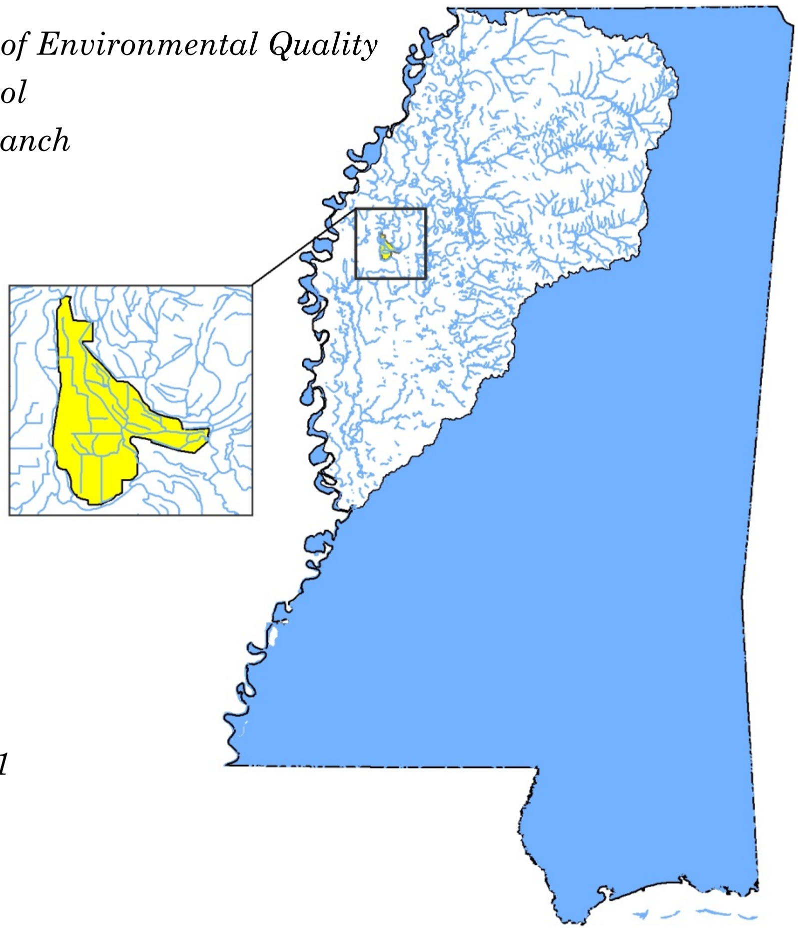
Final REPORT
September 2013

Organic Enrichment / Low DO TMDL for Lead Bayou Watershed

Yazoo River Basin
Bolivar County, Mississippi

Prepared By

Mississippi Department of Environmental Quality
Office of Pollution Control
Modeling and TMDL Branch



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FOREWORD

This report contains a Total Maximum Daily Loads (TMDL) for a water body segment found on Mississippi's 2012 Section 303(d) List of Impaired Water Bodies. The implementation of the TMDLs contained herein will be prioritized within Mississippi's rotating basin approach.

As additional information becomes available, the TMDL may be updated. Such additional information may include water quality and quantity data, changes in pollutant loadings, modifications to the water quality standards or criteria, or changes in landuse within the watershed. In some cases, additional water quality data may indicate that no impairment exists.

Table 1 Conversion Factors

To convert from	To	Multiply by	To convert from	To	Multiply by
$mile^2$	acre	640	Acre	ft^2	43560
km^2	acre	247.1	days	seconds	86400
m^3	ft^3	35.3	meters	feet	3.28
ft^3	gallons	7.48	ft^3	gallons	7.48
ft^3	liters	28.3	hectares	acres	2.47
cfs	gal/min	448.8	miles	meters	1609.3
cfs	MGD	0.646	tonnes	tons	1.1
m^3	gallons	264.2	µg/l * cfs	gm/day	2.45
m^3	liters	1000	µg/l * MGD	gm/day	3.79

Table 2 Fraction Prefixes

Fraction	Prefix	Symbol	Multiple	Prefix	Symbol
10^{-1}	deci	d	10	deka	da
10^{-2}	centi	c	10^2	hecto	h
10^{-3}	milli	m	10^3	kilo	k
10^{-6}	micro	µ	10^6	mega	M
10^{-9}	nano	n	10^9	giga	G
10^{-12}	pico	p	10^{12}	tera	T
10^{-15}	femto	f	10^{15}	peta	P
10^{-18}	atto	a	10^{18}	exa	E

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EXECUTIVE SUMMARY

Lead Bayou is a Mississippi Delta stream located in Cleveland, Mississippi in Bolivar County, Figure 1. The length of the water body is approximately 10.4 miles from the headwaters at the old Entergy Cooling Pond to the Big Sunflower River. There are two NPDES permitted point sources in the watershed. There are no MS4s in the watershed. The landuse of the watershed is predominantly agricultural cropland (76.5%) and urban (13.8%).

Table 3 Listing Information

Name	ID	County	Impaired Use	Impairment
Lead Bayou	951211	Bolivar	Fish and Wildlife	Organic Enrichment / Low Dissolved Oxygen

MDEQ collected water quality monitoring data in 2007 and 2008 which indicate potential for impairment of the dissolved oxygen water quality standard. This TMDL will provide an allocation for Total Biological Oxygen Demand ultimate (TBODu) for the watershed to meet the current water quality standard. According to the modeling, the TBODu load in the water body most likely exceeds the assimilative capacity of Lead Bayou for organic material at critical conditions. Therefore, reductions in TBODu loads are required to meet water quality standards.

Table 4 Water Quality Standards

Parameter	Beneficial use	Water Quality Criteria
Dissolved Oxygen	Aquatic Life Support	DO concentrations shall be maintained at a daily average of not less than 5.0 mg/l with an instantaneous minimum of not less than 4.0 mg/l

MDEQ will model this water body with the STREAM model to determine the TBODu limits needed for this Delta stream to meet the water quality standards.

