LITTLE RIVER WATERSHED TMDL FOR OXYGEN-DEMANDING SUBSTANCES INCLUDING A WATERSHED NONPOINT SOURCE LOAD ALLOCATION

SUBSEGMENT 030804

VOLUME I

TMDL Report
Appendices A-F

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

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EXECUTIVE SUMMARY

A Total Maximum Daily Load (TMDL) for oxygen-demanding substances has been developed for the Little River Watershed based on hydrologic and water quality data available as of August 23, 2000. Little River was not included on either the 1996 Section 303(d), the 1998 Section 303(d), or the Court Ordered Section 303(d) lists as not meeting the water quality standard for dissolved oxygen. However, Little River has been included in the year 2000 305(b) list as being impaired due to low dissolved oxygen. The year 2000 305(b) list was based upon data collected in 1999 and new assessment methodology. The suspected cause of impairment is natural sources, and the waterbody has been proclaimed by LDEQ to be naturally dystrophic. In addition, the sampling was done during drought conditions, which contribute to low dissolved oxygen conditions in the stream. Much of the landuse in the subsegment consists of agriculture and forests (naturally wooded). Forestry (silviculture) is practiced throughout a significant portion of the agricultural land use areas. The stream is believed to be naturally dystrophic due to low slopes, with much of the nonpoint loading coming from natural sources. This TMDL establishes load limitations for oxygen-demanding substances and goals for reduction of those pollutants.

The Little River watershed is subsegment 030804 of the Calcasieu River Basin (Basin 3). Subsegment 030804 is comprised of Little River and all tributaries, including Cypress Creek and numerous unnamed tributaries. TMDLs for the Calcasieu River Basin are scheduled for completion by December 31, 2001. Therefore the completion of a TMDL for Little River is considered to be high priority by LA DEQ.

According to the year 2000 Environmental Regulatory Code, Part IX Water Quality Regulations, the dissolved oxygen standards are 3 mg/L for the summer season (March – November) and 5.0 mg/L for the winter season (December – February) (LA DEQ, 2000). It is projected that compliance with dissolved oxygen criteria will require a 70 percent reduction of man-made nonpoint loading in the watershed.

Subsegment 030804 was void of any known oxygen-demanding point source dischargers. There is a CECOS facility along the lower reaches of Little River. Based upon permit file research and a site visit during the reconaissance survey, it was determined that all of the cells and lagoons at this site have been closed. The company uses this facility only for deep well injection. According to the permit file information, this facility discharges stormwater at three different outfalls during rainfall events. It is not permitted for oxygen-demanding substances, which this TMDL was intended to address. Therefore, the facility was acknowledged and documented but not included in the model.

Little River was modeled from its headwaters (River Kilometer 19.50) to its confluence with the West Fork Calcasieu River (River Kilometer 0.00). The survey was conducted during a period of subcritical (drought) conditions. Many of the traditionally perennial waterbodies in the basin were pooled or dry. Only one tributary had a velocity that could be measured with typical survey equipment. Consequently, it was the only tributary boundary site included in the model. Any gain or loss in flow between survey sites was treated as incremental inflow or outflow, respectively.

The headwater and tributary boundary loads were the only loads represented in the models as point source loads. The headwater load was modeled in the headwater section of the model and the tributary load was modeled in the wasteload section of the model. In reality, they are nonpoint loads, which represent the in-stream loads at those sites that are caused by the nonpoint loading in the drainage area upstream of those sites. These loads are actually results of the nonpoint loading existing in the drainage area upstream of the respective survey sites.

The nonpoint source loads included headwater loading (as a boundary condition), tributary loading (as a boundary condition), nonpoint loading associated with flow (incremental), and other nonpoint loading not associated with flow, such as benthic loading (sediment oxygen demand and resuspension).

The various spreadsheets that were used in conjunction with the modeling program may be found in the appendices in the order in which they were used. The flow calibration was based on measurements taken during the survey of Little River (June 27-29, 2000). Water quality calibration was also based on measurements taken during this survey.

Summer and winter projections were developed to meet the dissolved oxygen (D.O.) criteria by reducing boundary loads, incremental loads, sediment oxygen demand loads, and nonpoint source loads to obtain load allocations (LAs). Additional summer and winter projections were simulated. A summer projection was run with increased nonpoint source loads. This run violated the summer D.O. criteria.   Summer and winter projections that were void of man-made (anthropogenic) nonpoint loading were developed. These projections did not violate summer or winter criteria.

Land use in the Little River watershed is fairly homogeneous. It is approximately 36.14 percent agriculture, principally forestry and row crops. Forestlands occupy approximately 41.16 percent of the Little River watershed. Landuse activities may change periodically due to weather and/or economic conditions.

Summer and winter LAs and TMDLs have therefore been calculated for the entire watershed and are presented in the table on the following page. Due to the assumptions made while developing the model, the inherent error within the model algorithms, and the scale of a watershed-based model, the results of the model should be used only as an aid in making water quality based decisions.

In order to meet stream criteria the man-made portion of the nonpoint loads (nonpoint, incremental, and boundary loads) had to be reduced by 70%. A 20% margin of safety (MOS) had to be provided. Therefore, the actual required percent reduction of the man-made nonpoint loads was calculated to be 86%. For the purpose of reporting, this number was rounded off to 90%.

A table showing the summer and winter TMDLs, WLAs, LAs, and MOS's is presented below.

	Summer season (Mar – Nov)		Winter season (Dec – Feb)	
Point source allocations (WLA)	BOD Load (lbs./day)	% of TMDL	BOD Load (lbs./day)	% of TMDL
Total point source allocations (WLA)	0	0	0	0
Point source margin of safety (MOS)	0	0	0	0
Headwater/Tributary Loads	9	1	91	10
Benthic Loads (based upon nonpoint and SOD loads used in the projection)	1155	88	693	74
Incremental Loads	148	11	148	16
Total maximum daily load (TMDL)	1312	100	932	100
Nonpoint source margin of safety (MOS for benthic, incremental, and boundary loads)	262	20	186	20

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Little River Watershed TMDL
Subsegment 030804
Originated: March 16, 2001

1. Introduction

A total maximum daily load (TMDL) for oxygen-demanding substances to meet the dissolved oxygen (D.O.) criterion has been developed for the Little River Watershed. The TMDL was based on hydrologic and water quality data available as of August 23, 2000. The Little River Watershed is subsegment 030804 of the Calcasieu River Basin (Basin 03). Little River was not included on either the 1996 Section 303(d), the 1998 Section 303(d), or the Court Ordered Section 303(d) lists as not meeting the water quality standard for dissolved oxygen. However, Little River has been included in the year 2000 305(b) list as being impaired due to organic enrichment/low dissolved oxygen (D.O.). The year 2000 305(b) list was based upon data collected in 1999 and new assessment methodology. The suspected cause of impairment is natural sources, and the waterbody has been proclaimed by LDEQ to be naturally dystrophic. In addition, the sampling was done during drought conditions, which contribute to low dissolved oxygen conditions in the stream. Much of the landuse in the subsegment consists of agriculture and forests (naturally wooded). Forestry (silviculture) is practiced throughout a significant portion of the agricultural land use areas. The stream is believed to be naturally dystrophic due to low slopes, with much of the nonpoint loading coming from natural sources. This TMDL establishes load limitations for oxygen-demanding substances and goals for reduction of those pollutants.

The Little River watershed is subsegment 030804 of the Calcasieu River Basin (Basin 03). Subsegment 030804 is comprised of Little River and all tributaries, including Cypress Creek and numerous unnamed tributaries. TMDLs for the Calcasieu River Basin are scheduled for completion by December 31, 2001. Therefore the completion of a TMDL for Little River is considered to be high priority by LA DEQ.

A calibrated water quality model for the Little River watershed was developed and projections were run to quantify the nonpoint source load allocations (LAs) required to meet established dissolved oxygen criterion. This report presents the model development and results.

1.1 Seasonality and Margin of Safety

The Clean Water Act requires the consideration of seasonal variation of conditions affecting the constituent of concern, and the inclusion of a margin of safety (MOS) in the development of a TMDL. For the Little River TMDL, LA DEQ assessment data and USGS flow data have been employed to determine critical seasonal conditions and the appropriate MOS has been used.

Critical seasonal conditions for dissolved oxygen and flow were determined for the Little River Basin using water quality assessment data from station 0844 (Little River East of Buhler, LA) and flow data based upon drainage areas and 7Q10 data developed from USGS data for station 08016800 (Bear Head Creek near Starks, LA).

