HOUSTON RIVER WATERSHED TMDL
FOR BIOCHEMICAL OXYGEN-DEMANDING SUBSTANCES

SUBSEGMENT 030806

SURVEYED SEPTEMBER 19-21, 2000

TMDL REPORT

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EXECUTIVE SUMMARY

This report presents the results of a watershed based, calibrated modeling analysis of the Houston River. The modeling was conducted to establish a TMDL for biochemical oxygen-demanding pollutants for the Houston River watershed. The model extends from the headwaters at Creek Road north of Vinton, LA to just upstream of the Entergy power plant. The remaining stretch of the Houston River will be included in the Calcasieu River Estuary model. The Houston River is located in southwest Louisiana and its watershed includes the following tributaries: Persimmon Gully, Buxton Creek, and unnamed tributaries. The watershed is 154 square miles in area. The Houston River is in the Calcasieu River Basin and includes Water Quality Subsegment 030806. The area is sparsely populated and land use is dominated by forest land, agriculture, rangeland, and wetland. Five sewage treatment facilities were addressed in the TMDL effort; however, only one was included in the model.

Input data for the calibration model was developed from data collected during the September, 2000 intensive survey. A satisfactory calibration was achieved for the main stem and Buxton Creek. All other tributaries had no flow during the survey and were not included in the model. For the projection models, data was taken from the current municipal discharge permit 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.

The Houston River, Subsegment 030806, was not on any 303(d) list; however, the Houston River 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. The Houston River 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, pH, salinity/TDS/chlorides, and sulfates. The suspected sources were natural sources, hydromodification, and agriculture. This TMDL addresses the organic enrichment/low DO impairment.

The results of the projection modeling show that the 3.0 mg/L water quality standard for dissolved oxygen can be maintained during the summer critical season with a 67% reduction of total nonpoint source pollution. 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 46% reduction of total nonpoint source pollution. These results suggest that the criteria for the Houston River could be inappropriate and that further study or a Use Attainability Analysis (UAA) is needed.

The summer projection scenario resulted in a required reduction of more than 100% when the required reduction was differentiated between man-made and natural nonpoint pollution.

Therefore, the percentage reductions necessary to meet the DO standards were presented as total nonpoint pollution since a reduction of more than 100% is not possible.

Table 1. Total Maximum Daily Load (Sum of CBOD, NBOD, and SOD)

	3 mg/L DO, Mar-Nov	5 mg/L DO, Dec-Feb
Point Source WLA, lb/day of oxygen demand	322	322
Point Source MOS, lb/day of oxygen demand	79	79
Nonpoint LA, lb/day of oxygen demand	7162	11262
Nonpoint MOS, lb/day of oxygen demand	0	988
TMDL, lb/day of oxygen demand	7563	12651

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

The Houston River, Subsegment 030806, was not on any 303(d) list; however, the Houston River 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. The Houston River 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, pH, salinity/TDS/chlorides, and sulfates. The suspected sources were natural sources, hydromodification, and agriculture. This TMDL addresses the organic enrichment/low DO impairment.

A calibrated water quality model for the entire watershed (the last 3.2 km will be modeled by contractors) was developed and projections were modeled to quantify the point source and nonpoint source waste load reductions which would be necessary in order for the Houston River to comply with its established water quality standards and criteria. This report presents the results of that analysis.

