all remaining main stem reaches. The depth and width coefficients from this station were applied to the main stem from Thompson's Gully to the River. The remaining coefficients and constants for the main stem were determined for groups of similar reaches using the survey measurements. All tributaries except Bayou Alligator and the main stem headwaters were assumed to be similar streams, and the survey data combined with the USGS station depth exponent were used to determine the exponents, coefficients and constants to be used on the tributaries. There was scatter in the flow measurements made downstream of Little Bayou. Measurements made in the morning differed quite a bit from those made in the afternoon and evening, and the impact of the rice field discharges was readily apparent where downstream measurements were smaller than upstream measurements. Hydraulic determinations are presented in Appendices C1 and C2.

3.2.6 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 input values came from the survey station located closest to the reach or from an average of samples taken from adjacent streams considered similar. The input data and sources are shown in Appendix C5.

3.2.7 Reaeration Rates, Data Type 12

The reaeration spreadsheet was run for each of the discharge measurements and the applicability of the various equations was examined. The review showed that the Louisiana Equation was most applicable to the tributaries and the upper reaches while Owens was most applicable to the lower reaches. Although some of the measurements were slightly out of the range of values appropriate for the equations, the overall conformance to one equation for the upper reaches and tribs and one equation for the lower reaches met expectations for dredged waters. The available cross-section data confirmed that the discharge measurements taken in the lower reaches were taken at fairly typical cross-sections. The cross-section data also confirmed that there was a significant change near Thompson's Gully which had to be addressed in the reach-element design. The reaeration over the four weirs was increased until calibration was reached. The numbers are large, but not unreasonable for flow over weirs. The reaeration spreadsheets are shown in Appendix C6, and the reaeration rate equations selected for each reach are shown in Appendix C5.

3.2.8 Sediment Oxygen Demand, Data Type 12

The SOD values were achieved through calibration and are generally high in the upper reaches and lower in the lower, deeper reaches. The impact of the weirs is clearly seen since the SOD falls off sharply just below each weir then immediately builds up to quite high numbers again. The weirs obviously prevent scouring of the stream bottoms. Below the last weir and as the stream gets deeper, the SOD falls to an end value of roughly 3 $g/m^2/day$. This is high for waters that are 8 to 12 feet deep, but it may be attributable to the residual impact of the Calcasieu salt water barrier, which would prevent scouring in the same manner as the weirs. The salt water barrier was open during the survey so Bayou Serpent was free flowing. The SOD value for each reach is shown in Appendix C5. The conversion ratio of settled CBOD and settled NBOD to SOD was considered to be one for all reaches.

3.2.9 Carbonaceous BOD Decay and Settling Rates, Data Type 12

The decay rates used were based on the bottle rates from the survey or averages of the bottle rates for appropriate groups of stations. CBOD decay rates were fairly consistent with main stem rates ranging from .03 to .04 below the headwater reaches and tributary/headwater reaches ranging from .04 to .06. The concept of similar streams was used to transfer rates between streams in the watershed. The decay and settling rates used for each reach are shown in Appendix C5.

3.2.10 Nitrogenous BOD Decay and Settling Rates, Data Type 15

These rates are labeled Nonconservative Material (NCM) Decay and Settling in the model. The decay rates used were based on the bottle rates from the survey or multiples of the bottle rates in general. NBOD decay rates were fairly consistent with main stem rates ranging from .04 to .06 below the headwater reaches and tributary/headwater reaches ranging from .04 to .07. The concept of similar streams was used to transfer rates between streams in the watershed. The decay and settling rates used for each reach are shown in Appendix C5.

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

The incremental conditions were used in the calibration to represent nonpoint source loads associated with flows. There were rice fields discharging during the survey, and there was some input from groundwater as a result of the water standing in the rice fields prior to the survey recharging the underlying water table. Since both of these sources would have been naturally filtered prior to entering the stream, reference stream data and some of the survey data from relatively unimpacted “upstream” sampling sites were used to develop the Temperature, DO, Chlorides, Conductivity, UCBOD and UNBOD. The data and its source for each reach and a summary of the reference stream findings are presented in Appendix C5.