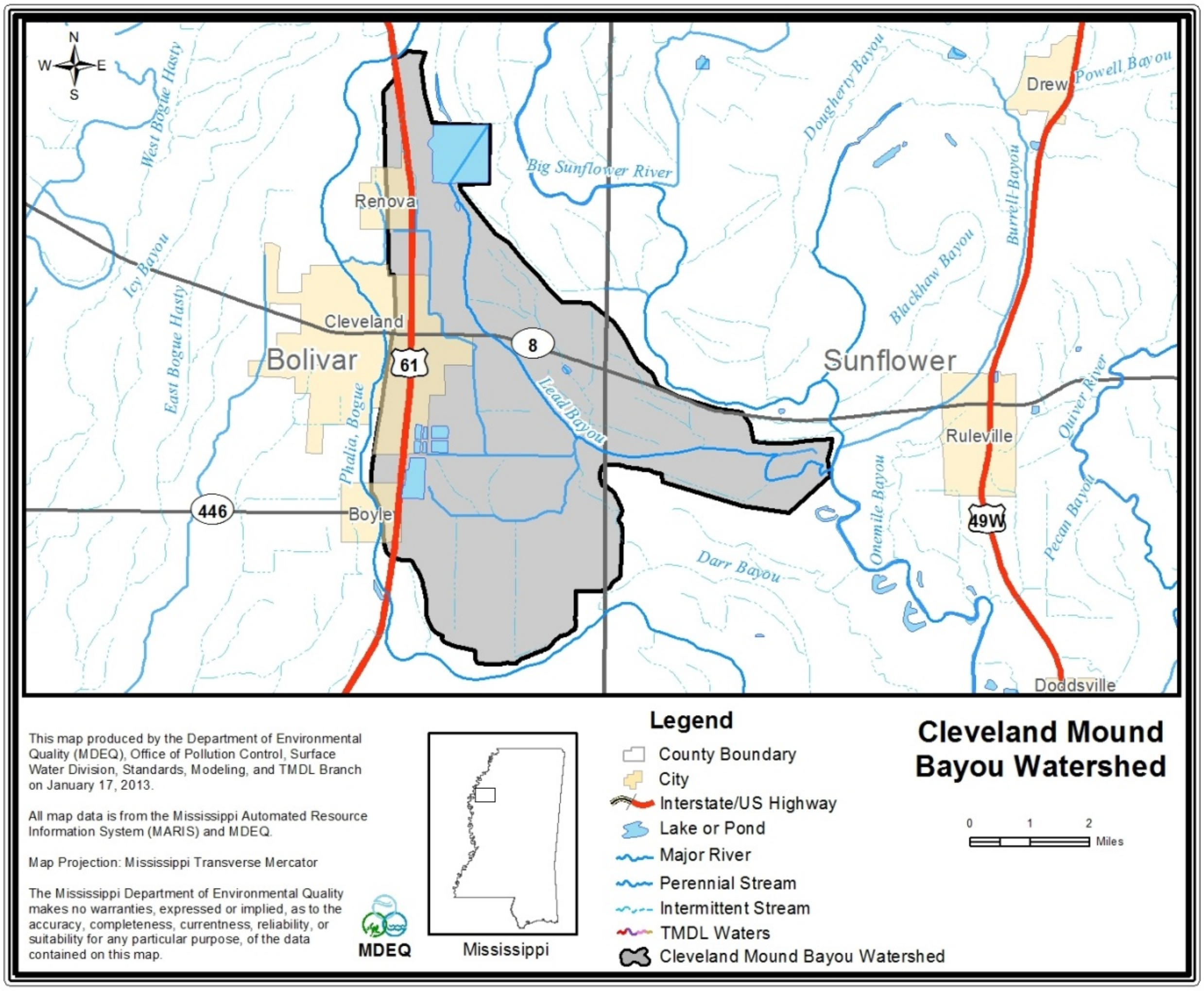

Figure 1 Lead Bayou Watershed

INTRODUCTION

1.1 Background

The identification of water bodies not meeting their designated use and the development of total maximum daily loads (TMDLs) for those water bodies are required by Section 303(d) of the Clean Water Act and the Environmental Protection Agency's (EPA) Water Quality Planning and Management Regulations (40 CFR part 130). The TMDL process is designed to identify impairment and restoration alternatives, and maintain the quality of those impaired water bodies through the establishment of pollutant specific allowable loads. This TMDL is for the 2012 §303(d) listed segment shown in Figure 2. The impaired segment of the stream is shown in green.

1.2 Listing History

The impaired segment was first listed on the 2010 Section 303(d) List of Impaired Water Bodies. The organic enrichment / low dissolved oxygen impairment was assessed based on diel DO data collected during a water quality study on Lead Bayou in 2007.

1.3 Applicable Water Body Segment Use

The water use classifications are established by the State of Mississippi in the document *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters WPC-2* (MDEQ, 2012). The designated beneficial use for the listed segment is fish and wildlife.

1.4 Applicable Water Body Segment Standard

The water quality standard applicable to the use of the water body and the pollutant of concern is defined in the *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters WPC-2* (MDEQ, 2012).