2. Study Area Description

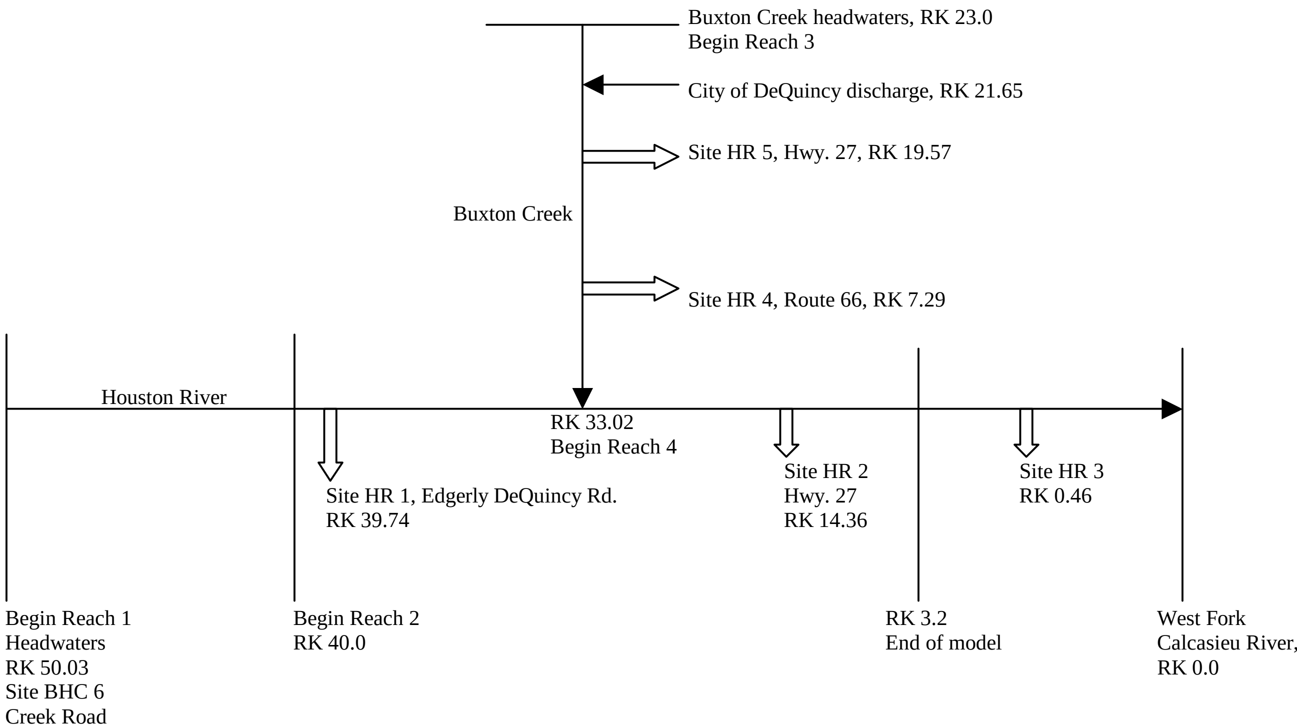
2.1 General Information

Water quality subsegment 030806 is part of the Calcasieu River Basin. The Calcasieu River Basin is located in southwestern Louisiana and is positioned in a north-south direction. The basin is bordered by the Mermentau River to the east and the Sabine River to the west. The drainage area of the basin comprises approximately 3,910 square miles. The landscape in this basin varies from pine forested hills in the upper end to brackish and salt marshes in the lower reach around the Calcasieu River (LDEQ, 1999). The Houston River enters the West Fork Calcasieu River which flows into the Calcasieu River upstream from the salt water barrier located on the Calcasieu River. Subsegment 030806 is located in Calcasieu parish and is 154 square miles in area. The Houston River flows from west to east and is influenced by the salt water barrier on the Calcasieu River. A vector diagram showing the model layout and the survey stations is presented in Figure 1. The land use in the watershed is shown in Appendix I and summarized in Table 2.

Table 2. Land Uses in Subsegment 030806

LAND USE	ACRES	PERCENT
Agricultural land	23005	23.29
Forest land	47017	47.59
Rangeland	13498	13.66
Urban or built-up	459	0.46
Water	2239	2.27
Wetland	12575	12.73
Total	98793	100

Figure 1. Vector Diagram (RK=River Kilometer)



The model extends from the headwaters at Creek Road north of Vinton, LA to just upstream of the Entergy power plant. The remaining stretch of the Houston River will be included in the Calcasieu River Estuary model. The Houston River's watershed includes the following tributaries: Persimmon Gully, Buxton Creek, and unnamed tributaries. The Houston River is in the Calcasieu River Basin and includes Water Quality Subsegment 030806. The area is sparsely populated. Five sewage treatment facilities were addressed in the TMDL effort; however, only one was included in the model.

2.2 Water Quality Standards

The water quality criteria and designated uses for the Houston River watershed are shown in Table 3.

Table 3. Water Quality Numerical Criteria and Designated Uses (LDEQ, 03/20/2001)

Subsegment	030806
Stream Description	Houston River – From junction with Bear Head Creek at Parish Road to West Fork Calcasieu River
Designated Uses	A B C F
Criteria:	
Cl	250
SO_4	75
DO	Designated Naturally Dystrophic Waters Segment; Seasonal DO Criteria: 5.0 mg/L December - February, 3.0 mg/L March - November.
pH	6.0-8.5
BAC	1 (=Primary Contact Recreation)
°C	32
TDS	500

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.

2.3 Wastewater Discharges

The discharger inventory for the Houston River watershed was reviewed. There are only nine 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, and best professional judgment. Only the City of DeQuincy was considered to have any ability to impact the target reaches. The City of DeQuincy discharges to Buxton Creek and is 13.5 miles from the Houston River. Buxton Creek and the City of DeQuincy were included in the model. The DO criteria in the Houston River were met with the City of DeQuincy discharging at its current permit limits of 10/2 ($CBOD_5/NH_3$-N). Therefore, its current permit limits will remain the same except for the addition of a 5.0 mg/L DO permit limit for its effluent.

The facilities in Table 4 will continue to be permitted according to state policy. Permit limits are based on monthly average values.

Table 4. Permit Limits for Facilities Not Included in the Model

FACILITY	CURRENT PERMIT LIMITS (BOD_5/NH_3-N), mg/L	POLICY PERMIT LIMITS ($CBOD_5$/NH_3-N), MONTHLY AVERAGE, mg/L
BIG OAKS RV PARK LAG530081	45/none (weekly average)	30/policy
DEQUINCY MIDDLE SCH, CALCASIEU PAR SCH BD, LAG540207	30/none (monthly average)	30/policy
PIERCE ACRES MOBILE HOME PARK LAG540561	30/none (monthly average)	30/policy
WESTERN GARDEN APT, CALHOUN PROPERTY MGMT INC LAG540855	30/none (monthly average)	30/policy

The list of facilities and the modeling decision for each is shown below in Table 5.

