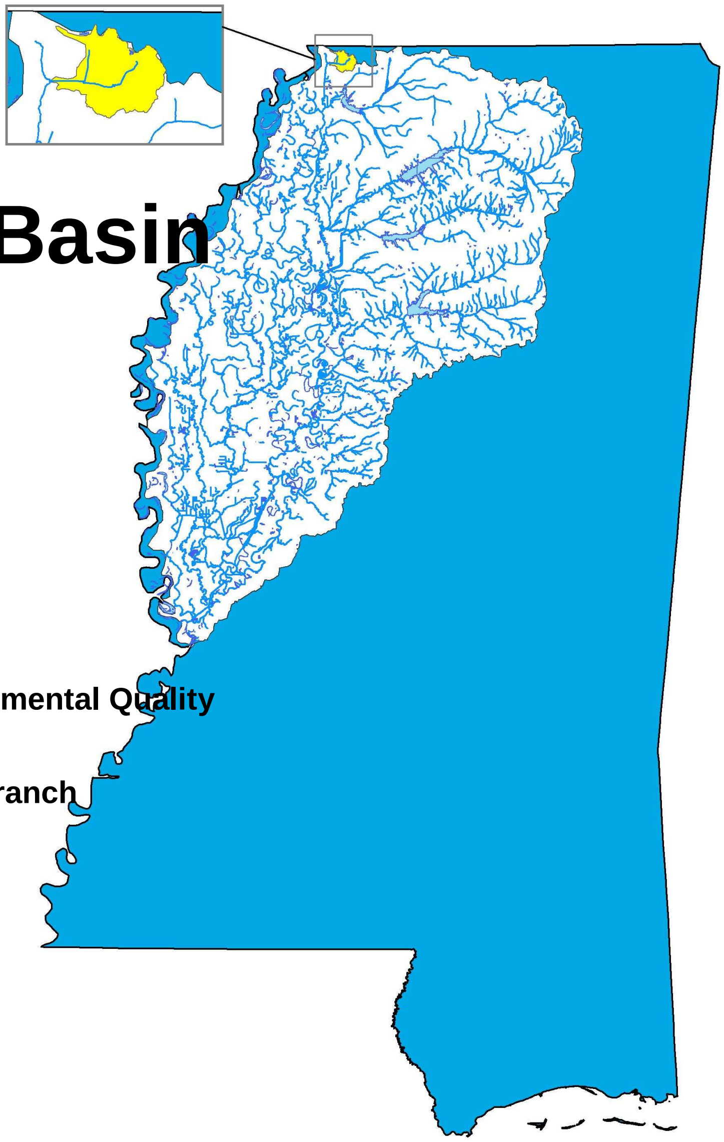
FINAL REPORT
June 2008
ID: 908063025

Total Maximum Daily Load

For Biological Impairment Due to Nutrients and Organic Enrichment / Low Dissolved Oxygen In Johnson Creek



Yazoo River Basin

Desoto County, Mississippi

Prepared By

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

MDEQ
PO Box 10385
Jackson, MS 39289-0385
(601) 961-5171
www.deq.state.ms.us

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.

Conversion Factors

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

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

TABLE OF CONTENTS

FIGURES

TABLES

TMDL INFORMATION PAGE

Table 1. Listing Information

Name	ID	County	HUC	Impaired Use	Causes
Johnson Creek	MS311E	Panola	08030204	Aquatic Life Support	Biological Impairment due to OE/Low DO, TN, and TP
Near Hornlake from headwaters at Twin Lakes Subdivision to Lake Cormorant Bayou					

Table 2. Water Quality Standards

Parameter	Beneficial use	Water Quality Criteria
Nutrients	Aquatic Life Support	Waters shall be free from materials attributable to municipal, industrial, agricultural, or other dischargers producing color, odor, taste, total suspended solids, or other conditions in such degree as to create a nuisance, render the waters injurious to public health, recreation, or to aquatic life and wildlife, or adversely affect the palatability of fish, aesthetic quality, or impair the waters for any designated uses.
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

Table 3. Total Maximum Daily Load for Johnson Creek

	WLA lbs/day	LA lbs/day	MOS	TMDL lbs/day
TBODu	225.06	7.66	Implicit	**232.72**
Total Nitrogen	135.4	186.0	Implicit	**321.4**
Total Phosphorous	13.8	32.1	Implicit	**45.9**

Table 4. Identified NPDES Permitted Facilities

Name	NPDES Permit	Permitted Discharge (MGD)	Receiving Water
Lake Forest Subdivision	MS0034118	0.667	Unnamed thence Johnson Creek
Scenic Hollow MHP	MS0031925	0.022	Big Six Creek
Wall Treatment Plant	MS0046841	0.404	Ditch #12 thence Johnson Creek
Twin Lakes #1	MS0022543	0.150	Johnson Creek
Twin Lakes #2	MS0029467	0.150	Johnson Creek

EXECUTIVE SUMMARY

This TMDL has been developed for Johnson Creek which was placed on the Mississippi 1996 Section 303(d) List of Impaired Water Bodies due to evaluated causes of pesticides, siltation, nutrients, organic enrichment/low dissolved oxygen, and pathogens. MDEQ completed biological monitoring on Johnson Creek that indicated the stream is impaired. It was determined that nutrients and organic enrichment / low dissolved oxygen are probable primary stressors. This TMDL will provide an estimate of the total nitrogen (TN) and total phosphorus (TP) allowable in the stream and will also provide an allocation for total ultimate biochemical oxygen demand (TBODu) for the point sources located in the watershed.

Mississippi does not have numeric criteria in its water quality standards for allowable nutrient concentrations. MDEQ currently has a Nutrient Task Force (NTF) working on the development of criteria for nutrients. Since the watershed is primarily in Ecoregion 74. An annual concentration range of 1.12 mg/l is an applicable target for TN and 0.16 mg/l for TP for water bodies located in Ecoregion 74. MDEQ is presenting these targets as preliminary target values for TMDL development which is subject to revision after the development of numeric nutrient criteria.

The Johnson Creek watershed is located in HUC 08030201. Segment MS311E of Johnson Creek begins at the headwaters at the Twin Lakes Subdivision and flows east to Lake Cormorant Bayou. Figure 1 shows Johnson Creek near Hernando. The location of the watershed for the listed segment is shown in Figure 2.