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

LDEQ interprets this phenomenon in its TMDL modeling by assuming that the annual nonpoint loading, rather than loading for any particular day, is responsible for the accumulated benthic blanket of the waterbody, 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.

Critical summer conditions were simulated as part of the model projections. The critical conditions were based upon flow and temperature. LA DEQ simulated critical summer flow conditions in the Little River dissolved oxygen TMDL projection modeling by using the greater of the estimated seasonal 7Q10 flow or 0.1 cfs for all headwaters, as stated in the Louisiana Total Maximum Daily Load Technical Procedures Manual (LTP). A headwater flow of 0.1 cfs was used for Little River. The LTP recommends a temperature of 30 C or, when appropriate data is available, the 90th percentile temperature for the summer months. Little River had assessment data, therefore the 90th percentile temperature for the summer months was used. The summer months were determined to be March through November, based upon the dissolved oxygen criteria set for Little River in the LA DEQ Environmental Regulatory Code. Incremental flow was not assumed to be zero because the survey data indicated that incremental flow (assumed to be groundwater) existed during the survey, which was conducted during subcritical conditions (drought); model loading was from headwater sources, a perennial tributary, incremental flow, sediment oxygen demand, and nonpoint sources (resuspension of sediments). In addition, a 20% MOS was applied to the estimated man-made portion of all loads. (LA DEQ, 2000)

Critical winter conditions were also simulated based upon flow and temperature. LA DEQ simulated critical winter flow conditions by using the greater of the estimated winter season 7Q10 flow or 1.0 cfs for all headwaters, as stated in the LTP. A headwater flow of 1.0 cfs was used for Little River. The LTP recommends a temperature of 20 C or, if appropriate data is available, the 90th percentile temperature for the winter months. Little River had assessment data, therefore the 90th temperature for the winter months was used. Again, incremental flow was not assumed to be zero; model loading was from headwater sources, perennial tributaries, incremental flow, sediment oxygen demand, and nonpoint sources (resuspension of sediments). Again, a 20% MOS was used. (LA DEQ, 2000)

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 model is established as if all of these had occurred at the same time. Other conservative assumptions regarding rates and loadings are also made during the modeling process. In addition to these conservative measures, the explicit MOS of 20% was used for all boundary, nonpoint, incremental, and SOD loads. The MOS was intended to account for future growth, model uncertainty, and data inadequacies.

Based upon available landuse data, 41.16 percent of the land in Subsegment 030804 occupied by forests. Agricultural practices existed on 36.14 percent of the land in Subsegment 030804. However, the majority of the land along the surveyed portion of the waterbody consisted of agricultural land uses, particularly forestry/timber. Minimal amounts of land in this area are available for further agricultural development. Also, nonpoint and incremental source loads had to be reduced in order to project to the seasonal criteria.

2. Study Area Description

2.1 Calcasieu River Basin

The Calcasieu River Basin is located in southwestern Louisiana. It begins in the hills west of Alexandria, LA and flows south for approximately 257.44 km (160 miles) to the Gulf of Mexico. The mouth of the river is approximately 48.27 km (30 miles) east of the Texas-Louisiana state border. (LA DEQ, 1996). The basin encompasses the hill region of the state, the terrace region, and a section of the coastal marsh. The upper end of the basin consists of pine forested hills, while the lower end of the basin consists of brackish and salt marshes. Originally, much of the area was covered by tall prairie grasses, among which there were scattered clumps of trees. (Soil Survey, 1962).

The hill region includes the longleaf pine forests, maximum elevations and relief, dendritic and trellis drainage, interior salt domes, wolds or cuestas (hard sedimentary rock), ironstone, excellent surface and groundwater resources, mature soils and the oldest rocks in the state. The soil types consist of coastal plain soils and flatwoods soils. Vegetation includes longleaf pine forests (longleaf pines, slash pines, some hardwoods) and bottomland hardwoods (cottonwood, sycamore, willow, water oaks, gum, maple, loblolly pine). (Kniffen, 1988)

The terrace region includes intermediate elevations and relief, older alluvium, and a large percentage of tabular surfaces. The terraces range from flatwoods to prairies. The flatwoods consist of low relief, mixed longleaf forests, bagols, pimple mounds, dendritic drainage, flatwoods soils. Vegetation includes flatwoods (longleaf pine, oak, palmetto, wiregrass), cypress forests (cypress, tupelo), and bottomland hardwoods. The prairies consist of low relief, prairie grassland, prairie soils, pimple mounds, dendritic streams, ice-age channels, and platin or marais (small, shallow undrained ponds in the prairies). Vegetative cover consists of prairie vegetation (bluestem, broomsedge), cypress forests, and bottomland hardwoods (Kniffen, 1988)

The coastal region includes fresh and salt/brackish marshes. It consists of muck and peat soils. Vegetation includes cattail, Roseau cane, three-corner grass and other types of marsh grasses. The region exists in the lower end of the basin. (Kniffen, 1988)

The Calcasieu River Basin is bounded on the north and west by the Sabine River Basin, on the north by the Red River Basin, and on the east by the Mermentau River Basin. The Gulf of Mexico marks the southern boundary of the Calcasieu River. The Calcasieu River Basin is approximately 3,910 square miles in area. (LA DEQ, 1996)

The slope of the land toward the Gulf is very gradual, especially in the coastal zone. This condition is ideal for agricultural use (LADEQ, 1999). Land use in the Calcasieu River Basin is largely agricultural, with many areas that have been impacted by industrial dischargers.

Although the low slope condition provides fewer problems for agricultural activities (LADEQ, 1999), it causes many of the streams in the Calcasieu River Basin to be characteristically sluggish. Many of the tributaries to the Calcasieu River, have low flows or become stagnant during critical times of the year. This statement is not accurate for the Calcasieu River itself, which tends to have a significant amount of flow throughout the year. Because many waterbodies in the basin have little gradient and sluggish flows, their reaeration potential is low.

Areas of the basin near I-10 and south of I-10 appear to be tidally influenced. These tides are primarily caused by wind action on Calcasieu Lake, Prien Lake, and Lake Charles. Due to the Calcasieu River Saltwater Barrier near Lake Charles, LA, the water surface elevation of some tributaries and reaches of the Calcasieu River tend to increase when the structure is closed and decrease when the structure is open.

Prior studies have shown nonpoint sources dominate the northern subsegments of the basin while a few municipal dischargers also exist in these subsegments. The nonpoint sources include runoff from pine forests, agricultural areas, and pastureland. Point source dischargers and saltwater intrusion dominate the southern subsegments of the basin below Lake Charles, LA. The point source discharges primarily include industrial and municipal dischargers, with the highest concentration of industry in the Lake Charles area.

2.2 Little River Watershed, Subsegment 030804

Segment 030804 is comprised of Little River as the main stem with several tributaries. The tributaries include Cypress Bayou and several unnamed tributaries. Little River is a tributary of West Fork Calcasieu River, which is a tributary of the Calcasieu River. Little River has a drainage area of approximately 93.5 km^2 (36.1 mi^2). It begins southeast of Dequincy, LA and flows approximately 27.6 km (17.2 mi) to the confluence with Calcasieu River.

Average annual precipitation in the segment is approximately 56 inches, according to information presented in Louisiana, Its Land and People (Kniffen, 1988).

This area is typical of the vast majority of the basin with its low relief and sluggish waterbodies. Land use in the Little River watershed is fairly homogeneous. In the subsegment under study, agricultural land and forestland account for 36.14 and 41.16 percent of the total subsegment area, respectively. Agricultural lands include lands used for forestry and row crops. Land uses in Subsegment 030804 are shown in Table 1 below (LA DEQ, 2000).

Table 1. Land uses in Subsegment 030804 of the Calcasieu River Basin (LDEQ, 2000)

Land use	Acres	%
Urban	24.83	0.11
Rangeland	2728.85	11.81
Agricultural Land	8352.00	36.14
Forestland	9511.91	41.16
Water	393.06	1.70
Wetland	2099.09	9.08
Barren Land	0.00	0.00

Based upon the reconnaissance surveys, forestry seemed to dominate the landscape along Little River from river kilometer 19.5 to approximately river kilometer 13.0. Some bottomland hardwoods dominated the riparian zones. Swamps and bottomland hardwoods dominated the lower reaches of Little River. The lower reaches appeared to be influenced by the Calcasieu River Saltwater Barrier and the tides in the lower reaches of the West Fork Calcasieu River and Calcasieu River.

2.3 Water Quality Standards

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

Designated uses for Little River from its headwaters to the Calcasieu River (waterbody subsegment 030804) include primary contact recreation, secondary contact recreation, and the propagation of fish and wildlife.