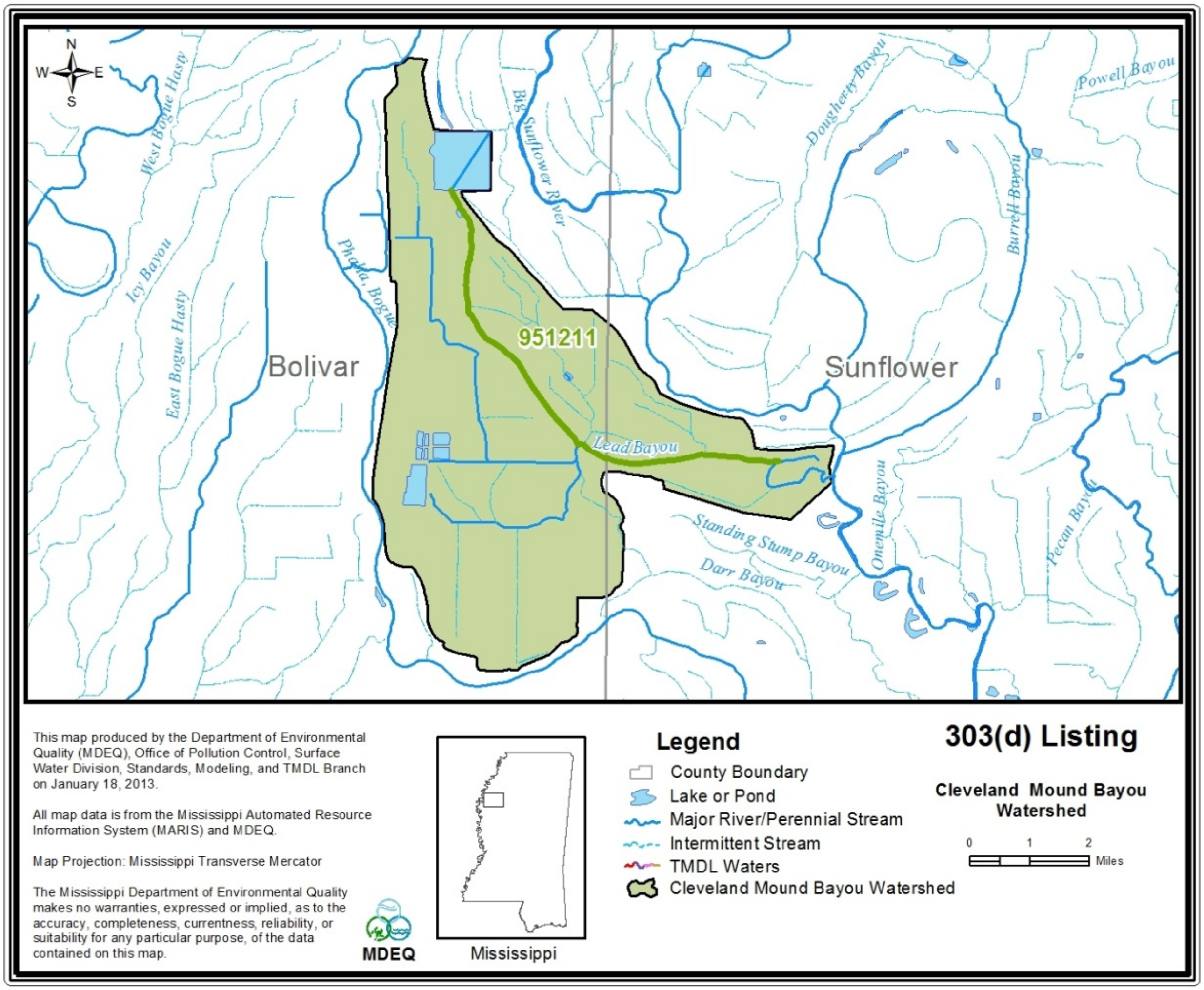

Figure 2 Lead Bayou Impaired Segment

The applicable standard specifies:

- *"<u>Dissolved Oxygen</u>: Dissolved oxygen concentrations shall be maintained at a daily average of not less than 5.0 mg/l with an instantaneous minimum of not less than 4.0 mg/l. When possible, samples should be taken from ambient sites according to the following guidelines:*
- *For water bodies that are not stratified, samples should be taken: At mid-depth if the total water column depth is 10 feet or less. At 5 feet from the water surface if the total water column depth is greater than 10 feet."*

WATER BODY ASSESSMENT

2.1 Lead Bayou Water Quality Data

Water quality data for Lead Bayou were gathered in 2007 and 2008 at Station 111B11 located at Mallett-Jones Road. Figure 3 includes a designation for the monitoring site. The samples were collected at mid-depth. This water body was not supporting the use of aquatic life support. This conclusion was based on the data collected and modeling of the watershed. The monitoring results are shown in Tables 5 and 6.

Table 5 Quarterly Chemical Data 2008

Date	Depth Ft	TOC Mg/L	COD Mg/L	Chlorophyll A Ug/L	Turbidity NTU	DO % Sat	DO Mg/L	TSS Mg/L	Temp °C
10/01/2007 14:00	0.5	10	35	18.3	107	40.7	3.33	22	24.73
03/26/2008 16:20	0.5	14	108	227	265	264.8	22.18	204	24.38
07/09/2008 18:25	2.0	7	20	23.6	16.8	104.9	7.14	26	31.55
09/24/2008 10:35	0.5	11	57	67.9	104.3	118.7	10.1	101	23.71

Table 6 Nutrient Data 2008

Date	TN, Ammonia Mg/L	Nitrite-Nitrate Mg/L	pH S.U.	TKN Mg/L	TP Mg/L	Ortho Mg/L
10/01/2007 14:00	< MDL (0.04)	0.06	7.12	1.6	1.05	0.82
03/26/2008 16:20	< MDL (0.04)	0.03	9.2	5.01	1.13	0.30
07/09/2008 18:25	0.22	0.99	7.75	1.39	0.16	0.15
09/24/2008 10:35	< MDL (0.04)	0.14	7.61	2.51	1.00	0.62

2.2 Assessment of Data

The data suggest photosynthesis produced very high DO saturation in the afternoon, and during the night, respiration exerted a load sufficient to fall below the minimum DO standard.

The total phosphorus data measured in 2007 and 2008 are above the targets established for this ecoregion by MDEQ for the Yazoo Delta nutrient TMDLs established in 2009.