3.2.12 Nonpoint Sources, Data Type 19

Nonpoint source loads which are not associated with a flow are input into this part of the model. These can be most easily understood as resuspended load from the bottom sediments and are modeled as SOD, CBOD and NBOD loads. Over the years LDEQ has collected data on heavily impacted streams in Louisiana. These data were reviewed and summarized by Smythe and Waldon and have been used to develop part of the input data for Bayou Serpent. A copy of the summary table is presented in Appendix G. LDEQ also determined these types of loadings as part of the Reference Stream work and these loads have also been used to determine some of the input data. The nonpoint source loading for a non-flowing stream is significantly greater than that for a flowing stream. The Bayou Serpent system is not a non-flowing stream, but neither is it a free-flowing stream due to the many weirs and the salt water barrier. It was therefore decided to use the non-flowing reference stream data mean values for this model. In some cases a percentage of the reference stream loading has been adequate to achieve calibration. Some of the nonpoint source loads in kg/km/day which were based on reference stream data appear to be very small loads, but they do not address stream width. An analysis was made of the calibration NPS and SOD loads in terms of gm-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). The analysis is presented in Appendix C5. In general the total NPS load exceeds the reference stream load. 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 data and sources are presented in Appendix C5.

3.2.13 Headwaters, Data Types 20, 21, and 22

The West Headwater and the tributaries where water quality samples and/or other measurements were taken some distance upstream from Bayou Serpent were grouped together under the headwater data. Since only one sample was taken for some of these waters, it was not possible to calibrate the tributaries. Using a similar streams concept, the survey data, percentage of the data, or an average of an appropriate group of stations was assumed to be representative of the temperature, DO, chlorides, conductivity, UCBOD and UNBOD of the headwaters. The data and sources are presented in Appendix C5.

3.2.14 Wasteloads, Data Types 24, 25, and 26

The tributaries where water quality samples and/or other measurements were taken immediately upstream from Bayou Serpent were grouped together under the wasteloads data. It was not possible to model these tributaries. Using a similar streams concept, the survey data, percentage of the data or an average of an appropriate group of stations was assumed to be representative of the temperature, some of the DO, chlorides, conductivity, UCBOD and UNBOD of the headwaters. Dissolved Oxygen was set at DO saturation at stations where the measured values exceeded that value. The data and sources are presented in Appendix C5.

3.2.15 Boundary Conditions, Data Type 27

The lower boundary conditions were assumed to be equivalent to the measurements taken at survey station BS018.