Little River is not listed on the either the 1996 303(d), 1998 303(d), or Court Ordered 303(d) lists as a waterbody requiring a TMDL for dissolved oxygen. However, Little River has been included in the year 2000 305(b) list as being impaired due to organic

Table 2. Current Numerical Criteria for Little River (LA DEQ, 2000)

Parameter	Criteria
Cl, mg/L	250
SO_4, mg/L	75
pH	6.0-8.5
BAC, # col./100 mL	200 and 400
Temperature, deg Celsius	34
TDS, mg/L	500

enrichment/low dissolved oxygen. The suspected source of impairment is natural sources, and LDEQ has proclaimed the waterbody to be naturally dystrophic. However, agriculture and forestry landuse and activities do exist in the area.

Based upon the 1999 assessment data and the new assessment methodology used for the year 2000 assessment, Little River did not meet the dissolved oxygen standard. In addition, the Calcasieu River Basin was being targeted for the development of TMDLs. Therefore, the development of a TMDL for Little River was designated as high priority.

Section 303(d) of the Clean Water Act requires the identification, listing, ranking and development of TMDLs for waters that do not meet applicable water quality standards after implementation of technology-based controls. Current dissolved oxygen criteria are shown in Table 3. Waterbodies are placed on the 303(d) list based on the comparison of data from ambient monthly samples and the criteria. Due to diurnal variations in dissolved oxygen, the time in which the assessment samples were taken was an important factor. Algae and macrophytes that produce dissolved oxygen in the water column in the presence of sunlight (photosynthesis) and utilize dissolved oxygen in the absence of sunlight (respiration) cause diurnal variations in dissolved oxygen. This process can cause the dissolved oxygen levels of the water to be depressed during the early morning hours and elevated during the evening hours. Either extreme is not representative of the stream. It is uncertain if the samples that were used to assess Little River and place it on the 303(d) waterbody list were representative of the diurnal effects of algae and macrophytes within the stream. Additionally, the ambient sampling was conducted in 1999, which is considered to be a drought year. The drought conditions may have contributed to the low flow, low D.O. conditions.

Table 3. Current Dissolved Oxygen Criteria, (mg/L) (LA DEQ, 2000)

March-November (Summer)	3.0
December-February (Winter)	5.0

2.4 Discharger Inventory

Subsegment 030804 was void of any known oxygen-demanding point source dischargers. There is a CECOS facility along the lower reaches of Little River. Based upon permit file research and a site visit during the reconaissance survey, it was determined that all of the cells and lagoons at this site have been closed. The company uses this facility only for deep well injection. According to the permit file information, this facility discharges stormwater at three different outfalls during rainfall events. It is not permitted for oxygen-demanding substances, which this TMDL was intended to address. Therefore, the facility was acknowledged and documented but not included in the model.

2.5 Previous Studies and Other Modeling Data

The majority of the data used for this project was obtained during a watershed survey conducted on June 27-29, 2000. Additional water quality data was obtained from LDEQ's ambient network water quality sites located on Little River east of Buhler, LA (Site No. 58010844) and Calcasieu River (West Fork) near Lake Charles, LA (Site No. 58010092). These sites were used in the summer and winter projection models.

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

Algal production can be an indicator of excessive nutrient loading, combined with adequate sunlight and a low advective velocity. The advective velocity of Little River was low enough for algal production. The waterbody did receive an adequate amount of sunlight for algal production, particularly at the sampling sites. Survey data and the historical water quality data from the LA DEQ Ambient Water Quality Site on Little River east of Buhler, LA (Site 58010844) were examined. The data sets did not indicate that the bayou was adversely impacted by algae.

The pH values[1] were typically below 7. The continuous monitor data[1] showed no diurnal swings[2] for dissolved oxygen or pH, which would have indicated algal production. (Smythe, 2000).

The sample taken at Site 3 during the survey conducted on July 27-29, 2000, was analyzed for chlorophyll a. The chlorophyll a value was 0.35 mg/L. This value did not indicate an algal bloom.

In order for the excessive nutrient loading to cause algal production, the nutrients, nitrogen and phosphorus, must be present in the proper relative amounts. This relative amount is referred to as the ratio of total nitrogen to total phosphorus.

A high nitrogen to phosphorus ratio may indicate that phosphorus is the limiting nutrient. This situation occurs in natural freshwater lakes and streams that do not receive

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[1] Generally, when algae production is significant, CO_2 is stripped from the water column, driving the pH up. This causes a distinct diurnal (sine) curve in which the pH is up in the late afternoon hours and down in the late morning hours (Smythe, 2000).

[2] In the presence of algal production, graph profiles for both dissolved oxygen and pH will show distinct diurnal (sine) curves (Smythe, 2000).

municipal and industrial wastewater discharges, which typically contain phosphorus. As the amount of municipal and industrial wastewater discharges increase, the phosphorus concentration in the receiving waterbody generally increases, lowering the ratio. This process may cause an algal bloom. However, the amount of phosphorus in a waterbody tends to accumulate because organic phosphorus is sorbed onto clay particles, making it unavailable to algae. The phosphorus recycles very slowly back into the water column. In these types of waterbodies, algae are controlled by controlling the amount of phosphorus in the waterbody. (Jarrell, 1999), (Smythe, 2000), (Tchobanoglous, 1985)

A low nitrogen to phosphorus ratio may indicate that nitrogen is the limiting nutrient. This situation is known to occur in streams that receive agricultural runoff and estuaries. (Jarrell, 1999), (Smythe, 2000)

The average nitrogen to phosphorous ratio for the Ambient Water Quality Network Site 58010092 (Little River East of Buhler, LA) was 9.37. The average nitrogen to phosphorus ratio for all of the samples taken during the survey conducted on July 27-29, 2000 was 8.15.

3. Model Documentation

3.1 Program Description

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

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

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

Between 1978 and 1984, Bruce L. Wiland with the Texas Department of Water Resources modified QUAL-II for application to the Houston Ship Channel estuarine system. Numerous modifications were made to enable modeling this very large and complex system including the addition of tidal dispersion, lower boundary conditions, nitrification inhibition, sensitivity analysis capability, branching tributaries, and various input/output changes. This model became known as QUAL-TX and was subsequently applied to streams though out 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 at this time. Subsequent modifications have also been made in order to enhance the abilities and usefulness of LA-QUAL program. LA-QUAL is a user-oriented model and is intended to provide the basis for evaluating total maximum daily loads in the State of Louisiana.

3.2 Model Schematic and Description

The Little River watershed was modeled according to the vector diagram on the following page. The modeled portion of Little River extended from river kilometer RKM 19.5 to RKM 0.0. Everything above RKM 19.5 was input as the headwaters for modeling purposes. In reality, it is the most upstream site that the survey crew could access and obtain a measurable velocity. It is also an upstream boundary condition, which accounts for the conditions of the waterbody, upstream of Holbrook Park Road. River kilometer 0.0 is located at the confluence of Little River and the West Fork Calcasieu River.

All tributaries to Little River, which were believed to be perennial, are indicated on the vector diagram. However, only the tributaries that had a measurable flow during the 2000 survey were included in the model as a boundary condition (headwater or wasteload). That included the unnamed tributary at Site 7. At the time of the watershed survey, some of the other tributaries contained water but were not flowing. Cypress Creek had the largest drainage area, but it was not flowing at the time of the survey. Other tributaries were completely dry or consisted of a series of unconnected pools. Therefore, they were not included in the model as a boundary condition.

3.3 Calibration and Projection

The various spreadsheets that were used in conjunction with the modeling program may be found in the appendices in the order in which they were used and are described in sections 3.3.1 through 3.3.3.

The flow and water quality calibrations were based on headwater, tributary, and main stem data and samples obtained from the field survey conducted on June 27-29, 2000.