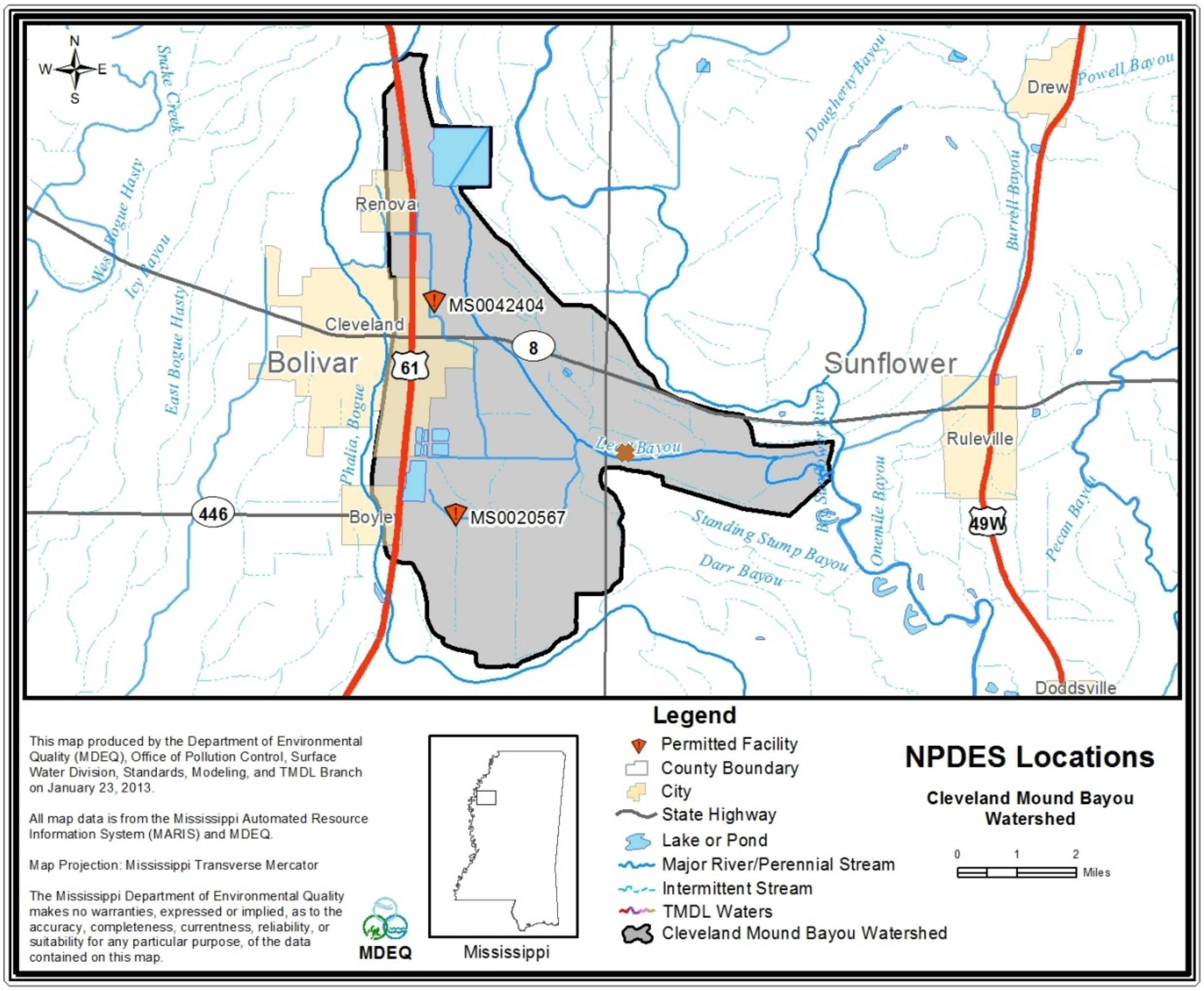

Figure 3 Point Source and Monitoring Locations

2.3 Assessment of Point Sources

An important part of the TMDL analysis is the identification of individual sources, source categories, or source subcategories in the watershed and the amount of pollutant loading contributed by each of these sources. Under the CWA, sources are broadly classified as either point or nonpoint sources. Under 40 CFR §122.2, a point source is defined as a discernible, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. The National Pollutant Discharge Elimination System (NPDES) program regulates point source discharges. Point sources can be described by two broad categories: 1) NPDES regulated municipal, commercial, and industrial wastewater treatment plants (WWTPs) and 2) NPDES regulated activities, which include construction activities and municipal storm water discharges (Municipal Separate Storm Sewer Systems [MS4s]).

The Lead Bayou Watershed has two NPDES permitted point sources, Baxter Heathcare (MS0042404) and Cleveland POTW (MS0020567). There are no MS4s in this area.

2.4 Assessment of Nonpoint Sources

Nonpoint loading of organic material in a water body results from the transport of the pollutants into receiving waters by overland surface runoff, groundwater infiltration, and atmospheric deposition.

The Lead Bayou watershed landuse is primarily agricultural. The land use information for the watershed is based on the 2006 National Land Cover Database (NLCD). The landuse distribution for the Lead Bayou Watershed is shown in Table 5 and Figure 4.

Table 5 Landuse Distribution

Area	Water	Urban	Forest	Pasture	Cropland	Wetland	Total
Acres	807.74	2,868.89	30.02	38.25	15,891.00	1,130.43	20,766.34
Percentage	3.9%	13.8%	0.1%	0.2%	76.5%	5.4%	