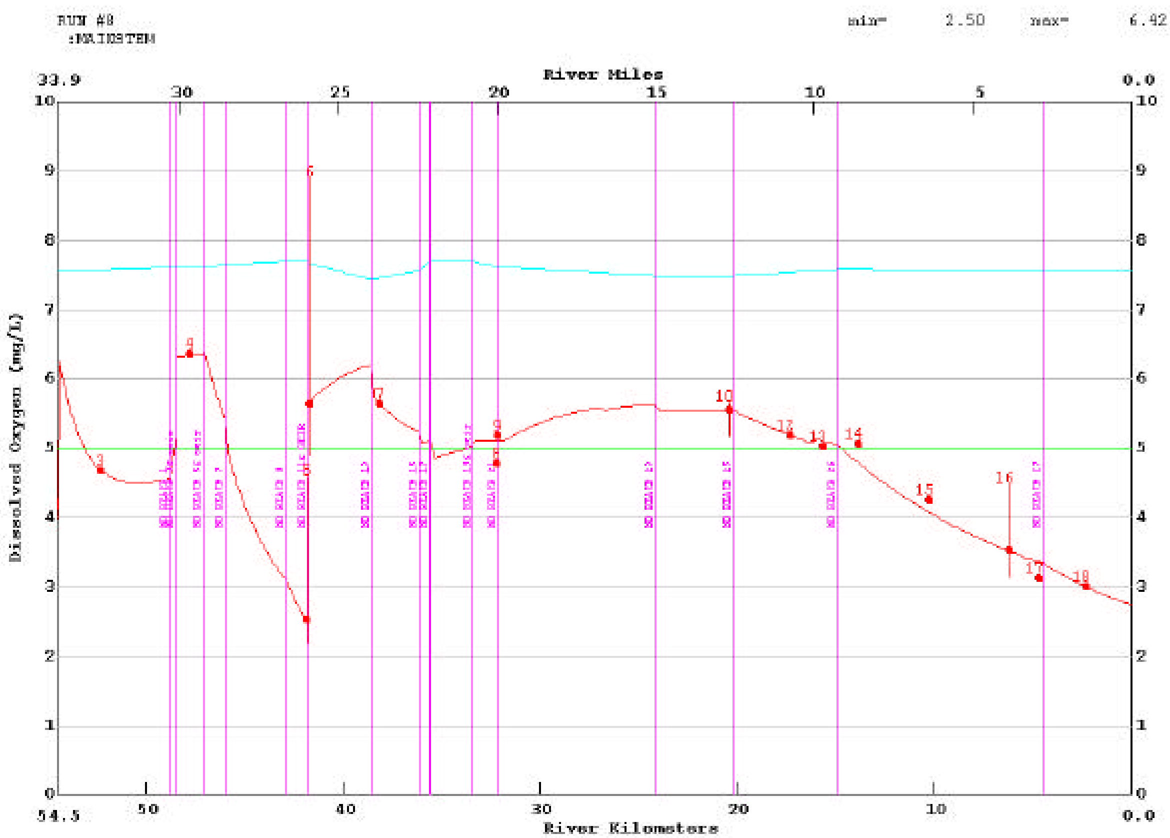
3.3 Model Discussion and Results

The calibration model input and output is presented in Appendix B. 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 3.

The calibration to flow, depth and width was very good from the headwaters to Little Bayou and then acceptable from Little Bayou to the Calcasieu River. The calibration to conductivity was good for the whole length of the main stem. The anion/cation balance was poor, and therefore a calibration to chlorides was not achieved.

Bayou Serpent main stem extends from the East Headwater to the Calcasieu River. None of the treatment plants discharge directly into the main stem. Very good calibration was achieved for DO, UCBOD, and UNBOD on the main stem. The calibration model shows that in the summer of 2000, the DO standard of 5 mg/l was not being met in Bayou Serpent at the headwaters, above the first, third and fourth weirs, and downstream of RK 14.860, the beginning of Reach 27 at the junction with Unnamed Trib 7. The minimum DO on the main stem was 2.50 mg/l at RK 41.78, just above weir C.

Figure 3. Calibration Model Dissolved Oxygen versus River Kilometer



- numbered points indicate survey stations
- vertical lines indicate beginning of reach
- the horizontal line indicates the DO Criterion
- upper plotted line indicates DO saturation
- lower plotted line indicates calibration model output

4. Water Quality Projections

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

4.1 Critical Conditions, Seasonality and Margin of Safety

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

Critical conditions for dissolved oxygen were determined for Bayou Serpent using long term water quality data from English Bayou and short term water quality data from Bayou Serpent on the LDEQ Ambient Monitoring Network. English Bayou was selected since it is adjacent to Bayou Serpent and is very similar in land use and stream characteristics. The short term data on Bayou Serpent for temperature agreed very well with the long term data for English Bayou. The 90th percentile temperature for each season and the corresponding 90% of saturation DO was determined. Ambient temperature data, critical temperature and DO saturation determinations are shown in Appendix E4. 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 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. 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.

Critical season conditions were simulated in the Bayou Serpent dissolved oxygen TMDL projection modeling by using the default flows from the Louisiana Technical Procedures Manual, 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. Output from the uncalibrated model of Little Bayou showed that the Village of Fenton had no impact on Bayou Serpent.

In reality, the highest temperatures occur in July-August, the lowest stream flows occur in October-November, and the maximum point source discharge occurs following a significant rainfall, i.e., high-flow conditions. The projection model is established as if all these conditions happened at the same time. 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 point source loads to account for future growth, safety, model uncertainty and data inadequacies. The explicit margin of safety was set at zero for the nonpoint source loads for the summer projection since the required reduction exceeded a reasonably achievable goal. The explicit margin of safety for the nonpoint source loads for the winter projection was set at 20% for the manmade portion.

