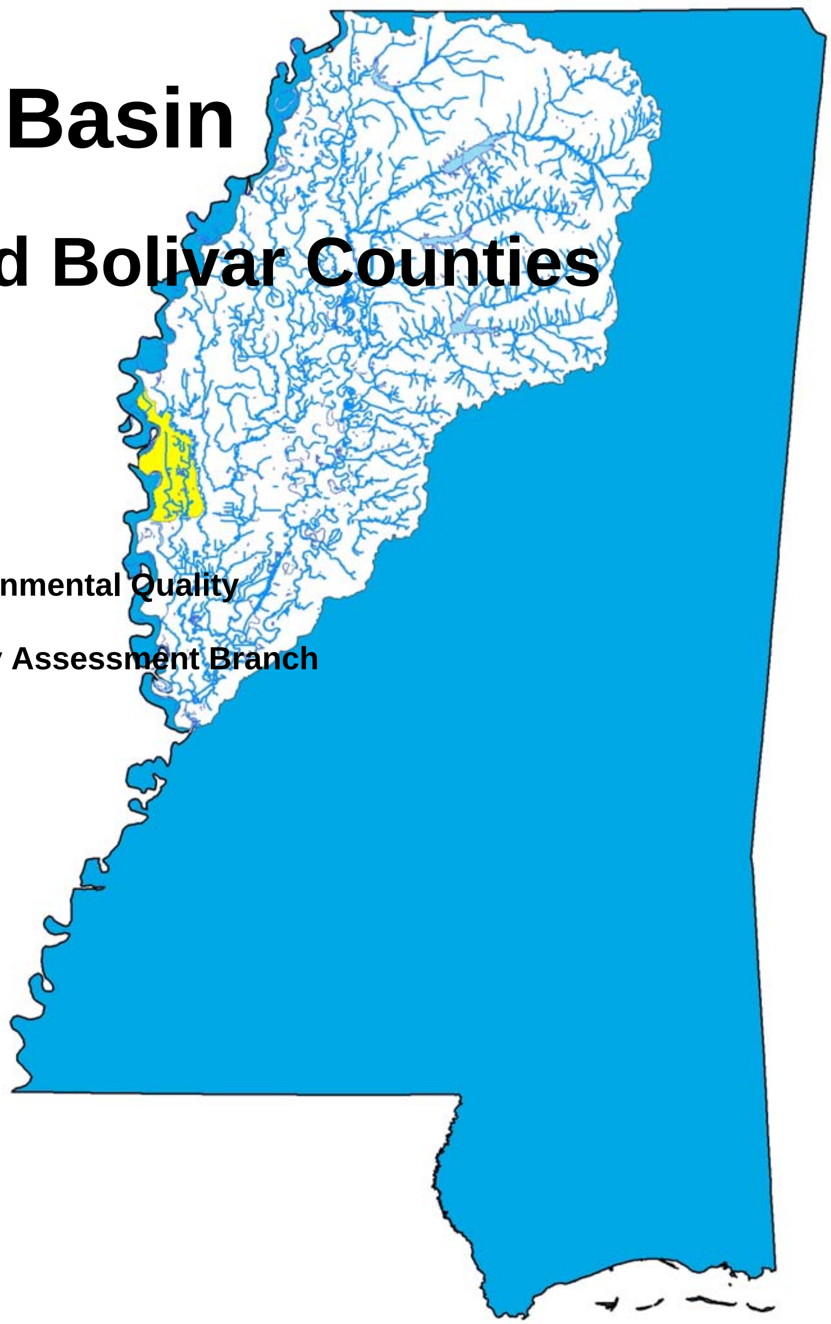
FINAL REPORT
June 2003
ID: 903063004

Phase 1
Total Maximum Daily Load
For Organic Enrichment/Low DO and Nutrients

Black Bayou
Yazoo River Basin

Washington and Bolivar Counties
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	0.028316847	Feet	Meters	0.3048
Cubic feet	Gallons	7.4805195	Gallons	Cu feet	0.133680555
Cubic feet	Liters	28.316847	Hectares	Acres	2.4710538
cfs	Gal/min	448.83117	Miles	Meters	1609.344
cfs	MGD	.6463168	mg/l	ppm	1
Cubic meters	Gallons	264.17205	μg/l * cfs	Gm/day	2.45

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TMDL INFORMATION PAGE

i. Listing Information

Name	ID	County	HUC	Cause	Mon/Eval
Black Bayou and Red Bridge Bayou	MS403M4	Washington	08030209	Organic Enrichment/Low DO	Monitored
Near Burdette: From Fish Lake to Confluence of Mound Bayou near Grace.					
Black Bayou-DA	MS403E	Bolivar and Washington	08030209	Organic Enrichment/Low DO and Nutrients	Evaluated
Drainage Area near Refuge.					
Granicus Bayou	MS403M5	Washington	08030209	Nutrients	Evaluated
Near Muskedine: From Terminus of Main Canal to Confluence with Granny Baker Bayou Including Old Channel used for Flood Control to Confluence with Black Bayou.					
Granny Baker Bayou and Silver Lake	MS403M3	Washington	08030209	Organic Enrichment/Low DO and Nutrients	Evaluated
Near James from Confluence with Granicus Bayou and Old Flood Channel including Silver Lake to Confluence at Weir E with Steele Bayou.					

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
MS0037311	Arcola POTW	0.085	Unnamed Ephemeral Ditch thence Black Bayou
MS0039535	Farm Fresh Catfish Co Outfalls 001 and 002.	Average Reported Flows: 0.22 (Outfall 001) 0.08 (Outfall 002)	Unnamed Ephemeral Ditch thence Black Bayou
MS0055603	Hollandale POTW	0.875	Unnamed Ditch thence Black Bayou
MS0020761	Leland POTW	0.90	Unnamed Ephemeral Ditch thence Red Bridge Bayou
MS0057541	Stokes Development	0.08	Main Canal thence Granicus Bayou
MS0051527	Riverside School	0.05	Unnamed Ditch thence Granicus Bayou
MS0027286	Leroy Percy State Park	0.05	Black Bayou

iv. Phase 1 Total Maximum Daily Load for TBODu

LA (lbs/day)	WLA (lbs/day)	MOS	TMDL (lbs/day)
509	769	Implicit	1,278

EXECUTIVE SUMMARY

Segments of Black Bayou, Red Bridge Bayou, Granicus Bayou, Granny Baker Bayou, and Silver Lake have been placed on the Mississippi 1998 Section 303(d) List of Water Bodies as evaluated water body segments, due to organic enrichment/low dissolved oxygen and nutrients. In addition, a segment of Black 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. A drainage area of Black Bayou has also been placed on the 303(d) List as an evaluated drainage area due to organic enrichment/low dissolved oxygen and nutrients. The applicable state 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. Mississippi currently does not have standards for allowable nutrient concentrations, so a TMDL specifically for nutrients will not be developed. However, since elevated levels of nutrients may cause low levels of dissolved oxygen, the TMDL developed for dissolved oxygen also addresses the potential impact of elevated nutrients in the Black Bayou watershed.

The Black Bayou watershed is located in the Mississippi River alluvial plane in HUC 08030209. The headwaters of Red Bridge Bayou begin at the southern end of Fish Lake, just north of Highway 82 near Greenville, MS. Red Bridge Bayou flows in a southeastern direction to its confluence with Black Bayou. Black Bayou continues south for approximately 25 miles to its confluence with Steele Bayou. Main Canal is a straight channel that flows south from Greenville. Granicus Bayou flows in a southern direction from near Muskedine, MS at the terminus of Main Canal to its confluence with Granny Baker Bayou. An old channel of Granicus Bayou continues East to its confluence with Black Bayou. However, this channel typically flows only during flood conditions. Granny Baker continues south from Granicus Bayou at the split with the old channel of Granicus Bayou to its confluence with Silver Lake at Whiskey Chute. Silver Lake continues to flow in a southern direction to Weir E at Swan Lake. Black Bayou and Main Canal have been cleared and straightened in several places. The lower end of Main Canal, as well as Granicus Bayou, Granny Baker Bayou, and Silver Lake have been widened to a channel bottom width of 60 feet. Several weirs have also been constructed within these channels. Photo 1 shows Black Bayou at Highway 12 near Leroy Percy State Park.

Photo 1. Black Bayou at Highway 12

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 developing the TMDL allocations for this study. A mass-balance approach was used to ensure that the instream concentration of ammonia nitrogen (NH_3-N) did not exceed the water quality criteria for ammonia toxicity. The critical modeling period was determined to occur during the early summer, during the month of June. Based on records of stage obtained from the Corps of Engineers for a gauging station recently installed on Black Bayou, the lowest stage occurs during the month of June. Measurements of flow in Black Bayou, however, are currently not available. Because of this, a flow coefficient was developed for this watershed based on flow data from the nearby Bogue Phalia watershed. The flow coefficient was then applied to the Black Bayou watershed to estimate the flow for this watershed in the month of June.

The model used in developing this TMDL included both nonpoint and point sources of total ultimate biochemical oxygen demand (TBODu) in the Black 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 estimated background concentration of TBODu in the stream. There are several NPDES Permitted discharges located in the watershed that are included as point sources in the model.

This report concludes that Black Bayou does not have sufficient assimilative capacity for the current NPDES permitted facilities. However, there were many uncertainties involved in developing the predictive model. Due to lack of data collected during the critical modeling period, the model was not calibrated, and is based primarily on assumed values. The available water quality data show that the measured dissolved oxygen levels are higher than the modeled dissolved oxygen levels. Thus, this TMDL has been prepared as a phased TMDL Report to indicate that more information about the Black Bayou watershed is needed. Implementation of the waste load allocation will be conducted as a multi-staged process.