Table 5. Discharger Inventory for Subsegment 030806

FACILITY	REC_WATER	FILE_NUM	Facility info.
BIG OAKS RV PARK	DITCH-HOUSTON RIVER	LAG530081	Treated sanitary sewage=1,250 gpd. Since the flow path is not on the map, assume the flow path is roadside ditch to Houston River. Facility is 1.3 miles (2.1 km) from the Houston River. BOD5 weekly avg=45 mg/L. No monthly avg values. No limits for NH3-N and DO. Not modeled.
ROY S. NELSON POWER STA. UNIT 6, ENTERGY GULF STATES UTILITIES INC	HOUSTON RIVER	LA0059030	Only outfall 002 is permitted for BOD. Outfall 002 is treated sanitary wastewater at 2,490 gpd long term avg. BOD5 daily avg=30 mg/L. BOD5 daily max=45 mg/L. No limits for NH3-N and DO. Not modeled since the contractors will include this facility in their model.
ROY S NELSON STATION, ENTERGY GULF STATES, INC	HOUSTON RIVER	LA0005843	This facility will be included in the model done by contractors.
DEQUINCY, CITY OF	Effluent Pipe-BUXTON CREEK-HOUSTON RIVER	LA0038709	Treated sanitary wastewater, design capacity=1.1 MGD. Facility is 13.5 miles (21.65 km) from the Houston River. Current permit limits=10 mg/L CBOD5 30-day avg, 2 mg/L NH3-N 30-day avg. No permit limit for DO. Included in the model.
DEQUINCY MIDDLE SCH, CALCASIEU PAR SCH BD	Unnamed ditch-Buxton Creek-HOUSTON RIVER	LAG540207	Treated sanitary sewage=6,660 gpd. Facility is 4.5 miles from Buxton Creek and 15.3 miles from the Houston River. BOD5 monthly avg=30 mg/L. No limits for NH3-N and DO. Not modeled.
PIERCE ACRES MOBILE HOME PARK	BEEFPEN GULLY-COWARDS GULLY-BUXTON Creek-Houston River	LAG540561	Treated sanitary sewage=7,800 gpd. Facility is 17.6 miles from the Houston River and 12.2 miles from Buxton Creek. BOD5 monthly avg=30 mg/L. No permit limits for NH3-N and DO. Not modeled.
WESTERN GARDEN APT, CALHOUN PROPERTY MGMT INC	There was conflicting information in the file regarding the flow path, so I contacted the permit writer. It is as follows: Highway 12 roadside ditch-Buxton Creek-Houston River	LAG540855	Treated sanitary wastewater =13,200 gpd. Facility is 16.7 miles from the Houston River and 2.3 miles from Buxton Creek. BOD5 monthly avg=30 mg/L. No limits for NH3-N and DO. Not modeled.
Discard the following:			
OAK HAVEN TRAILER PARK	Unnamed ditch-Jim Pickens roadside ditch-unnamed canal-Houston River. From the map, it appears that this facility discharges to the Houston River Canal, not the Houston River, so **discard**.	LAG540535	Treated sanitary wastewater=8,400 gpd. BOD5 monthly avg=30 mg/L. No permit limits for NH3-N and DO.
(OLD NAME/CALCASIEU PH WW DIST 11), HOUSTON RIVER WATERWORKS DIST. #11	Ditch-Drainage Canal-HOUSTON RIVER	LA0077534	This is a potable water treatment plant which is covered under a general permit. The general permit that covers this type of system does not include BOD as a permitted parameter, so **discard**. The discharge from this facility is 10,000 galllons of sand filter backwash, which is backwashed once a week. The discharge is 10 minutes/week.

2.4 Water Quality Conditions/Assessment

The Houston River, Subsegment 030806, was not on any 303(d) list; however, the Houston River 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. The Houston River 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, pH, salinity/TDS/chlorides, and sulfates. The suspected sources were natural sources, hydromodification, and agriculture.

2.5 Prior Studies

There have been no prior TMDL related studies on the Houston River.

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." (Shoemaker, May 1997)

The model used for this TMDL was LA-QUAL, a steady-state one-dimensional water quality model. 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 at various locations on the stream, location of the stream centerline and the boundaries of the watershed which drain 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 into the stream, gathering all available stream water quality chemistry and flow data from other agencies and groups, gathering population statistics for the watershed to assist in developing projections of future loadings to the water body, land use and crop rotation data where available, and any other information which may have some bearing on the quality of the waters within the watershed. During Stage 1, any data available from reference or least impacted streams which can be used to gauge the relative health of the watershed is also collected.

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

Stage 3 covers the projection modeling which results in the TMDL. The critical conditions of flow and temperature are determined for the waterbody, and the maximum pollutant discharge conditions from the point sources are determined. These conditions are then substituted into the model along with any related condition changes which are required to perform worst case scenario predictions. At this point, the loadings from the point and nonpoint sources (increased by an acceptable margin of safety) are run at various levels and distributions until the model output shows that dissolved oxygen criteria are achieved. It is critical that a balanced distribution of the point and nonpoint source loads be made in order to predict any success in future achievement of water quality standards. At the end of Stage 3, a TMDL is produced which shows the point source permit limits and the amount of reduction in man-made nonpoint source pollution which must be achieved to attain water quality standards. The man-made portion of the nonpoint source (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 on September 19-21, 2000 was used to establish the input for the model calibration and is presented in Appendix E. Each data type is discussed further in the sections below.

3.2.1 Model Schematics and Maps

A vector diagram of the modeled area is shown in Figure 1 of Section 2.1. The vector diagram shows the locations of survey stations, the reach design, and the location of the modeled tributary and facility. A land use map is presented in Appendix I.