Figure 1. Johnson Creek near Hernando

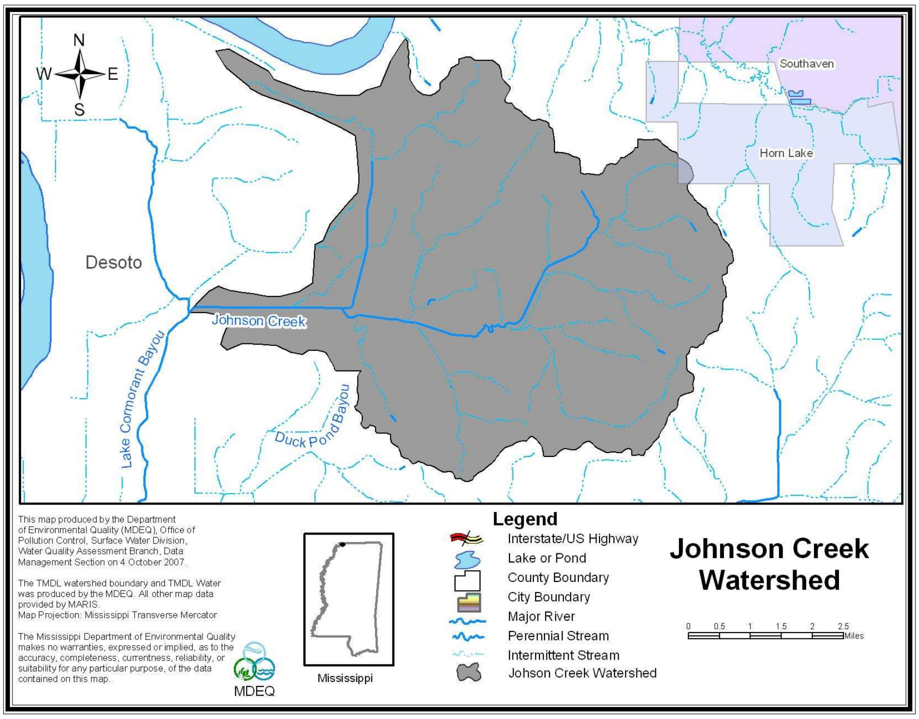


Figure 2. Johnson Creek Watershed

The predictive model used to calculate the dissolved oxygen TMDL is based primarily on assumptions described in MDEQ Regulations. A modified Streeter-Phelps dissolved oxygen sag model was selected as the modeling framework for developing the TMDL allocations. The critical modeling period usually occurs during the hot, dry summer period. The TMDL for organic enrichment was quantified in terms of (TBODu). The model used in developing this TMDL included both non-point and point sources of TBODu in the Johnson Creek Watershed. TBODu loadings from background and non-point sources in the watershed were accounted for by using an estimated concentration of TBODu and flows based on the critical flow conditions. There are five NPDES permitted dischargers located in the watershed that are included as point sources in the model.

According to the model, the current TBODu load in the water body exceeds the assimilative capacity of Johnson Creek for organic material at the critical conditions. Therefore, permit reductions are recommended in order to protect water quality.

Mass balance calculations showed that the estimated existing TP and TN concentrations indicate reductions of nutrients are needed from both point sources and non- point sources.

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 TMDL has been developed for the 2006 §303(d) listed segment shown in Figure 3.

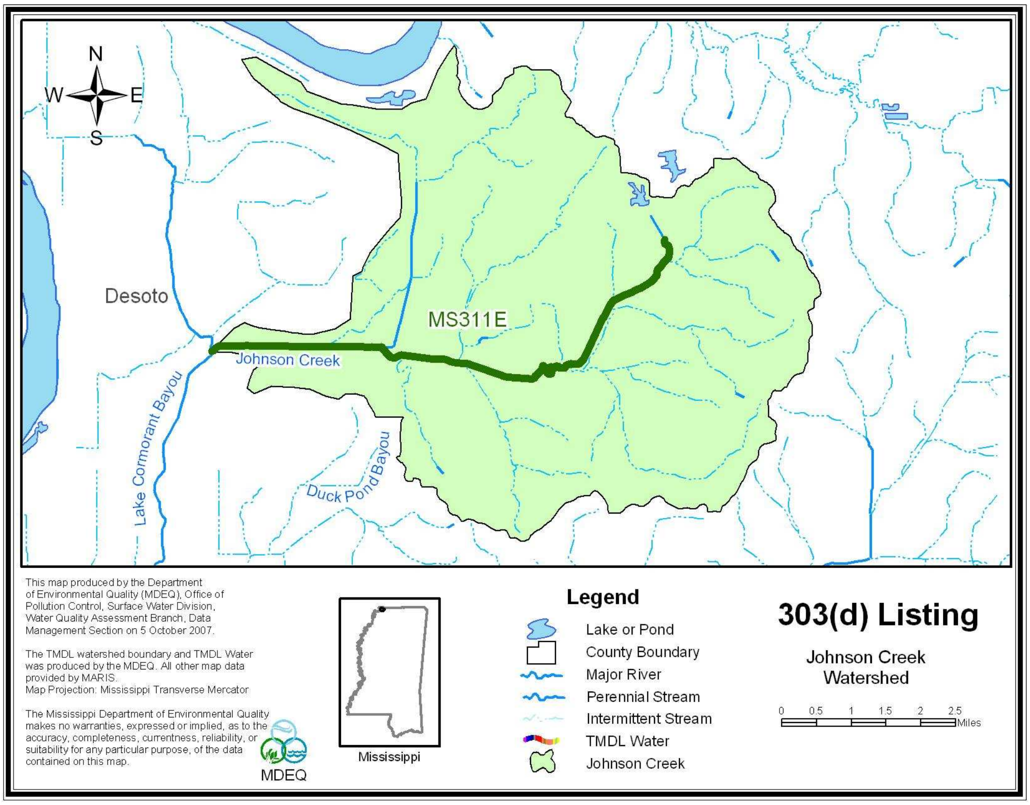


Figure 3. Johnson Creek §303(d) Listed Segment

1.2 Applicable Water Body Segment Use

The water use classifications are established by the State of Mississippi in the document *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters* (MDEQ, 2007). The designated beneficial use for the listed segment is fish and wildlife.

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* (MDEQ, 2007).

Mississippi's current standards contain a narrative criteria that can be applied to nutrients which states "*Waters shall be free from materials attributable to municipal, industrial, agricultural, or other discharges producing color, odor, taste, total suspended or dissolved solids, sediment, turbidity, or other conditions in such degree as to create a nuisance, render the waters injurious to public health, recreation, or to aquatic life and wildlife, or adversely affect the palatability of fish, aesthetic quality, or impair the waters for any designated use* (MDEQ, 2007)." In the 1999 Protocol for Developing Nutrient TMDLs, EPA suggests several methods for the development of numeric criteria for nutrients (USEPA, 1999). In accordance with the 1999 Protocol, "The target value for the chosen indicator can be based on: comparison to similar but unimpaired waters; user surveys; empirical data summarized in classification systems; literature values; or professional judgment." MDEQ believes the most economical and scientifically defensible method for use in Mississippi is a comparison between similar but unimpaired waters within the same region. This method is dependent on adequate data which are being collected in accordance with the EPA approved plan. The initial phase of the data collection process for wadeable streams is complete.

1.4 Nutrient Target Development

Nutrient data were collected quarterly at 99 discrete sampling stations state wide where biological data already existed. These stations were identified and used to represent a range of stream reaches according to biological health status, geographic location (selected to account for ecoregion, bioregion, basin and geologic variability) and streams that potentially receive non-point source pollution from urban, agricultural, and silviculture lands as well as point source pollution from NPDES permitted facilities.

Nutrient concentration data were not normally distributed; therefore, data were log transformed for statistical analyses. Data were evaluated for distinct patterns of various data groupings (stratification) according to natural variability. Only stations that were characterized as "least disturbed" through a defined process in the M-BISQ process (M-BISQ 2003) or stations that resulted in a biological impairment rating of "fully attaining" were used to evaluate natural variability of the data set. Each of these two groups was evaluated separately ("least disturbed sites" and "fully attaining sites). Some stations were used in both sets, in other words, they were considered "least disturbed" and "fully attaining". The number of stations considered "least disturbed" was 30 of 99, and the number of stations considered "fully attaining" was 53 of 99.

Several analysis techniques were used to evaluate nutrient data. Graphical analyses were used as the primary evaluation tool. Specific analyses used included; scatter plots, box plots, Pearson's correlation, and general descriptive statistics.