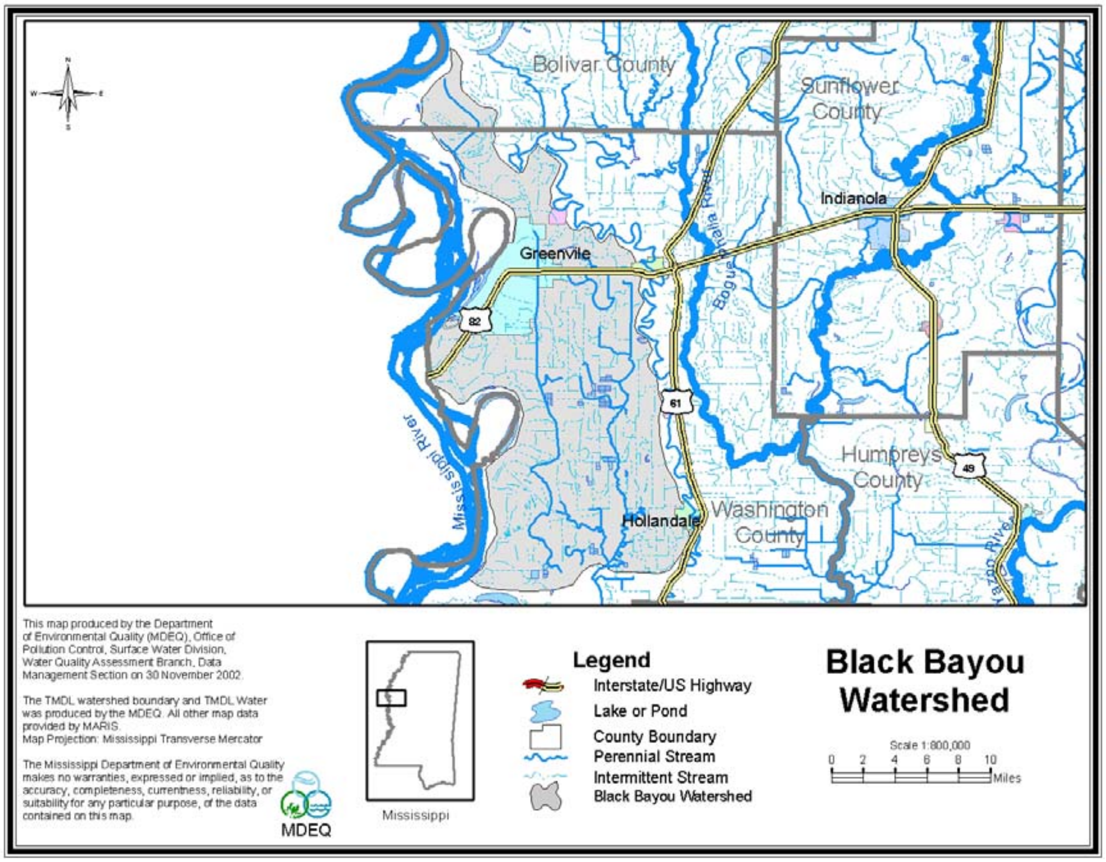


Figure 1. Black Bayou Watershed

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. The impairment is caused by reduced levels of dissolved oxygen (DO) in the creek due to oxidation of organic material. Thus, this TMDL has been developed for organic enrichment, for the 303(d) listed segments shown in Figure 2.

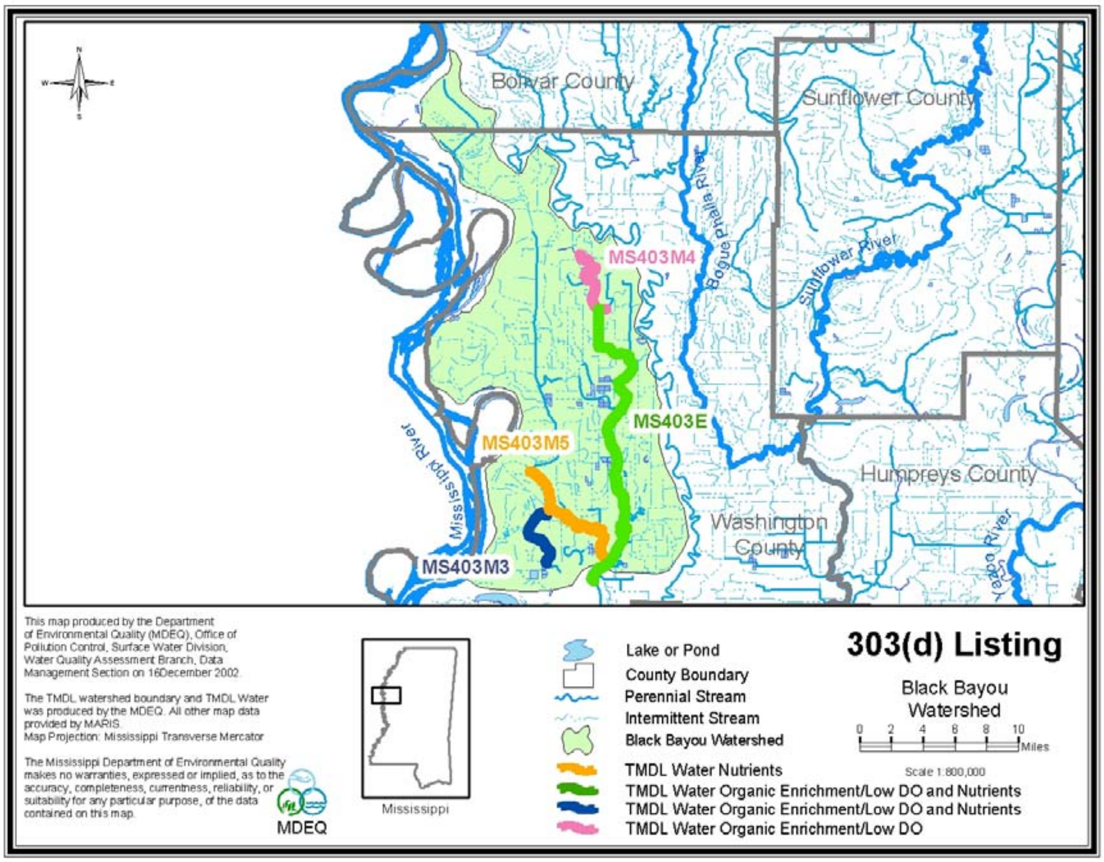


Figure 2. Black Bayou Watershed 303(d) Listed Segments

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.

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

1.2 Applicable Water Body Segment Use

The water use classification for the listed segments of Black Bayou, Red Bridge Bayou, Granicus Bayou, and Granny Baker 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 uses for Black Bayou and its tributaries are Secondary Contact and Aquatic Life Support. The Unnamed Drainage Ditches that carry effluent from the Arcola POTW, the Leland POTW, and Farm Fresh Catfish are classified as Ephemeral. Ephemeral streams are defined as streams that flow only in response to precipitation or irrigation return water without the influent of point source dischargers. Waters in this classification do not support a fisheries resource and are not required to maintain a specified dissolved oxygen level. The water bodies that carry water from the Hollandale POTW, Stokes Development, and Riverside School also have the water use classification of Fish and Wildlife 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 (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. These water quality standards will be used as targeted endpoints to evaluate impairments and establish this TMDL.

1.4 Selection of a Critical Condition

Low DO typically occurs during seasonal low-flow, high-temperature periods that occur during the 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 flow at critical conditions is typically defined as the 7Q10 flow, which is the lowest flow for seven consecutive days expected during a 10-year period. 7Q10 flows, however, have not been established for streams in the Mississippi Alluvial Plain. Because of this a low-flow condition, instead of a 7Q10 flow, is used to define the critical condition for streams in this area.

The low flow condition for the Black Bayou watershed occurs during the month of June. This period occurs prior to the influx of drainage from rice fields, which is present in the Black Bayou watershed during the late summer. Water draining from rice fields prior to the fall rice harvest has the potential to add a significant amount of flow to Black Bayou. However, based on information received from a literature review and communication with the Delta Research Extension Center, nutrient content of water draining from rice fields does not result in significantly elevated levels of ammonia nitrogen or other nutrients in downstream water bodies (Feagley et al, 1992 and Turner et al 1980). Thus, the elevated flow produced from rice field drainage may potentially increase the assimilative capacity of Black Bayou during the late summer.

1.5 Selection of a TMDL Endpoint

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.

The maximum impact of oxidation of organic material is generally not at the location of the sources, 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 point of maximum DO deficit, also called the DO sag, will be used to define the endpoint required for this TMDL. The endpoint for this TMDL will be based on a daily average of not less than 5.0 mg/l at the DO sag during the month of June. As previously discussed, this period occurs prior to the discharge of irrigation return water from rice fields. Also, based on stage records for Black Bayou at Highway 12, the lowest average water levels have been measured during the month of June.

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 Black 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 Black Bayou and its tributaries.

2.1 Discussion of the Channel Modifications and Drainage Pattern

Black Bayou and Main Canal are part of the Upper Steele Bayou Project. As part of this project these channels have been enlarged and straightened in some areas. There are five low water weirs located in Black Bayou. The most downstream weir (elevation 93.0 ft) is located near the terminus of Black Bayou, just upstream from its confluence with Steele Bayou. The next weir (elevation 96.0 ft) is located just south of Highway 12 at river mile 3.4 near Hollandale, Photo 2. Further upstream at river mile 15.0, a weir (elevation 101.5 ft) is located approximately one mile north of Highway 438. A weir is also located at elevation 107.0 ft in Black Bayou south of Highway 82 at river mile 23.3, just past the confluence of Red Bridge Bayou with Black Bayou. The most upstream weir (elevation 111.0 ft) is located in Red Bridge Bayou just north of Highway 82 at river mile 26.7. Black Bayou has also been cleared and straightened in several places, including the areas near Leroy Percy State Park, which were straightened by the drainage district in the 1940's. Portions of Black Bayou from Swan Lake to north of Leroy Percy State Park were improved utilizing selective clearing and snagging as part of the Upper Steele Bayou Project.

Modifications have also been made to the drainage pattern of Main Canal and the upper part of Steele Bayou. A series of rip rap chevron weirs have been placed in the upper part of Main Canal near Greenville. A sheet pile weir has been constructed further downstream in Main Canal, river mile 12.9, with an elevation of 103.5 ft. An additional weir, known as weir "E", was constructed at the mouth of Silver Lake or the upstream end of Steele Bayou. Work for the U.S. Fish and Wildlife Service was also part of the Upper Steele Bayou Project. This work included the construction of a 90 ft bottom channel around the east and north side of Swan Lake. This constructed channel forms the upper end of Steele Bayou. Prior to the construction of this channel, Silver Lake emptied into Swan Lake.

Many of the weirs in Black Bayou and Main Canal were installed to maintain a minimum water level sufficient to discourage the growth of woody vegetation in the channel during low flow conditions, which decreases the cost of required maintenance activities. The maintenance of a sufficient water level behind the weirs is beneficial to the fisheries community in the water body. This is because the weirs function to hold water in sections of the channel that may otherwise be dry during low flow conditions. Figure 3 shows the locations of weirs and channelized sections of Black Bayou and Main Canal. Figure 4 shows the upper portion of Steele Bayou, including the channel constructed around Swan Lake. These figures, as well as information on the weir locations and channel modifications, were provided to MDEQ by the Mississippi Levee Board[1].