3.2.2 Model Options, Data Type 2

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

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:

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

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 (Wiland, 2001).

3.2.4 Reach Identification Data, Data Type 8

Using the survey stations where data was collected and the ARCVIEW mapping as guides, the reaches and elements were established. The resulting design incorporated 4 reaches, 2 headwaters, 1 wasteload and 349 elements. A simple spreadsheet was used to calculate the number of elements in each reach. The element number of the discharger was determined by using a related spreadsheet. These spreadsheets are presented in Appendix C1.

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). There was no data available to calculate the coefficients and exponents; therefore, the stream geometry was assumed to be constant since the critical stream geometry during the summer and winter is not expected to be significantly different from the geometry measured during the survey. The input data and sources are shown in Appendix C2.

3.2.6 Dispersive Hydraulic Coefficients, Data Type 10

Dispersion was obtained by calibrating to in situ conductivity and TDS lab data. The input data are shown in Appendix C2.

3.2.7 Initial Conditions, Data Type 11

If the constituent is being modeled, the initial conditions serve only as a starting point in the iterative solution technique and do not affect the model results. If the constituent is not being modeled, they serve as the final values and can affect the model results. The values required for this model were temperature and DO by reach. The input data and sources are shown in Appendix C2.

3.2.8 Reaeration Rates, Data Type 12

No reaeration equation was applicable to the Houston River; therefore, 0.7/depth was used. The input data is shown in Appendix C2.

3.2.9 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 SOD value for each reach is shown in Appendix C2.

3.2.10 Carbonaceous BOD Decay and Settling Rates, Data Type 12

The decay rates used were based on the bottle rates from the survey. CBOD decay rates were fairly consistent with main stem rates ranging from 0.04 to 0.05. The decay and settling rates used for each reach are shown in Appendix C2.

3.2.11 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. NBOD decay rates ranged from 0.09 to 0.38. The decay and settling rates used for each reach are shown in Appendix C2.

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

The incremental conditions were used in the calibration to represent the flow of groundwater into the Houston River from the Sabine River Diversion System. A total flow of 1.08 cfs was distributed along the Houston River. The data and its source for each reach are presented in Appendix C2. A description of the Houston River hydrology is discussed in Appendix G.

3.2.13 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. Nonpoint source loads were determined by calibration. The data is presented in Appendix C2.

3.2.14 Headwaters, Data Types 20, 21, and 22

There was no flow during the survey at the headwaters. The data and sources are presented in Appendix C2.

3.2.15 Wasteloads, Data Types 24, 25, and 26

The City of DeQuincy discharges to Buxton Creek which is a tributary of the Houston River. Both were included in the Houston River modeling effort. The data is presented in Appendix C2.

3.2.16 Lower Boundary Conditions, Data Type 27

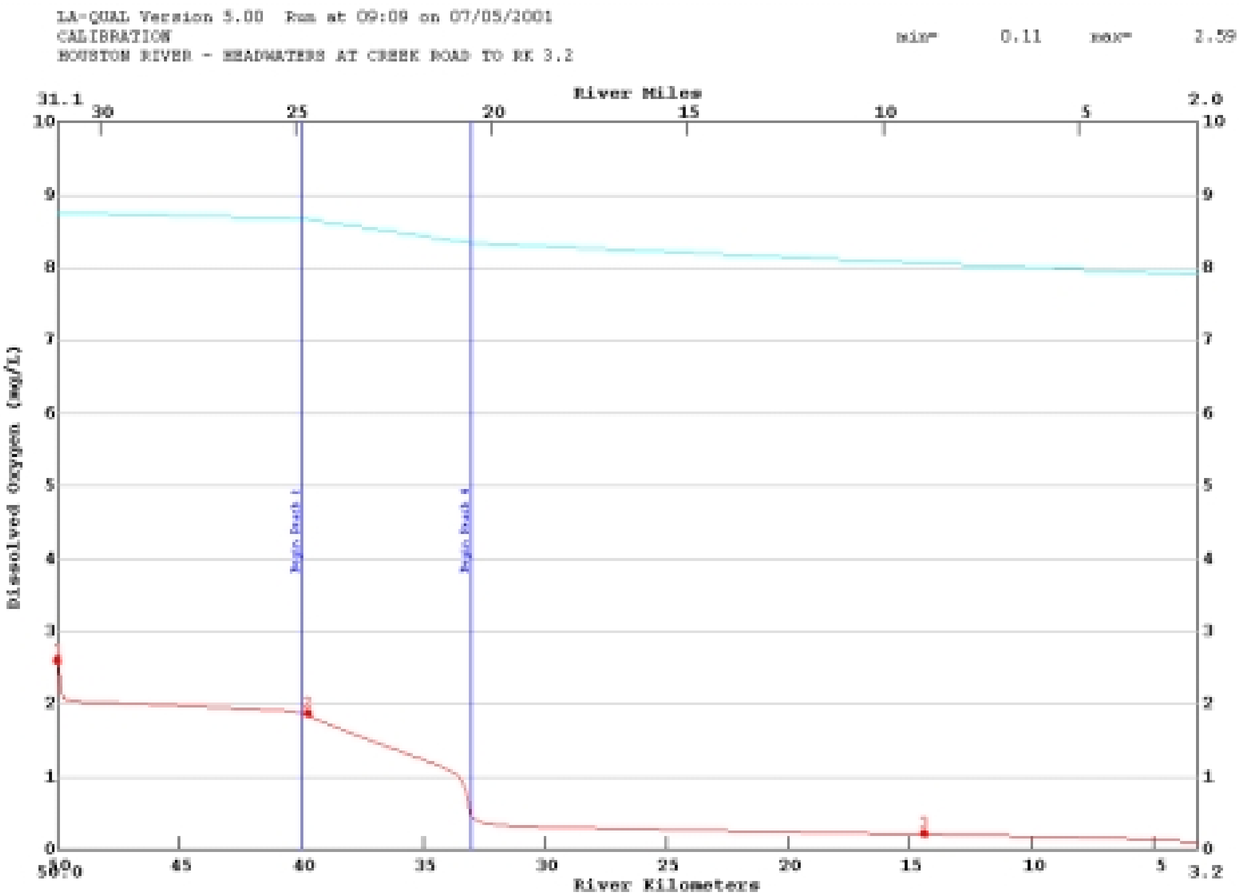
The lower boundary conditions were assumed to be equivalent to the measurements taken at survey site HR 3. The input data is shown in Appendix C2.