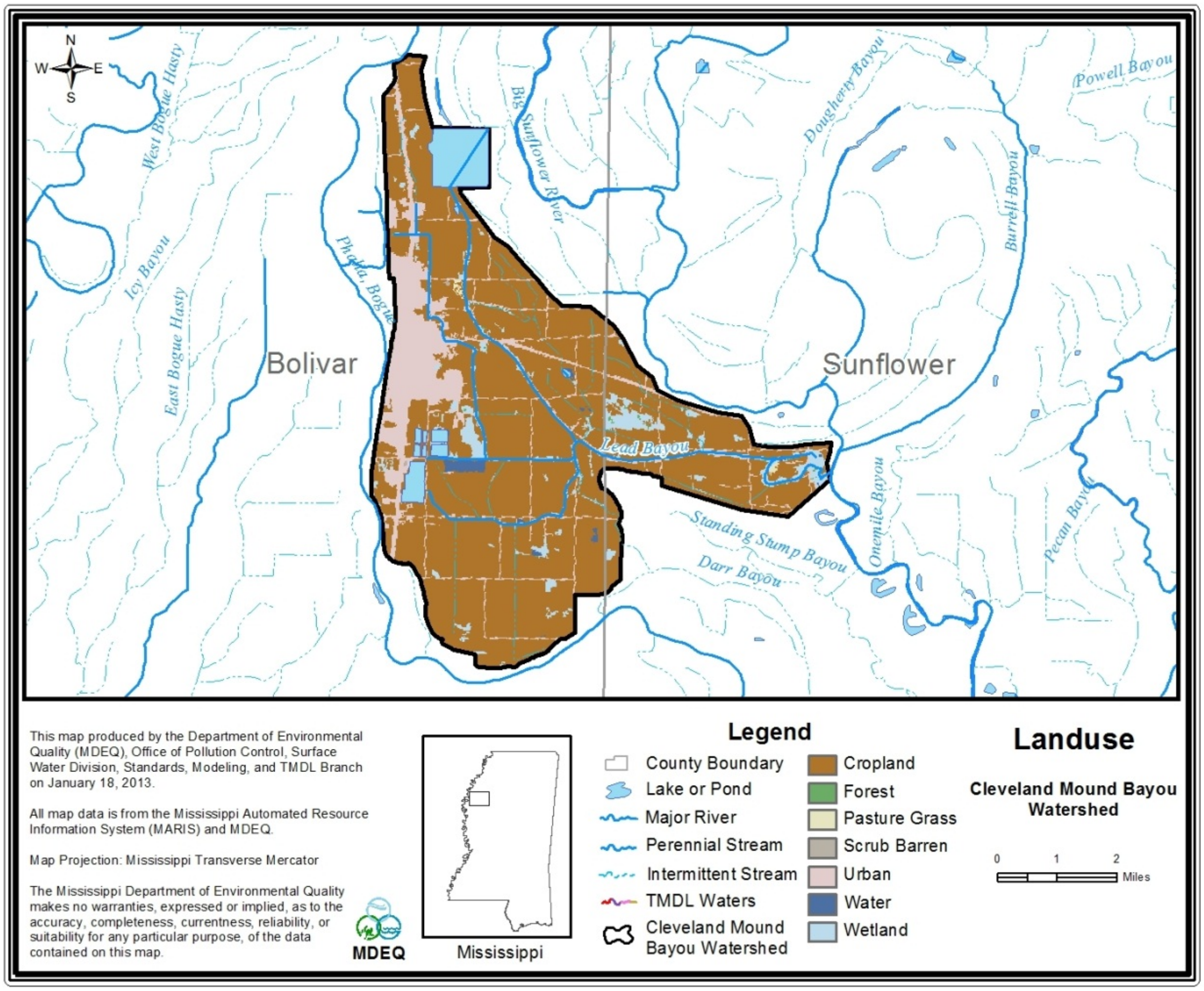

Figure 4 Landuse in Lead Bayou Watershed

MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Establishing the relationship between the instream water quality target and the source loading is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired source load reductions. The link can be established through a range of techniques, from qualitative assumptions based on sound scientific principles to sophisticated modeling techniques. Ideally, the linkage will be supported by monitoring data that allow the TMDL developer to associate certain water body responses to flow and loading conditions. In this section, the selection of the modeling tools, setup, and model application are discussed.

3.1 Modeling Framework Selection

MDEQ's steady state water quality model, STeady Riverine Environmental Assessment Model (STREAM), for DO distribution in freshwater streams was used for developing the TMDL. The use of STREAM is promulgated in the *Wastewater Regulations for National Pollutant Discharge Elimination System (NPDES) Permits, Underground Injection Control (UIC) Permits, State Permits, Water Quality Based Effluent Limitations and Water Quality Certification WPC-1* (MDEQ, 2010). This model is approved by EPA and used extensively at MDEQ. A key reason for using the STREAM model in TMDL development is its ability to assess instream water quality conditions in response to point and nonpoint source loadings.

3.2 Model Setup

The STREAM model for this TMDL was created with 5 stream segments and with 2 tributaries based on the NHDplus stream coverage. Tributary 1 flows from the Baxter Healthcare discharge point to Lead Bayou at river mile 8.8. Tributary 2 flows from the Cleveland POTW discharge point to Lead Bayou at river mile 5.3. A diagram showing the model setup is shown in Figure 6 on page 20. The model segments are identified by the river mile at the head of the segment. Table 6 STREAM Model Variables below provides the model inputs used.

Segment divisions were made at locations where there is a change in hydrological and water quality characteristics, such as the confluence of a point source or tributary or change in slope. The modeled segments were divided into computational elements of 0.1 mile. The simulated hydrological and water quality characteristics were calculated and output by the model for each computational element.

3.2.1 Base Equations

STREAM is a steady-state, daily average computer model that solves the partial differential modified Streeter-Phelps DO sag equation. Instream processes simulated by the model include CBODu decay, nitrification (NBODu load expresses as oxygen), reaeration, sediment oxygen demand, and respiration and photosynthesis of algae. Figure 5 shows how these processes are related in a typical DO model. Reaction rates for the instream processes are input by the user and corrected for temperature by the model. The model output includes water quality conditions in each computational element for DO, CBODu, and NH_3-N concentrations. The hydrological processes simulated by the model include stream velocity and flow from point sources and spatially distributed inputs.

3.2.2 Reaeration

The model calculates reaeration within each reach using the Tsivoglou formulation. The Tsivoglou formulation calculates the reaeration rate, K_a (day^{-1} base *e*), within each reach according to Equation 1.

$$\mathbf{K_a = C*S*U} \qquad \textbf{(Eq. 1)}$$

C is the escape coefficient, U is the reach velocity in mile/day, and S is the average reach slope in feet per mile (shown in Table 6 below). The value of the Tsivoglou escape coefficient is assumed to be 0.11 for streams with flows less than 10 cfs and 0.0597 for stream flows equal to or greater than 10 cfs.

Reach velocities were calculated using an empirical equation based on stream slope and flow. The slope of each reach was measured with 2010 LIDAR coverage and input into the model in units of feet per mile.

3.2.3 Temperature and Flow

The STREAM model simulates the critical flow and temperature conditions, which were determined to be the critical condition for this TMDL. MDEQ Regulations state that when the flow in a water body is less than 50 cfs, the temperature used in the model is 26°C. The instream CBODu decay rate at K_d at 20°C was input as 0.15 day^{-1} for non-effluent portions of the stream and 0.3 day^{-1} (base e) as specified in MDEQ regulations. The model adjusts the K_d rate based on temperature, according to Equation 2.

$$K_{d(T)} = K_{d(20^\circ C)}(1.047)^{T-20} \qquad \textbf{(Eq. 2)}$$

Where K_d is the CBODu decay rate and T is the assumed instream temperature. The assumptions regarding the instream temperatures, background DO saturation, and CBODu decay rate are required by the *Wastewater Regulations for National Pollutant Discharge Elimination System (NPDES) Permits, Underground Injection Control (UIC) Permits, State Permits, Water Quality Based Effluent Limitations and Water Quality Certification WPC-1* (MDEQ, 2010). Also based on MDEQ Regulations, the rates for photosynthesis, respiration, and sediment oxygen demand were set to zero because data for these model parameters are not available.

There are no USGS gages located on Lead Bayou. The flow for the model was taken from average flow estimates for incremental flow in the NHDplus database.

3.2.4 Organic Enrichment Loading

Organic material discharged to a stream from an NPDES permitted point source is typically quantified as 5-day biochemical oxygen demand (BOD_5). BOD_5 is a measure of the oxidation of carbonaceous and nitrogenous material over a 5-day incubation period. However, oxidation of nitrogenous material, called nitrification, usually does not take place within the 5-day period because the bacteria that are responsible for nitrification are normally not present in large numbers and have slow reproduction rates (Metcalf and Eddy, 1991). Thus, BOD_5 is generally considered equal to $CBOD_5$. Because permits for point source facilities are written in terms of $CBOD_5$ while TMDLs are typically developed using CBODu, a ratio between the two terms is needed, Equation 3.

$$\mathbf{CBODu = CBOD_5 * \mathit{f\ Ratio}} \qquad \textbf{(Eq.3)}$$

The CBODu to $CBOD_5$ *f ratios* are given in *Wastewater Regulations for National Pollutant Discharge Elimination System (NPDES) Permits, Underground Injection Control (UIC) Permits, State Permits, Water Quality Based Effluent Limitations and Water Quality Certification WPC-1* (MDEQ, 2010). These values are recommended for use by MDEQ regulations when actual field data are not available. The value of the ratio depends on the wastewater facility treatment type. The *f ratio* for Baxter Healthcare was set at 2.3 and Cleveland POTW at 1.5 based on MDEQ regulations. The proposed permit limits for Baxter Healthcare are 10-2-6 (BOD5 - NH_3-N - DO). The Cleveland limits are 4-1-6 respectively. The resulting point source TBODu load is 652.97 lbs. per day. This is the WLA portion of the TMDL.