In general, natural nutrient variability was not apparent based on box plot analyses according to the 4 stratification scenarios. Bioregions were selected as the stratification scheme to use for TMDLs in the Pascagoula Basin. However, this was not appropriate for some water bodies in smaller bioregions. Therefore, MDEQ now uses ecoregions as a stratification scheme for the water bodies in the remainder of the state.

In order to use the data set to determine possible nutrient thresholds, nutrient concentrations were evaluated as to their correlation with biological metrics. That thorough evaluation was completed prior to the Pascagoula River Basin TMDLs. The methodology and approach were verified. The same methodology was applied to the subsequent ecoregions.

For the preliminary target concentration range for each ecoregion, the 75th and 90th percentiles were derived from the mean nutrient value at each site found to be fully supporting of aquatic life support according to the M-BISQ scores. For the estimate of the existing concentrations the 50th percentile (median) was derived from the mean nutrient value at each site of sites that were not attaining and had nutrient concentrations greater than the target. For this report, only the 90th percentile was used.

1.5 Selection of a Critical Condition

Low DO typically occurs during seasonal low-flow, high-temperature periods 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. The critical low flow period for Johnson Creek is 0.57 cfs and was determined based on *Techniques for Estimating 7-Day, 10-Year Low-Flow Characteristics on Streams in Mississippi* (Telis, 1992).

1.6 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 are needed in order to obtain accurate diurnal oxygen levels. Therefore, based on the limited data available and the relative simplicity of the model, the daily average target is appropriate.

The TMDL for DO will be quantified in terms of organic enrichment. 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.

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

There are no state criteria in Mississippi for nutrients. These criteria are currently being developed by the Mississippi Nutrient Task Force in coordination with EPA Region 4. MDEQ proposed a work plan for nutrient criteria development that has been approved by EPA and is on schedule according to the approved plan in development of nutrient criteria (MDEQ, 2007). Data were collected for wadeable streams to calculate the nutrient criteria.

For this TMDL, MDEQ is presenting preliminary targets for TN and TP. Since the watershed is primarily in Ecoregion 74, an annual concentration of 1.12 mg/l is an applicable target for TN and 0.16 mg/l for TP for water bodies located in this ecoregion. However, MDEQ is presenting these targets as preliminary target values for TMDL development which is subject to revision after the development of nutrient criteria, when the work of the NTF is complete.

WATER BODY ASSESSMENT

2.1 Johnson Creek Water Quality Data

Nutrient and DO data for the Johnson Creek Watershed were gathered and reviewed. Data exist for IBI Site 2. Based upon this completed stressor identification report, the strength of evidence analysis showed low DO to be a primary probable cause of impairment. Some biological metrics also indicated altered food sources (nutrient enrichment). During the M-BISQ monitoring, the total organic carbon and all nutrients (N and P) were much higher than the least disturbed (LD) reference site and site specific comparators (SSC). Physical/chemical data from the M-BISQ indicate DO and DO% saturation measurements comparable to LD and all SSC during the non-critical season. Historical data also show comparable DO but a 2006 study found lower DO including a reading of 1.2 mg/L. No diurnal data are available. A few potential sources exist - agriculture (crops and possible cattle though none were seen directly), two residential subdivision lakes in the headwaters, moderate and high density residential (urban encroachment from city of Horn Lake in upper watershed), and two small point sources with chronic compliance issues (BOD, TSS, and fecal coliform violations). The location of the water quality station is shown in Figure 4, and the available data are given in Table 5.

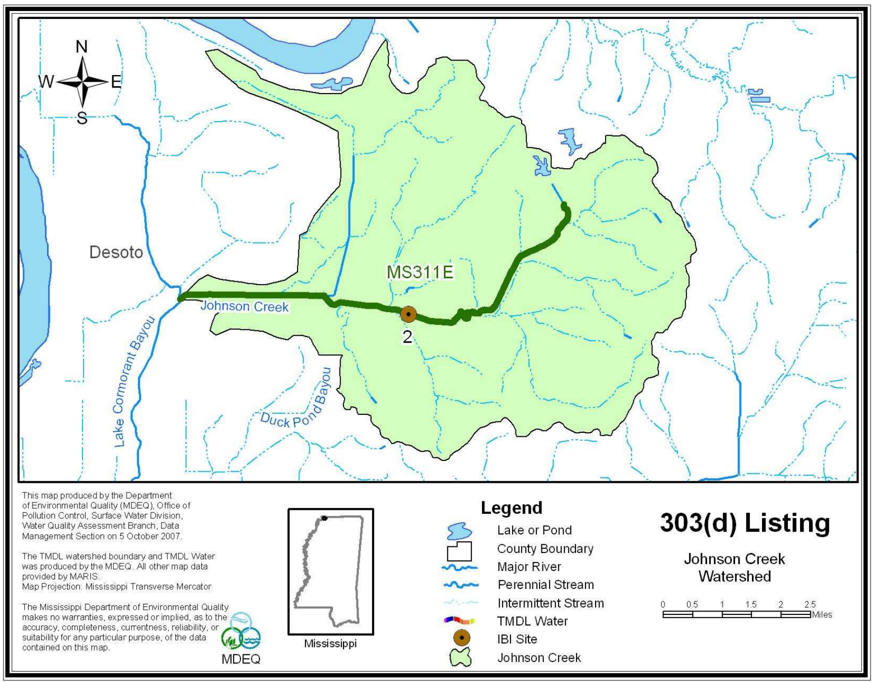


Figure 4. Johnson Creek Water Quality Monitoring Station

Table 5. Johnson Creek Available Data

Date	Time	TN	TP	DO (mg/L)	Temperature (oC)
1/22/2001	12:30:00	3.1	0.36	13.9	2.2
1/22/2001	12:30:00	3.2	0.37	NA	NA
3/22/2004	15:50:00	1.6	0.27	10.3	14.2
4/7/2004	16:20:00	1.2	0.07	12.3	16.4
8/16/2004	15:40:00	1.5	0.09	10.3	22.9
9/8/2004	14:40:00	1.4	0.1	9.1	24.7
Summer 2006	NA	NA	NA	1.2	NA

2.2 Assessment of Point Sources

An important step in assessing pollutant sources in Johnson Creek watershed is locating the NPDES permitted sources. There are five facilities permitted to discharge organic material into this portion of Johnson Creek watershed, Table 6. The locations of these facilities are shown in Figure 5.