1 Jim Wanamaker, personal communication via email on 1/2/2003, 2/25/2003, 2/28/2003.

Photo 2. Aerial Photo of the Weir Located on Black Bayou Downstream of Highway 12

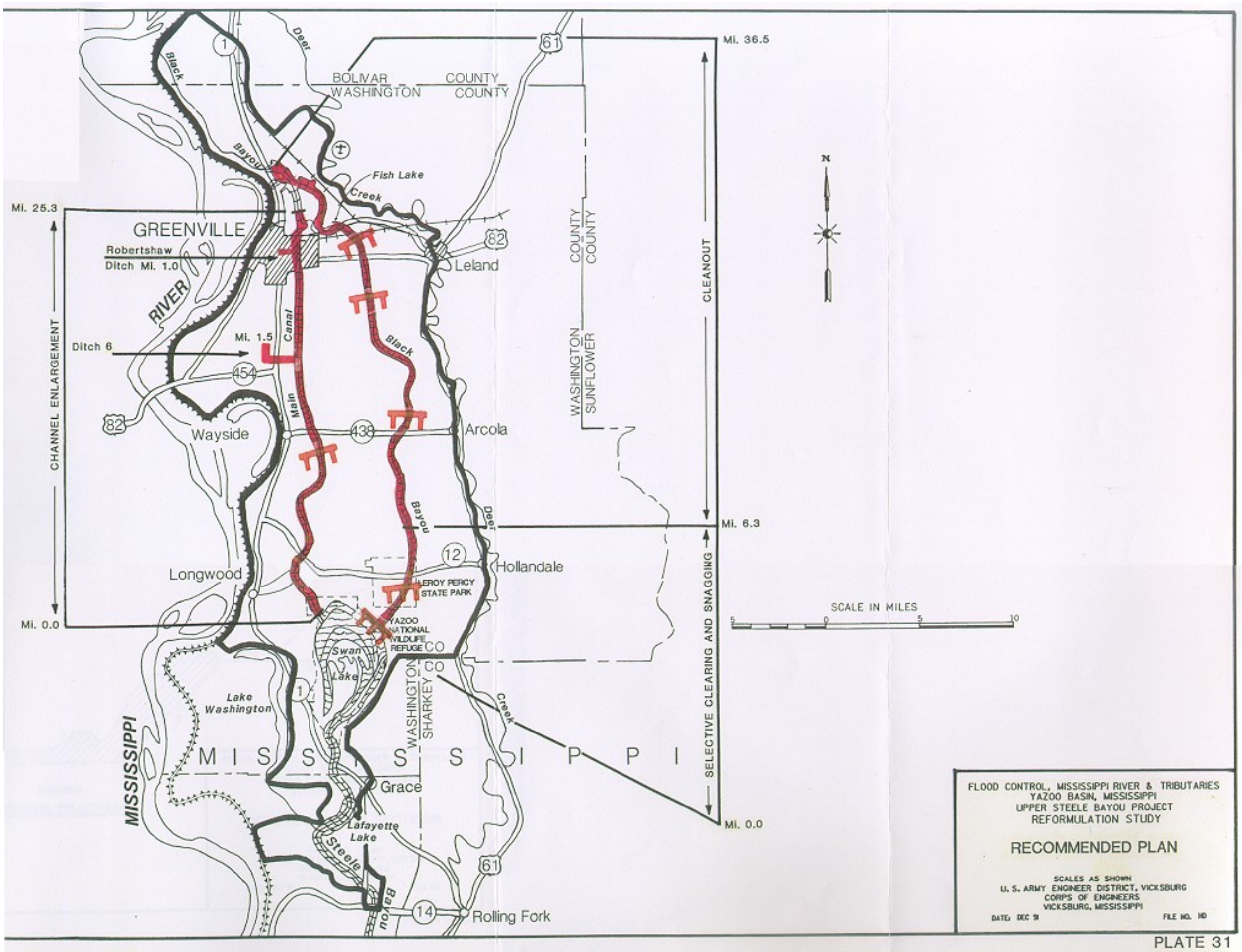


Figure 3. Modifications in the Black Bayou Watershed

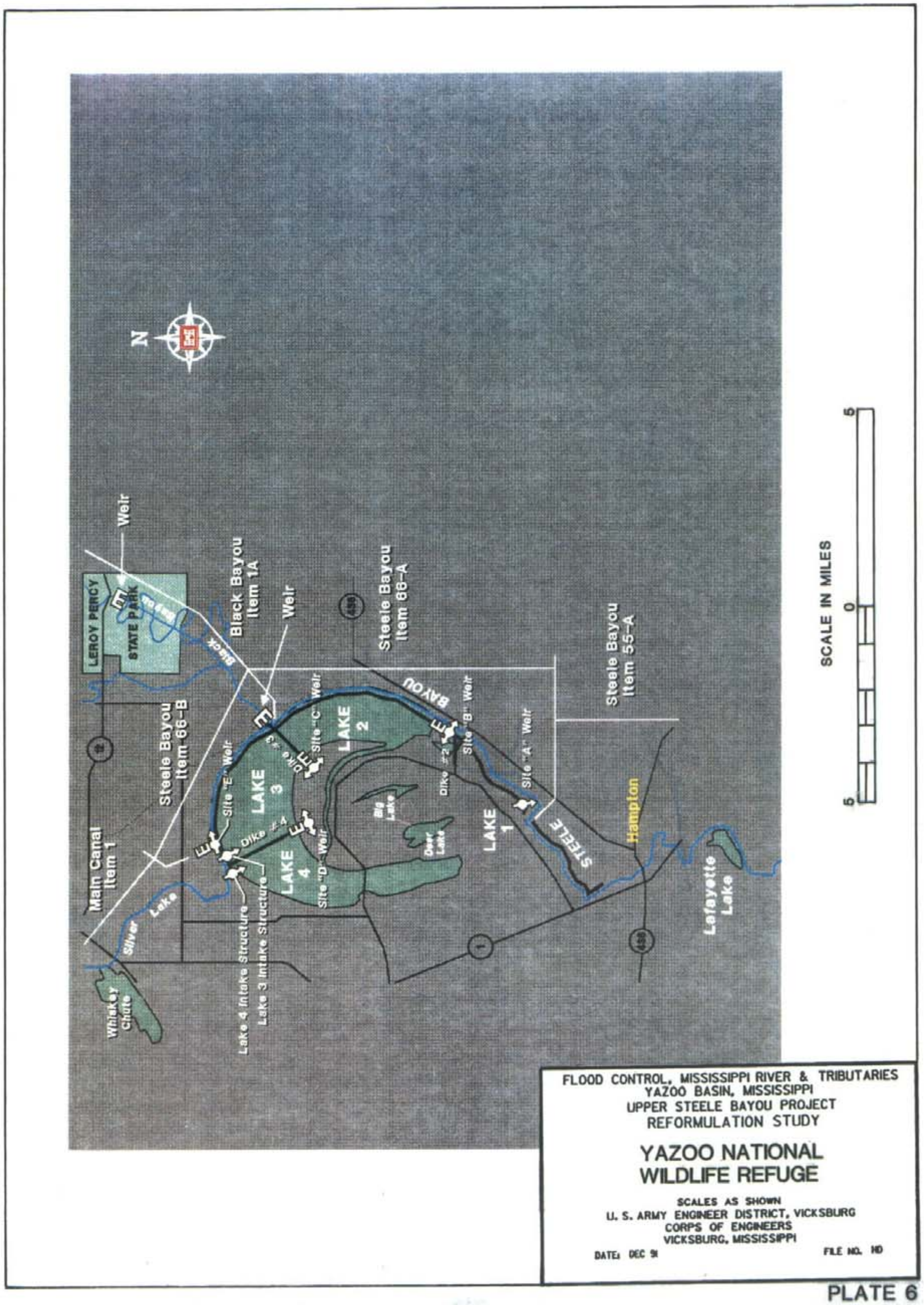


Figure 4. Channel Modifications in the Upper Steele Bayou Watershed

Comparison of the elevation of the weir at Black Bayou river mile 3.4 and the stage data available from the COE station 442 indicates that the water level occasionally drops below the weir elevation during low flow conditions. The COE gage station 442 is located on the downstream side of Highway 12, while the weir is just downstream of the bridge. Thus, it can be assumed that there is no water flowing over the weir when the stage at this station falls below 96.0 ft. During the month of June 2001, for example, the monthly average stage was 95.9 ft. The lowest stage for this year, 93.8 ft, was measured on June 27, 2001. The weirs in the Black Bayou watershed represent a significant change in the hydrology of the system. During low flow conditions, the weirs create pooled areas with relatively no water velocity. During these conditions, processes such as reaeration that add oxygen to the water body are significantly reduced. The impact of these channel modifications may be reflected in the water quality monitoring data that are collected near these stations. For example, data collected during the early summer at USGS station 7288830, located on Highway 12 likely reflects pooled conditions instead of free-flowing conditions in the water body. Several other water quality monitoring stations are located near the weirs.

2.2 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 303(d) listed water bodies in the Black Bayou watershed. Limited water quality data are available for the listed segments of Black Bayou, Red Bridge Bayou, Granicus Bayou, and Granny Baker Bayou. According to the report these water bodies are not supporting for the use of aquatic life support. These conclusions were based on instantaneous water chemistry collected at numerous monitoring stations located within the watershed. Monitoring data for Black Bayou are available from stations 7288830, located on Highway 12 near Hollandale, and station 7288843, located south of the confluence of Granicus Bayou near Percy. Additional data for Black Bayou are available from station 7288820 near Arcola on Highway 438 and station 7288825 near Estill on Avon-Darlove Road. Data for Red Bridge Bayou near Leland are available from station 7288815, located on Highway 82. Data for Granicus Bayou near Hollandale are available from station 7288842, located on Highway 12. Finally, data from Granny Baker Bayou near James are available from station 7288844 on Riverside Road. The data available from these locations for selected nutrient species and DO are given in the Table 1 through Table 7 below. The data given in these tables were obtained from the US Geological Survey.

Table 1. Water Quality Data for Black Bayou, Station 07288830

Date	Time	DO (mg/L)	Ammonia as N (mg/L)	Nitrite + Nitrate N (mg/L)	Total Phosphorous as P (mg/L)
3/7/1990	14:00	8.5	0.11	0.53	0.39
4/19/1990	15:00	6.8	0.13	1.00	0.46
5/24/1990	13:00	5.1	0.24	1.40	0.38
6/27/1990	10:45	6.4	0.03	0.03	0.57
7/24/1990	14:30	8.5	0.50	1.70	0.42
8/27/1990	15:30	10.4	0.02	0.08	0.34
9/18/1990	13:00	6.0	0.06	0.27	0.32
10/23/1990	13:20	10.4	0.08	0.45	0.34
11/28/1990	13:00	6.1	0.06	0.25	0.37
12/18/1990	13:30	7.1	0.23	0.74	0.51
2/12/1991	13:00	9.3	0.05	0.48	0.34
1/16/1992	11:45	10.4	0.10	0.5	0.43
3/25/1992	13:45	9.1	0.06	0.67	0.48
5/12/1992	10:30	7.5	0.03	0.04	0.32
7/22/1992	12:30	4.9	0.34	0.96	0.34
9/8/1992	13:45	6.4	0.12	0.12	0.12
11/17/1992	13:00	7.6	0.19	0.76	0.39
1/27/1993	11:30	10.1	0.10	0.31	0.38
5/16/1995	14:00	8.8	-	-	-
8/8/1995	12:45	12.8	-	-	-
2/29/1996	11:30	9.1	-	-	-
5/21/1996	12:10	5.2	-	-	-