It should be noted that the flow measurement obtained at site 3 was obtained by using a single drogue. This method has proven to be substandard. Streamflow measurements based upon single drogue velocity measurements usually overestimate the streamflow. The velocity
determined using the single drogue represented a centerline, surface velocity, which is the maximum velocity of the cross-section. This velocity does not exist across the entire

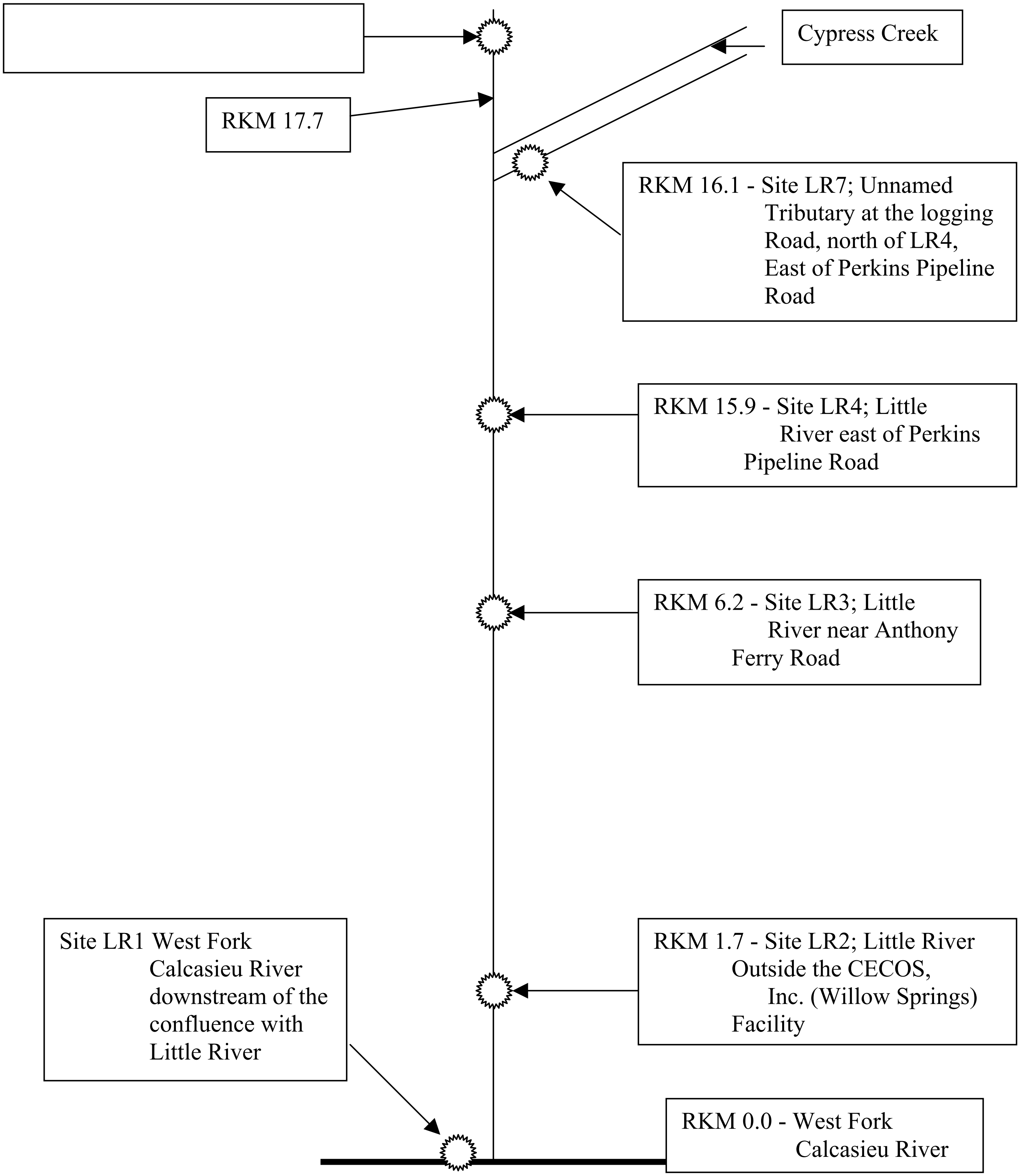

Figure 1. Vector Diagram of the Little River Watershed

cross-section. Instead, the average velocity of the cross-section is needed to estimate the streamflow.

According to survey personnel, approximately eight feet of the width on each edge of the stream had no measurable flow at site 3. This was probably caused by the debris and vegetation in the edges of the stream. Therefore, the effective cross-sectional area was reduced to approximately 40 percent of the measured cross-sectional area. This produced a conversion factor of 0.4.

The product of the drogue velocity at site 3, the measured cross-sectional area, and the conversion factor of 0.4 was the calibration streamflow value that was used at site 3. The resulting streamflow was considered to be more accurate and believable than the streamflow based upon the drogue velocity and the measured cross-sectional area.

Although none of the tributaries had a flow that could be detected by LA DEQ equipment, Little River did gain flow between site 4 and site 3. According to the survey personnel, none of the remaining tributaries had a measurable flow. Most of the tributaries of the tributaries are historically intermittent and were dry at the time of the survey. The local geomorphology consists of little relief and much of the stream is incised. The local elevations vary from 0.0 ft to 30.0 ft. This indicated that the water table is probably shallow. Some groundwater flow was seen percolating from the bank at several locations. Therefore, the gain in flow was assumed to be caused by groundwater flow. Tributary flow that was either immeasurable or inaccessible may have also been involved. The additional flow was handled in the model as incremental flow in reaches 2 through 13.

Water quality values for $CBOD_U$, $NBOD_U$, and dissolved oxygen had to be associated with the incremental flow values. Ground water data for these parameters was unavailable. Site 7 (unnamed tributary) was considered to be representative of the same type of geomorphology, geography, soils, and landuse. Therefore, the water quality data that was obtained at site 7 was assumed to be representative of the incremental flow.

Projections were adjusted to meet the dissolved oxygen criteria by reducing anthropogenic (man-made) nonpoint source loading to obtain load allocations. Spreadsheets were developed in order to aid in the calculation of headwater, tributary, nonpoint, and incremental load reductions and the input values to be used in the projection models.

The survey was conducted during subcritical (drought) conditions. The projections are intended to simulate the combined effects of critical flow and critical temperature. Therefore, the incremental flow data used in the calibration model were also used in the summer and winter projection models.

However reduced concentration values were estimated for the man-made portion of the incremental loads. These man-made load reductions were based upon the assumption that the reference stream data obtained from Indian Bayou was representative of the natural background $CBOD_U$ and $NBOD_U$ parameters for groundwater flow. The differences between the calibration incremental water quality data values and the natural background water quality data values were assumed to be representative of the man-made concentrations. These values were reduced by specified percentages in order to meet criteria. The incremental flows were not modified from the values used in the calibration model. Similar reductions were applied to the headwater and tributary water quality concentrations for $CBOD_U$ and $NBOD_U$.

The reduction in nonpoint loads were estimated based upon average reference stream data for all reference streams available at the time the model was developed and the calibration model values. Total benthic loads were estimated by adding the $CBOD_U$, $NBOD_U$, and sediment oxygen demand in terms of g O_2/m^2/day. This was done for the calibration model values and the reference stream values. The reference stream total benthic values were assumed to be representative of the "natural background" total benthic values. The difference in the calibration total benthic values and the "natural background" total benthic values were then reduced by a specified percentage. The resulting value was then redistributed as $CBOD_U$, $NBOD_U$, and sediment oxygen demand based. The redistributed values were based upon the ratios of the individual parameter loads to the total benthic load that were exhibited in the calibration model.

The summer season was the critical season and required a greater reduction in the man-made nonpoint and incremental loading. Therefore the same reduction of man-made nonpoint and incremental loads was applied when projecting to critical conditions for the winter season.

In actuality, the winter projection model required a lesser reduction in the man-made load to meet the winter water quality standard.

"No Load" models were developed to simulate summer and winter scenarios void of all man-made loads. This was developed in order to demonstrate that the bayou meets the dissolved oxygen criteria under "natural conditions".

3.3.1 Flow Calibration

The vector diagram is presented in Figure 1 and Appendix A. The spreadsheets in items 2 through 5 are presented in Appendix C in the order in which they are explained.

1. Vector Diagram
   The vector diagram shows the main stem of Little River, the major tributaries, and significant dischargers. The length of the bayou was digitally measured in order to set up the model reaches and elements.

2. Reach and Element Layout for Little River LA-QUAL Model
   This spreadsheet lists the descriptions and details of every reach. The details include river kilometers, reach length, element sizes, and the number of elements in each reach.

3. Little River Flow Calibration

   The spreadsheet was used to perform a preliminary flow calibration for the model using headwater and tributary flows. Distributed flow was varied to obtain calibration. The spreadsheet calculated an incremental flow and a characteristic flow for each reach. These characteristic flows were used to calculate some of the width and depth parameters in the spreadsheet explained in item 5. The incremental flow (cms) is simply the distributed flow (cms/kilometer) times the reach length (kilometer).

4. Little River Stream Geometry

   The various cross-sectional data used for the hydrologic calibration of the model is listed in the spreadsheet. Cross-sections were grouped based upon location within individual reaches. In cases where there were multiple values, the spreadsheet calculates the average for the reach. Otherwise, the single value was used.