4.2 Input Data Documentation

The flow in each headwater and unmodeled tributary was set at 0.1 cfs = 0.00283 cms for summer critical conditions in accordance with the LTP. The flow in each headwater and unmodeled tributary was set at 1.0 cfs = 0.0283 cms for winter critical conditions in accordance with the LTP.

4.2.1 Model Options, Data Type 2

Three constituents were modeled during the calibration process. These were dissolved oxygen, carbonaceous biochemical oxygen demand, and nitrogenous biochemical oxygen demand.

4.2.2 Temperature Correction of Kinetics, Data Type 4

The temperature correction factors specified in the LTP were entered in the model.

4.2.3 Reach Identification Data, Data Type 8

The reach-element design from the calibration was used in the projection modeling.

4.2.4 Advective Hydraulic Coefficients, Data Type 9

The stream cross-section was automatically adjusted for the projection flows by the model through the use of the Leopold coefficients and exponents established during the calibration.

4.2.5 Initial Conditions, Data Type 11

The initial conditions were set to the 90^{th} percentile critical season temperature in accordance with the LTP. The dissolved oxygen values for the initial conditions were set at the stream criteria.

4.2.6 Reaeration Rates, Carbonaceous BOD Decay and Settling Rates, Nitrogenous BOD Decay and Settling Rates, Data Types 12 and 15

The reaeration rate equations, CBOD decay and settling rates, NBOD decay and settling rates, and the fractions converting settled CBOD and settled NBOD to SOD were not changed from the calibration.

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

The incremental conditions were used in the calibration to represent nonpoint source loads associated with flows. For the projection runs, the incremental flows were set to zero to emulate the critical conditions for dissolved oxygen.

4.2.8 Sediment Oxygen Demand, Nonpoint Sources, Headwaters, Wasteloads, Data Type 12, 19, 20, 21, 22, 24, 25, and 26

The NPS values were calculated for each projection scenario using a load equivalent spreadsheet. An analysis was made of the calibration NPS and SOD loads in terms of total loading in units of gm-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 headwaters and wasteloads. The values and sources of the input data and the load analyses are presented in Appendix E for each of the projection runs.

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 run-off events, and subsequently settle to the bottom in our slow moving streams. These benthic loads decay and breakdown during the year, becoming easily resuspended into the water column during the low flow/high temperature season. This season has historically been identified as the critical dissolved oxygen season.

LDEQ simulates part of the non-point source oxygen demand loading as resuspended benthic load and SOD. The calibrated non-point loads, UCBOD, UNBOD, 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 it's 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 reading 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 two 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 60 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 LDEQ decided to use the sum of reference stream benthic loads as background values.

4.2.9 Boundary Conditions, Data Type 27

The lower boundary conditions were set at the 90^{th} percentile critical season temperature, the dissolved oxygen criteria, and the measured stream UCBOD and UNBOD loads for all projections and scenarios.

4.3 Model Discussion and Results

The projection model input and output data sets are presented in Appendix D.

4.3.1 No Load Scenario

Under this Scenario, the SOD, NPS, headwater and wasteload values were reduced to reference stream values except where the calibration value was less than the reference stream value. Several reduction runs were made after the original No Load run revealed that 100% removal of man-made nonpoint sources would result in a minimum DO of 2.81 mg/l. As shown in Figures 4 and 5, a 90% removal of total nonpoint sources would be required in order for the main stem to meet the existing dissolved oxygen criteria of 5.0 mg/l. The minimum DO is 5.07 mg/l at RK 1.80 to RK 2.25. It is obvious that the current DO criterion should be reevaluated. As noted previously, UAAs have been completed for surrounding similar waters and resulted in summer DO criterion of 3.0 mg/l. Also as previously noted, the survey which formed the basis for the modeling analysis was conducted during the third year of a severe drought for South Louisiana, and therefore the modeling analysis may be more conservative than necessary.