Table 2. Water Quality Data for Black Bayou, Station 07288843

Date	Time	DO (mg/L)	Ammonia as N (mg/L)	Nitrite + Nitrate N (mg/L)	Total Phosphorous as P (mg/L)
3/7/1990	12:00	8.2	0.12	0.6	0.41
4/20/1990	9:00	7.1	0.12	0.84	1.1
5/24/1990	12:00	5.8	0.21	1.3	0.45
6/28/1990	9:30	4.7	0.49	0.43	0.34
7/24/1990	12:30	6.6	0.28	1.5	0.36
8/27/1990	14:00	6.4	0.03	0.08	0.55
9/18/1990	11:15	5.5	0.06	0.32	0.33
10/23/1990	11:15	6.8	0.07	0.78	0.61
11/28/1990	11:15	6.9	0.1	0.59	0.5
12/18/1990	12:00	6.6	0.17	2.2	1.8
1/10/1991	10:40	-	0.17	0.57	0.86
2/12/1991	11:30	9.3	0.07	0.43	0.34

Table 3. Water Quality Data for Black Bayou, Station 07288820

Date	Time	DO (mg/L)	Ammonia as N (mg/L)	Nitrite + Nitrate N (mg/L)	Total Phosphorous as P (mg/L)
3/7/1990	17:00	9.0	0.19	0.60	0.35
4/19/1990	13:00	8.5	0.08	0.82	0.34
5/24/1990	16:00	6.5	0.14	1.80	0.37
6/28/1990	15:00	11.2	0.01	0.06	0.40
7/24/1990	16:30	8.9	0.38	1.20	0.32
8/27/1990	16:30	16.6	0.04	0.11	0.41
9/18/1990	14:30	8.9	0.08	0.32	0.57
10/24/1990	9:20	9.0	1.70	0.49	0.98
11/29/1990	10:00	6.2	0.20	1.50	0.86
12/19/1990	10:10	6.6	0.11	1.00	0.67
1/11/1991	14:30	9.5	0.16	0.44	0.54
2/13/1991	9:30	9.2	0.20	0.57	0.33

Table 4. Water Quality Data for Black Bayou, Station 07288825

Date	Time	DO (mg/L)	Ammonia as N (mg/L)	Nitrite + Nitrate N (mg/L)	Total Phosphorous as P (mg/L)
3/7/1990	16:00	8.4	0.15	0.60	0.33
4/19/1990	14:00	8.1	0.06	0.85	0.36
5/24/1990	16:30	5.8	0.19	1.60	0.28
6/27/1990	12:30	9.4	0.02	0.02	0.44
7/24/1990	16:00	10.1	0.54	2.10	0.29
8/27/1990	16:00	11.2	0.02	0.13	0.31
9/18/1990	14:00	6.9	0.09	0.31	0.40
10/23/1990	14:15	11.2	0.11	0.29	0.27
11/28/1990	14:15	10.6	0.02	0.61	0.32
12/18/1990	14:15	6.6	0.21	1.10	0.59
1/10/1991	12:00	-	0.18	0.66	0.47
2/12/1991	13:45	10.2	0.07	0.59	0.33

Table 5. Water Quality Data for Red Bridge Bayou, Station 07288815

Date	Time	DO (mg/L)	Ammonia as N (mg/L)	Nitrite + Nitrate N (mg/L)	Total Phosphorous as P (mg/L)
3/8/1990	9:00	8.7	0.17	0.41	2.10
4/19/1990	10:00	8.3	0.10	0.33	0.78
5/25/1990	8:00	6.1	0.11	2.20	1.30
6/28/1990	17:30	7.6	0.01	0.26	1.20
7/25/1990	10:00	12.0	0.20	0.30	1.50
10/24/1990	8:00	4.1	0.13	0.30	1.20
11/29/1990	8:30	5.5	0.11	0.30	1.70
12/19/1990	8:00	6.5	0.11	1.20	2.70
1/11/1991	8:30	8.8	0.21	0.56	3.10
2/13/1991	7:45	7.6	0.16	0.45	1.40

Table 6. Water Quality Data for Granicus Bayou, Station 07288842

Date	Time	DO (mg/L)	Ammonia as N (mg/L)	Nitrite + Nitrate N (mg/L)	Total Phosphorous as P (mg/L)
3/7/1990	14:45	9.5	0.22	0.46	0.30
4/19/1990	16:00	9.6	0.04	0.62	0.36
5/24/1990	13:45	5.8	0.41	1.20	0.56
6/29/1990	9:00	5.5	0.13	0.53	0.15
7/24/1990	14:00	6.1	0.99	0.85	0.14
8/27/1990	15:00	7.7	0.06	0.14	0.23
9/18/1990	12:30	6.2	0.97	0.36	0.35
10/23/1990	13:00	10.2	0.02	0.02	0.23
11/28/1990	12:30	7.5	0.52	0.58	0.32
12/18/1990	13:00	7.0	0.06	1.00	0.31
1/12/1991	10:30	9.8	0.26	0.64	0.45
2/12/1991	12:30	9.4	0.10	0.43	0.28
1/16/1992	11:30	11.4	0.27	0.81	0.33
3/25/1992	12:30	11.0	0.38	0.76	0.32
5/12/1992	10:00	6.1	0.09	0.41	0.14
7/22/1992	13:15	7.3	0.34	0.94	0.21
9/8/1992	13:20	5.6	0.01	0.02	0.40
11/17/1992	12:00	8.0	0.04	0.87	0.25
1/27/1993	11:15	10.3	0.21	0.38	0.28

Table 7. Water Quality Data for Granny Baker Bayou, Station 07288844

Date	Time	DO (mg/L)	Ammonia as N (mg/L)	Nitrite + Nitrate N (mg/L)	Total Phosphorous as P (mg/L)
3/8/1990	12:15	9.1	0.18	0.42	0.81
4/20/1990	17:00	6.3	0.09	0.62	0.22
5/24/1990	14:30	5.0	0.28	1.40	0.35
6/29/1990	10:00	6.0	0.04	0.32	0.27
7/24/1990	13:30	3.9	0.76	1.00	0.21
8/27/1990	14:30	4.4	0.02	0.06	0.32
9/18/1990	12:00	2.2	0.05	0.06	0.33
10/23/1990	12:30	5.2	0.19	0.20	0.22
11/28/1990	12:00	7.5	0.04	0.16	0.28
12/18/1990	12:30	5.7	0.30	0.74	0.55
1/10/1991	12:45	-	0.18	0.70	1.10
2/12/1991	12:00	6.2	0.09	0.20	0.34

The data shown in Tables 1 through 7 show that the dissolved oxygen remains above the daily average water quality standard of 5.0 mg/L in almost all of the samples. There are not water quality standards available for the nutrient species.

Additional data from Black Bayou and its tributaries are available from a water quality study conducted in 1990 by the Corps of Engineers Waterways Experiment Station (Ashby et al, 1991). This study was conducted to analyze the potential impact of proposed flood control measures in the watershed upstream of Steele Bayou. During this study, water chemistry data were collected on a monthly basis at several locations on Black Bayou, Granicus Bayou, and Granny Baker Bayou. The parameters collected included dissolved oxygen, nutrients, and pesticides in both the water column and sediment. The study also included collection of chlorophyll-a samples and measurement of algal photosynthesis and respiration rates at selected stations. Diurnal DO measurements were collected on August 13-14, 1990 at some of the stations. DO concentrations in Black Bayou varied from approximately 4.0 mg/L in the early morning to approximately 9.0 mg/L in the late afternoon. Overall, the study concluded that the instantaneous dissolved oxygen standard of 4.0 mg/L was the only water quality standard that was not consistently met. However, the daily average dissolved oxygen standard was met due to the photosynthetic activity during daylight hours.

2.3 Assessment of Point Sources

Photo 3. Farm Fresh Catfish Co. Outfall 001

The first step in assessing pollutant sources in the Black Bayou watershed was locating the NPDES permitted sources. There are seven facilities permitted to discharge into Black Bayou or tributaries of Black Bayou. 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 data are vital to characterizing effluent from each facility.

The permit limits as well as the average flows and BOD_5 concentrations, as reported in DMRs for the past two years (8/1/2000 through 8/1/2002), are given in Table 8. DMR data are not available for some of the smaller commercial facilities. The wastewater treatment plant at Stokes Development has not been constructed yet. The facility has been included in the source assessment, however, because the NPDES permit will allow the facility to discharge once it is constructed. Ammonia nitrogen permit limits and monitoring is not required for any of the facilities. As shown in Table 8, with the exception of Farm Fresh Outfall 001, all facilities are currently discharging BOD_5 concentrations below their allowable permit limits.

Table 8. Identified NPDES Permitted Facilities

Name	NPDES Permit	Permitted Discharge (MGD)	Actual Average Discharge (MGD)	Permitted Average BOD_5 (mg/L)	Actual Average BOD_5 (mg/L)
Arcola POTW	MS0037311	0.085	0.04	30	24.4
Farm Fresh Catfish Co. Outfall 001	MS0039535	Report	0.22	75	85.1
Farm Fresh Catfish Co. Outfall 002	MS0039535	Report	0.08	75	22.3
Hollandale POTW	MS0055603	0.875	0.26	30	21.8
Leland POTW	MS0020761	0.90	0.68	30	26.2
Stokes Development	MS0057541	0.08	-	30	-
Riverside School	MS0051527	0.05	0.008	30	8.1
Leroy Percy State Park	MS0027286	0.05	-	30	-

Three of the point sources, Arcola POTW, Farm Fresh Catfish, and the Leland POTW discharge into ditches that are classified as ephemeral. Water bodies that are classified as ephemeral typically flow only in response to rainfall. Thus, these water bodies do not support aquatic life and are not required to meet the water quality standard of a daily average of 5.0 mg/l of dissolved oxygen.

2.4 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 Leland, 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 169,000-acre drainage area of Black Bayou contains many different landuse types, including urban, forest, 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. Agriculture is the dominant landuse within this watershed. The landuse distribution within the Black Bayou Watershed is shown in Table 9 and Figure 5.