5. Reaches and elements

   The spreadsheet lists the model reaches that were selected, and details the layout of elements.

   The spreadsheet referenced some values from other spreadsheets. The columns containing widths and depths were filled in based upon the average values from item 4. The characteristic flow was obtained from item 3. The Leopold equation exponents used in the model were set to 0.4 if the width or depth appeared to vary greatly with changes in the flow. The exponents were set to 0.1 if the width or depth appeared to vary only slightly with changes in flow. The width and depth coefficients were determined by calibration. The width and depth constants were estimated based upon the stream cross-sectional measurements and the assumption of whether the geometry values change with variations in flow.

   An assumption was made that the cross-sectional geometry for reach 1 did vary greatly with flow, and there were probably periods of time when no water existed in the reach. Therefore the width and depth constants were set to 0.0 meters. The widths and depths for reaches 2 through 4 were assumed to vary slightly with changes in flow and the width. The width and depth constants were set to 50 percent of the values obtained in the field or estimated for the reaches in which data was not available. The estimated values were based upon field data from nearby reaches. The cross-sections for the remaining reaches were assumed to not vary much with flow changes. The width and depth constants were set to 100 percent of the values found in the field or estimated for the reaches in which data was not available, based upon field data from bordering reaches.

   At this point, the input file was created and the model was run. Output plots were created for flow, velocity, width, and depth versus river kilometer. The measured flows were overlaid on their simulated plots. The output plots confirmed that the model was hydrologically calibrated. The velocities were comparable to the measured velocities. The plots are presented in Appendix C along with the complete calibration output file and additional water quality plots.

3.3.2 Water quality calibration

The basic premise governing water quality calibration and projection for Little River is that the dominant oxygen-demanding load in the watershed at low flow is from an accumulation of benthic material washed into the streams during periods of higher flow. This load is exerted as sediment oxygen demand and as resuspension of material from the bottom. This phenomenon has been detailed in steady-state models on other rivers modeled by LA DEQ. The LA-QUAL model can accommodate both a baseline SOD and a steady state SOD from the settling of CBOD and NBOD. It is suspected that in most of the Little River subsegment, the accumulation of benthic material is considerable during high flow events and that the settling of BOD at low flow as simulated by the model does not significantly alter the sediment oxygen demand. SOD was therefore not tied to settling in the execution of this model.

Except where indicated, the following spreadsheets, reports, and plots are presented in Appendix D in the order in which they are explained.

1. $CBOD_U$, $NBOD_U$, and Dissolved Oxygen Loads, Little River Watershed Calibration Model
   The point source loads, incremental flows and concentrations, and nonpoint loads are listed by reach.

2. BOD_U plots
   All BOD_U plots from the watershed survey are presented in Appendix B, along with the survey data. It should be noted that the analyzed BOD_U data has presented $NBOD_U$ values that are extremely low. The ratio of the $CBOD_U$ to $NBOD_U$ concentrations appears to be abnormally high. This phenomenon has occurred in other streams that were surveyed during the same period of time. We are uncertain as to whether this is due to a problem with the BOD analyses method or activities actually occurring in these streams.

3. Model Output File
   The model output file is presented. It includes all input values.

4. Model Output Plots
   The model output plots are presented. They include plots for flow, width, depth, velocity, dissolved oxygen concentrations, $CBOD_U$ concentrations, $NBOD_U$ concentrations, sediment oxygen demand (SOD), reaeration, and dispersion. In addition, the dissolved oxygen plot can be seen in Figure 2.

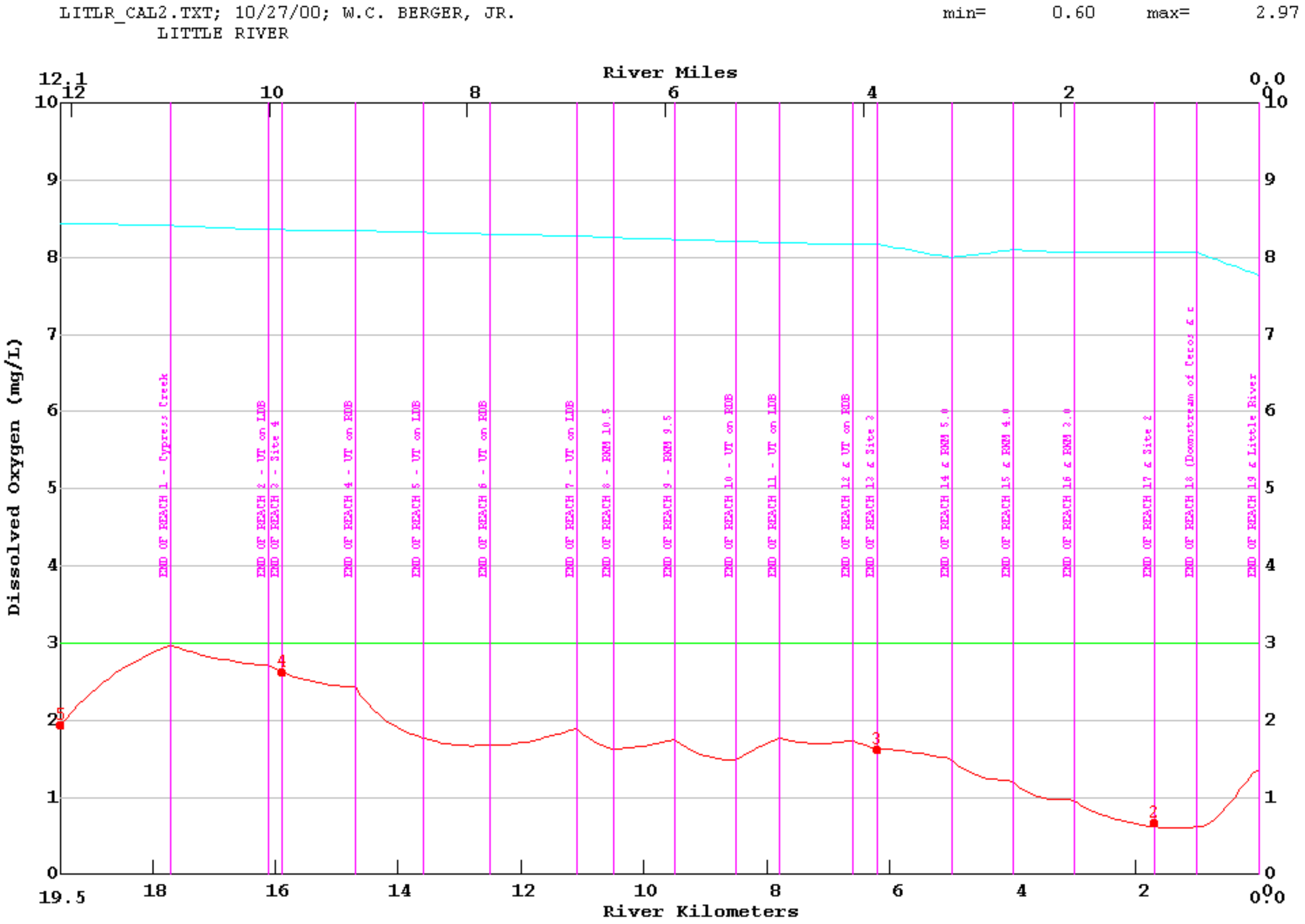

Figure 2. Dissolved Oxygen vs. River Kilometer Plot for the Little River Calibration Model

5. Little River Water Quality Calibration Model Input Description

These spreadsheets present all the data that were used in the calibration model. They also provide the source of the data or justifications for their usage. Some of the data included are:

a. Advective dispersion

LA-QUAL uses the equation $D_L = 18.53nuh^{5/6}$ for advective dispersion, where n is Manning's "n", u is the velocity in m/s, and h is the depth in meters.

b. Tidal Dispersion

Slopes were estimated for all reaches of the Little River model using digitized USGS 1:24,000 quadrangle maps. Reaches 14 through 19 had little or no slope. The reaches were assumed to be influenced by tidal dispersion from Calcasieu Lake, Calcasieu River, and West Fork Calcasieu River. Therefore, dispersion values were used for reaches 14 through 19.

c. Reaeration Rates

The Louisiana Reaeration Equation produced reaeration rates that were unbelievably high in reaches 1 through 6. Therefore, the Long (Texas) Reaeration Equation was used in reaches 1 through 6 of the watershed model. The Louisiana Reaeration Equation was used in the remaining reaches of the Little River Model.

The Louisiana Reaeration Equation is applicable to streams with velocities between 0.006 and 0.244 m/sec (0.02 and 0.8 ft/sec) and depths between 0.091 and 0.914 meters (0.3 and 3.0 feet).

