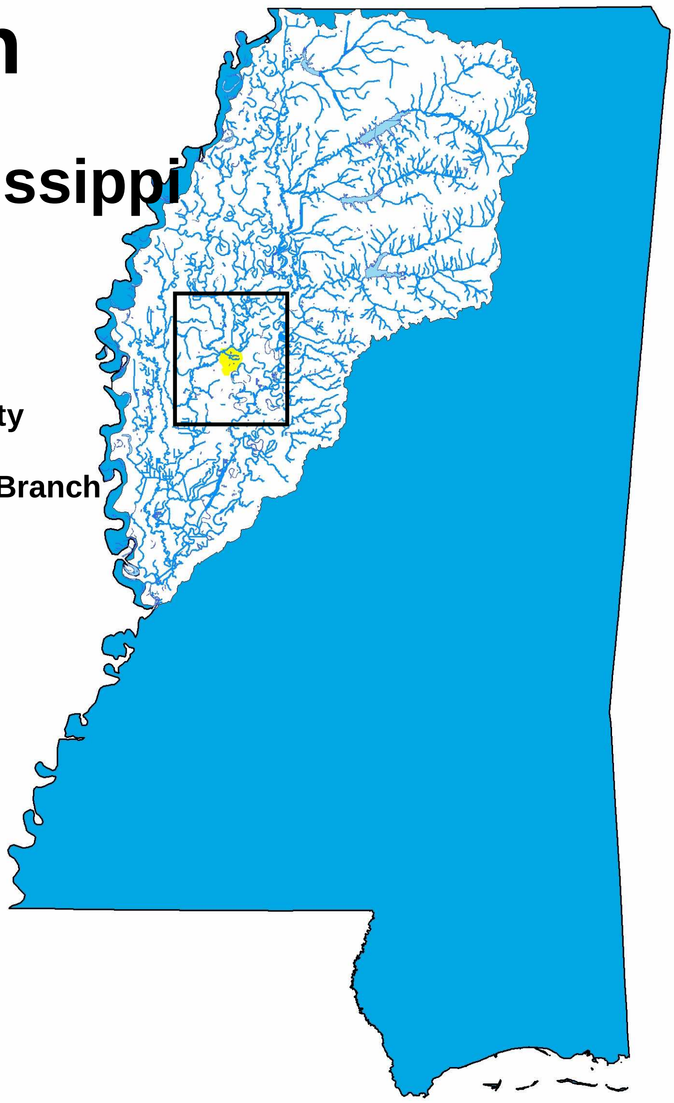
FINAL REPORT
June 2003
ID: 903062305

Phase I
Total Maximum Daily Load
For Biological Impairment due to Organic Enrichment/Low DO and Nutrients

Moorhead Bayou
Yazoo River Basin
Sunflower County Mississippi



Prepared By

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FOREWORD

This report has been prepared in accordance with the schedule contained within the federal consent decree dated December 22, 1998. The report contains one or more Total Maximum Daily Loads (TMDLs) for water body segments found on Mississippi's 1996 Section 303(d) List of Impaired Water bodies. Because of the accelerated schedule required by the consent decree, many of these TMDLs have been prepared out of sequence with the State's rotating basin approach. The implementation of the TMDLs contained herein will be prioritized within Mississippi's rotating basin approach.

The amount and quality of the data on which this report is based are limited. As additional information becomes available, the TMDLs may be updated. Such additional information may include water quality and quantity data, changes in pollutant loadings, or changes in landuse within the watershed. In some cases, additional water quality data may indicate that no impairment exists.

Prefixes for fractions and multiples of SI units

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

Conversion Factors

To convert from	To	Multiply by	To Convert from	To	Multiply by
Acres	Sq. miles	0.0015625	Days	Seconds	86400
Cubic feet	Cu. Meter	0.0283	Feet	Meters	0.3048
Cubic feet	Gallons	7.4805195	Gallons	Cu feet	0.13368
Cubic feet	Liters	28.316847	Hectares	Acres	2.471
cfs	Gal/min	448.83117	Miles	Meters	1609.3
cfs	MGD	.6463168	mg/l	ppm	1
Cubic meters	Gallons	264.172	μg/l * cfs	Gm/day	2.45

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TMDL INFORMATION PAGE

i. Listing Information

Name	ID	County	HUC	Cause	Mon/Eval
Moorhead Bayou	MS386M	Sunflower	08030207	Biological Impairment*	Monitored
At Moorhead: From Headwaters to mouth at Quiver River					
Moorhead Bayou-DA	MS386E	Sunflower	08030207	Low DO/Organic Enrichment and Nutrients	Evaluated
Drainage Area near Moorhead					

ii. Water Quality Standard

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

iii. NPDES Facilities

NPDES ID	Facility Name	Permitted Discharge (MGD)	Receiving Water
MS0046299	Allen Canning	0.60	Moorhead Bayou
MS0024961	Moorhead POTW	0.45	Moorhead Bayou

iv. Loads based water quality standards

LA - (lbs/day)	WLA (lbs/day)	MOS	TMDL (lbs/day TBODu)
25.78	**20.43**	**Implicit**	**46.21**

* In 1998, the evaluated causes were replaced with Biological Impairment (BI). Based on the limited data available, it has been determined that Low DO/Organic Enrichment was the cause of impairment in the stream. Additionally, the original test for BI was determined not to be sufficient in this area of the state.

EXECUTIVE SUMMARY

A segment of Moorhead Bayou was placed on the Mississippi 1998 Section 303(d) List of Waterbodies as a monitored water body segment, due to biological impairment. It was determined that the biological impairment was due to organic enrichment/low dissolved oxygen. The applicable state standard specifies that the Dissolved Oxygen (DO) concentration 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. Because elevated levels of nutrients may also cause low levels of dissolved oxygen, the TMDL developed for dissolved oxygen also addresses the potential impact of elevated nutrients in Moorhead Bayou.

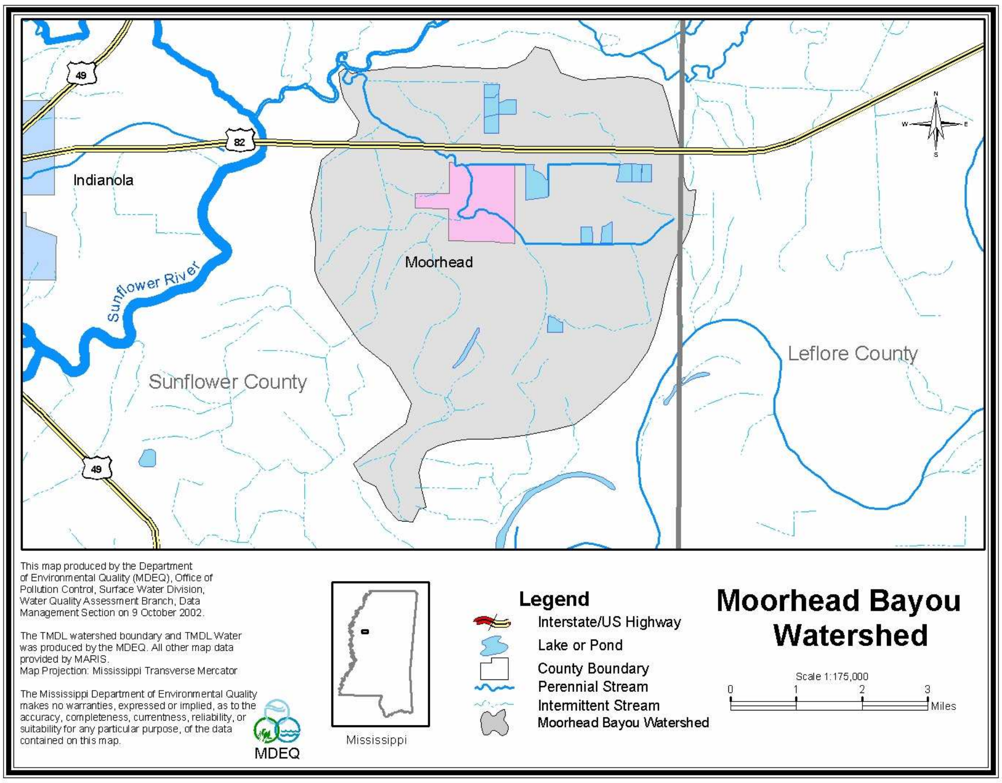
The headwaters of Moorhead Bayou are in Sunflower County south of Moorhead, MS. It flows in a northwestern direction to its confluence with the Quiver River. This TMDL was developed for this impaired segment, photo 1, as well as the drainage area.