The spatially distributed loads were distributed evenly into each computational element of the modeled water body. The headwaters TBODu load is 1.59 lbs. per day (2-1-6 at 0.12 cfs). The distributed TBODu load is 26.49 lbs. per day (2-1-6 at 0.4 cfs). The dissolved oxygen level was initiated at 7.0 mg/l. These two are the LA portion of the TMDL.

Direct measurements of background concentrations of CBODu were not available for the Lead Bayou Watershed. Because there were no background data available, the background concentrations of CBODu and NH_3-N were estimated based on MDEQ regulation values.

3.2.5 Nitrogen Loading

In order to convert the ammonia nitrogen (NH_3-N) loads to an oxygen demand, a factor of 4.57 pounds of oxygen per pound of ammonia nitrogen (NH_3-N) oxidized to nitrate nitrogen (NO_3-N) was used. Using this factor is a conservative modeling assumption because it assumes that all of the ammonia is converted to nitrate through nitrification. The oxygen demand caused by nitrification of ammonia is equal to the NBODu load. The sum of CBODu and NBODu is equal to the load of TBODu. The loads of TBODu from the calibrated STREAM model are given in Table 7 STREAM Model Loads .

$$\textbf{TBODu = CBODu + NBODu} \qquad \textbf{(Eq. 4)}$$

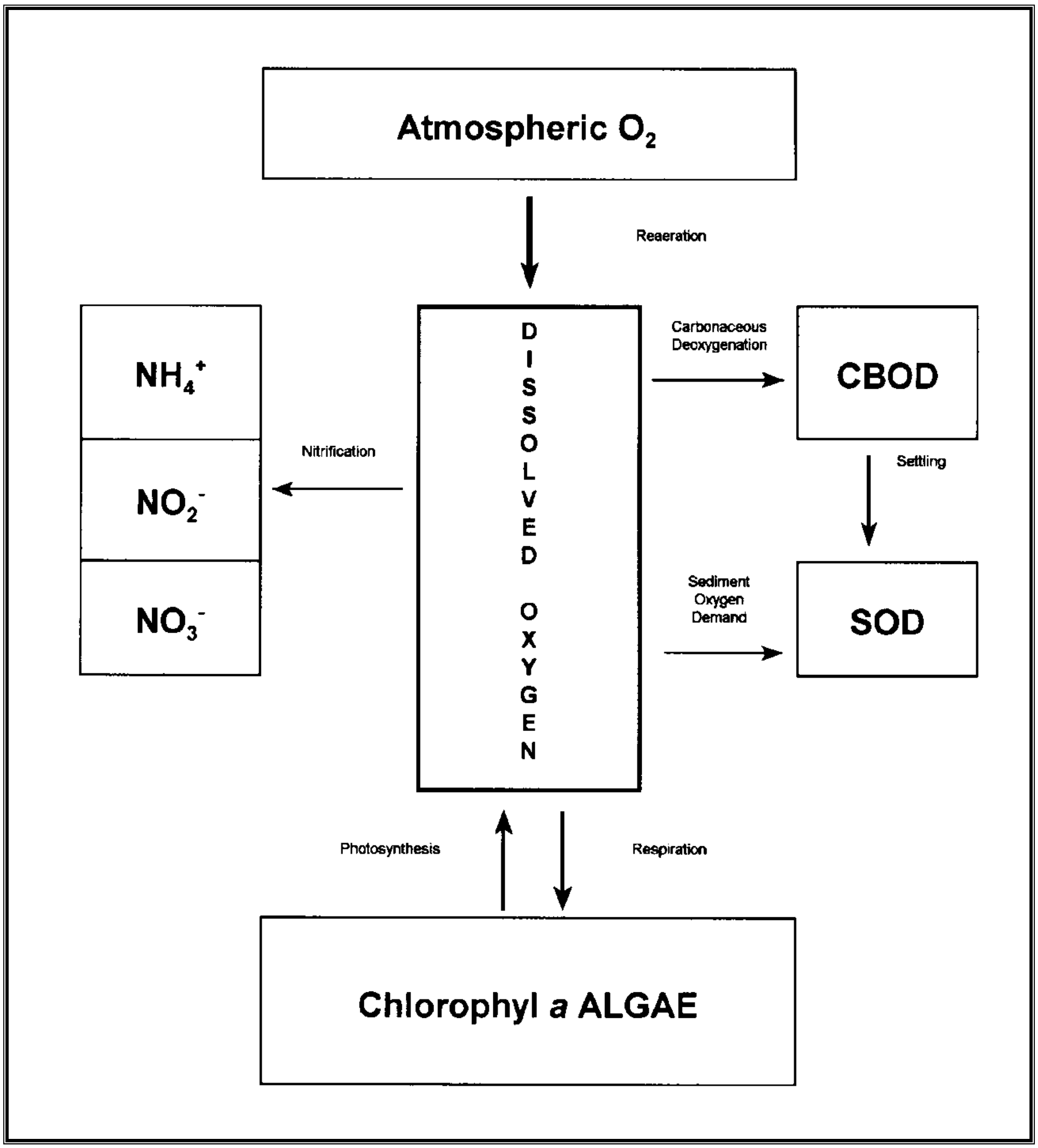

Figure 5 Instream Processes in a Typical DO Model

3.2.6 STREAM Model Identification

The STREAM model in this study is based on establishing the permit limits for Baxter Healthcare and Cleveland POTW to protect the dissolved oxygen level in the stream. In Figure 9, this is represented with the green line for DO. The value of this parameter must stay above 5.0 mg/l of dissolved oxygen.