4.3.2 Summer Projection

After the failure of the original No Load Scenario to result in meeting the DO criteria, a summer projection run was made to estimate the impact of a partial removal of man-made NPS loads. The summer projection run was based on an 85% removal of man-made nonpoint source loads. The results of the model showed that the minimum DO would be 1.71 mg/l at RK 12.995 and RK 41.996. A graph of the dissolved oxygen concentration versus river kilometer for the summer projection is presented in Figure 6.

4.3.3 Winter Projection

The results of the model show that the water quality criterion for dissolved oxygen for Bayou Serpent of 5.0 mg/l can be maintained during the winter critical season. The minimum dissolved oxygen is 5.08 mg/l at RK 0.00. This is acceptable. To achieve the criterion, the model assumed a 50% reduction from all nonpoint sources. A graph of the dissolved oxygen concentration versus river kilometer for the winter projection is presented in Figure 7.

Figure 4. No Load Scenario with 100 % Removal of Man-Made NPS Loads

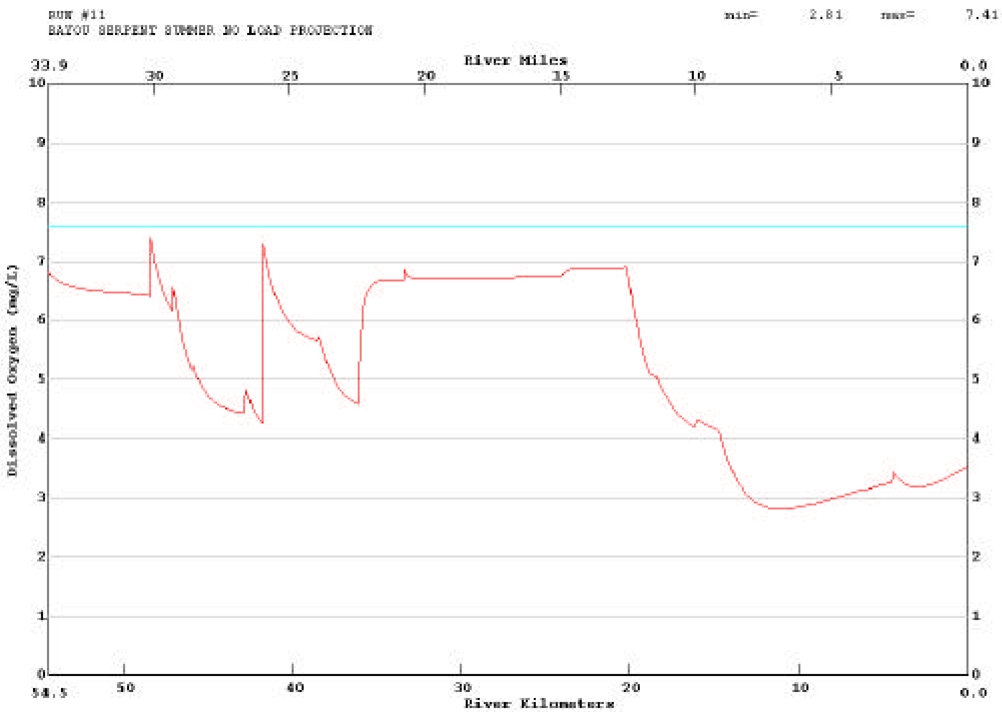


Figure 5. No Load Scenario with 100 % Removal of Man-Made NPS Loads and 50% Removal of Natural Background Load