Photo 1. Moorhead Bayou

The predictive model used to calculate this TMDL is based primarily on assumptions described in MDEQ Regulations. A modified Streeter-Phelps DO sag model was selected as the modeling framework for performing the TMDL allocations for this study. A mass-balance approach was used to ensure that the instream concentration of total ammonia (NH_3) did not exceed the water quality criteria for toxicity. The critical modeling period was determined to be during low-flow, high-temperature conditions that occur during the summer (May – October) period. This flow condition is typically represented as the 7-day, 10-year low flow (7Q10 flow). However, because streams located in the Mississippi River alluvial plain are known to have a decreasing flow trend with time, 7Q10 flows are not available for streams in this area. Because of this, a low-flow coefficient was developed for this watershed based on flow data from a nearby watershed, the Bogue Phalia watershed. The Moorhead Bayou watershed contains several catfish farms and rice farms. This landuse modifies the flow patterns in the watershed due to crop rotation and water use. Several months were modeled to determine the flows that give the critical condition. The low-flow coefficient was then applied to the Moorhead Bayou watershed in order to estimate the low-flow critical condition for this watershed.

The model used in developing this TMDL included both nonpoint and point sources of total ultimate biochemical oxygen demand (TBODu) in the Moorhead Bayou Watershed. The location of the watershed is shown in Figure 1. TBODu loading from nonpoint sources in the watershed was accounted for by using an assumed background concentration of TBODu in the stream as directed in MDEQ Regulations. The background concentration was determined based on *Empirical Stream Model Assumptions for Conventional Pollutants and Conventional Water Quality Models*. There are two NPDES Permitted discharges located in the watershed that are included as point sources in the model. The load and waste load allocations developed for TBODu exceed the maximum assimilative capacity of Moorhead Bayou, as indicated by predictive modeling. Thus, according to the model, a reduction of TBODu is required.

Figure 1. Moorhead 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 restore and maintain the quality of those impaired water bodies through the establishment of pollutant specific allowable loads. This water body was listed as biologically impaired. MDEQ determined the impairment is caused by reduced levels of dissolved oxygen (DO) due to enrichment of the water body with nutrients and oxidation of organic material. Thus, this TMDL has been developed for organic enrichment and nutrients. This TMDL was developed for the 303(d) listed segment shown in Figure 2.

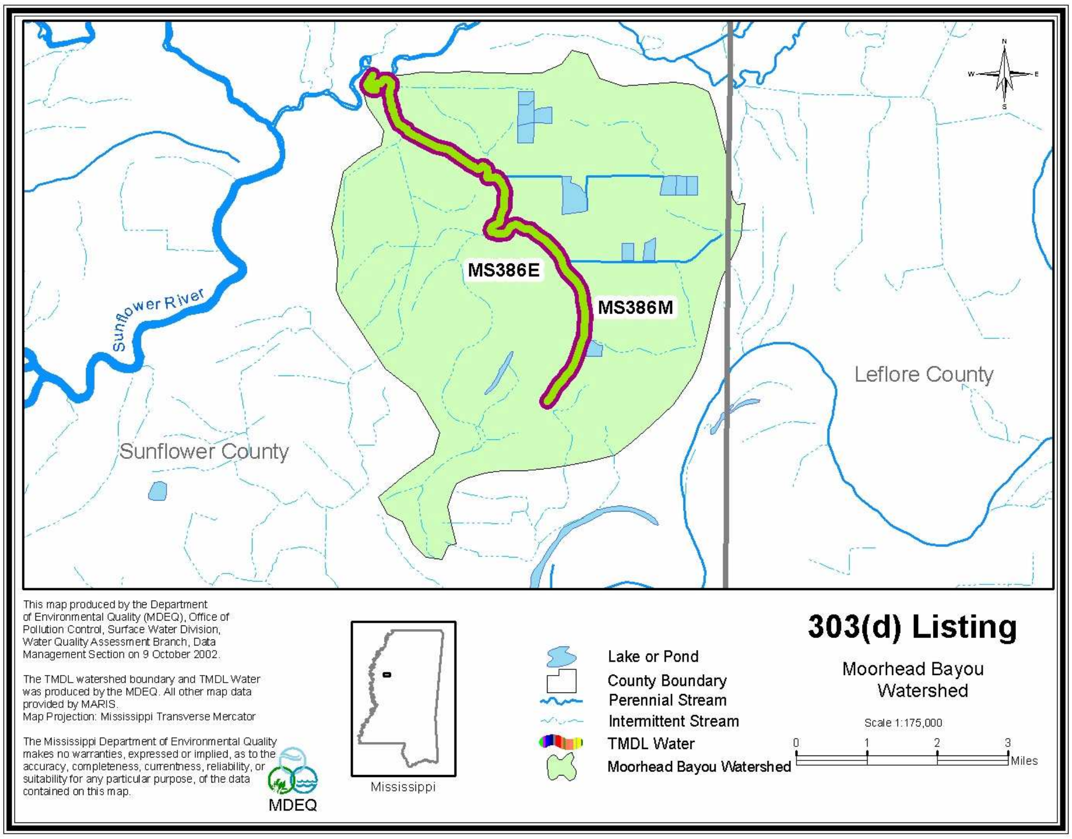


Figure 2. Location of 303(d) Listed Segments.

Organic enrichment is measured in terms of total ultimate biochemical oxygen demand (TBODu). TBODu represents the oxygen consumed by microorganisms while stabilizing or degrading carbonaceous and nitrogenous compounds under aerobic conditions over an extended time period. The carbonaceous compounds are referred to as CBODu, and the nitrogenous compounds are referred to as NBODu. TBODu is equal to the sum of NBODu and CBODu, Equation 1.

$$\textbf{TBODu} = \textbf{CBODu} + \textbf{NBODu} \qquad \textbf{(Equation 1)}$$

1.2 Applicable Water body Segment Use

The water use classification for the listed segment of Moorhead Bayou, as established by the State of Mississippi in the *Water Quality Criteria for Intrastate, Interstate and Coastal Waters* regulation, is Fish and Wildlife Support. The designated beneficial use for Moorhead Bayou is Aquatic Life Support.

1.3 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*. The applicable standard specifies that the 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. The 5.0 mg/l water quality standard will be used as the targeted endpoint to compare the model results, evaluate, and establish this TMDL.

1.4 Selection of a TMDL Endpoint and Critical Condition

One of the major components of a TMDL is the establishment of instream numeric endpoints, which are used to evaluate the attainment of acceptable water quality. Instream numeric endpoints, therefore, represent the water quality goals that are to be achieved by meeting the load and wasteload allocations specified in the TMDL. The endpoints allow for a comparison between observed instream conditions and conditions that are expected to restore designated uses. The instream DO target for this TMDL is a daily average of not less than 5.0 mg/l. The instantaneous minimum portion of the DO standard was considered when establishing the instream target for this TMDL. However, it was determined that using the daily average standard with the conservative modeling assumptions would protect the instantaneous minimum standard. The daily average choice is supported by the use of the existing modeling tools in a desktop modeling exercise such as this. More specific modeling and calibration is needed in order to obtain diurnal oxygen levels with any expectation of accuracy. Therefore, based on the limited data available and the relative un-sophistication of the model, the daily average target is sufficient.

Low DO typically occurs during seasonal low-flow periods of late summer and early fall. Elevated oxygen demand is of primary concern during low-flow periods because the effects of minimum dilution and high temperatures combine to produce the worst-case potential effect on water quality (USEPA, 1997). The low-flow, high-temperature period is referred to as the critical condition. The maximum impact of oxidation of organic material is generally not at the location of the point source discharge, but at some distance downstream, where the maximum DO deficit occurs. The DO deficit is defined as the difference between the DO concentration at 100% saturation and the actual DO. The endpoint for this TMDL will be based on a daily average of not less than 5.0 mg/l DO within the 303(d) listed segment during critical conditions in Moorhead Bayou.

WATER BODY ASSESSMENT

This TMDL Report includes an analysis of available water quality data and the identification of all known potential pollutant sources in the Moorhead Bayou watershed. The potential point and nonpoint pollutant sources were characterized by the best available information, monitoring data, and literature values. This section documents the available information for Moorhead Bayou.

2.1 Discussion of Instream Water Quality Data

The State's 1998 Section 305(b) Water Quality Assessment Report was reviewed to assess water quality conditions and data available for the watershed. Limited water quality data are available for Moorhead Bayou. According to the report, Moorhead Bayou is non-supporting for the use of aquatic life support. These conclusions were based on a WLA study conducted by MDEQ in 1992. The data from this study are listed in Tables 1 and 2. Violations of the DO standard are shown in italics. Table 3 gives details of the locations associated with the site numbers in Tables 1 and 2. Additional water quality data from 2001 are listed in Table 4.