The Long Equation (1984) was based on data collected from streams in Texas.

d. Decay Rates, Settling Rates, and SOD Rates

Decay and settling rates were based upon "Louisiana Total Maximum Daily Load Technical Procedures, 2000", and calibration. The SOD rates were determined by calibration.

e. Chlorophyll a

Algal production was not simulated in the calibration or projection models, although a value was used in the model input for chlorophyll a. This value was obtained from the sample taken at site 3.

f. Incremental Loads (with flow)

The model designates incremental concentrations as being associated with incremental flow. The incremental flows and concentrations were used to simulate the increase in streamflow that was experienced between sites 4 and 3. The primary cause of the increase in streamflow was determined to be hydrostatic groundwater flow (bank flow). Another possible, but less likely cause, is additional flow from tributaries that were unnoticed during the field survey.

Since incremental flow had to be used to calibrate the model, water quality data had to be estimated to use as input for the model. The unnamed tributary at site 7 has similar landuse characteristics and geology. Therefore, the loading concentrations obtained from site 7 were used to represent the incremental $CBOD_U$, $NBOD_U$, and dissolved oxygen concentrations in the Little River calibration model.
The chloride and sulfate concentrations from site 7 data were used to represent the incremental chloride and sulfate concentrations.

g. Nonpoint Loads (without flow)
Nonpoint $CBOD_U$ and $NBOD_U$ were added to calibrate the model. This loading is assumed to represent the combined impact of resuspension of benthic material and other loading entering the water column without an associated flow.

h. Lower boundary conditions
Lower boundary condition values for the calibration model were taken from site 1 of the watershed survey conducted on June 27 – 29, 2000. This site was located in the West Fork Calcasieu River slightly downstream of the confluence with Little River. However, values for CBODU, NBODU, and dissolved oxygen were omitted and the ocean exchange ratio was set to zero. This allowed the model to simulate stream conditions without being forced to end up at the lower boundary condition values.

3.3.3 Water quality projections

Projections were developed for the summer critical (March-November) and winter critical (December-February) seasons. The only parameters changed for the projection models were headwater flow and concentrations, wasteload (tributary) flow and concentrations, initial conditions temperature values, initial conditions dissolved oxygen concentrations, incremental concentrations, and nonpoint loads. Projection models were also created to simulate summer and winter critical conditions without man-made loading.

Spreadsheets, reports, and plots developed to estimate the nonpoint and incremental load input data required for the projection models are presented in Appendix F. They are presented in the order in which they are explained in the following text.

1. Reference Stream Nonpoint Loading

It is the purpose of the projections to produce wasteload allocations (WLAs) for point source dischargers and percent reductions of anthropogenic nonpoint and incremental loading (LAs) for nonpoint sources. For modeling purposes, incremental loading is associated with flow and nonpoint loading is not associated with flow. Nonpoint loading is usually associated with resuspended benthic loading.

In order to differentiate anthropogenic nonpoint loading from natural background nonpoint loading, some measure of natural background nonpoint loading is needed. Toward that end, the available calculated loading from the reference stream program is listed. From this spreadsheet, the total natural benthic load was estimated to be 2.0 g O_2/m^2/day (Smythe, 1999).

2. Calibration Model Nonpoint Input Equivalent Load Determinations

   Also needed for the calculation of percent reduction of man-made nonpoint loading is the calibration total benthic loading. The total benthic loading was calculated for each reach in this spreadsheet.

3. Calculation of Background and Anthropogenic (Man-Made) Headwater and Tributary Boundary Water Quality (Summer)

   This spreadsheet estimates projection concentrations for the headwater and tributary boundary sites. The calculations were based upon the calibration concentrations, reference stream data, and a value for the percentage of reduction of the man-made portion of the load.

4. Calculation of Background and Anthropogenic (Man-Made) Headwater and Tributary Boundary Water Quality (Winter)

   The explanation is the same as for item 3.

5. Calculation of Background and Anthropogenic (Man-Made) Incremental Water Quality (Summer)

   The spreadsheet calculates the concentrations used in the projection model with a 70 % reduction of the man-made concentrations. The calculations were based on two assumptions. The first assumption was that incremental flow would be the same as the incremental flow determined during development of the calibration model. The second assumption was that the reduction would be obtained with lower concentrations based upon the calibration concentrations, not reduced incremental flows.

   The most appropriate incremental water quality data available for the calibration model was the data that was obtained from the tributary at site 7 during the survey. The in-stream water quality data from Indian Bayou (Subsegment 101501) were used to represent the natural background values for the incremental and boundary water quality data for Little River. Based upon the available reference stream data, Indian Bayou was considered to be the reference stream that was most similar to Little River. Like Little River, Indian Bayou was not flowing, it had an extremely low slope, and it had a silty streambed.

The man-made incremental concentrations for $CBOD_U$ were estimated as the difference between the calibration concentrations and the natural background incremental concentrations. The reduction percentage was then applied to this portion of the concentration. The background $CBOD_U$ concentration was then added back to the remaining portion of the man-made concentration to determine the concentration to put in the projection model.

Values used for the $NBOD_U$ concentrations were already lower than the values obtained for the reference stream data. Therefore, the $NBOD_U$ concentrations values were assumed to be at background levels for all practical purposes.

Similar calculations were performed for the headwater and wasteload input data. They were actually boundary sites that represented significant portions of the drainage area which existed upstream of sites 5 and 7 respectively. The calculations were performed by the spreadsheets in items 5 and 6.

6. Calculation of Background and Anthropogenic (Man-Made) Incremental Water Quality (Winter)
   The explanation is the same as for item 5.

7. Summer Projection Nonpoint Load Model Input Determinations
   This spreadsheet estimates the nonpoint and SOD loads used in the projection model, based on a 70 % reduction of the man-made nonpoint and SOD loading, calibration values, and the total benthic loading estimated from the reference stream values.

8. Winter Projection Nonpoint Load Model Input Determinations
   The explanation is the same as for item 7.

9. Summer No Load Projection Nonpoint Load Model Input Determinations
   This spreadsheet estimates the nonpoint and SOD loads used in the projection model, based on a 100 % reduction of the total man-made nonpoint and SOD loads, the total benthic loading developed for the calibration model, and the total benthic loading estimated from the reference stream values.

10. Winter No Load Projection Nonpoint Load Model Input Determinations
    The explanation is the same as for item 9.

11. Little River Total Natural Background Loads: Summer Incremental and Nonpoint
    A summary of the natural background incremental and nonpoint loads for summer critical conditions are provided in this spreadsheet. The natural background incremental and nonpoint loads as provided by the headwater and tributary boundary sites are also estimated. The loads are in lbs./day.

12. Little River Total Natural Background Loads: Winter Incremental and Nonpoint
    The spreadsheet provides the same information for winter critical conditions that item 9 provides for summer critical conditions.

The following spreadsheets, reports, and plots present the input data justifications and the projection results. They are presented in Appendix F1 in the order in which they are explained.

1. Summer Projection Model Output and Plots (70 % reduction of Man-Made Incremental, Nonpoint, and Boundary Loading)
   The output file for the summer projection model is provided. It includes a summary of the input data. Values for $CBOD_U$, $NBOD_U$, and dissolved oxygen were omitted from the Lower Boundary Condition card for the summer models. The ocean exchange ratio was set to zero. Plots produced by the model are also provided. The plot for dissolved oxygen is also presented in Figure 3.

2. Little River Water Quality Summer Projection Model Input Description
   The input data and data sources or justifications are provided in spreadsheet format.

3. Summer No Load Projection Model Output and Plots
   The output file for the summer no load projection model is provided. The term “no load” means no man-made load. Included is a summary of the input data. Plots produced by the model are also provided.

4. Little River Water Quality Summer No Load Projection Model Input Description
   The input data and data sources or justifications are provided in spreadsheet format.

5. Plots for Additional Summer Projections
   Additional summer projections were developed made to demonstrate reductions of 50%, 60%, and 65% in the man-made incremental, nonpoint, and boundary loading did not meet criteria. Projections using reductions of 75%, 80%, and 90% were also developed.

The following spreadsheets, reports, and graphs are presented in Appendix F2.

1. Winter Projection Model Output and Plots (70 % reduction of Man-Made Incremental, Nonpoint, and Boundary Loading)
   The output file for the winter projection model is provided. It includes a summary of the input data. Plots produced by the model are also provided. The dissolved oxygen plot is presented in Figure 4 for convenience.