Table 6. NPDES Permitted Facilities Treatment Types

Name	NPDES Permit	Treatment Type
Lake Forest Subdivision	MS0034118	Activated Sludge
Scenic Hollow MHP	MS0031925	Activated Sludge
Wall Treatment Plant	MS0046841	Conventional Lagoon
Twin Lakes #1	MS0022543	Activated Sludge
Twin Lakes #2	MS0029467	Activated Sludge

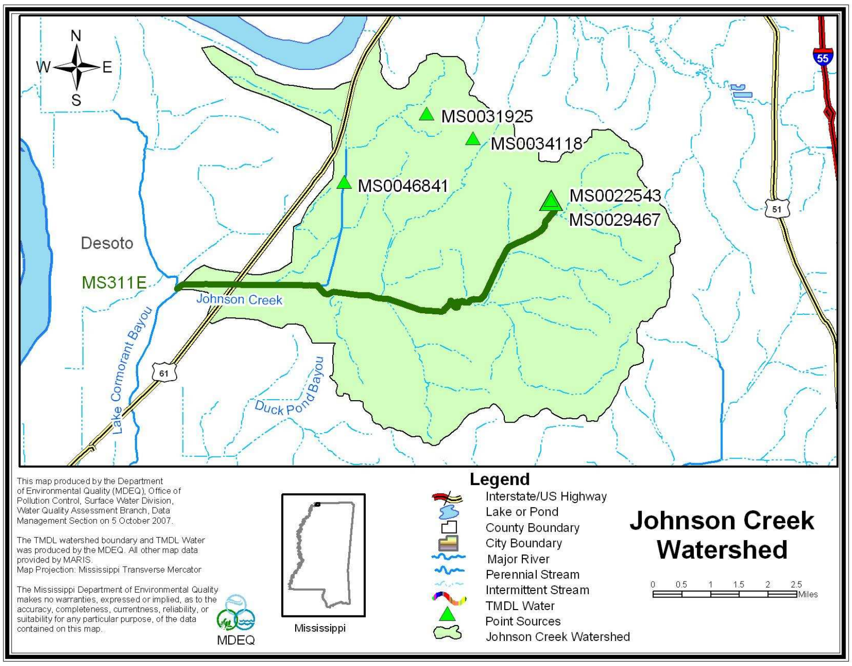


Figure 5. Johnson Creek Point Sources

The effluent from the facilities was characterized based on all available data including information on their wastewater treatment system, permit limits, and discharge monitoring reports. The permit limits are given in Table 7.

Table 7. Identified NPDES Permitted Facilities

Name	NPDES Permit	Permitted Discharge (MGD)	Permitted Average BOD_5 (mg/l)
Lake Forest Subdivision	MS0034118	0.667	25
Scenic Hollow MHP	MS0031925	0.022	30
Wall Treatment Plant	MS0046841	0.404	30
Twin Lakes #1	MS0022543	0.150	30
Twin Lakes #2	MS0029467	0.150	30

2.3 Assessment of Non-Point Sources

Non-point loading of nutrients and organic material in a water body results from the transport of the pollutants into receiving waters by overland surface runoff, groundwater infiltration, and atmospheric deposition. The two primary nutrients of concern are nitrogen and phosphorus. Total nitrogen is a combination of many forms of nitrogen found in the environment. Inorganic nitrogen can be transported in particulate and dissolved phases in surface runoff. Dissolved inorganic nitrogen can be transported in groundwater and may enter a stream from groundwater infiltration. Finally, atmospheric gaseous nitrogen may enter a stream from atmospheric deposition.

Unlike nitrogen, phosphorus is primarily transported in surface runoff when it has been sorbed by eroding sediment. Phosphorus may also be associated with fine-grained particulate matter in the atmosphere and can enter streams as a result of dry fallout and rainfall (USEPA, 1999). However, phosphorus is typically not readily available from the atmosphere or the natural water supply (Davis and Cornwell, 1988). As a result, phosphorus is typically the limiting nutrient in most non-point source dominated rivers and streams, with the exception of watersheds which are dominated by agriculture and have high concentrations of phosphorus contained in the surface runoff due to fertilizers and animal excrement or watersheds with naturally occurring soils which are rich in phosphorus (Thomann and Mueller, 1987).

Watersheds with a large number of failing septic tanks may also deliver significant loadings of phosphorus to a stream. All domestic wastewater contains phosphorus which comes from humans and the use of phosphate containing detergents. Table 8 presents typical nutrient loading ranges for various land uses.

Table 8. Nutrient Loadings for Various Land Uses

Landuse	Total Phosphorus [lb/acre-y]			Total Nitrogen [lb/acre-y]		
	Minimum	Maximum	Median	Minimum	Maximum	Median
Roadway	0.53	1.34	0.98	1.2	3.1	2.1
Commercial	0.61	0.81	0.71	1.4	7.8	4.6
Single Family-Low Density	0.41	0.57	0.49	2.9	4.2	3.6
Single Family-High Density	0.48	0.68	0.58	3.6	5.0	5.2
Multifamily Residential	0.53	0.72	0.62	4.2	5.9	5.0
Forest	0.09	0.12	0.10	1.0	2.5	1.8
Grass	0.01	0.22	0.12	1.1	6.3	3.7
Pasture	0.01	0.22	0.12	1.1	6.3	3.7

Source: Horner et al., 1994 in Protocol for Developing Nutrient TMDLs (USEPA 1999)

The drainage area of Johnson Creek is approximately 21,812.5 acres or 34.1 square miles. The watershed contains many different landuse types, including urban, forest, cropland, pasture, and wetlands. The landuse information given below is based on data collected by the Multi-Resolution Land Characteristics (MRLC) Consortium. This data set is the National Land Cover Database (NLCD) 2001 and is based on satellite imagery from 2001. Pasture is the dominant landuse within this watershed, although cropland is the dominant landuse surrounding the water body. The landuse distribution for the Johnson Creek Watershed is shown in Table 9 and Figure 6. Please refer to Section 3.6, Table 12 for nutrient calculations utilizing the distributed landuse values for Johnson Creek that are shown below.

Table 9. Landuse Distribution for Johnson Creek Watershed

In Acres	Urban	Forest	Cropland	Pasture	Scrub/Barren	Water	Wetlands
Johnson Creek Acreage	445	4320	5722	9686	1105	243	288
Percentage	2	20	26	44	5	1	1

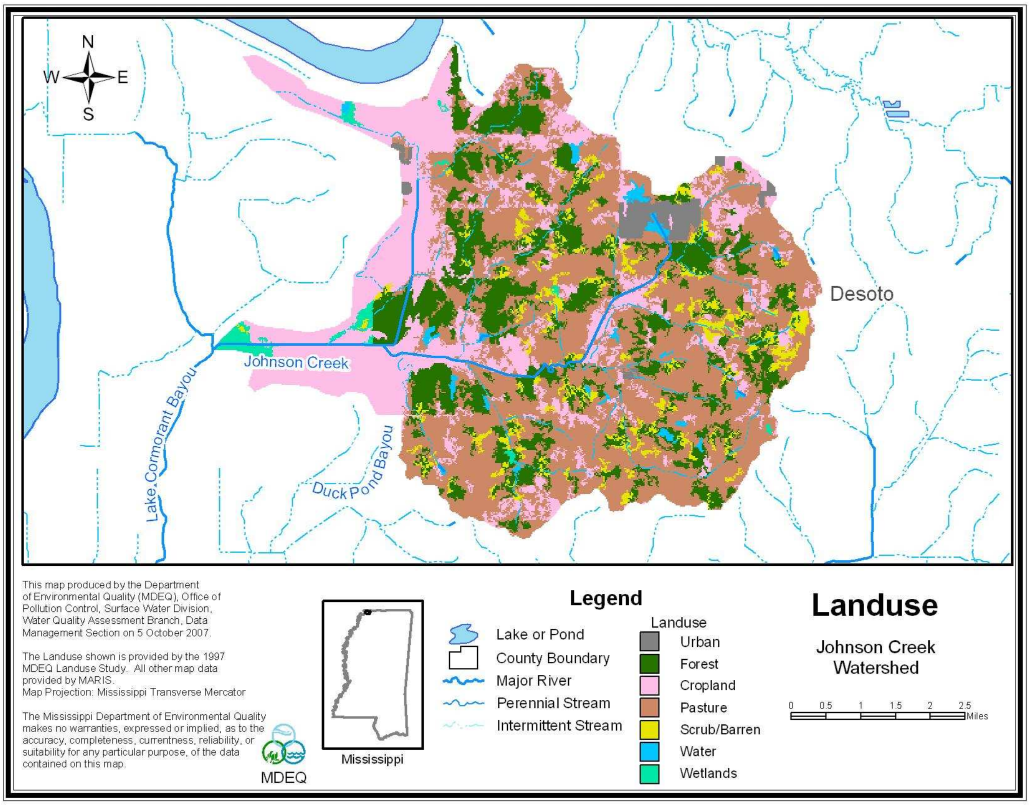


Figure 6. Johnson Creek Watershed Landuse

MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

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

3.1 Modeling Framework Selection

A mathematical model, STeady Riverine Environmental Assessment Model (STREAM), for DO distribution in freshwater streams was used for developing the TMDL. STREAM is an updated version of the AWFWUL1 model, which had been used by MDEQ for many years. 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 STREAM model in TMDL development is its ability to assess instream water quality conditions in response to point and non-point source loadings.