Table 1. Moorhead Bayou WLA Site Assessment (September 16, 1992)

Site Number	Time	DO	pH
1	1430	8.20	7.71
2	1400	8.20	7.73
Moorhead POTW effluent	1455	6.80	8.25
3	1410	7.90	7.65
4	1510	***4.75***	7.72
5	1535	6.50	7.58
6	1555	6.85	7.55

Table 2. Moorhead Bayou WLA Site Assessment (September 17, 1992)

Site Number	Time	DO	pH
1	0715	5.70	7.35
2	0725	***3.50***	7.33
Moorhead POTW effluent	0700	7.10	8.02
3	0735	***2.90***	7.30
4	0750	***0.68***	7.47
5	0800	***1.33***	7.35
6	0810	***2.80***	7.30

Table 3. Location Descriptions for Moorhead Bayou WLA Site Assessment (9/16-9/17, 1992)

Site Number	Location Description
1	Bridge Crossing on County Rd, 1 mile above confluence of effluent
2	40 yards above confluence
Moorhead POTW effluent	Moorhead POTW effluent
3	350 yards below confluence, above Allen Canning
4	Bridge crossing in Moorhead, 1.2 miles below confluence and below Allen Canning
5	Bridge crossing in Moorhead approximately 2 miles below confluence
6	Bridge crossing on County Rd, approximately 3.6 miles below confluence

Table 4. Additional Water Quality Data (October 18, 2001)

Parameter	MB1 Above Allen Canning Outfall	Allen Canning Outfall	MB2 Below Allen Canning Outfall
Water Temperature (°C)	14.3	17.3	15
PH (SU)	7.5	8.9	8
DO (mg/L)	5.0	11	7.9
BOD (mg/L)	14	41*	15
Total Phosphorous (mg/L)	0.83	9	3.58
TKN (mg/L)	5.14	7.97	6.77
Ammonia (mg/L)	1.07	<0.1	0.79
Nitrate + Nitrite (mg/L)	1.1	0.24	0.88

* exceeds permit limit

Measurements of DO collected during the study in October 2001 showed that DO levels in Moorhead Bayou were at the levels for Mississippi's Water Quality Standards. Also, the BOD values indicated that the levels of organic enrichment in the creek were elevated.

2.2 Assessment of Point Sources

The first step in assessing pollutant sources in the Moorhead Bayou Watershed was locating the NPDES permitted sources. There are two sources permitted to discharge into Moorhead Bayou, Table 5. The effluent from each facility was characterized based on all available data including information on each facility's wastewater treatment system, permit limits, and discharge monitoring reports. Discharge monitoring reports (DMR) are vital to characterizing effluent from each facility. DMR data from the past 5 years were reviewed for this TMDL. It is noted that in the past, Allen Canning did not meet the discharge limits in the NPDES Permit.

Table 5. Identified NPDES Permitted Facilities

Name	NPDES Permit	Permitted Discharge (MGD)	Actual Average Discharge (MGD)	Actual Average BOD_5 (mg/L)	Permitted BOD_5 (mg/L)	Actual NH_3-N (mg/L)
Allen Canning	MS0046299	0.600	0.427	57.9	30.0	Not Required in Permit
Moorhead POTW	MS0024961	0.450	0.343	38.0	45.0	Not Required in Permit

2.3 Assessment of Nonpoint Sources

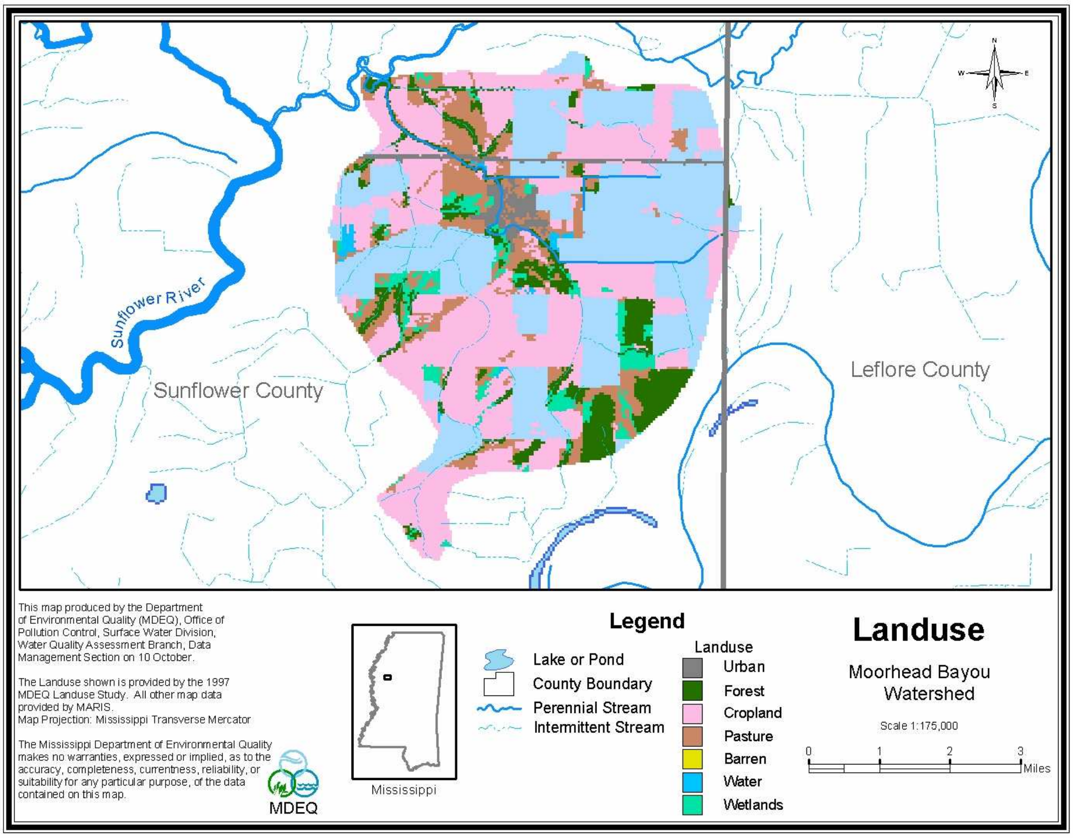
Nonpoint loading of TBODu in a water body results from the transport of the pollutants into receiving waters by overland surface runoff and groundwater infiltration. Nonpoint pollution sources of concern are storm sewer drainage from the City of Moorhead, runoff from catfish ponds, and runoff from cotton and rice fields that border the creek. Nonpoint loading of TBODu in a waterbody results from the transport of the pollutants into receiving waters by overland surface runoff and groundwater infiltration. Landuse activities within the drainage basin, such as agriculture, and urbanization contribute to nonpoint source loading. Other nonpoint pollution sources include atmospheric deposition and natural weathering of rocks and soil.

The 15,569-acre drainage area of Moorhead Bayou contains many different landuse types, including urban, cropland, pasture, water, and wetlands. The landuse information is based on data collected by the State of Mississippi’s Automated Resource Information System (MARIS) 1997. This data set is based on Landsat Thematic Mapper digital images taken between 1992 and 1993. Cropland and Aquaculture are the dominant landuses within this watershed. The landuse distribution within the Moorhead Bayou Watershed is shown in Table 6 and Figure 3.

Table 6. Landuse Distribution

	Urban	Cropland	Pasture	Aquaculture	Water	Wetlands	Total
Area (acres)	461	5,783	2,250	5,353	95	1,627	15,569
Percentage	3%	37%	14%	34%	1%	10%	100%

Figure 3. Landuse Distribution Map for Moorhead Bayou Watershed



MODELING PROCEDURE

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

A mathematical model, previously named AWFWUL1, for DO distribution in freshwater streams was used for developing the TMDL. The use of AWFWUL1 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* (MDEQ, 1994). This model has been approved by EPA and has been used extensively at MDEQ. A key reason for using the AWFWUL1 model in TMDL development is its ability to assess instream water quality conditions in response to point and nonpoint source loadings. This model is currently being upgraded in computer code and renamed to STREAMS.