3.3 Model Discussion and Results

The calibration model input and output are 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 2. Very good calibration was achieved for DO, UCBOD, and UNBOD on the main stem. UCBOD and UNBOD calibration plots are in Appendix B.

The lower reaches of the Houston River exhibit tidal characteristics due to the salt water barrier on the Calcasieu River. During the survey, flows ranged from no flow at the headwaters to substantial flow near the confluence with the West Fork Calcasieu River. Furthermore, flow was observed going upstream and downstream. Due to inconsistencies in flow, a headwater of 0.1 cfs was used. Buxton Creek, the City of DeQuincy, and groundwater were also included in the model. Buxton Creek was the only tributary that was flowing during the survey; therefore, the other tributaries were not included in the model. Calibration plots for Buxton Creek are presented in Appendix H.

Figure 2. Calibration Model - Dissolved Oxygen versus River Kilometer



- numbered points indicate survey stations
- vertical lines indicate beginning of reach (from left to right: Begin Reach 2, Begin Reach 4)
- upper plotted line indicates DO saturation
- lower plotted line through points indicates calibration model output

4. Water Quality Projections

Projections were performed for the following conditions:

1. Summer, 3.0 mg/L DO, March-November
2. Winter, 5.0 mg/L DO December- February

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 Houston River TMDL, an analysis of LDEQ ambient data has been employed to determine critical seasonal conditions.

Critical conditions for dissolved oxygen were determined for the Houston River using water quality data from Site 0846 on the Houston River northeast of Sulphur, LA. The 90th percentile temperature for each season was determined. Ambient temperature data and critical temperature determinations are shown in Appendix F. Graphical and regression analysis techniques have been used by LDEQ historically to evaluate the temperature and dissolved oxygen data from the Ambient Monitoring Network and run-off determinations from the Louisiana Office of Climatology water budget. Since nonpoint loading is conveyed by run-off, this was a reasonable correlation to use. Temperature is strongly inversely proportional to dissolved oxygen and moderately inversely proportional to run-off. Dissolved oxygen and run-off are also moderately directly proportional. The analysis concluded that the critical conditions for stream dissolved oxygen concentrations were those of negligible nonpoint run-off and low stream flow combined with high stream temperature.

When the rainfall run-off (and non-point loading) and stream flow are high, turbulence is higher due to the higher flow and the temperature is lowered by the run-off. In addition, run-off coefficients are higher in cooler weather due to reduced evaporation and evapotranspiration, so that the high flow periods of the year tend to be the cooler periods. Reaeration rates and DO saturation are, of course, much higher when water temperatures are cooler, but BOD decay rates are much lower. For these reasons, periods of high loading are periods of higher reaeration and dissolved oxygen but not necessarily periods of high BOD decay.

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

Critical season conditions were simulated in the Houston River dissolved oxygen TMDL projection modeling by using the default flows from the Louisiana Technical Procedures Manual and the 90th percentile temperature. Incremental flow was used to simulate groundwater; model loading was from one tributary, the City of DeQuincy, sediment oxygen demand, and resuspension of sediments.

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

4.2 Input Data Documentation

The flow in the Houston River headwater was set at 0.1 cfs = 0.0028 cms for summer critical conditions in accordance with the LTP. The flow in the headwater was set at 1.0 cfs = 0.028 cms for winter critical conditions in accordance with the LTP.

4.2.1 Model Options, Data Type 2

Three constituents were modeled during the projection scenarios. 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 values were not changed from the calibration. The stream geometry was assumed to remain constant with no significant change during critical flow conditions for summer and winter.

4.2.5 Dispersive Hydraulic Coefficients, Data Type 10

The values from the calibration were used.

4.2.6 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.

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

CBOD decay, CBOD settling rates, NBOD decay, and NBOD settling rates were not changed from the calibration. The reaeration rate equations for the summer projection run were not changed from the calibration. However, for the winter run, the reaeration equations were changed in two reaches.