Table 9. Landuse Distribution, Black Bayou Watershed

	Urban	Forest	Agriculture	Barren	Water	Wetlands	Total
Area (acres)	5,966	30,271	106,872	4	8,307	17,863	169,283
Percentage	4%	18%	63%	0%	5%	11%	100%

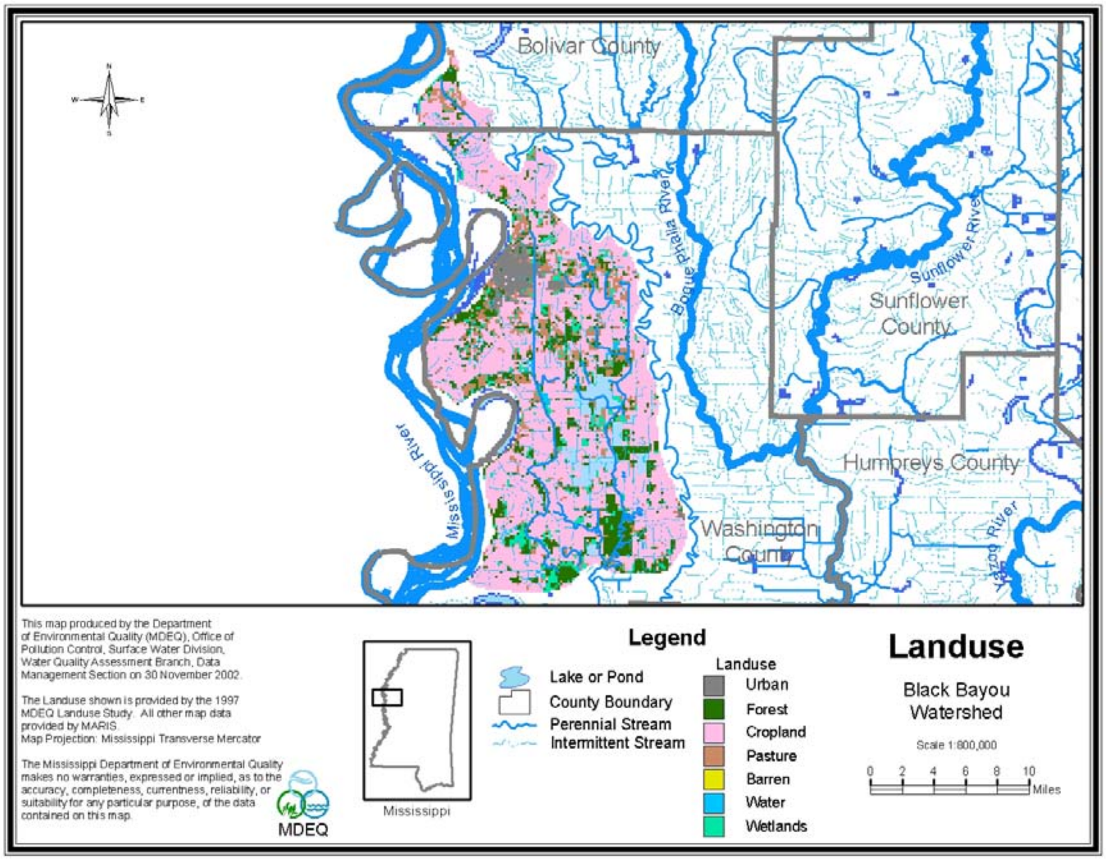


Figure 5. Landuse Distribution Map for Black Bayou Watershed

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.

4.1 Modeling Framework Selection

A mathematical model, 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.

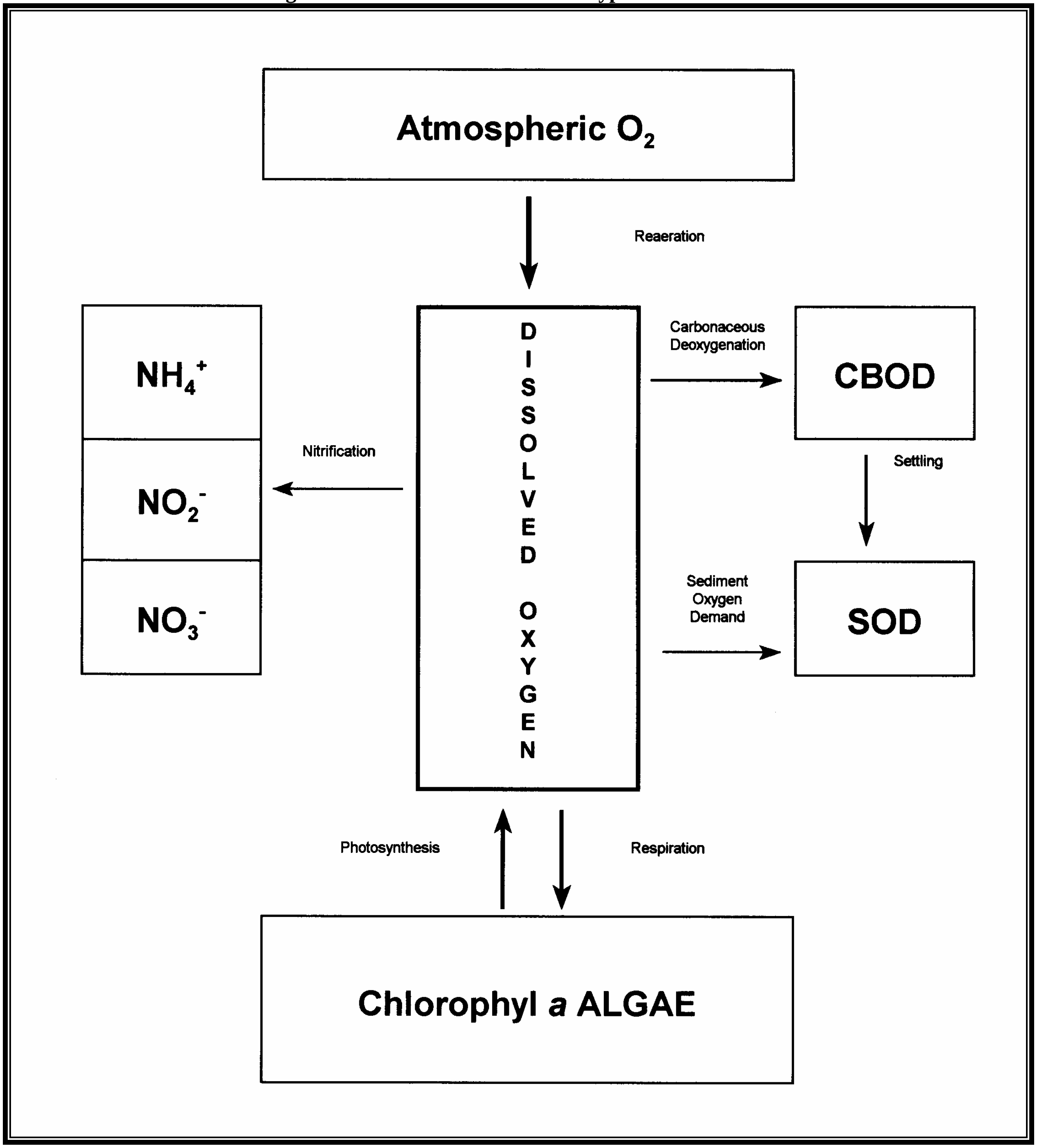
The model is a steady-state, daily average computer model that utilizes a modified Streeter-Phelps DO sag equation. Instream processes simulated by the model include CBODu decay, nitrification, reaeration, sediment oxygen demand, and respiration and photosynthesis of algae. Figure 6 shows how these processes 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 reaches with flow less than 10 cfs and 0.0597 for reaches with flow greater than 10 cfs and less than 280 cfs. The slope of each reach was estimated from USGS quad maps and input into the model in units of feet/mile.

Figure 6. Instream Processes in a Typical DO Model



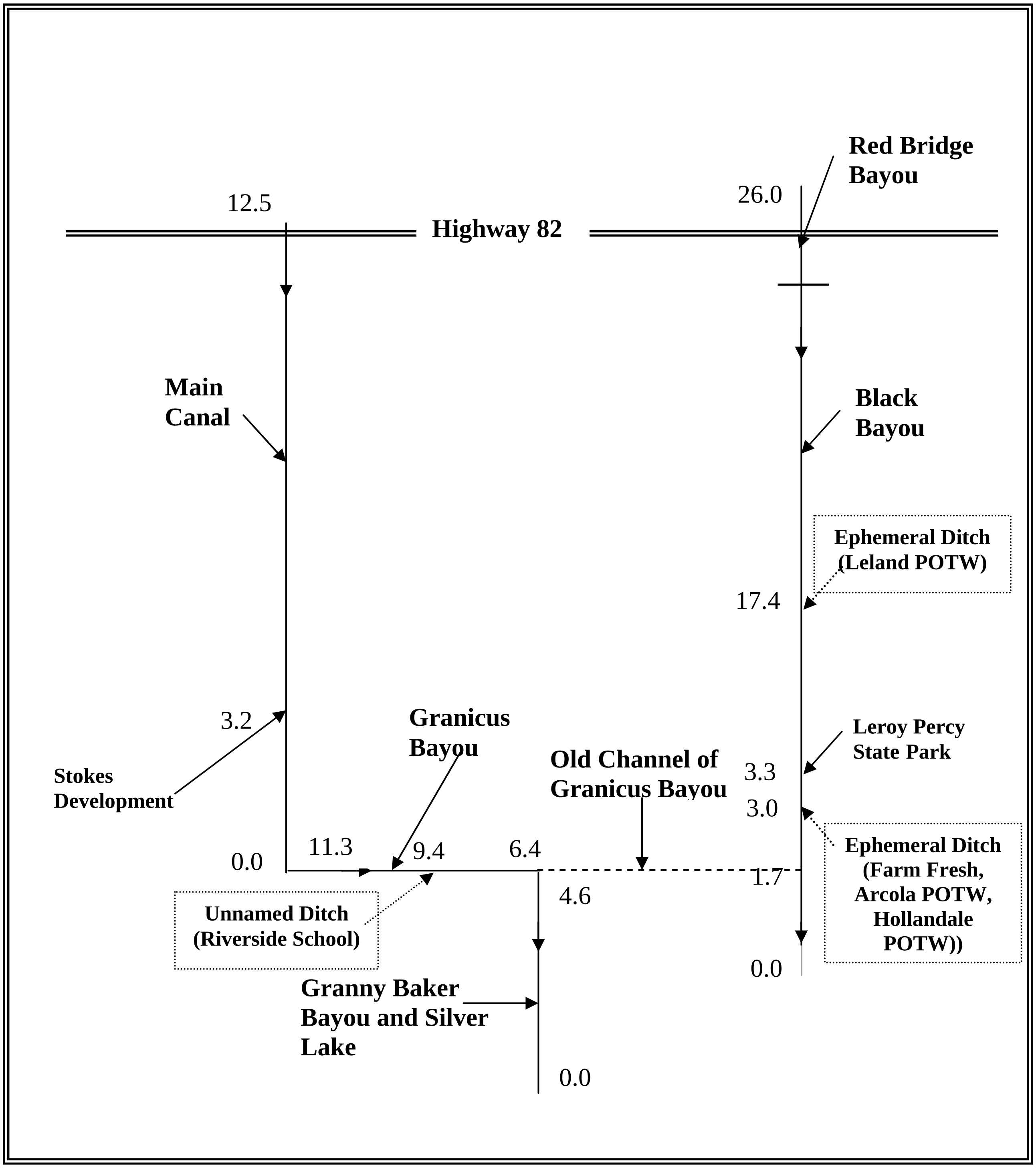
4.2 Model Setup

The Black Bayou TMDL model includes the 303(d) listed portions of Black Bayou, from the headwaters south of Fish Lake to the confluence of Black Bayou with Steele Bayou south of Hollandale. The upper end of this water body is referred to as Red Bridge Bayou. The model also includes Main Canal, from its headwaters in Greenville to Granicus Bayou. Granny Baker Bayou and Silver Lake to its confluence with Steele Bayou at Weir E are also included.