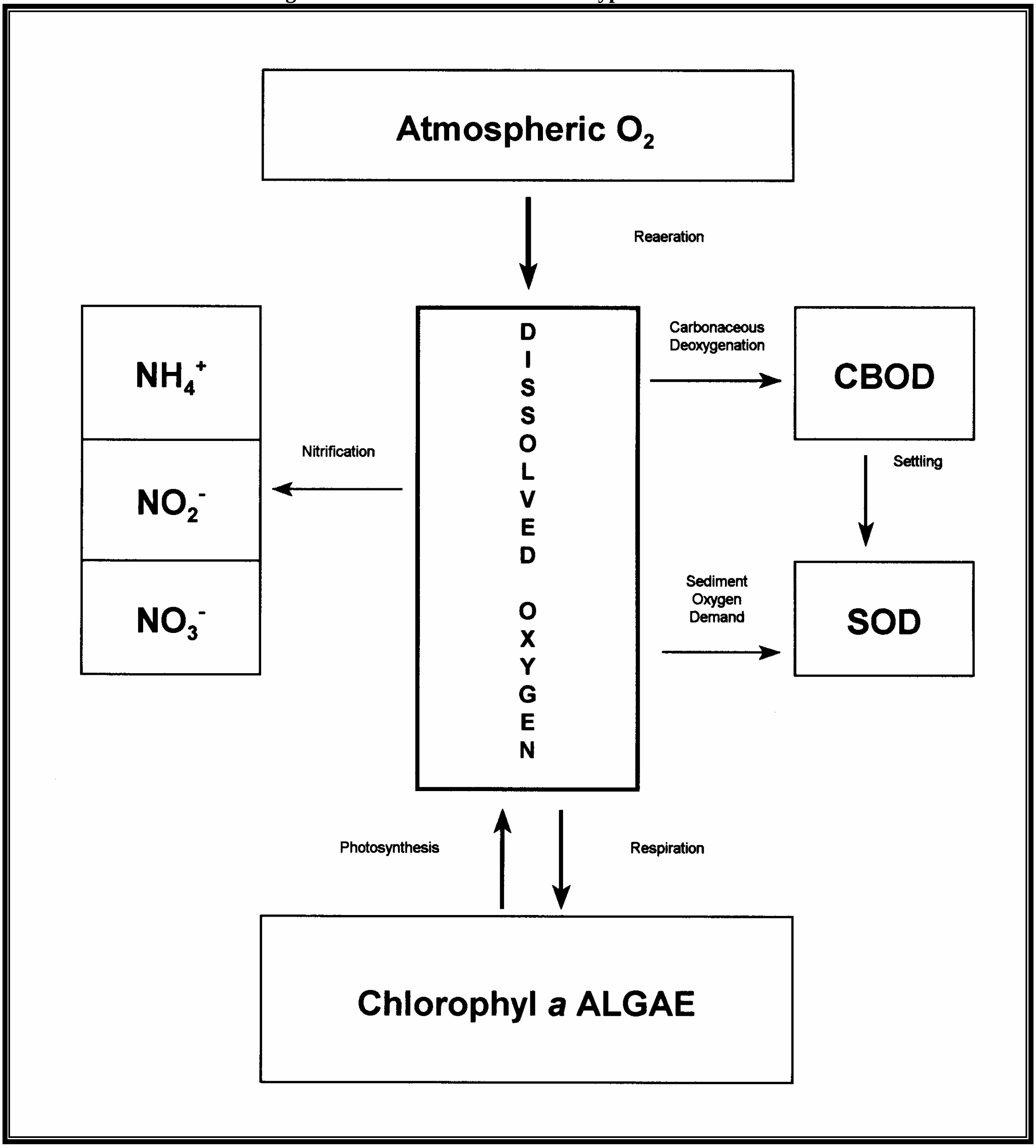
The model is a steady state, daily average computer model that utilizes a modified Streeter-Phelps DO sag equation. Instream processes simulated by the model include CBODu decay, nitrification, reaeration, sediment oxygen demand, and respiration and photosynthesis of algae. Figure 4 shows how these processes 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.

The model was set up to calculate reaeration within each reach using the Tsivoglou formulation. The Tsivoglou formulation calculates reaeration (Ka) within each reach according to Equation 2.

$$\mathbf{Ka = CSU} \qquad \textbf{(Equation 2)}$$

S is the slope in ft/mile, U is the reach velocity in mile/day, and C is the escape coefficient, which is 0.11 for streams with flow less than 10 cfs.

Figure 4. Instream Processes in a Typical DO Model



3.2 Model Setup

The Moorhead Bayou TMDL model includes the 303(d) listed portion of Moorhead Bayou, from the headwaters to the mouth at the Quiver River, as well as the drainage area. The modeled water body was divided into reaches for input into the AWFWUL1 model. Reach divisions were made at any major change in the hydrology of the water body, such as a significant change in slope or the confluence of a tributary or point source discharge. The watershed was modeled according to the diagram shown in Figure 5. The numbers on the figure represent river miles at which point sources discharge or the confluence of the creeks is located. River miles are assigned to water bodies, beginning with zero at the mouth. The slope of each reach was estimated from USGS quad maps and input into the model in units of feet/mile. Within each reach, the modeled segments were divided into computational elements of 0.1 mile. The hydrological and water quality characteristics are calculated and output by the model for each computational element.

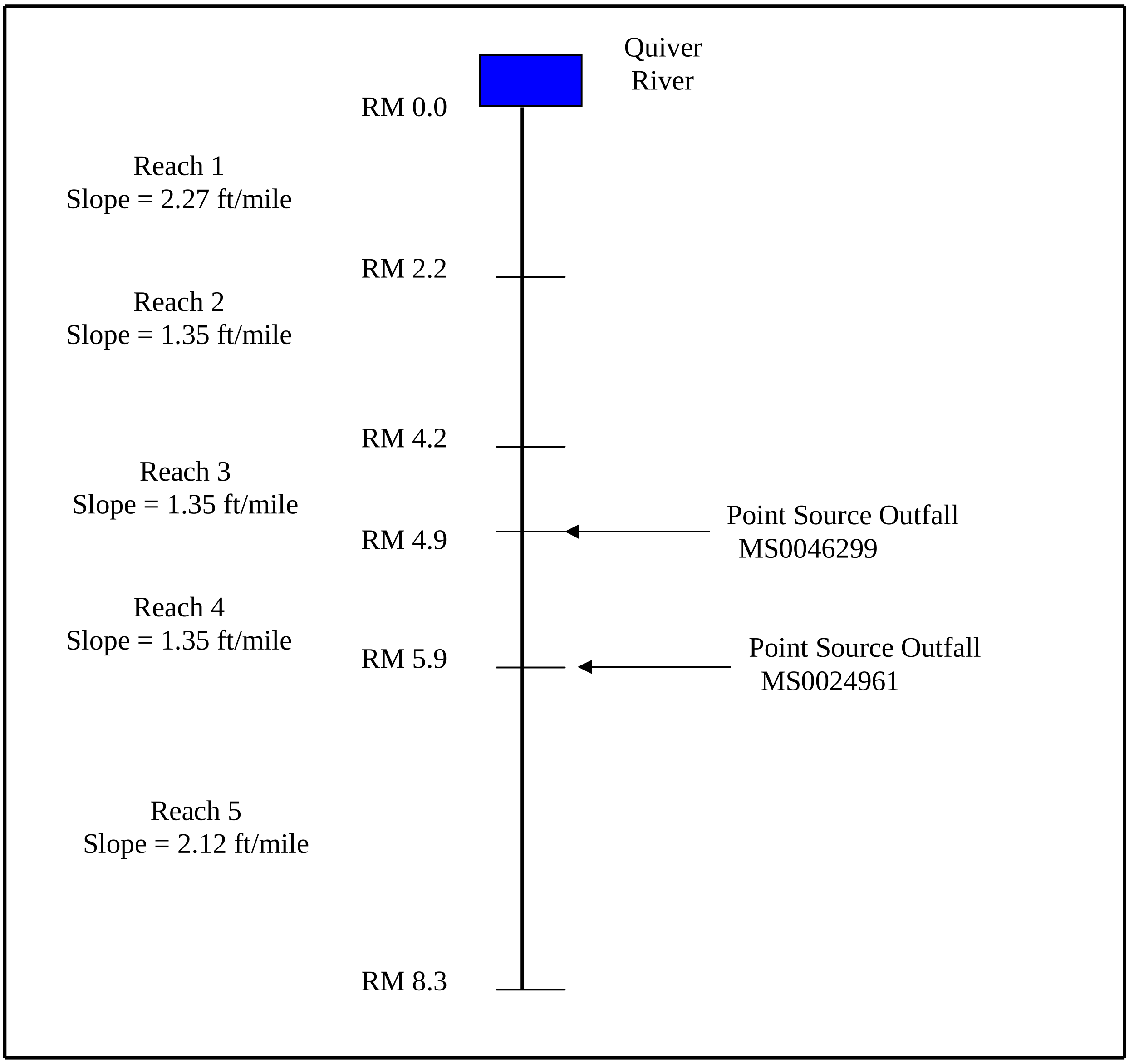


Figure 5. Moorhead Bayou Model Setup (Note: Figure not to Scale)

3.3 Source Representation

Both point and nonpoint sources were represented in the model. The loads from NPDES permitted sources were added as direct inputs into the appropriate reach of the water body as a flow in cfs and a load of CBODu and ammonia nitrogen in lbs/day. Spatially distributed loads, which represent nonpoint sources of flow, CBODu, and ammonia nitrogen were distributed evenly into each computational element of Moorhead Bayou.

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 BOD_5 while predictive models used for TMDL development are typically developed using CBODu, a ratio between the two terms is needed, Equation 3.

$$\mathbf{CBODu = CBOD_5 * Ratio} \qquad \textbf{(Equation 3)}$$

The CBODu to $CBOD_5$ ratios are given in *Empirical Stream Model Assumptions for Conventional Pollutants and Conventional Water Quality Models* (MDEQ, 1995). These values are recommended for use by MDEQ regulations when actual field data are not available. The value of the ratio depends on the treatment type. A ratio of 3:1 was used for the Allen Canning vegetable processing WWTP, and a ratio of 1.5:1 was used for Moorhead's POTW.