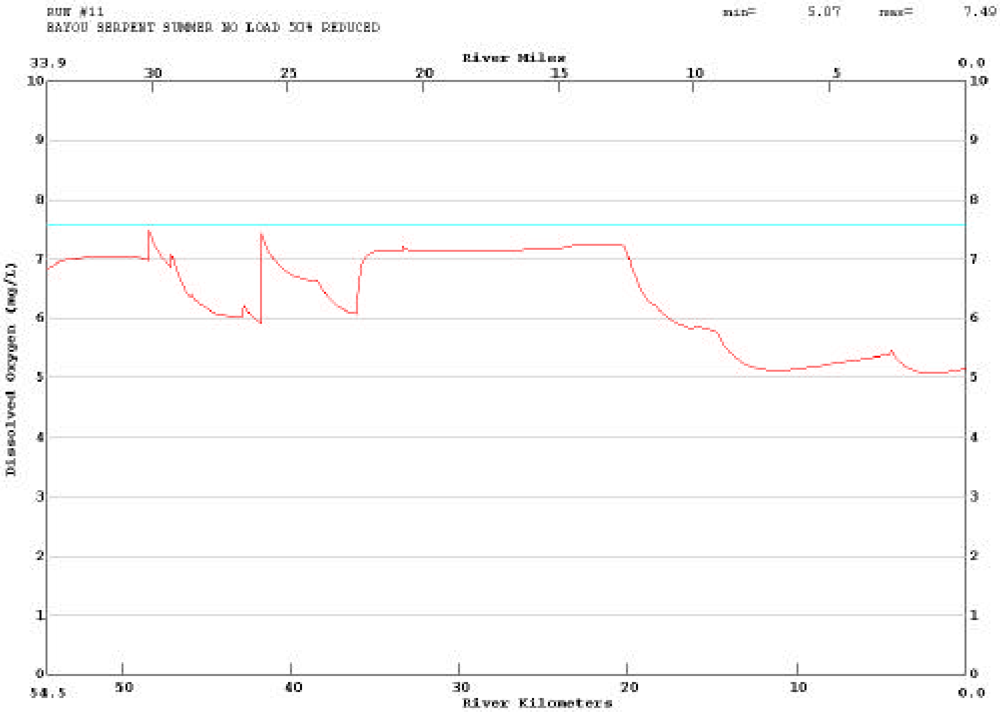


Figure 6. Summer Projection at 85% Removal of Man-Made NPS Loads

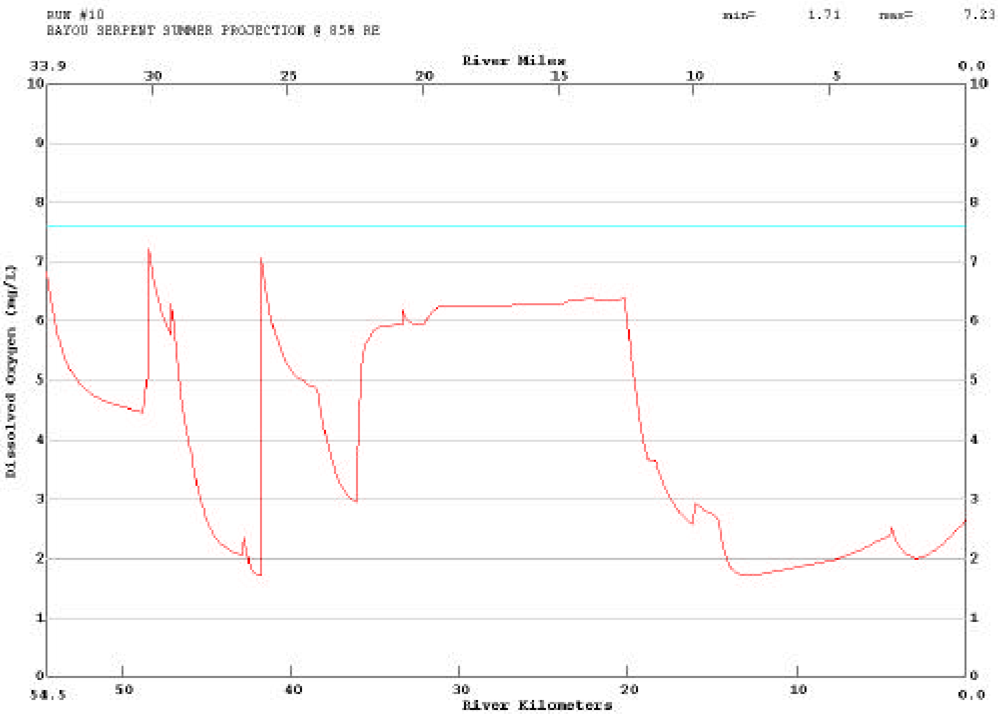
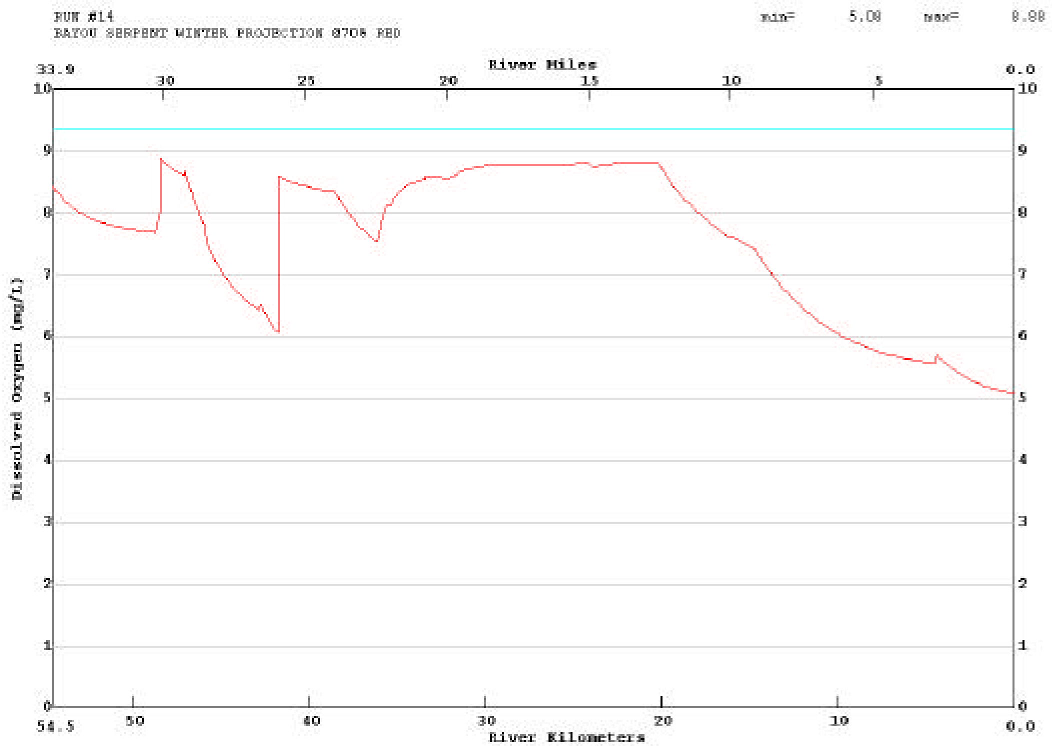


Figure 7. Winter Projection at 70% Removal of Man-Made NPS Loads



4.4 Calculated TMDL, WLAs and LAs

4.4.1 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.

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

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

- Calibration resuspension and SOD loads were summed for each reach as gm O_2/m^2-day to get the calibration benthic loading.
- The natural background benthic loading was subtracted from the calibration benthic loading to obtain the man-made calibration benthic loading.

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

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

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

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

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

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

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

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

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

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

4.4.2 Bayou Serpent TMDL

The TMDLs for the biochemical oxygen demanding constituents (CBOD, NH3N, and SOD), have been calculated for the summer and winter critical seasons. The TMDLs for the Bayou Serpent watershed were set equal to the total stream loading capacity. They are presented in Appendix A by point source and reach. A summary of the loads is presented in Table 5.