The modeled water bodies were divided into reaches for input into the Phase 1 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 weirs located in Black Bayou and Main Canal were not included in the Phase 1 model, even though their potential effects on water quality have been discussed.

The watershed was modeled according to the diagram shown in Figure 7. The locations of the confluence of unnamed tributaries and ephemeral streams that carry discharge from point sources are shown in the figure. Arrows represent the direction of flow in each segment. The numbers on the figure represent approximate river miles on each modeled segment. River miles are assigned to water bodies, beginning with zero at the mouth. Within each reach, 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.

Figure 7. Black Bayou Model Setup (Note: Figure not to Scale)



The model was setup to simulate flow and temperature conditions, which were determined to be the critical condition for this TMDL. The temperature used in the model is 26°C. 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 3.

$$Kd_{(T)} = Kd_{(20°C)}(1.047)^{T-20} \qquad \textbf{(Equation 3)}$$

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). Because field data for the rates of photosynthesis, respiration, and sediment oxygen demand were unavailable, these processes were not included in the phase 1 model.

4.3 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 Black Bayou and its tributaries.

The discharge points of many of the NPDES permitted dischargers are located on ephemeral ditches or small tributaries that flow for several miles before reaching Black Bayou and Granicus Bayou. Due to the distance between these discharge points and Black Bayou, it is likely that the amount of oxygen-demanding material in the effluent would be reduced before reaching Black Bayou and Granicus Bayou. In order to account for this in the model, three of the ephemeral ditches that carry effluents to Black Bayou were modeled separately. The first ephemeral ditch carries effluent for approximately 5 miles from the Leland POTW to Black Bayou south of Leland. The second ephemeral ditch carries effluent from Farm Fresh Inc, the Hollandale POTW, and the Arcola POTW for a distance of approximately 5 miles. This ditch, flows into Black Bayou south of Hollandale. The third ditch carries effluent from Riverside School into Granicus Bayou, for a distance of approximately 1.3 miles. This ditch flows into Granicus Bayou east of Avon, MS.

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 4.

$$CBODu = CBOD_5 * Ratio \qquad \textbf{(Equation 4)}$$

The CBODu to $CBOD_5$ ratios are given in *Empirical Stream Model Assumptions for Conventional Pollutants and Conventional Water Quality Models* (MDEQ, 1994). 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. For secondary treatment systems, this ratio is

1.5. A CBODu to $CBOD_5$ ratio of 1.5 was used for all of the facilities in the Black Bayou watershed, with the exception of Farm Fresh Catfish Company. A ratio of 2.5 was used for this facility. MDEQ regulations specify that a ratio of 2.5 should be used for meat processing facilities.

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 permitted loads of TBODu from each of the existing point sources are given in Table 10. Note that most of the $CBOD_5$ concentrations are greater than the actual concentrations, as reported in the DMR data, Table 8. The exception to this is that the measured concentration of BOD_5 from the Farm Fresh Catfish Outfall 001 exceeds the permitted concentration. Because none of these facilities have permit or monitoring requirements for ammonia nitrogen, an assumed value of 2.0 mg/L was used to calculate the NBODu load. The average discharge reported in the past two years of DMR data was used to estimate the flow from both outfalls of Farm Fresh Catfish. This facility does not have specified permit limits for flow, and is required to report their monthly average flow.

Table 10. Point Source Loads, Maximum Permitted Loads

Facility	Flow (MGD)	$CBOD_5$ (mg/l)	$CBOD_u$:$CBOD_5$ Ratio	CBODu (lbs/day)	NH_3-N (mg/l)	NBODu (lbs/day)	TBODu (lbs/day)
Arcola POTW	0.085	30	1.5	32	2	6.5	38
Farm Fresh Catfish Co. Outfall 001	0.22	75	2.5	344	2	16.8	361
Farm Fresh Catfish Co. Outfall 002	0.08	75	2.5	125	2	6.1	131
Hollandale POTW	0.875	30	1.5	328	2	66.7	395
Leland POTW	0.90	30	1.5	338	2	68.6	406
Stokes Development	0.08	30	1.5	30	2	6.1	36
Riverside School	0.05	30	1.5	19	2	3.8	23
Leroy Percy State Park	0.08	30	1.5	30	2	6.1	36
Total				**1,246**		**180.7**	**1,427**

Direct measurements of nonpoint source loads of CBODu and NH_3-N were not available for the Black Bayou Watershed. The background contributions of CBODu and ammonia 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 Black Bayou were also estimated. Because there is not a continuous record of flow available for Black Bayou, the flow coefficient representative of the month of June was estimated. The estimation was based on data for a nearby water body in the Mississippi River alluvial plain. The water body located nearest to Black Bayou 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 the Black Bayou Watershed. Due to lack of flow data for Black Bayou, the accuracy of this method could not be determined.

Flow data from the USGS monitoring station on Bogue Phalia near Leland, which were available for 1986 through 2000, were used to develop a flow duration curve. The flow data were used to determine the minimum flow in Bogue Phalia Creek for the month of June for each year that flow data were available. The average of the minimum flows was then determined to be 70.3 cfs. This flow falls on the 67^{th} percentile of the flow duration curve, meaning that this flow is equaled or exceeded 67 percent of the time. Lower flows occurred 33 percent of the time in Bogue Phalia. The contributing drainage area of Bogue Phalia, 484 square miles, was used to determine the flow coefficient for Bogue Phalia and extrapolate it to the Black Bayou watershed as shown below.

Flow Coefficient (cfs/square mile) = 70.3 cfs/484 square miles = **0.145 cfs/square miles**

Then the flow condition representative of the month of June was estimated by multiplying the flow coefficient by the contributing drainage area of Black Bayou, 265 square miles.

Flow in Black Bayou = 0.145 cfs/square mile * 265 square miles = **38.5 cfs**

After determining the drainage area of the Black Bayou Watershed, the flow coefficient (flow value in cfs/drainage area in square miles) was used to estimate the amount of water draining into Black Bayou and its tributaries during conditions representative of the month of June. 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 11.

Table 11. Nonpoint Source Loads Input into the Model

Water body	Flow (cfs)	$CBOD_5$ (mg/l)	CBODu:$CBOD_5$ Ratio	CBODu (lbs/day)	NH_3-N (mg/l)	NBODu (lbs/day)	TBODu (lbs/day)
Black Bayou and Red Bridge Bayou	18.3	1.33	1.5	196.8	0.1	45.1	241.9
Main Canal	8.9	1.33	1.5	95.7	0.1	21.9	117.6
Granicus Bayou	8.0	1.33	1.5	86.0	0.1	19.7	105.8
Granny Baker Bayou and Silver Lake	3.3	1.33	1.5	35.5	0.1	8.1	43.6
Total	**38.5**			**414.1**		**94.9**	**508.9**

4.4 Model Calibration

The model used to develop the phase 1 Black Bayou TMDL was not calibrated due to lack of flow data and instream monitoring data collected during critical conditions. Comparison of the available data shows that the predicted daily average dissolved oxygen levels are lower than instantaneous dissolved oxygen measurements in Black Bayou.

4.5 Model Results

Once the model setup was complete, the model was used to predict water quality conditions in Black 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 8. Thus, baseline model runs reflect the current condition of Black Bayou without any reduction of TBODu loads. The baseline condition model was run again with the permits set at the maximum loads allowed in the NPDES permits. 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. The modeled loads from the NPDES permits were reduced during this process. These model runs are called maximum load scenarios.

4.5.1 Baseline Model Runs

The model results from the baseline model runs are shown in Figure 8 through Figure 10. Figure 8 shows the modeled daily average DO in Red Bridge Bayou and Black Bayou with the NPDES permits at their existing loads. The red line represents the TMDL endpoint of 5.0 mg/l DO. The figure shows the daily average instream DO concentrations, beginning with river mile 26 and ending with river mile 0.0. The DO sag, or maximum DO deficit, occurs in Black Bayou below the confluence of the ephemeral ditch carrying the load from Farm Fresh Catfish, Hollandale POTW, and Arcola POTW, at river mile 4.0. A DO sag also occurs upstream of this point due to the load from the ephemeral ditch carrying the load from the Leland POTW. As shown, the model does predict that the DO goes below the standard of 5.0 mg/l. Figures 9 and 10 show the modeled DO in Granicus Bayou, Granny Baker Bayou, and Silver Lake. These figures also reflect the NPDES permits at their existing loads. They indicate that the DO does not fall below 5.0 mg/L in these segments.