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 (NO_3) was used. Using this factor is a conservative modeling assumption because it assumes that all of the ammonia is converted to nitrate through nitrification, which is not necessarily accurate. The oxygen demand caused by nitrification of ammonia is equal to the NBODu load. The sum of CBODu and NBODu is equal to the point source load of TBODu. The loads of TBODu from each of the existing point sources are given in Table 7. The loads were based on the average data from discharge monitoring reports. Note that the concentrations given for the NH_3-N values are 2 mg/L. These values were assumed because currently both facilities are not required to report monthly NH_3-N values.

Table 7. Point Source Loads as Input into the Model (Existing)

Facility	Flow (cfs)	$CBOD_5$ (mg/l)	$CBOD_u$:$CBOD_5$ Ratio	CBODu (lbs/day)	NH_3-N (mg/l)	NBODu (lbs/day)	TBODu (lbs/day)
Allen Canning	0.66	57.9	3.0	619.0	2	7.12	651.9
Moorhead POTW	0.53	38.0	1.5	163.0	2	5.72	189.2
Total				**782.0**		**12.8**	**841.1**

Direct measurements of nonpoint source loads of CBODu and NH_3-N were not available for the Moorhead Bayou Watershed. The background contributions of CBODu and total ammonia as nitrogen (NH_3–N) were estimated based on *Empirical Stream Model Assumptions for Conventional Pollutants and Conventional Water Quality Models* (MDEQ, 1994). According to these regulations, the background concentrations used in modeling are CBODu = 2.0 mg/l and NH_3-N = 0.1 mg/l.

Due to the lack of data, the nonpoint source flows in Moorhead Bayou were also estimated. Low flow, critical conditions are typically estimated as the 7Q10 flow condition. However, due to extensive man-made modifications and groundwater pumping, which have caused a significant decrease in baseflow, 7Q10 flows are not available for streams in the Mississippi River alluvial plain. For the Moorhead Bayou watershed, a low-flow coefficient, rather than a 7Q10 flow, was used to represent low-flow conditions.

Because there is not a continuous record of flow available for Moorhead Bayou, the low-flow coefficient was estimated based on data from a nearby water body in the Mississippi River alluvial plain. The water body located closest to the Moorhead Bayou Watershed that has a long-term continuous record of flow is Bogue Phalia. The Bogue Phalia Watershed occupies an area of approximately 309,760 acres (484 square miles) and lies in parts of Washington, Bolivar, and Sunflower Counties. Bogue Phalia flows in a southern direction from its headwaters to its confluence with the Big Sunflower River near Darlove. USGS gage 07288650 is located on Bogue Phalia near Leland, MS. Though there are differences in the hydrological characteristics of these two water bodies due to variations in watershed size, geology, and man-made modifications to the landscape, a flow coefficient (amount of flow per drainage area size) was extrapolated from Bogue Phalia to Moorhead Bayou.

Flow data for the USGS monitoring station on Bogue Phalia near Leland were available for 1986 through 2000. The critical flow for Bogue Phalia was determined to be 40 cfs in the month of October. The contributing drainage area of Bogue Phalia, 484 square miles, was used to determine the low flow coefficient as shown below.

Low-Flow Coefficient (cfs/square mile) = 40 cfs/484 square miles = **0.083 cfs/square mile**

Then the critical condition low-flow for Moorhead Bayou was estimated by multiplying by the contributing drainage area size of Moorhead Bayou, 24.3 square miles.

Low-Flow in Moorhead Bayou = 0.083 cfs/square mile * 24.3 square miles = **2.00 cfs**

After determining the drainage area of the Moorhead Bayou Watershed, the low-flow coefficient (low-flow value in cfs/drainage area in square miles) was used to estimate the amount of water draining into each modeled reach of Moorhead Bayou during low-flow conditions. The estimated flows were multiplied by the background concentrations of CBODu and NH_3-N to calculate the nonpoint source loads in the model, Table 8. It was assumed that the nonpoint source loads were evenly distributed within each reach.

Table 8. Nonpoint Source Loads as Input into the Model (Existing)

Watershed	Flow (cfs)	$CBOD_5$ (mg/l)	CBODu:$CBOD_5$ Ratio	CBODu (lbs/day)	NH_3-N (mg/l)	NBODu (lbs/day)	TBODu (lbs/day)
1	0.530	1.33	1.5	5.70	0.1	1.31	7.01
2	0.482	1.33	1.5	5.18	0.1	1.19	6.37
3	0.169	1.33	1.5	1.82	0.1	0.42	2.23
4	0.241	1.33	1.5	2.59	0.1	0.59	3.19
5	0.528	1.33	1.5	5.68	0.1	1.30	6.98
Total				**20.97**		**4.80**	**25.78**

3.4 Selection of Representative Modeling Periods

The model was setup to simulate low-flow, high-temperature conditions, which was determined to be the critical condition for this TMDL. The temperature used in the model is 26°C annually. The headwater instream DO was assumed to be 85% of saturation at the stream temperature. The instream CBODu decay rate is dependent on temperature, according to Equation 4.

$$\mathbf{Kd_{(T)} = Kd_{(20°C)}(1.047)^{T-20}} \qquad \textbf{(Equation 4)}$$

Where Kd 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 *Empirical Stream Model Assumptions for Conventional Pollutants and Conventional Water Quality Models* (MDEQ, 1994). According to the guidance in this document, the SOD, photosynthesis, and respiration rates were set to zero due to lack of field measurements of these parameters. Further monitoring will be required in order to accurately define these parameters in subsequent models. MDEQ plans to request SOD monitoring assistance from EPA Region 4 for this stream within the next two years.

3.5 Model Calibration Process

The model used to develop the Moorhead Bayou TMDL was not calibrated due to lack of instream monitoring data collected during critical conditions. Future monitoring is essential to improve the accuracy of the model and the results.

3.6 Model Results

Once the model setup was complete, the model was used to predict water quality conditions in Moorhead Bayou and its tributaries. The model was first run under baseline conditions. Under baseline conditions, the loads from NPDES permitted point sources were set at their existing load scenarios as determined from the discharge monitoring reports, Table 6. Thus, baseline model runs reflect the current condition of Moorhead Bayou without any reduction of TBODu loads. The model was then run using a trial-and-error process to determine the maximum TBODu loads from the point source facilities, which would not violate water quality standards for DO. These model runs are referred to as maximum load scenarios.

3.6.1 Baseline Model Runs

The model results from the baseline model run using DMR data are shown in Figure 6. The graph shows the modeled daily average DO in Moorhead Bayou. The red line represents the DO standard of 5.0 mg/l. Figure 6 shows the daily average instream DO concentrations in Moorhead Bayou under existing conditions, beginning with river mile 8.3 and ending with river mile 0.0 (the mouth of Moorhead Bayou at Quiver River). The model results indicate the DO standard would violate in this reach as a result of the effluent from Moorhead POTW. The model output shows, furthermore, that the DO standard continues to be violated as a result of the effluent from Allen Canning.