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

The incremental conditions were used in the calibration to represent groundwater from the Sabine River Diversion System. For the projection runs, the characteristics of the groundwater remained at the same values that were used in calibration. Appendix G contains documentation about the Houston River hydrology and calculation of 7Q10s.

4.2.9 Sediment Oxygen Demand, Nonpoint Sources, Headwaters, Data Types 12, 19, 20, 21, and 22

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 g-O_2/m^2/day. The same spreadsheet also calculated load reductions for the headwaters. The values of the input data and the load analyses are presented in Appendix A for each of the projection runs.

4.2.10 Wasteloads, Data Types 24, 25, and 26

The City of DeQuincy discharges 1.1 MGD of treated sanitary wastewater to Buxton Creek. The facility is 13.5 miles from the Houston River. Buxton Creek and the City of DeQuincy were included in the model. The DO criteria in the Houston River were met with the City of DeQuincy discharging at its current permit limits of 10/2 ($CBOD_5/NH_3$-N). Therefore, its current permit limits will remain the same except for the addition of a 5.0 mg/L DO permit limit for its effluent.

4.2.11 Lower Boundary Conditions, Data Type 27

The ocean exchange ratio was set to zero so that the model would not be forced through any particular values at the most downstream point. However, even with the ocean exchange ratio at zero, the temperature is still forced to terminate at the lower boundary temperature. Therefore, the lower boundary temperatures were set at the 90^{th} percentile critical season temperatures.

4.3 Model Discussion and Results

Appendix G discusses the hydrology and 7Q10 estimation for the Houston River. Downstream flow from backwater effects was not included in this model. The value for “input from DeQuincy wastewater treatment plant” was not used. The DeQuincy plant was input at 1.1 MGD plus a 20% margin of safety. The projection model input and output are presented in Appendix D.

The summer projection scenario resulted in a required reduction of more than 100% when the required reduction was differentiated between man-made and natural nonpoint pollution. Therefore, the percentage reductions necessary to meet the seasonal DO standards are presented as total nonpoint pollution since a reduction of more than 100% is not possible.

4.3.1 Summer Projection

The results of the projection modeling show that the 3.0 mg/L water quality standard for dissolved oxygen can be maintained during the summer critical season with a 67% reduction of total nonpoint source pollution. These results suggest that the criterion for the Houston River could be inappropriate and that further study or a Use Attainability Analysis (UAA) is needed. The DO plot is shown is Figure 3.

4.3.2 Winter Projection

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 46% reduction of total nonpoint source pollution. These results suggest that the criterion for the Houston River could be inappropriate and that further study or a UAA is needed. A graph of the dissolved oxygen concentration versus river kilometer for the winter projection is presented in Figure 4.

Figure 3. DO vs. RK - Summer Projection with a 67% reduction of total nonpoint source pollution