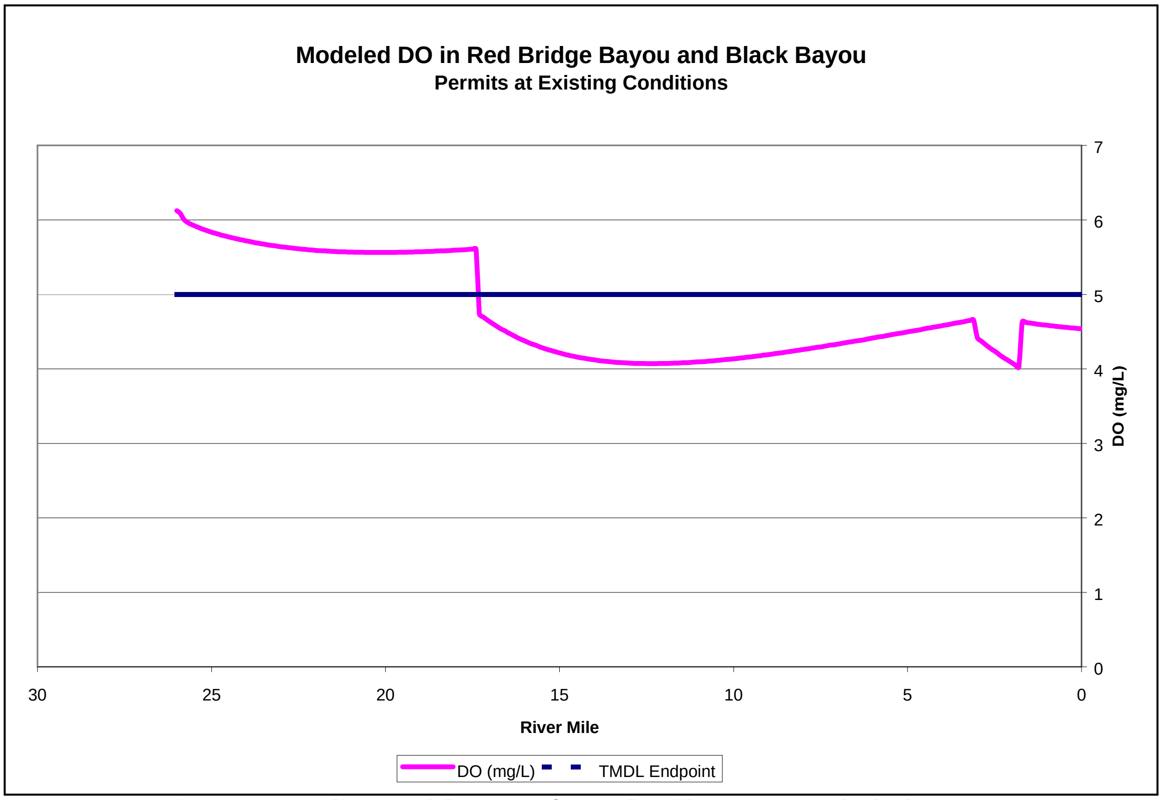


Figure 8. Baseline Model Output for Red Bridge Bayou and Black Bayou

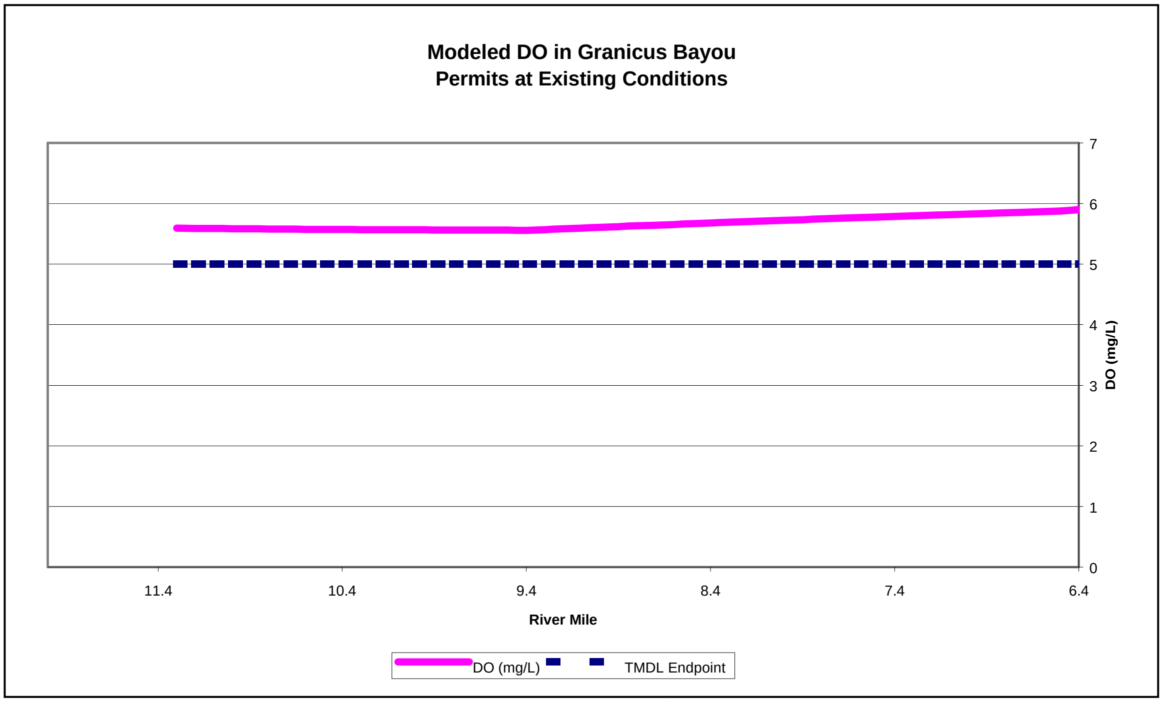


Figure 9. Baseline Model Output for Granicus Bayou

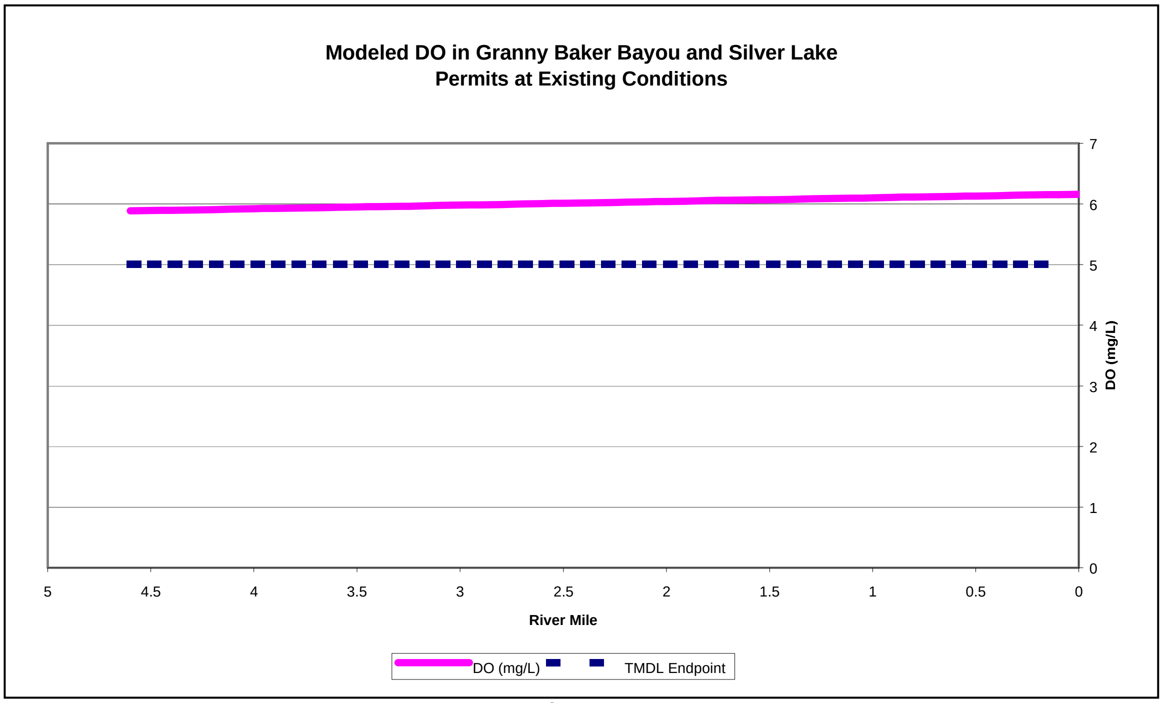


Figure 10. Baseline Model Output for Granny Baker Bayou and Silver Lake

A second baseline model run was completed in order to predict the dissolved oxygen in Black Bayou if the NPDES permits were discharging at their actual permit limits. The results of this model run for Red Bridge Bayou and Black Bayou are shown in Figure 11. As shown, the modeled DO in Black Bayou falls to 3.0 mg/l as a result of the increased point sources loads. The model output for Granicus Bayou, Granny Baker Bayou, and Silver Lake are not shown, as the TMDL endpoint for DO is not violated in these water bodies.

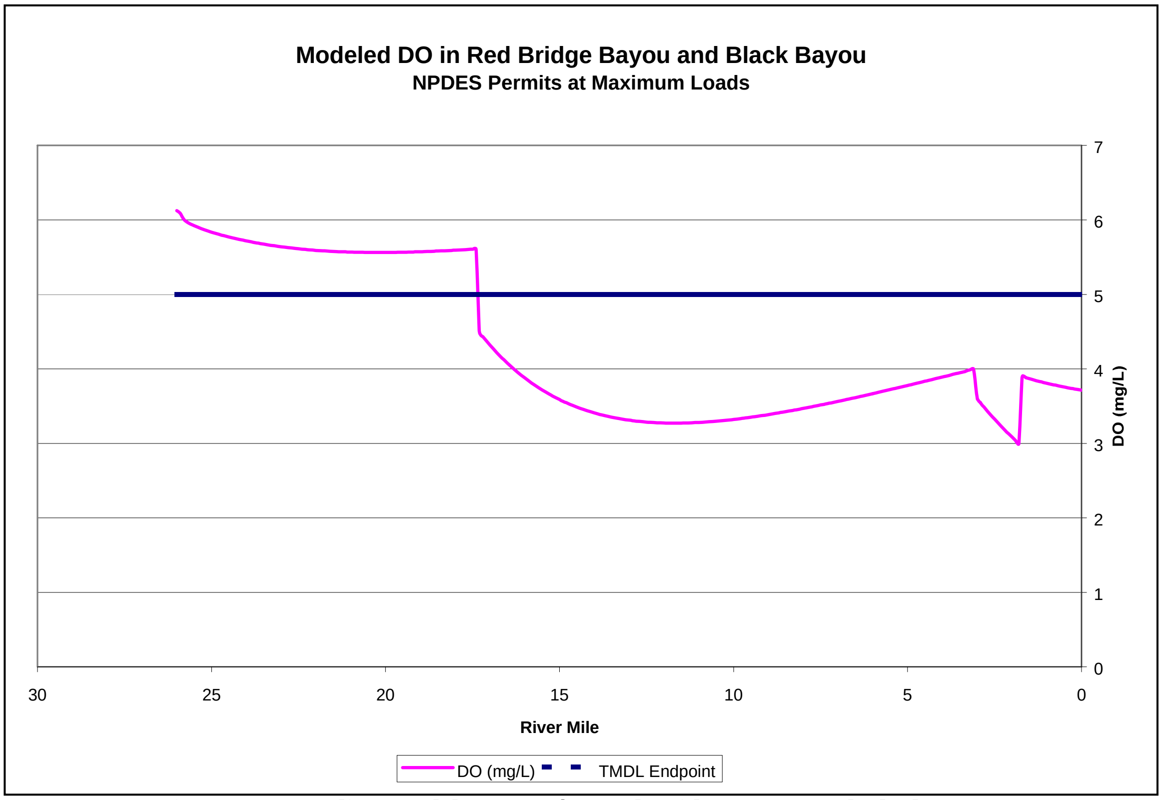


Figure 11. Baseline Model Output for Red Bridge Bayou and Black Bayou

4.5.2 Maximum Load Scenarios

The graphs of baseline model output show that the predicted DO falls below the DO standard in Black Bayou during the simulated conditions for the month of June. As a result, reductions from the baseline loads of TBODu are necessary in order to maintain a daily average DO of at least 5.0 mg/l. Reductions are only needed for facilities that discharge directly to Black Bayou or tributaries of Black Bayou. No reductions were needed for Granicus Bayou, Granny Baker Bayou, and Silver Lake because these water bodies meet the TMDL endpoint at their existing loads.

The maximum load scenarios involved running the model using a trial-and-error process. The maximum load, that allowed the maintenance of water quality standards, was selected. The maximum load was used to develop the waste load allocations proposed in this TMDL. Figure 12 shows the modeled instream DO concentrations in Red Bridge Bayou and Black Bayou after application of the selected maximum load scenario for the month of June. The lowest DO concentration in Black Bayou, approximately 5.0 mg/l occurs near river mile 17.2, just downstream from the confluence of the ephemeral stream that carries the discharge from the Leland POTW. The TBODu loads included in the maximum load scenario are given in Table 12. The overall percent reduction is based on a reduction from the maximum permitted loads given in Table 12. The reductions for each individual source are given in Section 5.1. It should be noted that larger reductions were made to some of the point sources in Black Bayou. This is due to the location of the source and the modeled water quality response downstream of each source. The highest percentage reduction was needed for the Leland POTW due to the location where the ephemeral ditch that carries the effluent from the facility joins Black Bayou. This ephemeral ditch is located farther upstream, where the flow and assimilative capacity of Black Bayou are not a large as they are downstream.