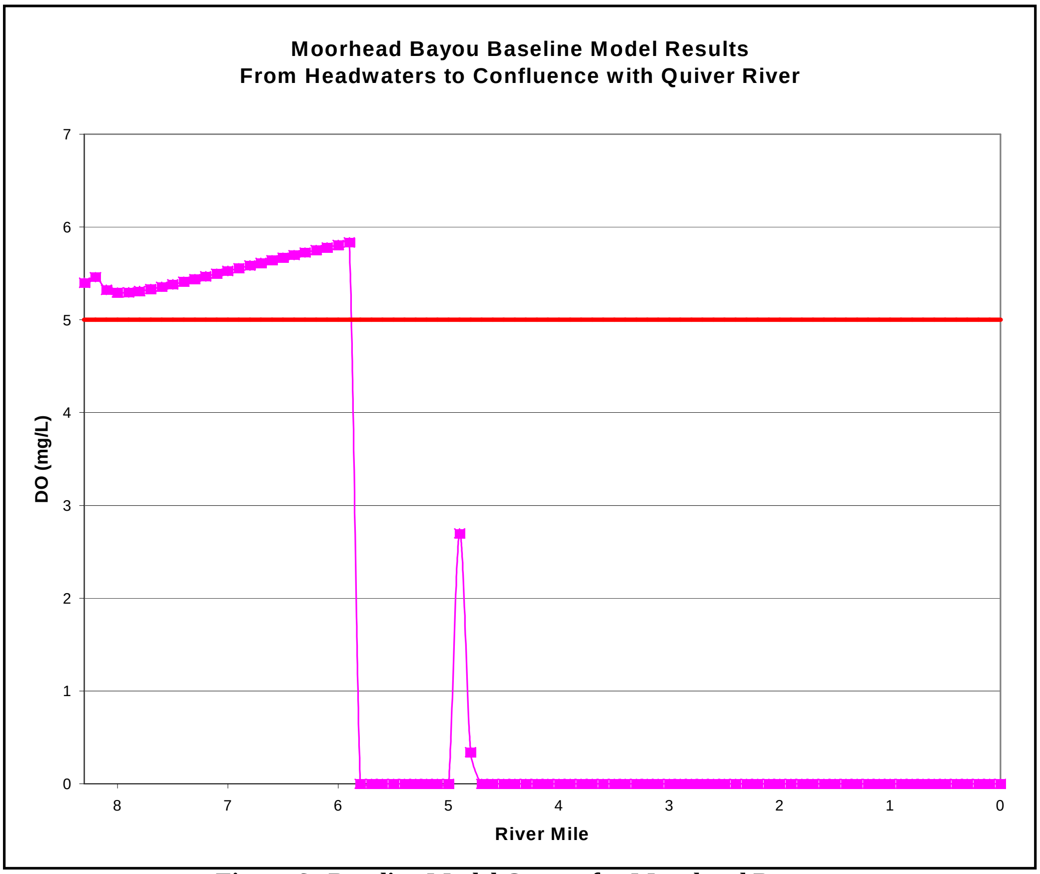


Figure 6. Baseline Model Output for Moorhead Bayou

3.6.2 Maximum Load Scenarios

The graphs of baseline model output show that the predicted DO falls below the DO standard in Moorhead Bayou during critical conditions. As a result, reductions from the baseline loads of TBODu would be necessary in order to meet the water quality standard. The TMDL is based on this baseline result. There is a 90 % reduction needed in point source loads based on this preliminary model.

The maximum load scenarios involved running the model using a trial-and-error process. This trial and error process also takes into account that Allen Cannng will not discharge during the critical period. This non-discharging by Allen Canning is discussed in section 4.1.2. The maximum load that allowed the maintenance of water quality standards was selected to be 3 BOD_5 –0.2 Ammonia –6 Dissolved Oxygen. The maximum load was used to develop the waste load allocations proposed in this TMDL. Figure 7 shows the modeled instream DO concentrations in Moorhead Bayou after application of the selected maximum load scenario for the month of October. The lowest DO concentration in Moorhead Bayou, approximately 5.0 mg/l occurs near river mile 3.5, just downstream from the discharge from the Moorhead POTW. The TBODu loads included in the maximum load scenario are given in Table 9.

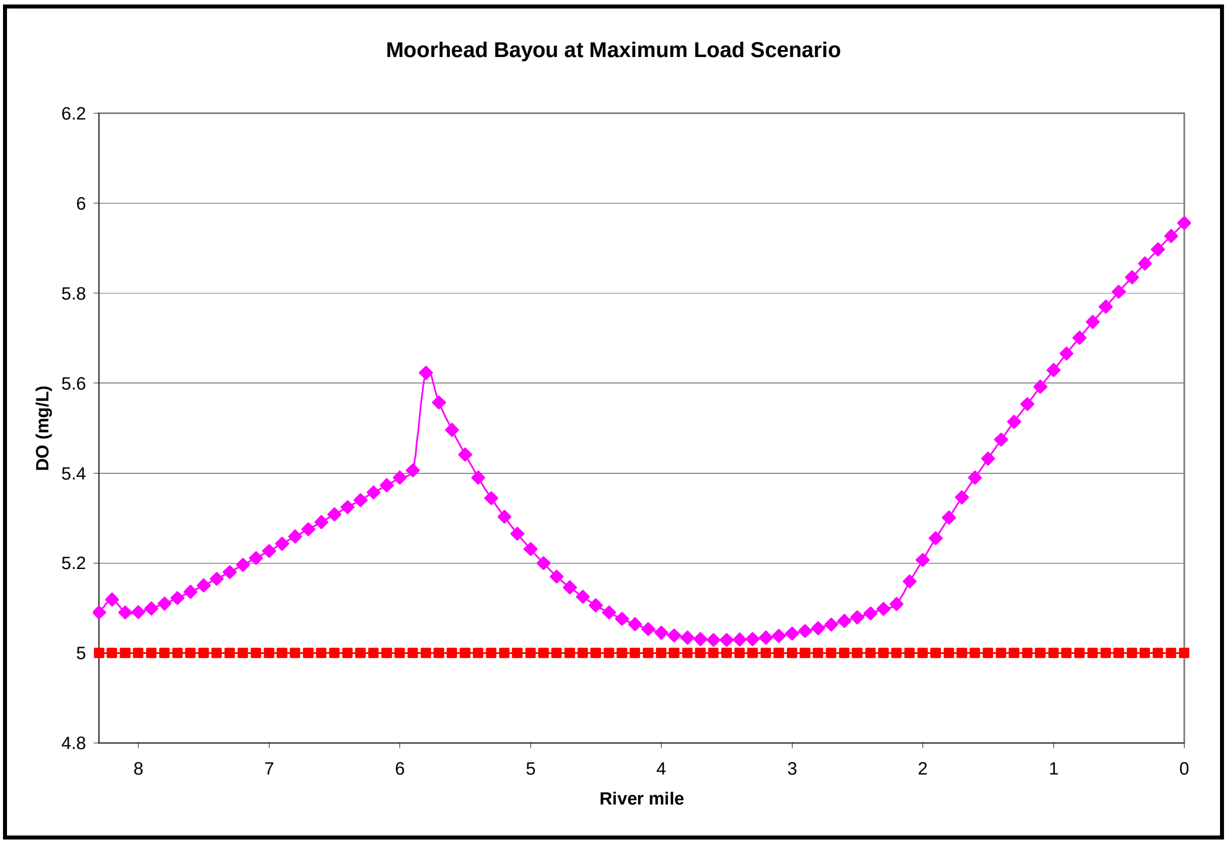


Figure 7. Maximum Load Scenario Model Output for Moorhead Bayou

Table 9. Maximum Load Scenario, Critical Conditions

Source	CBODu (lbs/day)	NBODu (lbs/day)	TBODu (lbs/day)	Percent Reduction
NPDES Permits	16.98	3.45	20.43	90%
Nonpoint Sources	20.97	4.80	25.78	0%
Total	**37.95**	**8.25**	**46.21**	**80%**

3.6 Evaluation of Ammonia Toxicity

Ammonia must not only be considered due to its effect on dissolved oxygen in the receiving water, but also its toxicity potential. Ammonia nitrogen concentrations can be evaluated using the criteria given in 1999 Update of Ambient Water Quality Criteria for Ammonia (EPA-822-R-99-014). The maximum allowable instream ammonia nitrogen (NH_3-N) concentration at a pH of 7.0 and stream temperature of 26°C is 2.82 mg/l. Based on the model results, this criterion was not exceeded in Moorhead Bayou under the current NH_3-N loads.

ALLOCATION

The allocation for this TMDL involves a wasteload allocation for point sources and a load allocation for nonpoint sources necessary for attainment of water quality standards in segment MS386M. The load and wasteload allocations for Moorhead Bayou were developed as annual loads, based on the model results for critical conditions.

4.1 Wasteload Allocation

Federal regulations require that effluent limits developed to protect water quality criteria be consistent with the assumptions and requirements of any available wasteload allocation for the discharge prepared by the state and approved by EPA. Due to economic and environmental considerations in the watershed, MDEQ will stage the implementation of this TMDL. This TMDL recommends a 5-year compliance schedule be included in the NPDES permit of each NPDES Permitted facility in the watershed. The compliance schedule should require each facility to meet permit limits during the first four years of the permit. Prior to the end of the fifth year of the permit, the compliance schedule will require each facility to meet limits as determined by the state necessary to meet whatever applicable water quality standards that are in place at that time.

4.1.1 Wasteload Allocation for the TMDL

The TMDL based on the model is 46.21 TBODu(lbs/day). This represents a 90% reduction in point sources. More monitoring and model development are scheduled in the next two years to improve the accuracy of these calculations.

4.1.2 Wasteload Allocation Implementation Plan

Two NPDES Permitted facilities in the Moorhead Bayou watershed are included in the wasteload allocation, Table 10. The loads given in Table 10 are based on permit limits of 3 BOD_5 –0.2 Ammonia –6 Dissolved Oxygen for the town of Moorhead and no discharge from Allen Canning during the critical time of the year (a modified HCR facility).

Table 10. Wasteload Allocation

Facility	CBODu (lbs/day)	NBODu (lbs/day)	TBODu (lbs/day)
Allen Canning	0	0	0
Moorhead POTW	16.98	3.45	20.43
Total	**16.98**	**3.45**	**20.43**

It is noted that Allen Canning, which had compliance problems in the past, recently installed an additional treatment process WWTP in October of 2002. This new upgrade, which cost the facility approximately $2 million dollars, included the installation of a Dissolve Air Flotation (DAF) Unit, photo 2. This new unit has resulted in an immediate improvement to the quality of water in the stream. Allen Canning has reduced water intake by 70% due to recycling cleaned water. This has resulted in no discharge from the facility since the new unit began operation. Future stream monitoring is already scheduled to verify how well this equipment is performing.