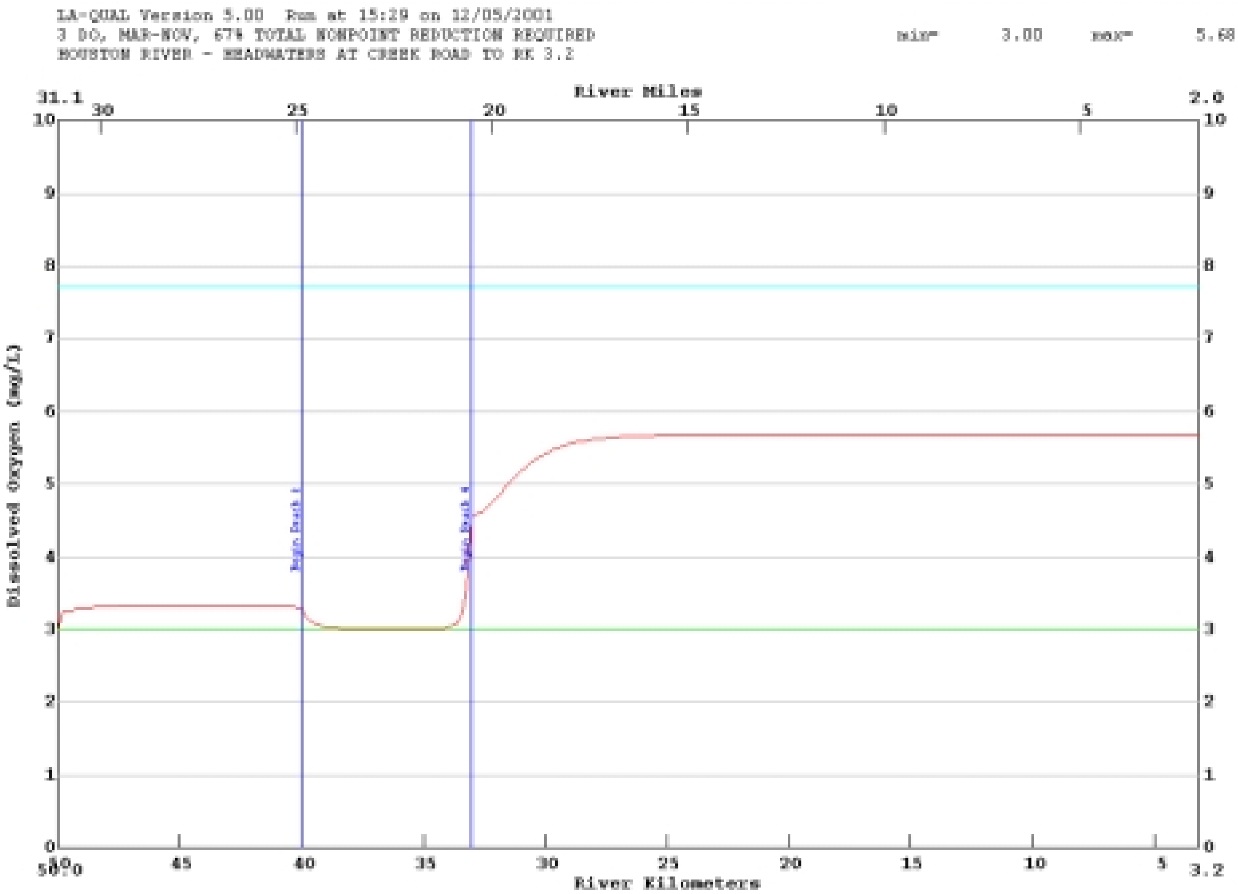
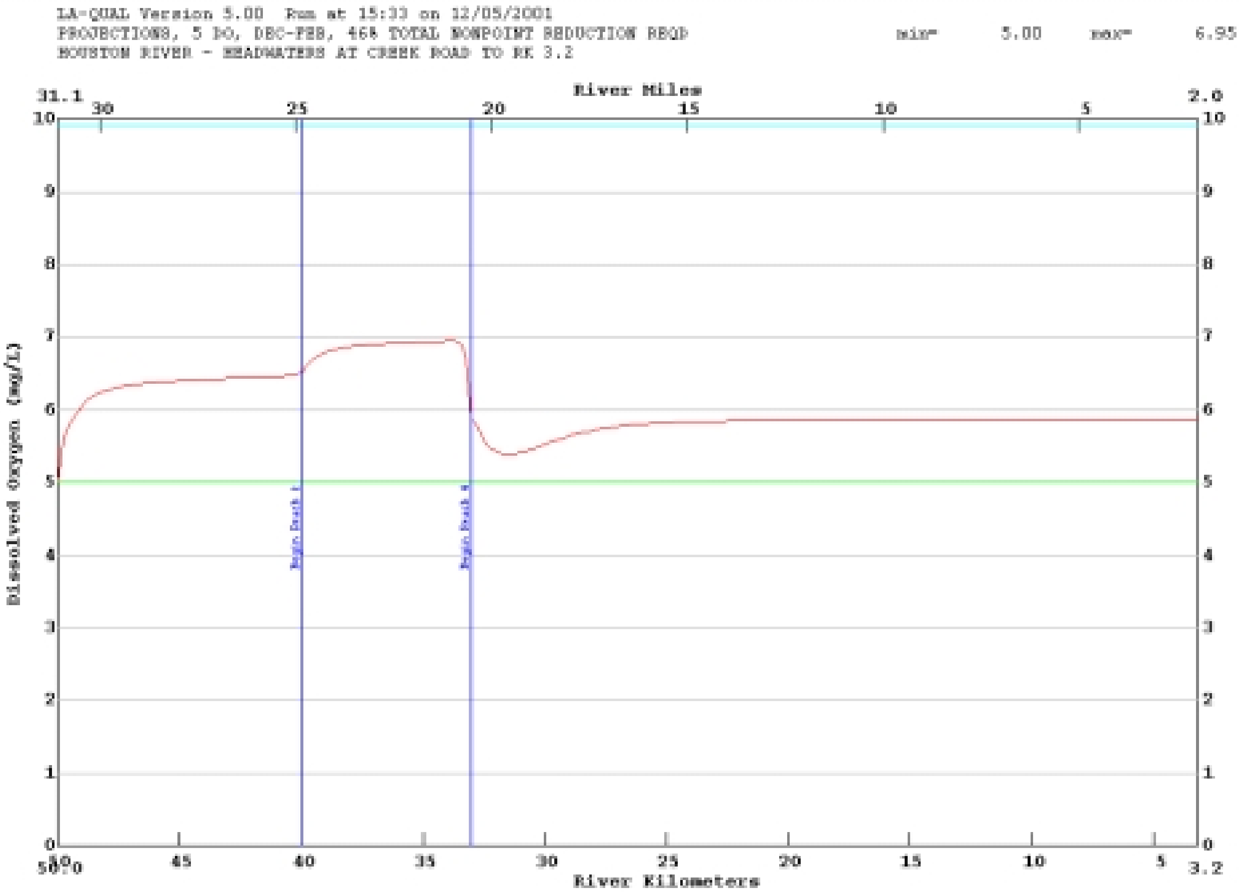


Figure 4. DO vs. RK - Winter Projection with a 46% reduction of total nonpoint source pollution



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.

In some cases, percent reductions of more than 100% are calculated when the reductions are differentiated between man-made and natural nonpoint pollution. When this occurs, the percentage reduction is calculated as a reduction in total nonpoint pollution.

4.4.1.1 The natural background benthic loading was estimated from reference stream resuspension (nonpoint CBOD and NBOD), and SOD load data. A natural background benthic load of 3.3 g O_2/m^2-

day was used and is the same value used for the Bear Head Creek model. This value is a best estimate and is the average taken from three reference streams. The reference streams and corresponding total benthic loads are Chemin-a-Haut Bayou=3.171, Middle Fork Bayou D'Arbonne=1.85, and Beaucoup Creek=4.867 all in g O_2/m^2-day (Smythe, 1997).