   Assumptions were made when determining the percent reductions of man-made incremental and nonpoint loading. LA DEQ has documented that the incremental

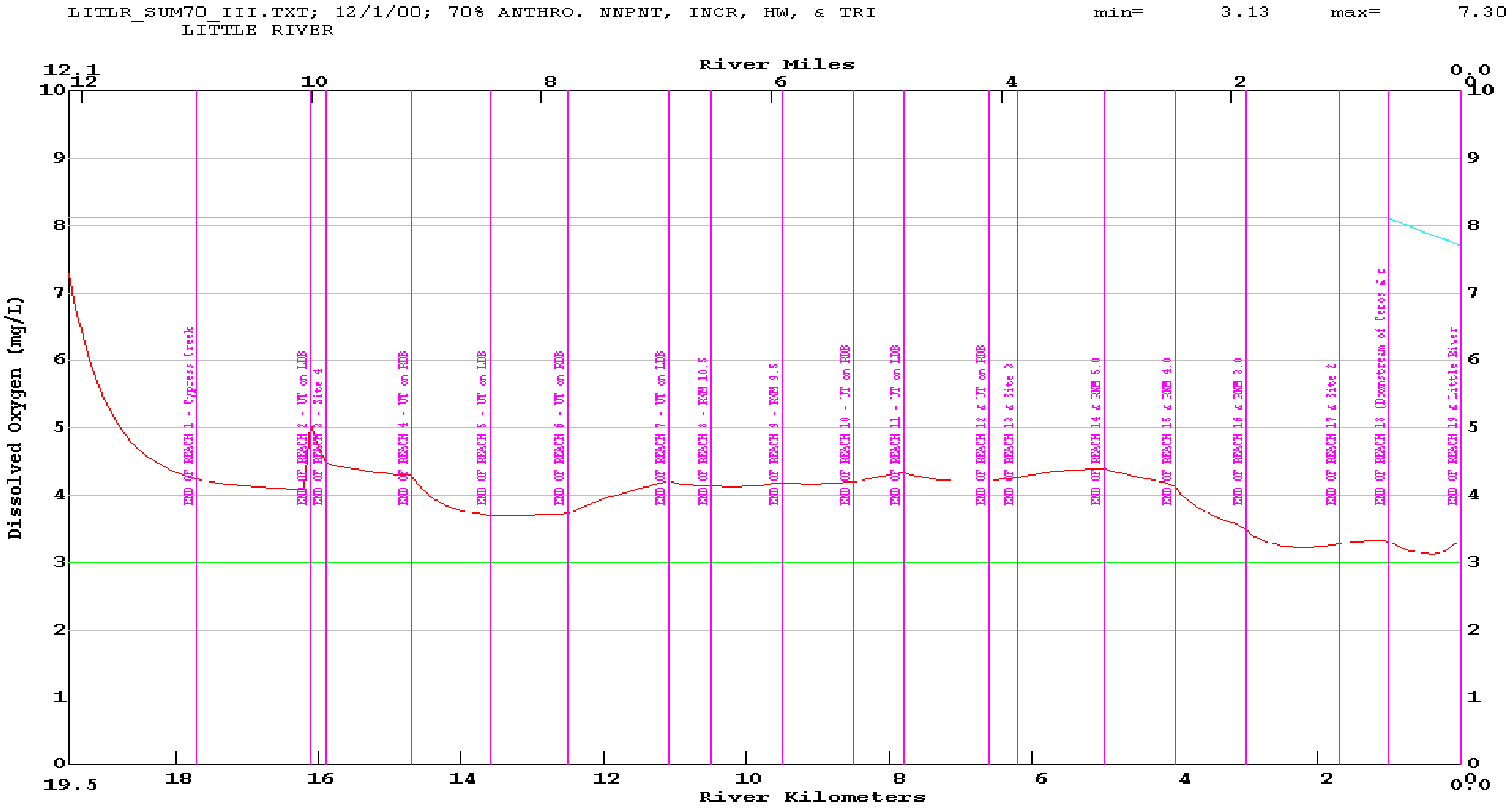

Figure 3. Dissolved Oxygen vs. River Kilometer Plot for the Summer Projection Model

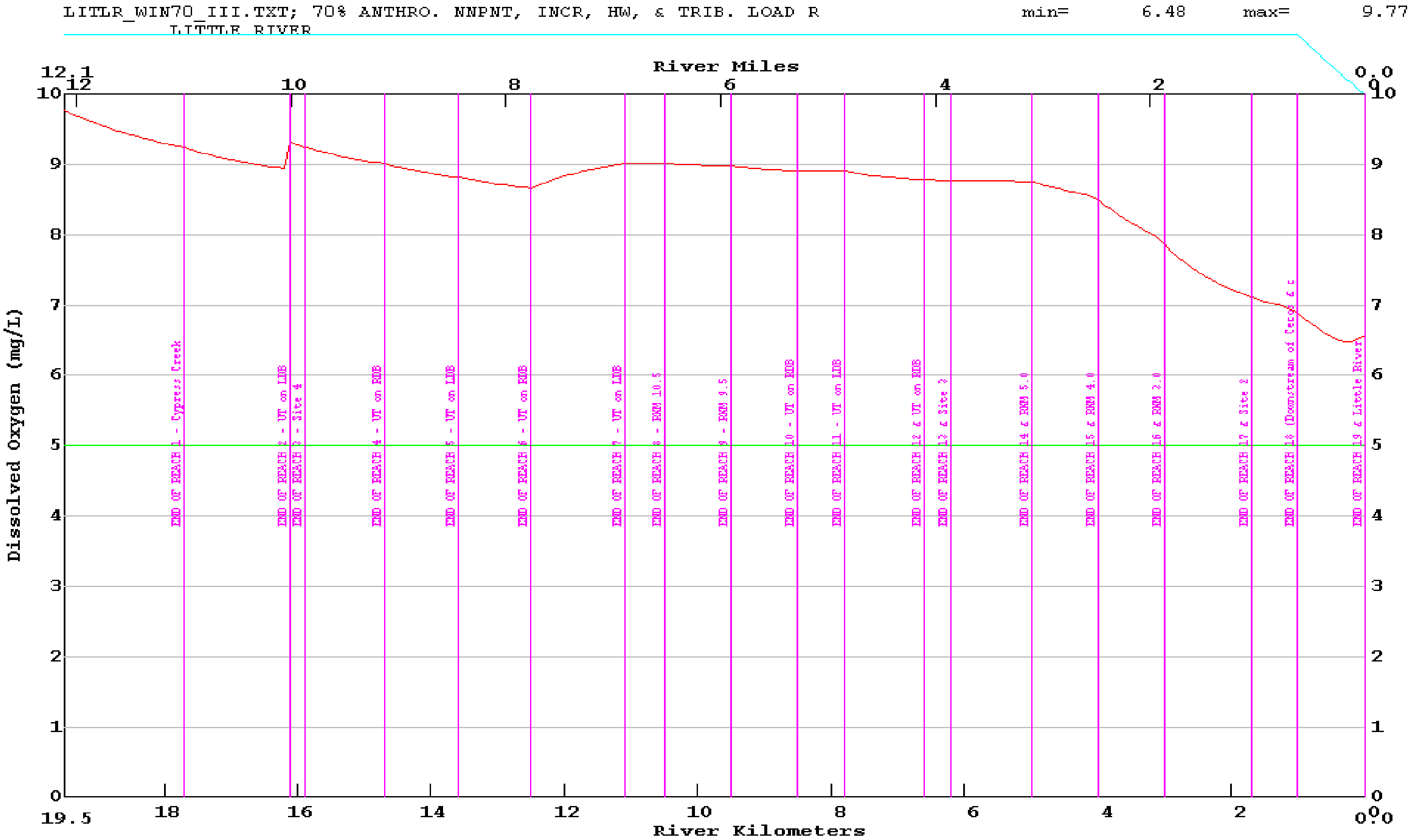

Figure 4. Dissolved Oxygen vs. River Kilometer Plot for the Winter Projection Model

loading occurs throughout the year, but has its greatest effect during summer critical conditions in the form of benthic loads (SOD) and nonpoint loads (resuspension). Recognizing this fact, and the fact that LA DEQ cannot implement percentage load reductions on a seasonal basis, the percentage load reductions for the winter critical conditions were set equivalent to the percentage load reductions that protected the dissolved oxygen criteria for the summer critical conditions. The values for $CBOD_U$, $NBOD_U$, and dissolved oxygen were omitted from the Lower Boundary Condition card for the winter models. The ocean exchange ratio was set to zero.