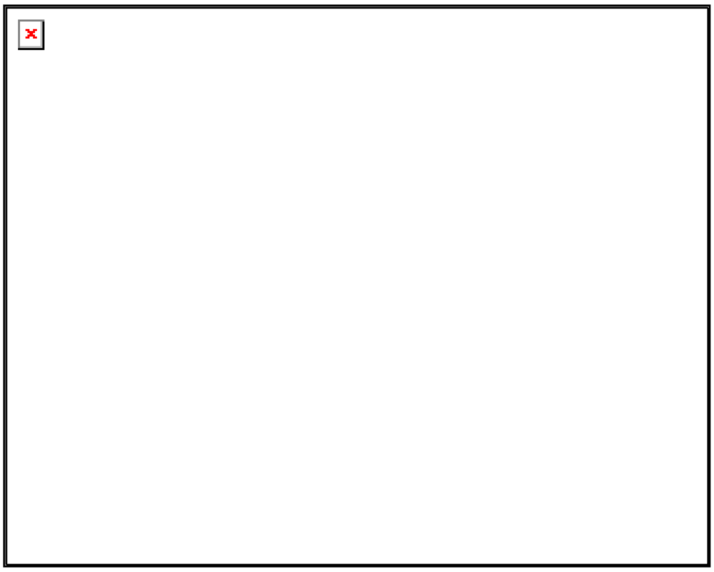


Photo 2. Allen Canning's Newly Installed DAF Unit

4.2 Load Allocation

The headwater and spatially distributed loads are included in the load allocation. The TBODu concentrations of these loads were estimated by using an assumed $CBOD_5$ concentration of 1.33 mg/l and an NH_3-N concentration of 0.1 mg/l. These concentrations should be assumed when reliable field data are not available, according to *Empirical Stream Model Assumptions for Conventional Pollutants and Conventional Water Quality Models* (MDEQ, 1994). The headwater and spatially distributed flows were calculated for the Moorhead Bayou Watershed by delineating the drainage area into subwatersheds. Flows from each subwatershed were based on the low flow coefficient for the watershed and the watershed size. Then, the load allocations were calculated to determine the $CBOD_u$ and $NBOD_u$ loads in lbs/day, Table 11.

Table 11. Load Allocation-Nonpoint Sources

Watershed	Flow (cfs)	$CBOD_5$ (mg/l)	CBODu:$CBOD_5$ Ratio	CBODu (lbs/day)	NH_3-N (mg/l)	NBODu (lbs/day)	TBODu (lbs/day)
1	0.530	1.33	1.5	5.70	0.1	1.31	7.01
2	0.482	1.33	1.5	5.18	0.1	1.19	6.37
3	0.169	1.33	1.5	1.82	0.1	0.42	2.23
4	0.241	1.33	1.5	2.59	0.1	0.59	3.19
5	0.528	1.33	1.5	5.68	0.1	1.30	6.98
Total				**20.97**		**4.80**	**25.78**

4.3 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 model is implicit.

Conservative assumptions, which place a higher demand of DO on the water body than may actually be present, are considered part of the margin of safety. The assumption that all of the ammonia nitrogen present in the water body is oxidized to nitrate nitrogen, for example, is a conservative assumption. In addition, the TMDL is based on the critical condition of the water body, which is represented by the low flow coefficient. The low flow coefficient for Moorhead Bayou is very small. Therefore, modeling the water body at this flow provides protection in the worst-case scenario.

4.4 Seasonality

Seasonal variation may be addressed in the TMDL by using seasonal water quality standards or developing model runs to reflect seasonal variations in temperature and other parameters. Mississippi's water quality standards for dissolved oxygen, however, do not vary according to the seasons. The model was set up to simulate dissolved oxygen during the critical condition period, the low-flow, high-temperature period that typically occurs during the summer season. Since the critical condition represents the worst-case scenario, the TMDL developed for critical conditions is protective of the water body at all times. Thus, this TMDL will ensure attainment of water quality standards for each season.

4.5 Calculation of the TMDL

The TMDL was calculated based on Equation 5.

$$\mathbf{TMDL = WLA + LA + MOS} \qquad \textbf{(Equation 5)}$$

Where WLA is the wasteload allocation, LA is the load allocation, and MOS is the margin of safety. All units are in lbs/day of TBODu. The TMDL for TBODu was calculated based on the maximum allowable loading of the pollutants in Moorhead Bayou and its tributaries, according to the model. The TMDL calculations are shown in Table 12.

The wasteload allocations incorporate the CBODu and NH_3-N contributions from identified NPDES Permitted facilities. The load allocations include the headwaters and spatially distributed TBODu and NH_3-N contributions from surface runoff and groundwater infiltration. The implicit margin of safety for this report is derived from the conservative assumptions used in setting up the model.

Table 12. TMDL for $TBOD_u$ for Moorhead Bayou

	WLA (lbs/day)	LA (lbs/day)	TMDL (lbs/day)
$CBOD_u$	16.98	20.97	**37.95**
$NBOD_u$	3.45	4.80	**8.25**
$TBOD_u$	**20.43**	**25.78**	**46.21**

CONCLUSION

This TMDL indicates that the point source load in Moorhead Bayou is greater than the assimilative capacity of the stream. An 80% reduction overall from the current loads would be needed to eliminate the standards violation in the stream. As this is not practical based on the modeling done for this TMDL, therefore, further monitoring is scheduled for this stream.

The current model used for these calculations does not have adequate data to support all of the assumptions used, however, it is clear that the stream is impaired. The TMDL therefore recommends the following:

1. No increases in load allowed for Moorhead Bayou;
2. Allen Canning and Moorhead POTW begin in-stream monitoring and increase effluent monitoring to ensure proper operation of the current facilities;
3. MDEQ and EPA schedule intensive monitoring to refine the model; and
4. Allen Canning will be prohibited from discharging during critical period.
5. The facilities or EPA may request a Use Attainability Analysis (UAA) based on the modeling results.

5.1 Future Monitoring

Additional monitoring needed for model refinement needs to be prioritized by the local stakeholders, MDEQ, and EPA. MDEQ has adopted the Basin Approach to Water Quality Management, a plan that divides Mississippi's major drainage basins into five groups. During each yearlong cycle, MDEQ's resources for water quality monitoring will be focused on one of the basin groups. Within the next two years, Moorhead Bayou will receive additional monitoring to identify improvement in water quality. The additional monitoring may allow confirmation of the assumptions used in the model used for calculating the TMDL.

5.2 Public Participation

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 TMDL 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. TMDL mailing list members may request to receive the TMDL reports through either, email or the postal service. Anyone wishing to become a member of the TMDL mailing list should contact Greg Jackson at (601) 961-5098 or Greg_Jackson@deq.state.ms.us.

All comments received during the public notice period become a part of the record of this TMDL. All comments will be considered in the submission of this TMDL to EPA Region 4 for final approval.

REFERENCES

MDEQ. 1994. *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.* Office of Pollution Control.

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USEPA. 1997. *Technical Guidance Manual for Developing Total Maximum Daily Loads, Book 2: Streams and Rivers, Part 1: Biochemical Oxygen Demand/Dissolved Oxygen and Nutrients/ Eutrophication*. United States Environmental Protection Agency, Office of Water, Washington, D.C. EPA 823-B-97-002.

DEFINITIONS

5-Day Biochemical Oxygen Demand: Also called BOD_5, the amount of oxygen consumed by microorganisms while stabilizing or degrading carbonaceous or nitrogenous compounds under aerobic conditions over a period of 5 days.

Activated Sludge: A secondary wastewater treatment process that removes organic matter by mixing air and recycled sludge bacteria with sewage to promote decomposition

Aerated Lagoon: A relatively deep body of water contained in an earthen basin of controlled shape which is equipped with a mechanical source of oxygen and is designed for the purpose of treating wastewater.

Ammonia: Inorganic form of nitrogen (NH_3); product of hydrolysis of organic nitrogen and denitrification. Ammonia is preferentially used by phytoplankton over nitrate for uptake of inorganic nitrogen.

Ammonia Nitrogen: The measured ammonia concentration reported in terms of equivalent ammonia concentration; also called total ammonia as nitrogen (NH_3-N)

Ammonia Toxicity: Under specific conditions of temperature and pH, the unionized component of ammonia can be toxic to aquatic life. The unionized component of ammonia increases with pH and temperature.

Ambient Stations: A network of fixed monitoring stations established for systematic water quality sampling at regular intervals, and for uniform parametric coverage over a long-term period.

Assimilative Capacity: The capacity of a body of water or soil-plant system to receive wastewater effluents or sludge without violating the provisions of the State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters and Water Quality regulations.

Background: The condition of waters in the absence of man-induced alterations based on the best scientific information available to MDEQ. The establishment of natural background for an altered water body may be based upon a similar, unaltered or least impaired, water body or on historical pre-alteration data.

Biological Impairment: Condition in which at least one biological assemblages (e.g. , fish, macroinvertabrates, or algae) indicates less than full support with moderate to severe modification of biological community noted.