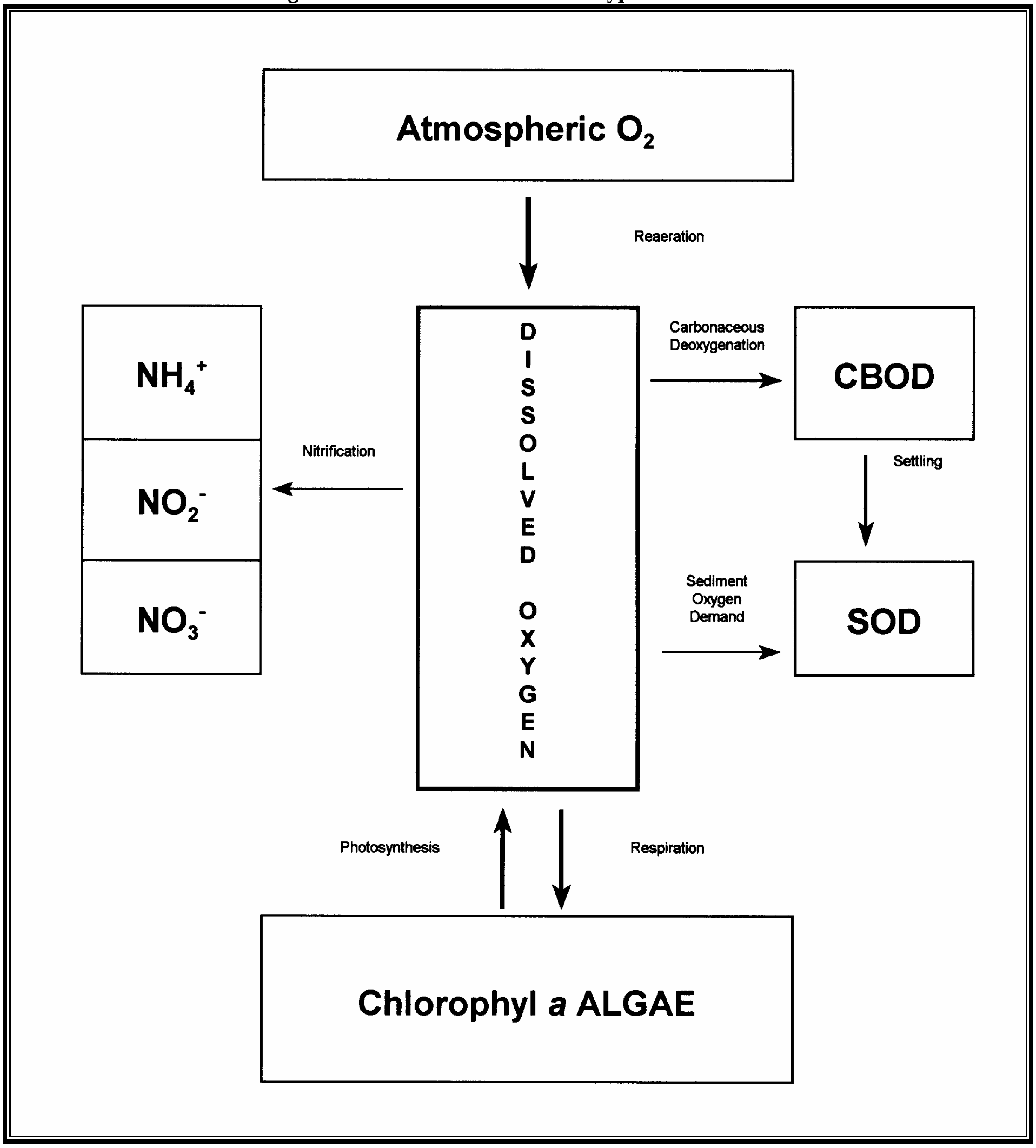
STREAM is a steady-state, daily average computer model that utilizes a modified Streeter-Phelps DO sag equation. Instream processes simulated by the model include CBODu decay, nitrification, reaeration, sediment oxygen demand, and respiration and photosynthesis of algae. Figure 6 shows how these processes 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 the reaeration rate, K_a (day^{-1} base *e*), within each reach according to Equation 2.

$$\mathbf{K_a = C*S*U} \qquad \textbf{(Eq. 2)}$$

C is the escape coefficient, U is the reach velocity in mile/day, and S is the average reach slope in ft/mile. The value of the escape coefficient is assumed to be 0.11 for streams with flows less than 10 cfs and 0.0597 for stream flows equal to or greater than 10 cfs. Reach velocities were calculated using an equation based on slope. The slope of each reach was estimated electronically and input into the model in units of feet/mile.