2. Little River Water Quality Winter Projection Model Input Description.
   The input data and data sources or justifications are provided in spreadsheet format.

3. Winter No Load Projection Model Output and Plots
   The output file for the winter no load projection model is provided. The term "no load" means no man-made load. Included is a summary of the input data. The model output plots are also provided.

4. Little River Water Quality Winter No Load Projection Model Input Description
   The input data and data sources or justifications are provided in spreadsheet format.

The following spreadsheets are in Appendix G.

Summer and Winter TMDL Calculations

Land use in the Little River watershed is fairly homogeneous, comprised principally of forestry and row crops. Summer and winter TMDLs have been calculated for the entire watershed. The spreadsheets sum loading from headwaters, point sources, incremental (nonpoint associated with flow), nonpoint (resuspension), and SOD.

The following spreadsheets are presented in Appendix H.

1. Calculation of the Background and Anthropogenic (Man-Made) Headwater and Tributary Boundary Water Quality (Calibration)
   This spreadsheet was used to develop the boundary concentrations to be input into the calibration natural background model.

2. Calculation of Background and Anthropogenic (Man-Made) Incremental Water Quality (Calibration)
   This spreadsheet was used to develop the incremental concentrations to be ainput into the calibration natural background model.

3. Calibration Natural Background Nonpoint Load Model Input Determinations

This spreadsheet was used to develop the nonpoint loads to be input into the calibration natural background model.

4. Little River Calibration Loading Calculations
   The named set of spreadsheets was used to calculate the total load produced by the calibration model. The total load included the anthropogenic and natural background portions of each of the boundary, incremental, and nonpoint (SOD and benthic) loads.

5. Little River Calibration Natural Background Loading Calculations
   This group of spreadsheets was used to calculate the total load produced by the calibration natural background model.

6. Little River Summer Natural Background Loading Calculations
   This set of spreadsheets was used to calculate the total load produced by the summer projection model without any man-made loads.

7. Little River Winter Natural Background Loading Calculations
   This group of spreadsheets was used to calculate the total load produced by the winter projection model without any man-made loads.

8. Summer Calculation of Actual Percent Reduction of Man-Made (Anthropogenic) Nonpoint Loads (including headwater and tributary boundary loads, nonpoint (resuspension) loads, and incremental loads)
   This spreadsheet was used to calculate the actual percent reduction of the man-made boundary, incremental, and nonpoint loads required to provide a 20 percent margin of safety. The result was rounded to the nearest ten percent and reported as 90 percent, due to the gross or broad nature of the model.

3.3.4 Sensitivity Analysis

Sensitivity analysis was performed for the calibration model. A spreadsheet presenting the results of the analysis is provided in Appendix E.

The model was most dependent upon depth and temperature related parameters. Five of the top ten parameters affecting the minimum dissolved oxygen value were related to depth. They include reaeration, benthal, depth, velocity, and BOD settling. Two of the top ten parameters were related to temperature. They include temperature and aerobic BOD decay. The three remaining top ten parameters are related to flow or load. They include baseflow, incremental flow, and incremental BOD.

4. TMDLs and Allocations

Oxygen-demanding TMDLs have been calculated for the entire watershed for both the summer and winter critical conditions.

The summer TMDL was higher than the winter TMDL. A percent reduction, which met the summer critical season criteria, was determined with the summer projection. An equivalent percent reduction was then applied to the winter conditions because the loading occurs annually, although the greatest impact is felt during the summer. Also, LA DEQ cannot implement seasonal Best Management Practices (BMPs). Therefore the summer and winter TMDLs were approximately the same except for two areas, the boundary loads (headwater/tributary) and the SOD loads. The boundary loads were higher in the winter projection due to higher flows. When considering SOD, the percent reduction for both the summer and winter models were based upon the same calibration SOD value at 20 degrees. After this value was reduced, it was put into the summer and winter projections, which were at different stream temperatures. The models then corrected the SOD values for stream temperature. The temperature-corrected SODs were then used in the TMDL calculations, producing a higher summer TMDL value.

The following text contains a brief outline of the projection and TMDL calculations. It will help explain some of the calculations in the Appendices. The TMDLs and allocations are summarized in Table 4 on page 25.

1. The natural background total benthic loading was estimated from reference stream nonpoint $NBOD_U$, nonpoint $CBOD_U$, and SOD data.
2. The calibration anthropogenic (man-made) benthic loading was determined as follows:
   - Calibration non-point CBOD and NBOD (resuspension), and SOD were summed for each reach as gm/m^2d to get the total calibration benthic loading.
   - The natural background benthic loading was subtracted from the total calibration benthic loading to get the total anthropogenic (man-made) calibration benthic loading.
3. Projection runs were made with:
   - Boundary (headwater and tributary) flows at seasonal 7Q10 or 0.1(summer)/1.0(winter) cfs, whichever was greater.
   - Boundary (headwater and tributary) and incremental concentrations of CBOD and NBOD were reduced from the calibration levels by a stated percentage of reduction. The dissolved oxygen levels were set at 90 percent of the dissolved oxygen saturation concentration at the 90th percentile temperature.
4. For each reach, the non-point CBOD and NBOD (resuspension), and SOD were adjusted by incremental percentages to bring the projected in-stream dissolved oxygen in compliance with criteria. The loading capacity and percent reduction of anthropogenic non-point were calculated as follows:
   - The total projection benthic loading at 20^oC was calculated as the sum of projection NBOD, CBOD, and SOD expressed as gm O_2/m^2d.

  - The natural background benthic loading was subtracted from the total projection benthic loading to get the total anthropogenic (man-made) projection benthic loading.
  - The total anthropogenic projection benthic loading was multiplied by a percentage of reduction to estimate the benthic loading that would meet the in-stream water quality standard.
5. The total projection benthic loading for each reach was calculated as follows:
   - The projection SOD at 20°C was adjusted to stream critical temperature.
   - The projection CBOD, NBOD, and SOD were summed to get the total benthic loading at stream temperature critical in lb/d for each reach.

6. Boundary Concentrations (Headwater and Tributary) and Incremental Concentrations were calculated as follows:
   - The natural background concentrations were subtracted from the calibration concentrations and the result was reduced by a stated percentage.
   - The natural background was then added back to the resulting concentration.

7. The total stream loading capacity at stream critical temperature was calculated as the sum of the:
   - Boundary (headwater and tributary) CBOD_U and NBOD_U loads in lb/d.
   - Incremental Loads in lb/d.
   - Projection benthic loads for all reaches of the stream in lb/d.
   - The margins of safety for the boundary, incremental, and benthic loads.

The TMDL for the Little River watershed was set equal to the total stream loading capacity.

Table 4. Total Maximum Daily Loads

	Summer season (Mar – Nov)		Winter season (Dec – Feb)	
Point source allocations (WLA)	BOD Load lbs./day	% of TMDL	BOD Load lbs./day	% of TMDL
Total point source allocations (WLA)	0	0	0	0
Point source margin of safety (MOS)	0	0	0	0
Headwater/Tributary Loads	9	1	91	10
Benthic Loads (based upon nonpoint and SOD loads used in the projection)	1155	88	693	74
Incremental Loads	148	11	148	16
Total maximum daily load (TMDL)	1312	100	932	100
Nonpoint source margin of safety (MOS for benthic, incremental, and boundary loads)	262	20	186	20

In order to meet criteria, the nonpoint, incremental, and boundary loads were reduced by 70% from the calibration loads. However, to provide a 20% margin of safety (MOS), the actual required percentage of reduction of the man-made loads was calculated to be 86%. This value was calculated by creating a modified run of the calibration model in which only the estimated background loads were used. The total loads were then summed for the calibration model, the calibration model without any man-made loads, the summer projection load allocations (without a MOS), and the summer projection without any man-made load. Again, the summer projection values were used because the summer critical conditions were the limiting conditions and the BMPs cannot be applied on a seasonal basis. The following equation was then used to estimate the actual percent reduction of the man-made load required to meet the stream criteria while providing a 20% MOS:

Actual % reduction of anthropogenic nonpoint loading = [(calibration total nonpoint load – calibration background nonpoint load) – (projection total nonpoint allocations w/o MOS – projection background nonpoint load) / (calibration total nonpoint load – calibration background nonpoint load)] X 100

Actual % reduction of anthropogenic nonpoint loading = 86%
After rounding off to the nearest ten percent, the actual % reduction of the anthropogenic loading becomes 90 percent.

5. Conclusion

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 database 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 first five-year cycle is shown below.

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

(Atchafalaya and Mississippi Rivers will be sampled continuously.)
The Calcasieu River Basin will be sampled again in 2004.

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