Table 6 STREAM Model Variables

River Mile	Temp °C	Slope Ft/mile	Kr Day^{-1}	Kd Day^{-1}	Kn Day^{-1}	Escape Coeff	Velocity fps
10.4	26	2.942	.15	.15	.3	0.11	0.1
8.8	26	3.678	.4	.4	.3	0.11	0.25
7.6	26	5.195	.3	.3	.3	0.11	0.29
5.3	26	0.497	.3	.3	.3	0.11	0.24
1.9	26	3.119	.3	.3	.3	0.11	0.49

3.3 Source Representation

Nonpoint source flows were included in the model to account for water entering due to groundwater infiltration, overland flow, and small, unmeasured tributaries. The nonpoint source loads were assumed to be distributed evenly on a river mile basis throughout the modeled reaches.

3.4 Model Results

The STREAM model was set to the water quality standard target of 5.0 mg/l of dissolved oxygen (green line). Table 7 shows the loads predicted by this model at the head of each segment. As the water flows downstream oxygen sources and sinks are applied that are calculated for each modeling element within the segment. The resulting TBODu TMDL is shown in Table 8. The TMDL components are shown in Table 9.

CBODu is calculated by multiplying the concentration in mg/L by the flow in cfs and a conversion factor of 5.39.

$$\textbf{CBODu (lbs./day) = CBODu mg/L * Flow (cfs) * 5.39} \qquad \textbf{(Eq. 4)}$$

NBODu is similarly calculated with the addition of a multiplier of 4.57 which converts the equivalent oxygen load.

$$\textbf{NBODu (lbs./day) = NBODu mg/L * Flow (cfs) * 5.39 * 4.57 lbs. } \mathbf{O_2} \qquad \textbf{(Eq. 5)}$$

TBODu is the sum of NBODu and CBODu.