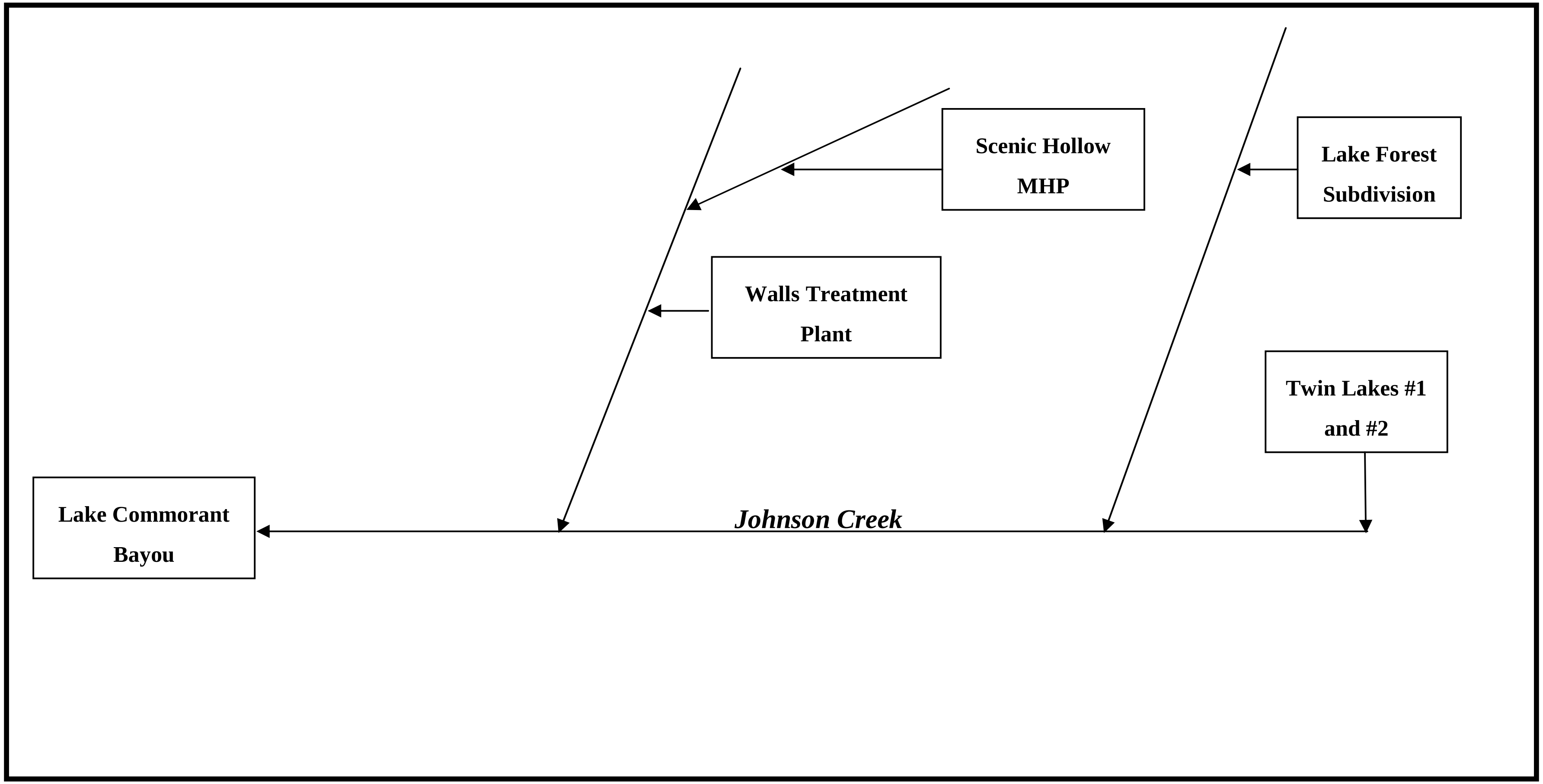
Figure 7. Instream Processes in a Typical DO Model



3.2 Model Setup

The model for this TMDL includes the §303(d) listed segment of Johnson Creek, beginning at the headwaters. A diagram showing the model setup is shown in Figure 8.

Figure 8. Johnson Creek Model Setup (Note: Not to Scale)



The water body was divided into reaches for modeling purposes. Reach divisions were made at locations where there is a significant change in hydrological and water quality characteristics, such as the confluence of a point source or tributary. 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.

The STREAM model was setup to simulate flow and temperature conditions, which were determined to be the critical condition for this TMDL. MDEQ Regulations state that when the flow in a water body is less than 50 cfs, the temperature used in the model is 26°C. The headwater instream DO was assumed to be 85% of saturation at the stream temperature. The instream CBODu decay rate at K_d at 20°C was input as 0.3 day^{-1} (base e) as specified in MDEQ regulations. The model adjusts the K_d rate based on temperature, according to Equation 3.

$$\mathbf{K_{d(T)} = K_{d(20°C)}(1.047)^{T-20}} \qquad \textbf{(Eq. 3)}$$

Where K_d is the CBODu decay rate and T is the assumed instream temperature. The assumptions regarding the instream temperatures, background DO saturation, and CBODu decay rate are required by the *Empirical Stream Model Assumptions for Conventional Pollutants and Conventional Water Quality Models* (MDEQ, 1994). Also based on MDEQ Regulations, the rates for photosynthesis, respiration, and sediment oxygen demand were set to zero because data for these model parameters are not available.

Johnson Creek currently has no USGS flow gage. The flow in Johnson Creek watershed was modeled at critical conditions based on data available from USGS flow gage 07272500, USGS (Telis, 1991).

3.3 Source Representation

Both point and non-point sources were represented in the model. The loads from the NPDES permitted point sources was added as a direct input into the appropriate reaches as a flow in MGD and concentration of $CBOD_5$ and ammonia nitrogen in mg/l. Spatially distributed loads, which represent non-point sources of flow, $CBOD_5$, and ammonia nitrogen were distributed evenly into each computational element of the modeled water body.

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 TMDLs are typically developed using CBODu, a ratio between the two terms is needed, Equation 4.

$$\mathbf{CBODu = CBOD_5 * Ratio} \qquad \textbf{(Eq. 4)}$$

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 wastewater treatment type.

In order to convert the ammonia nitrogen (NH_3-N) loads to an oxygen demand, a factor of 4.57 pounds of oxygen per pound of ammonia nitrogen (NH_3-N) oxidized to nitrate nitrogen (NO_3-N) was used. Using this factor is a conservative modeling assumption because it assumes that all of the ammonia is converted to nitrate through nitrification. The oxygen demand caused by nitrification of ammonia is equal to the NBODu load. The sum of CBODu and NBODu is equal to the point source load of TBODu. The maximum permitted loads of TBODu from the existing point sources are given in Table 10.

Table 10. Point Sources, Maximum Permitted Loads

NPDES	Flow (MGD)	$CBOD_5$ (mg/l)	NH_3-N (mg/l)	$CBOD_u$: $CBOD_5$ Ratio	CBODu (lbs/day)	NH_3-N (lbs/day)	NBODu (lbs/day)	TBODu (lbs/day)
Lake Forest Sbdv.	0.667	25	2	2.3	319.8	11.1	50.7	370.5
Scenic Hollow MHP	0.022	30	2	2.3	12.6	0.4	1.8	14.4
Wall WWTP	0.404	30	2.23	1.5	151.6	7.5	34.3	185.9
Twin Lakes #1	0.15	30	2	2.3	86.3	2.5	11.4	97.7
Twin Lakes #2	0.15	30	2	2.3	86.3	2.5	11.4	97.7
				Total	**656.6**		**109.6**	**766.2**

Direct measurements of background concentrations of CBODu were not available for Johnson Creek. Because there were no data available, the background concentrations of CBODu and 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 concentration used in modeling for BOD_5 is 1.33 mg/l and for NH_3-N is 0.1 mg/l. These concentrations were also used as estimates for the CBODu and NH_3-N levels of water entering the water bodies through non-point source flow and tributaries.

Non-point source flows were included in the model to account for water entering due to groundwater infiltration, overland flow, and small, unmeasured tributaries. These flows were estimated based on USGS data for the 7Q10 flow condition in Johnson Creek watershed. The non-point source loads were assumed to be distributed evenly on a river mile basis throughout the modeled reaches as shown in Table 11.

Table 11. Non-Point Source Loads Input into the Model

	Flow (cfs)	$CBOD_5$ (mg/l)	CBODu (lbs/day)	NH_3-N (mg/l)	NBODu (lbs/day)	TBODu (lbs/day)
Johnson Creek background	0.01	1.33	0.11	0.1	0.02	0.13
Johnson Creek nps	0.57	1.33	6.13	0.1	1.40	7.53
Total			**6.24**		**1.42**	**7.66**

3.4 Model Calibration

The model used to develop Johnson Creek 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.

3.5 Model Results

Once the model setup was complete, the model was used to predict water quality conditions in Johnson Creek. The model was first run under regulatory load conditions. Under regulatory load conditions, the loads from the NPDES permitted point sources were based on their current location and maximum permit limits, Table 10.