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

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

- The percent reduction of man-made loads for each reach is determined from the difference between the projected man-made 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 Houston River TMDL

The TMDLs for the biochemical oxygen demanding constituents (CBOD, NBOD, and SOD) have been calculated for the summer and winter critical seasons. The TMDLs for the Houston River watershed were set equal to the total stream loading capacity. They are presented in Appendix A. A summary of the loads is presented in Table 6.

Table 6. Total Maximum Daily Load (Sum of CBOD, NBOD, and SOD)

	3 mg/L DO, Mar-Nov	5 mg/L DO, Dec-Feb
Point Source WLA, lb/day of oxygen demand	322	322
Point Source MOS, lb/day of oxygen demand	79	79
Nonpoint LA, lb/day of oxygen demand	7162	11262
Nonpoint MOS, lb/day of oxygen demand	0	988
TMDL, lb/day of oxygen demand	7563	12651

5. Sensitivity Analysis

All modeling studies necessarily involve uncertainty and some degree of approximation. It is therefore of value to consider the sensitivity of the model output to changes in model coefficients and in the hypothesized relationships among the parameters of the model. The 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. Parameters were varied by +/- 30%, except temperature, which was adjusted +/- 2 degrees Celsius. 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 of the model’s minimum DO showed that DO is most sensitive to benthal demand, temperature, and reaeration. The sensitivity analysis is shown in Table 7.

Table 7. Summary of Calibration Model Sensitivity Analysis

SENSITIVITY ANALYSIS SUMMARY

Plot 1 Base Model Minimum DO = 0.11

Parameter	%Param Chg	Min D.O.	%D.O. Chg	%Param Chg	Min D.O.	%D.O. Chg
Stream Baseflow	30.	0.11	0.1	-30.	0.11	-0.1
Stream Velocity	30.	0.10	-4.2	-30.	0.11	1.7
Stream Depth	30.	0.10	-11.1	-30.	0.12	10.4
Stream Dispersion	30.	0.11	0.0	-30.	0.11	0.0
Stream Reaeration	30.	0.17	57.9	-30.	0.00	-100.0
BOD Decay Rate	30.	0.10	-3.7	-30.	0.11	3.0
BOD Settling Rate	30.	0.11	0.6	-30.	0.11	-0.7
Benthal Demand	30.	0.00	-100.0	-30.	0.16	49.1
Nonconservative Decay	30.	0.10	-10.6	-30.	0.12	7.5
Nonconservative Settling	30.	0.11	0.7	-30.	0.11	-1.8
Initial Temperature	2.	0.04	-65.9	-2.	0.13	23.8
Incremental Inflow	30.	0.11	0.1	-30.	0.11	-0.1
Incremental DO	30.	0.11	0.0	-30.	0.11	0.0
Incremental BOD	30.	0.11	0.0	-30.	0.11	0.0
Incremental Nonconservative	30.	0.11	0.0	-30.	0.11	0.0
Headwater Flow	30.	0.11	0.0	-30.	0.11	0.0
Headwater Temperature	2.	0.11	0.0	-2.	0.11	0.0
Headwater DO	30.	0.11	0.0	-30.	0.11	0.0
Headwater BOD	30.	0.11	0.0	-30.	0.11	0.0
Headwater Nonconservative	30.	0.11	0.0	-30.	0.11	0.0
Wasteload Flow	30.	0.11	0.0	-30.	0.11	0.0
Wasteload DO	30.	0.11	0.0	-30.	0.11	0.0
Wasteload BOD	30.	0.11	0.0	-30.	0.11	0.0
Wasteload Nonconservative	30.	0.11	0.0	-30.	0.11	0.0
Ocean Exchange Ratio	30.	0.11	0.2	-30.	0.11	-0.1
Lower Boundary Temperature	2.	0.11	0.0	-2.	0.11	0.0
Lower Boundary DO	30.	0.12	8.4	-30.	0.09	-20.4
Lower Boundary BOD	30.	0.11	-2.7	-30.	0.11	1.9
Lower Boundary Nonconservative	30.	0.10	-9.8	-30.	0.12	6.8

6. Conclusions

The TMDL requires a 67% reduction of total nonpoint source pollution in order to meet the DO criterion in the summer. A 46% reduction in total nonpoint source pollution is required to meet the DO criterion in the winter. These results suggest that the criteria for the Houston River could be inappropriate and that further study or a UAA is needed.

The City of DeQuincy’s permit limits will remain the same with the addition of a 5.0 mg/L DO criterion for its effluent. The four smaller facilities in the watershed will continue to be permitted according to state policy.

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.

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.)

As part of the monitoring program, compliance inspections are also being conducted in the targeted basins each year as part of the watershed approach to monitoring and to identify enforcement needs. Compliance inspections conducted during 1999 were as follows:

Calcasieu Basin - 33 major NPDES facilities, 260 minor facilities

Ouachita Basin - 348 facilities (total) inspected

7. References

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Smythe, E. deEtte. *Overview of the 1995 Reference Streams*. Louisiana Department of Environmental Quality. Baton Rouge, LA: August 15, 1997.

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8. Appendices

See Attached Appendices A - I.