Table 5. Total Maximum Daily Load (Sum of UCBOD, UNBOD, and SOD)

ALLOCATION	SUMMER		WINTER	
	% Reduction Required	(MAR-NOV) (lbs/day)	% Reduction Required	(DEC-FEB) (lbs/day)
Point Source WLA	0	35	0	35
Point Source MOS (20%)	0	9	20	9
Nonpoint Source LA	90	545	50	3471
Nonpoint Source MOS (0%, Summer; 10% Winter)	0	0	10	371
TMDL		589		3886

5. Sensitivity Analyses

All modeling studies necessarily involve uncertainty and some degree of approximation. It is therefore of value to consider the sensitivity of the model output to changes in model coefficients, and in the hypothesized relationships among the parameters of the model. The LAQUAL model allows multiple parameters to be varied with a single run. The model adjusts each parameter up or down by the percentage given in the input set. The rest of the parameters listed in the sensitivity section are held at their original projection value. Thus the sensitivity of each parameter is reviewed separately. A sensitivity analysis was performed on the summer No Load projection and on the calibration. The sensitivity of the model's minimum DO projections to these parameters is presented in Appendix I. Parameters were varied by +/- 30%, except temperature, which was adjusted +/- 2 degrees Centigrade.

Values reported in Appendix I are sorted by percentage variation of minimum DO in the main stem Bayou Serpent from largest percentage variation to the smallest. As shown in Table 6, stream reaeration and benthal demand are the parameters to which DO is most sensitive. The other parameters creating major variations in the minimum DO values are depth, initial temperature, and velocity. The calibration model is more sensitive to the various types of flows than the projection model. The model is slightly to not sensitive to the remaining parameters.

6. Conclusions

The TMDL requires a watershed wide 90% decrease in nonpoint source loads in order to meet the DO criteria in the summer. A 50% reduction in nonpoint sources is required to meet the DO criteria in the winter. The existing point sources have no impact on the main stem of Bayou Serpent and require no changes to their permitted discharges.

The modeling which has been conducted for this TMDL is very conservative and based on limited information. The effect of the drought on the model is thought to be conservative. Future studies may show that this TMDL is smaller than that which can actually be accommodated by the watershed.

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

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

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

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
Benthal Demand	30	1.84	-26.4	-30	3.45	37.9
Stream Reaeration	30	3.34	33.5	-30	1.57	-37.3
Stream Velocity	30	3.07	22.8	-30	1.58	-36.9
Initial Temperature	2	1.86	-25.8	-2	3.15	26
Stream Baseflow	30	2.83	13.2	-30	2.04	-18.4
Stream Depth	30	2.4	-4.1	-30	2.16	-13.8
Incremental Inflow	30	2.72	8.7	-30	2.23	-11
Incremental DO	30	2.68	7.1	-30	2.32	-7.1
Headwater Flow	30	2.64	5.4	-30	2.36	-5.8
Wasteload Flow	30	2.62	4.6	-30	2.38	-4.9
BOD Decay Rate	30	2.43	-2.8	-30	2.56	2.3
Headwater DO	30	2.53	1.1	-30	2.47	-1.1
Headwater BOD	30	2.47	-1.1	-30	2.53	1.1
BOD Settling Rate	30	2.48	-0.7	-30	2.52	0.7
Wasteload BOD	30	2.49	-0.4	-30	2.51	0.4
Headwater Nonconservative	30	2.49	-0.3	-30	2.51	0.3
Nonconservative Settling	30	2.5	-0.2	-30	2.51	0.2
Incremental BOD	30	2.5	-0.2	-30	2.51	0.2
Wasteload Nonconservative	30	2.5	-0.1	-30	2.5	0.1
Nonconservative Decay	30	2.5	0	-30	2.5	0
Headwater Temperature	30	2.5	0	-30	2.5	0
Wasteload Temperature	30	2.5	0	-30	2.5	0
Wasteload DO	30	2.5	0	-30	2.5	0
Incremental Temperature	30	2.5	0	-30	2.5	0
Incremental Nonconservative	30	2.5	0	-30	2.5	0

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

2001 - Lake Pontchartrain Basin and Pearl River Basin
2002 - Red and Sabine River Basins
2003 - Mermentau and Vermilion-Teche River Basins
2004 - Calcasieu and Ouachita River Basins
2005 - Barataria and Terrebonne Basins
(Atchafalaya and Mississippi Rivers will be sampled continuously.)

7. References

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8.0 Appendices

See Attached Appendices A - I.