3.5.1 Regulatory Load Scenario

The regulatory load scenario model results are shown in Figure 9. Figure 9 shows the modeled daily average DO with the NPDES permitted facilities at their current maximum allowable loads and with estimated non-point source loads. The figure shows the daily average instream DO concentrations, beginning at the headwaters and ending at river mile 0.0 at the mouth with Lake Commorant Bayou. As shown in the figure, the model predicts that the DO goes below the standard of 5.0 mg/l using the maximum allowable loads, thus reductions are needed.

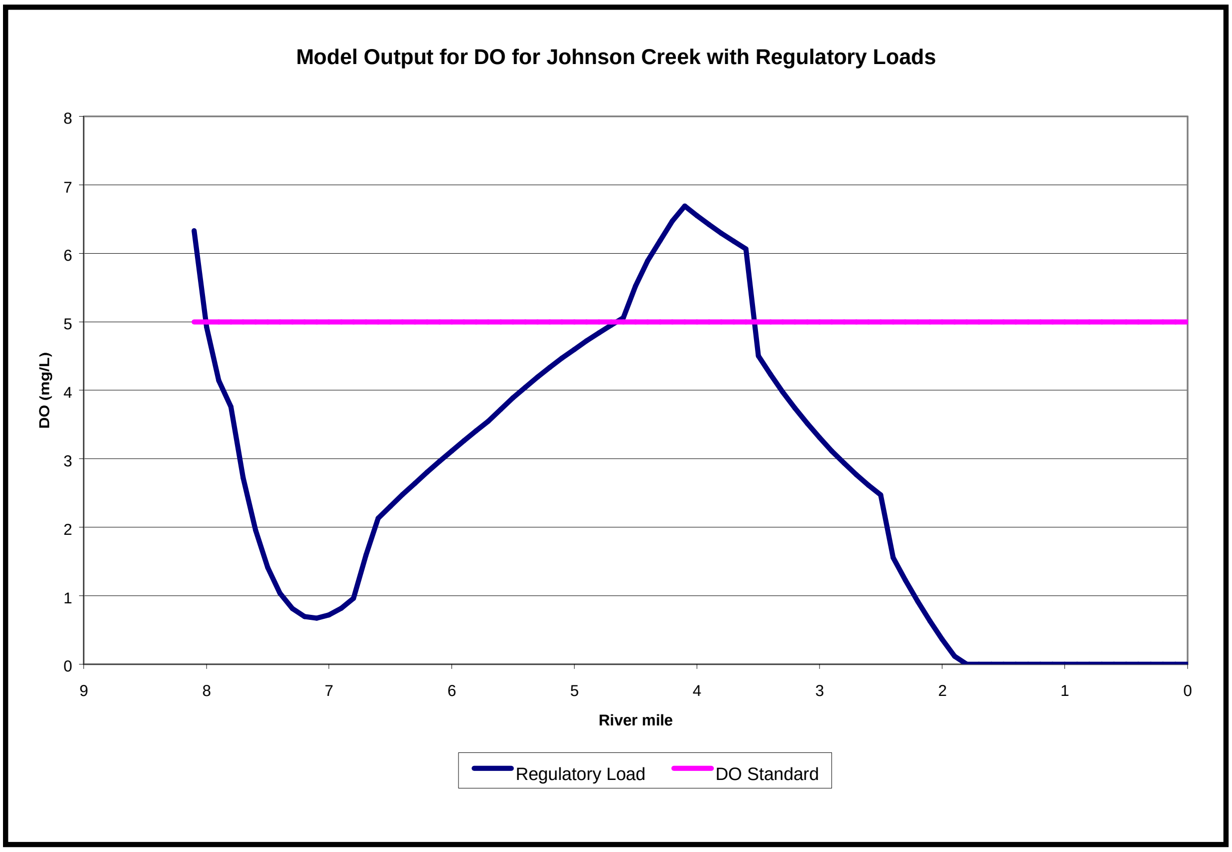


Figure 9. Model Output for DO in Johnson Creek, Regulatory Load Scenario

3.5.2 Maximum Load Scenario

The graph of the regulatory load scenario output shows that the predicted DO falls below the DO standard in Johnson Creek during critical conditions. Thus, reductions of the loads of TBODu are necessary. Calculating the maximum allowable load of TBODu involved decreasing the model loads until the modeled DO was just above 5.0 mg/l. The non-point source loads in this model were already set at background conditions based on MDEQ regulations so no reductions were necessary. Thus, the permitted limits were reduced until the modeled DO was 5 mg/L. The decreased loads were then used to develop the allowable maximum daily load for this report. The model output for DO with the permit reductions is shown in Figure 10.

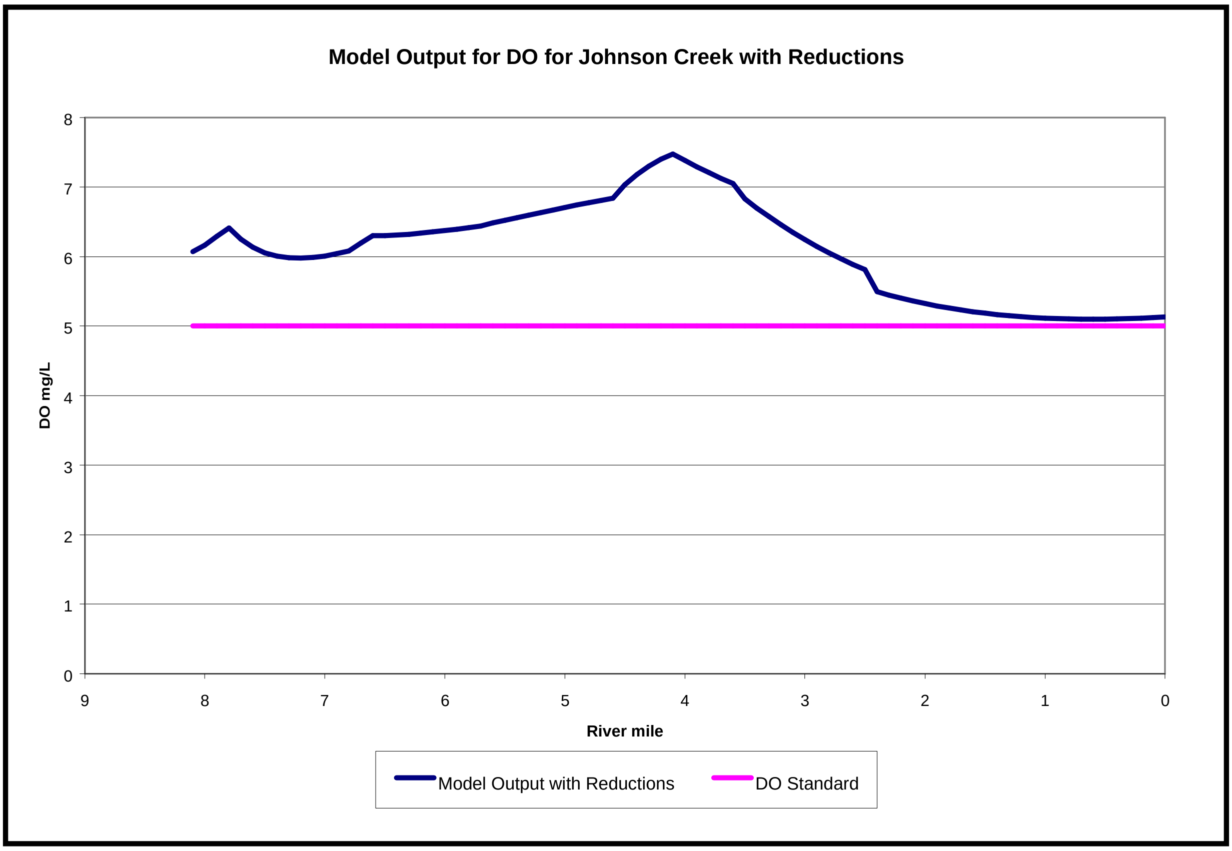


Figure 10. Model Output for DO in Johnson Creek, Maximum Load Scenario

3.6 Estimated Existing Load for Total Nitrogen and Total Phosphorus

The average annual flow in the watershed was estimated based on flow data from USGS gage 07277700 located on Hickahala Creek. The average annual flow for this gage is 189.3 cfs. To estimate the amount of flow in Johnson Creek, a drainage area ratio was calculated (189.3 cfs/121 square miles = 1.56 cfs/square miles). The ratio was then multiplied by the drainage area of the impaired segment. The TMDL for TN and TP loads were then calculated using Equation 5 and the results are shown in Tables 12.