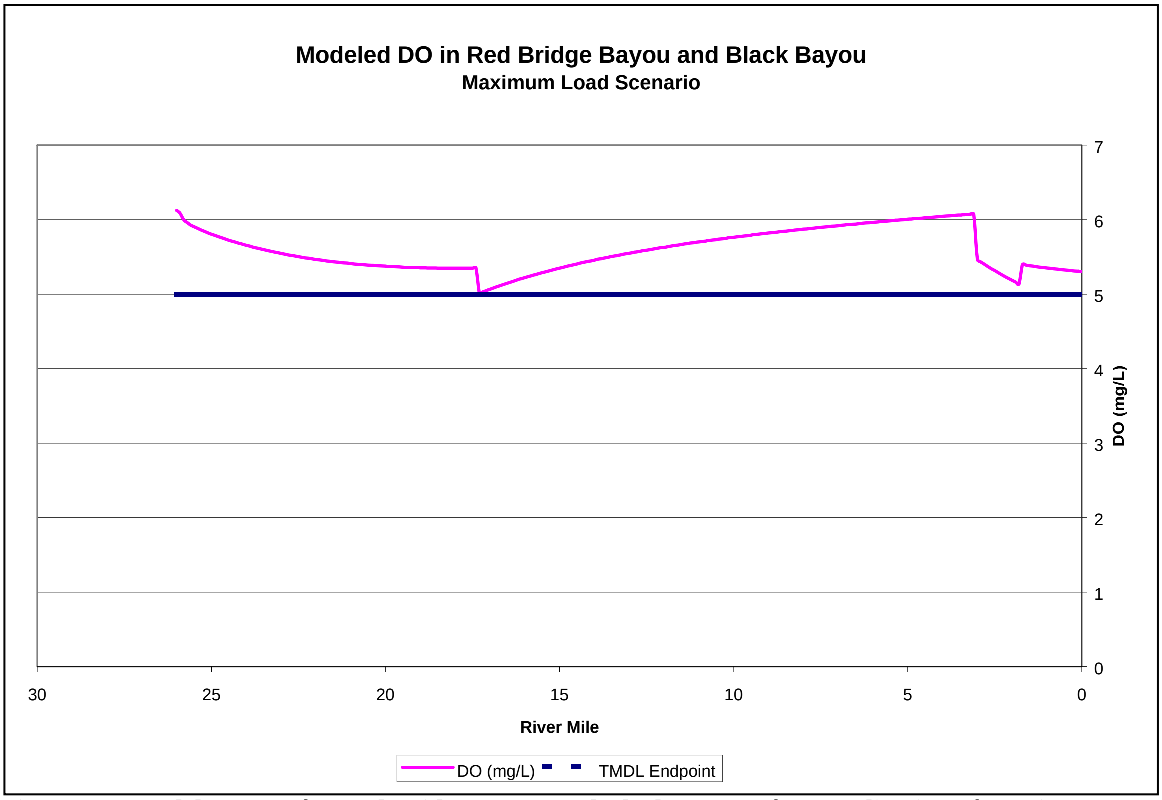


Figure 12. Model Output for Red Bridge Bayou and Black Bayou after Application of Maximum Load Scenario

Table 12. Maximum Load Scenario, Critical Conditions

Source	Flow (cfs)	CBODu (lbs/day)	NBODu (lbs/day)	TBODu (lbs/day)	Overall Percent Reduction
Point Sources	2.3	681	88	769	46%
Nonpoint Sources	38.5	414	95	509	0%
Total	**40.8**	**1,095**	**183**	**1,278**	**34%**

4.6 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 criteria was not exceeded in Black Bayou under the current NH_3-N loads.

ALLOCATION

The allocation for this phase 1 TMDL involves a wasteload allocation for point sources and a load allocation for nonpoint sources necessary for attainment of water quality standards in segments MS403M4, MS403M5, and MS403M3, and drainage area MS403E.

5.1 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.

5.1.1 Wasteload Allocation for the TMDL

Seven NPDES Permitted facilities in the Black Bayou watershed are included in the wasteload allocation, Table 13. An overall reduction of 46% of the permitted TBODu load is needed in order for the model to show compliance with the TMDL endpoint.

5.1.2 Wasteload Allocation Implementation Plan

The loads given in Table 13 are equal to the wasteload allocation for the critical condition, which was determined to be during the month of June. Table 13 shows a much greater percent reduction for the Leland POTW than for the other facilities. This is due to the location of the ephemeral ditch that carries effluent from the facility.

Implementation of this wasteload allocation, through modification of NPDES permits, will be done as a multi-staged process. This is largely due to the uncertainties involved with the development of the phase 1 model. At the present time, MDEQ recommends that the existing facilities take steps to ensure that they remain in compliance with their permit limits. It should be noted that the Hollandale POTW recently moved their outfall from Deer Creek to Black Bayou in order to improve water quality in Deer Creek. Initially, the municipal POTWs will be required to meet secondary limits at the end of pipe. Also, changes will be made to the permit for the Farm Fresh Catfish Company such that water quality standards will be met in Black Bayou downstream from its effluent. The Farm Fresh Catfish Company should take immediate steps to bring the effluent from outfall 001 back into compliance. In addition, no new facilities will be issued permits to discharge into Black Bayou or tributaries of Black Bayou. More monitoring and model development are scheduled in the next two years to improve the accuracy of the WLA calculations. The second phase of the implementation will require compliance with the improved WLA.

Table 13. Wasteload Allocation

Facility	CBODu (lbs/day)	NBODu (lbs/day)	TBODu (lbs/day)	Percent Reduction
Arcola POTW	22.3	4.5	26.8	30%
Farm Fresh Catfish Co. Outfall 001	240.8	11.7	252.6	30%
Farm Fresh Catfish Co. Outfall 002	87.6	4.3	91.9	30%
Hollandale POTW	229.3	46.6	275.8	30%
Leland POTW	33.7	6.9	40.6	90%
Stokes Development	29.1	5.9	35.0	0%
Riverside School	18.7	3.8	22.5	0%
Leroy Percy State Park	19.4	3.9	23.3	0%
Total	**680.9**	**87.6**	**768.5**	**46%**

5.2 Load Allocation

The headwater and spatially distributed loads are included in the load allocation. The TBODu concentrations of these loads were determined 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 load allocations were calculated for each water body, Table 14.

Table 14. Load Allocation

Water body	Flow (cfs)	$CBOD_5$ (mg/l)	CBODu:$CBOD_5$ Ratio	CBODu (lbs/day)	NH_3-N (mg/l)	NBODu (lbs/day)	TBODu (lbs/day)
Black Bayou and Red Bridge Bayou	18.3	1.33	1.5	196.8	0.1	45.1	241.9
Main Canal	8.9	1.33	1.5	95.7	0.1	21.9	117.6
Granicus Bayou	8.0	1.33	1.5	86.0	0.1	19.7	105.8
Granny Baker Bayou and Silver Lake	3.3	1.33	1.5	35.5	0.1	8.1	43.6
Total	**38.5**			**414.1**		**94.9**	**508.9**

5.3 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 condition that occurs during the month of June. Modeling the water body at this flow provides protection during the worst-case scenario.

5.4 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 Black Bayou TMDL 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

5.5 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 phase 1 TMDL for TBODu was calculated based on the maximum allowable loading of the pollutants in Black Bayou and its tributaries, according to the model. The TMDL calculations are shown in Table 15. As shown in the table, TBODu is the sum of CBODu and NBODu. 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 TMDL is derived from the conservative assumptions used in setting up the model.

Table 15. Phase 1 TMDL for TBODu, for Critical Conditions in the Black Bayou Watershed

	WLA (lbs/day)	**LA (lbs/day)**	**MOS**	**TMDL (lbs/day)**
CBODu	681	414	Implicit	**1,095**
NBODu	88	95	Implicit	**183**
TBODu	**769**	**509**	**Implicit**	**1,278**

CONCLUSION

This Phase 1 TMDL is based on a desktop model using MDEQ's regulatory assumptions and literature values in place of actual field data. The model results indicate impairment in the stream at the present loading of TBODu. This TMDL recommends that no additional NPDES permit be issued for Black Bayou or tributaries of Black Bayou. Also no increase in the current loadings specified in the existing permits will be allowed. Further steps are needed to ensure that the overall loads of TBODu placed in this water body from point and nonpoint sources do not exceed the water body's assimilative capacity.

According to the model, a 34% reduction overall from the current loads would be needed to eliminate the standards violation in the stream during critical conditions. 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 occasionally does not meet water quality standards. The TMDL therefore recommends the following:

1. No increases in load allowed for the Black Bayou Watershed;
2. MDEQ and EPA schedule intensive monitoring to refine the model;
3. The facilities or EPA may request a Use Attainability Analysis (UAA) based on the modeling results; and
4. NPDES Permits will be modified with a schedule of compliance.

6.1 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 year-long cycle, MDEQ's resources for water quality monitoring will be focused on one of the basin groups. During the next monitoring phase in the Yazoo Basin, the Black Bayou Watershed may receive additional monitoring to identify any change in water quality.

Additional monitoring may also be conducted in Black Bayou in order to provide a data set for calibration of the water quality model used to develop the phase 1 TMDL. Parameters such as flow, water velocity, and background concentrations of CBODu and NH_3-N during the critical modeling period would be beneficial. Also, measurements of rates of CBODu decay, algal photosynthesis and respiration, and sediment oxygen demand would allow for a more accurate model. Finally, additional characterization of the effluent from point source facilities, such as determinations of CBODu to $CBOD_5$ ratios, would increase the model's accuracy. The additional monitoring would allow confirmation of the assumptions used in the model used for calculating the TMDL. If additional data show that the assumptions used in the phase 1 model were not accurate, the model and the TMDL will be updated. Future work may also include the development of a more complex model, which could more accurately represent Red Bridge Bayou, Black Bayou, Main Canal, Granicus Bayou, Granny Baker Bayou, and Silver Lake.

6.2 Public Participation

MDEQ held meetings with the Cities of Leland, Arcola, and Hollandale as well as Farm Fresh

Catfish Inc. to present and discuss the results of this TMDL report. 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.

At the end of the 30-day period, MDEQ will determine the level of interest in the TMDL and make a decision on the necessity of holding a public hearing. If a public hearing is deemed appropriate, the public will be given a 30-day notice of the hearing to be held at a location near the watershed. That public hearing would be an official hearing of the Mississippi Commission on Environmental Quality, and would be transcribed.

All comments received during the public notice period and at any public hearings 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.

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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, macroinvertebrates, 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; silviculture; 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

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