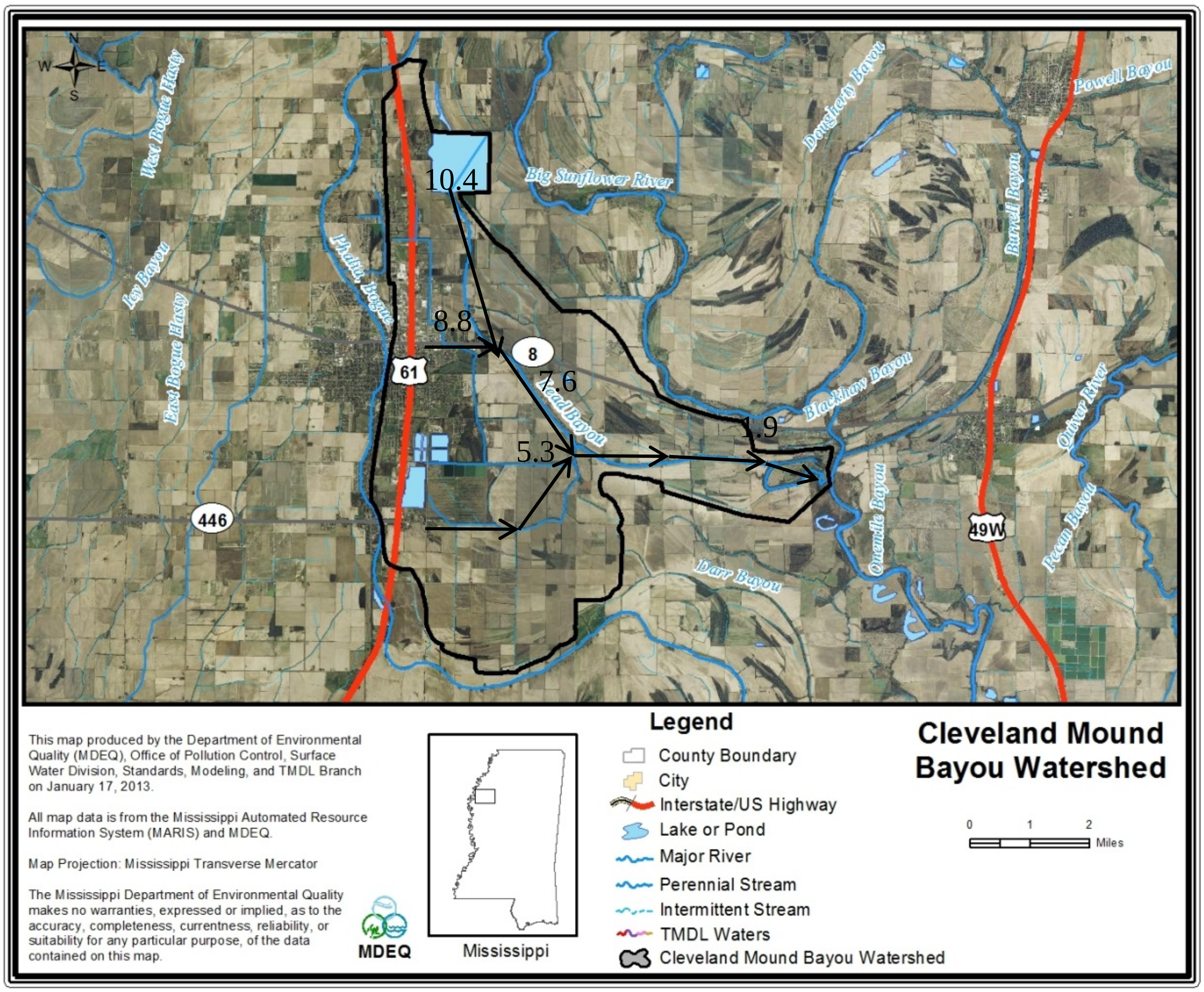

Figure 6 Model Segment with River Mile shown

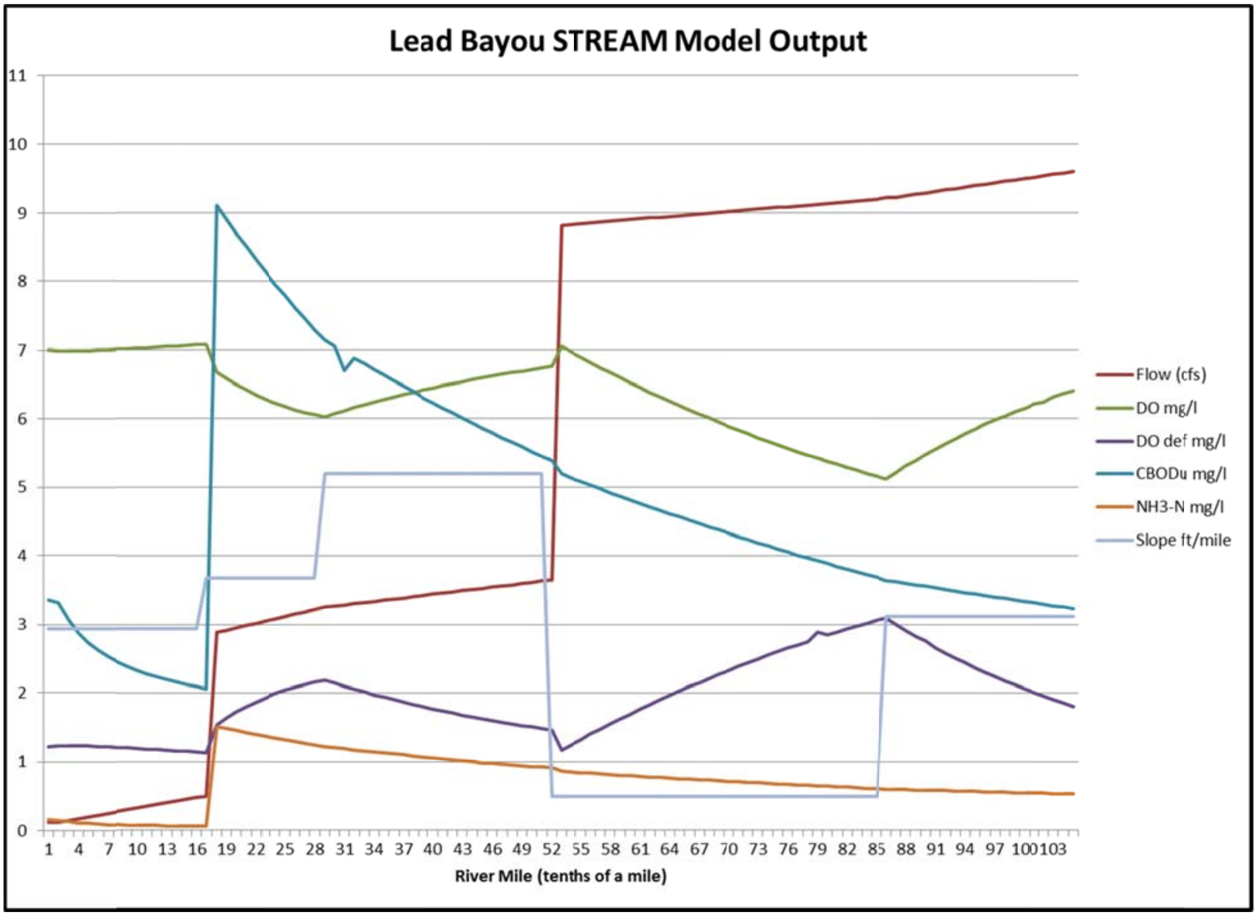

Figure 7 Model Output

Table 7 STREAM Model Loads

Segment	Flow (cfs)	CBODu (mg/L)	NH3-N (mg/L)	CBODu (lbs./day)	NBODu (lbs./day)	TBODu (lbs./day)
10.4	0.125	3.362	0.157	2.264	0.483	2.748
8.8	0.5	2.065	0.056	5.563	0.689	6.253
7.6	3.253	7.147	1.221	125.273	97.806	223.080
5.3	3.653	5.389	0.91	106.074	81.857	187.931
1.9	9.225	3.644	0.60	181.132	136.296	317.429

Table 8 TMDL Loads

TMDL	WLA	LA	MOS	TMDL
TBODu	652.97	28.08	implicit	681.05

ALLOCATION

The allocation for this TMDL involves the permit load reductions from the historical NPDES permits necessary for attainment of the dissolved oxygen water quality standards in the Lead Bayou Watershed.

4.1 Wasteload Allocation

There is 2 point source included in the model for the Lead Bayou Watershed. The WLA is 652.97 lbs. per day TBODu. The permit limits are 10-2-6 for Baxter Healthcare and 4-1-6 for Cleveland POTW. These limits are protective of dissolved oxygen in the stream based on the STREAM model output.

4.2 Wasteload Allocation Stormwater

There is no MS4 designation in this watershed. Stormwater NPDES permits require the establishment of controls or BMPs to reduce the pollutants entering the environment. The WLA for stormwater is not considered in this TMDL.

4.3 Load Allocation

The load allocation for the TBODu TMDL is shown is based on the regulated loading used in the model. It is 28.08 lbs. per day TBODu.

4.4 Incorporation of a Margin of Safety

The margin of safety is a required component of a TMDL and accounts for the uncertainty about the relationship between pollutant loads and the quality of the receiving water body. The two types of MOS development are to implicitly incorporate the MOS using conservative model assumptions or to explicitly specify a portion of the total TMDL as the MOS. The MOS selected for this TMDL is implicit.

4.5 Calculation of the TMDL

The TMDL is calculated based on the following equation.

TMDL = WLA +WLAsw + LA +MOS **(Eq. 6)**

where WLA is the Wasteload Allocation, WLAsw is Wasteload Allocation from stormwater activities, LA is the Load Allocation, and MOS is the Margin of Safety.

Table 9 TBODu TMDL Components

	WLA (lbs./day)	WLAsw (lbs./day)	LA (lbs./day)	MOS (lbs./day)
CBODu	428.15	0	22.85	Implicit
NBODu	224.82	0	5.22	Implicit
TBODu	**652.97**	**0**	**28.08**	**Implicit**

4.6 Seasonality and Critical Condition

This TMDL accounts for seasonal variability by requiring allocations that ensure year-round protection of water quality standards, including during critical conditions.

CONCLUSION

A NPDES Permit limit reduction is needed for the Cleveland POTW from the phase 1 limits in the current permit. The current Cleveland POTW permit has phase 2 limits that are more conservative than these limits. These newer phase 2 limits are revised within this TMDL based on the availability of the LIDAR imaging which gave more accurate slope measurements used in this STREAM model. The Baxter Healthcare NPDES Permit was already set at 10-2-6 which remains protective of water quality standards.

This TMDL will be published for a 30-day public notice. During this time, the public will be notified by publication in the statewide newspaper. The public will be given an opportunity to review the TMDLs and submit comments. MDEQ also distributes all TMDLs at the beginning of the public notice to those members of the public who have requested to be included on a TMDL mailing list. Anyone wishing to become a member of the TMDL mailing list should contact Greg Jackson at Greg_Jackson@deq.state.ms.us.

All comments should be directed to Greg_Jackson@deq.state.ms.us or Greg Jackson, MDEQ, PO Box 2261, Jackson, MS 39225. All comments received during the public notice period and at any public hearings become a part of the record of this TMDL and will be considered in the submission of this TMDL to EPA Region 4 for final approval.

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