Carbonaceous Biochemical Oxygen Demand: Also called CBODu, the amount of oxygen consumed by microorganisms while stabilizing or degrading carbonaceous compounds under aerobic conditions over an extended time period.

Calibrated Model: A model in which reaction rates and inputs are significantly based on actual measurements using data from surveys on the receiving water body.

Conventional Lagoon: An un-aerated, relatively shallow body of water contained in an earthen basin of controlled shape and designed for the purpose of treating water.

Critical Condition: Hydrologic and atmospheric conditions in which the pollutants causing impairment of a water body have their greatest potential for adverse effects.

Daily Discharge: The "discharge of a pollutant" measured during a calendar day or any 24-hour period that reasonably represents the calendar day for purposes of sampling. For pollutants with limitations expressed in units of mass, the "daily discharge" is calculated as the total mass of the pollutant discharged over the day. For pollutants with limitations expressed in other units of measurement, the "daily average" is calculated as the average.

Designated Use: Use specified in water quality standards for each water body or segment regardless of actual attainment.

Discharge Monitoring Report: Report of effluent characteristics submitted by a NPDES Permitted facility.

Dissolved Oxygen: The amount of oxygen dissolved in water. It also refers to a measure of the amount of oxygen that is available for biochemical activity in a water body. The maximum concentration of dissolved oxygen in a water body depends on temperature, atmospheric pressure, and dissolved solids.

Dissolved Oxygen Deficit: The saturation dissolved oxygen concentration minus the actual dissolved oxygen concentration.

DO Sag: Longitudinal variation of dissolved oxygen representing the oxygen depletion and recovery following a waste load discharge into a receiving water.

Effluent Standards and Limitations: All State or Federal effluent standards and limitations on quantities, rates, and concentrations of chemical, physical, biological, and other constituents to which a waste or wastewater discharge may be subject under the Federal Act or the State law. This includes, but is not limited to, effluent limitations, standards of performance, toxic effluent standards and prohibitions, pretreatment standards, and schedules of compliance.

Effluent: Treated wastewater flowing out of the treatment facilities.

First Order Kinetics: Describes a reaction in which the rate of transformation of a pollutant is proportional to the amount of that pollutant in the environmental system.

Groundwater: Subsurface water in the zone of saturation. Groundwater infiltration describes the rate and amount of movement of water from a saturated formation.

Impaired Water body: Any water body that does not attain water quality standards due to an individual pollutant, multiple pollutants, pollution, or an unknown cause of impairment.

Land Surface Runoff: Water that flows into the receiving stream after application by rainfall or irrigation. It is a transport method for nonpoint source pollution from the land surface to the receiving stream.

Load Allocation (LA): The portion of a receiving water's loading capacity attributed to or assigned to nonpoint sources (NPS) or background sources of a pollutant

Loading: The total amount of pollutants entering a stream from one or multiple sources.

Mass Balance: An equation that accounts for the flux of mass going into a defined area and the flux of mass leaving a defined area, the flux in must equal the flux out.

Nonpoint Source: Pollution that is in runoff from the land. Rainfall, snowmelt, and other water that does not evaporate become surface runoff and either drains into surface waters or soaks into the soil and finds its way into groundwater. This surface water may contain pollutants that come from land use activities such as agriculture; construction; silvaculture; surface mining; disposal of wastewater; hydrologic modifications; and urban development.

Nitrification: The oxidation of ammonium salts to nitrites via *Nitrosomonas* bacteria and the further oxidation of nitrite to nitrate via *Nitrobacter* bacteria.

Nitrogenous Biochemical Oxygen Demand: Also called NBODu, the amount of oxygen consumed by microorganisms while stabilizing or degrading nitrogenous compounds under aerobic conditions over an extended time period.

NPDES Permit: An individual or general permit issued by the Mississippi Environmental Quality Permit Board pursuant to regulations adopted by the Mississippi Commission on Environmental Quality under Mississippi Code Annotated (as amended) §§ 49-17-17 and 49-17-29 for discharges into State waters.

Photosynthesis: The biochemical synthesis of carbohydrate based organic compounds from water and carbon dioxide using light energy in the presence of chlorophyll.

Point Source: Pollution loads discharged at a specific location from pipes, outfalls, and conveyance channels from either wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving stream.

Pollution: Contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the State, including change in temperature, taste, color, turbidity, or odor of the waters, or such discharge of any liquid, gaseous, solid, radioactive, or other substance, or leak into any waters of the State, unless in compliance with a valid permit issued by the Permit Board.

Publicly Owned Treatment Works (POTW): A waste treatment facility owned and/or operated by a public body or a privately owned treatment works which accepts discharges which would otherwise be subject to Federal Pretreatment Requirements.

Reaeration: The net flux of oxygen occurring from the atmosphere to a body of water across the water surface.

Regression Coefficient: An expression of the functional relationship between two correlated variables that is often empirically determined from data, and is used to predict values of one variable when given values of the other variable.

Respiration: The biochemical process by means of which cellular fuels are oxidized with the aid of oxygen to permit the release of energy required to sustain life. During respiration, oxygen is consumed and carbon dioxide is released.

Sediment Oxygen Demand: The solids discharged to a receiving water are partly organics, which upon settling to the bottom decompose aerobically, removing oxygen from the surrounding water column.

Storm Runoff: Rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate than rainfall intensity, but instead flows into adjacent land or water bodies or is routed into a drain or sewer system.

Streeter-Phelps DO Sag Equation: An equation which uses a mass balance approach to determine the DO concentration in a water body downstream of a point source discharge. The equation assumes that the stream flow is constant and that CBODu exertion is the only source of DO deficit while reaeration is the only sink of DO deficit.

Total Ultimate Biochemical Oxygen Demand: Also called TBODu, the amount of oxygen consumed by microorganisms while stabilizing or degrading carbonaceous or nitrogenous compounds under aerobic conditions over an extended time period.

Total Kjeldahl Nitrogen: Also called TKN, organic nitrogen plus ammonia nitrogen.

Total Maximum Daily Load or TMDL: The calculated maximum permissible pollutant loading to a water body at which water quality standards can be maintained.

Waste: Sewage, industrial wastes, oil field wastes, and all other liquid, gaseous, solid, radioactive, or other substances which may pollute or tend to pollute any waters of the State.

Wasteload Allocation (WLA): The portion of a receiving water's loading capacity attributed to or assigned to point sources of a pollutant.

Water Quality Standards: The criteria and requirements set forth in *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters*. Water quality standards are standards composed of designated present and future most beneficial uses (classification of waters), the numerical and narrative criteria applied to the specific water uses or classification, and the Mississippi antidegradation policy.

Water Quality Criteria: Elements of State water quality standards, expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports the present and future most beneficial uses.

Waters of the State: All waters within the jurisdiction of this State, including all streams, lakes, ponds, wetlands, impounding reservoirs, marshes, watercourses, waterways, wells, springs, irrigation systems, drainage systems, and all other bodies or accumulations of water, surface and underground, natural or artificial, situated wholly or partly within or bordering upon the State, and such coastal waters as are within the jurisdiction of the State, except lakes, ponds, or other surface waters which are wholly landlocked and privately owned, and which are not regulated under the Federal Clean Water Act (33 U.S.C.1251 et seq.).

Watershed: The area of land draining into a stream at a given location.

ABBREVIATIONS

7Q10 .... Seven-Day Average Low Stream Flow with a Ten-Year Occurrence Period

BASINS .... Better Assessment Science Integrating Point and Nonpoint Sources

BMP .... Best Management Practice

$CBOD_5$ .... 5-Day Carbonaceous Biochemical Oxygen Demand

CBODu .... Carbonaceous Ultimate Biochemical Oxygen Demand

CWA .... Clean Water Act

DMR .... Discharge Monitoring Report

DO .... Dissolved Oxygen

EPA .... Environmental Protection Agency

GIS .... Geographic Information System

HUC .... Hydrologic Unit Code

LA .... Load Allocation

MARIS .... Mississippi Automated Resource Information System

MDEQ .... Mississippi Department of Environmental Quality

MGD .... Million Gallons per Day

MOS .... Margin of Safety

NBODu .... Nitrogenous Ultimate Biochemical Oxygen Demand

NH_3 .... Total Ammonia

NH_3-N .... Total Ammonia as Nitrogen

NO_2+ NO_3 .... Nitrite Plus Nitrate

NPDES .... National Pollution Discharge Elimination System

RBA .... Rapid Biological Assessment

$TBOD_5$ .... 5-Day Total Biochemical Oxygen Demand

TBODu .... Total Ultimate Biochemical Oxygen Demand

TKN .... Total Kjeldahl Nitrogen

TN .... Total Nitrogen

TOC .... Total Organic Carbon

TP .... Total Phosphorous

USGS .... United States Geological Survey

WLA .... Waste Load Allocation

WWTP .... Wastewater Treatment Plant