Nutrient Load (lb/day) = Flow (cfs) * 5.394 (conversion factor)* Nutrient Concentration (mg/L) (Eq. 5)

Table 12. Estimated Existing Total Nitrogen and Total Phosphorous Loads for Johnson Creek

Water body	**Johnson Creek**		**Water**	**Urban**	**Scrub/Barren**	**Forest**	**Pasture/Grass**	**Cropland**	**Wetland**	**Total**	
		Acres	243	445	1105	4320	9686	5722	288	21, 809	
Land Use	**TN kg/mile^2**	Percent (%)	1.1	2.0	5.1	19.8	44.4	26.2	1.3	100.0	
Forest	111.3	Miles^2 in watershed	0.4	0.7	1.7	6.8	15.1	8.9	0.5	34.0	
Pasture	777.2	Flow in cfs based on area	53.2								
Cropland	5179.9										
Urban	296.4	TN Load kg/day	0.3	0.6	0.5	2.1	32.2	126.9	0.3	162.9	kg/day
Water	257.4	TP Load kg/day	0.3	1.2	0.3	1.2	32.2	63.4	0.3	98.9	kg/day
Wetland	265.2										
Scrub/Barren	111.3	TN target concentration	1.12	mg/l							
		TP target concentration	0.16	mg/l							
Land Use	**TP kg/mile^2**										
Forest	62.1	TN target load	321.4	lbs/day							
Pasture	777.2	TP target load	45.9	lbs/day							
Cropland	2589.9										
Urban	3.12	TN estimated load per day	358.4	lbs/day							
Water	257.4	TP estimated load per day	217.6	lbs/day							
Wetland	265.2										
Scrub/Barren	62.1	TN estimated concentration	1.25	mg/l							
		TP estimated concentration	0.76	mg/l							
		TN reduction needed	10.3%								
		TP reduction needed	78.9%								

The land use calculations are based on 2004 data. The nutrient estimates are based on USDA ARS. The TMDL targets are based on EPA guidance for calculation of targets when considering all available data.

The existing TN and TP loads consists of both point and non-point components. Since many treatment facilities in Mississippi do not have permit limits for nitrogen, nor are they currently required to report effluent nitrogen or phosphorous concentrations, MDEQ used an estimated effluent concentration based on literature values for different treatment types. Table 13 shows the median effluent nitrogen and phosphorous concentrations for four conventional treatment processes. The appropriate concentration for each of the facilities was then used in Equation 5 to estimate the TN and TP loads from point sources, Table 14.

Table 13. Median Nitrogen and Phosphorous Concentrations in Wastewater Effluents

	Treatment Type			
	Primary	**Trickling Filter**	**Activated Sludge**	**Stabilization Pond**
No. of plants sampled	55	244	244	149
Total P (mg/L)	6.6 ± 0.66	6.9 ± 0.28	5.8 ± 0.29	5.2 ± 0.45
Total N (mg/L)	22.4 ± 1.30	16.4± 0.54	13.6 ±0 .62	11.5 ± 0.84

Source: After Ketchum, 1982 in EPA 823-B-97-002 (USEPA, 1997)

Table 14. NPDES Permitted Facilities Treatment Types with Nitrogen and Phosphorous Estimates

Facility Name	NPDES	Treatment Type	Permitted Discharge (mgd)	TN (mg/l)	TN Load estimate (lbs/day)	TP (mg/l)	TP Load estimate (lbs/day)
Lake Forest	MS0034118	AS	0.667	13.6	75.7	5.8	32.3
Scenic Hollow	MS0031925	AS	0.022	13.6	2.5	5.8	1.1
Walls WWTP	MS0046841	CL	0.404	11.5	38.7	5.2	17.5
Twin Lakes #1	MS0022543	AS	0.15	13.6	17.0	5.8	7.3
Twin Lakes #2	MS0029467	AS	0.15	13.6	17.0	5.8	7.3
		Total			**150.9**		**65.5**

The TN and TP point source loads given in Table 14 are estimated to be 150.9 and 65.5 lbs/day, respectively. The TN point source load is 42.1% of the TN watershed load, and the TP point source load is 30.1% of the TP watershed load.

ALLOCATION

The allocation for this TMDL involves a wasteload allocation for the point sources and a load allocation for the non-point sources necessary for attainment of water quality standards in Johnson Creek.

4.1 Wasteload Allocation

There are currently five NPDES permits issued for the Johnson Creek watershed. The NPDES permitted facilities included in the wasteload allocation are shown in Table 15. A permit reduction is necessary for all of the facilities in order to meet TBODu water quality standards, as shown in Figure 8. Table 16 gives the estimated permit limits from each point source that is equivalent to the necessary reductions at the current scenario with all point sources remaining in Johnson Creek.

Table 15. Wasteload Allocation

Facility Name	CBODu (lbs/day)	NBODu (lbs/day)	TBODu (lbs/day)	Perent Reduction
Lake Forest Sbdv.	89.6	50.7	140.3	62.1
Scenic Hollow MHP	0.42	0.84	1.26	91.3
Walls WWTP	5.1	15.4	20.5	88.9
Twin Lakes #1	20.1	11.4	31.5	67.8
Twin Lakes #2	20.1	11.4	31.5	67.8
Total	**135.32**	**89.74**	**225.06**	

Table 16. Wasteload Allocation Estimated Permit Limits

NPDES	Flow (MGD)	$CBOD_5$ (mg/l)	NH_3-N (mg/l)	DO (mg/l)
Lake Forest Sbdv.	0.667	7	2	6
Scenic Hollow MHP	0.022	1	1	6
Wall WWTP	0.404	1	1	6
Twin Lakes #1	0.150	7	2	6
Twin Lakes #2	0.150	7	2	6

Table 17 gives the nutrient wasteload allocation for the TMDL. The table gives the estimated load of TN from the point sources as described in Section 3.6. Table 17 also gives the estimated load of TP from the point as also described in Section 3.6. The overall TN reduction is 10.3%, and the overall TP reduction is 78.9%. These reductions are reflected in the nutrient wasteload allocation listed in the table below.

Table 17. Nutrient Wasteload Allocation

Facility Name	Existing Estimated TN Point Source Load (lbs/day)	Allocated Average TN Point Source Load (lbs/day)	Existing Estimated TP Point Source Load (lbs/day)	Allocated Average TP Point Source Load (lbs/day)
Lake Forest Sbdv.	75.7	67.9	32.3	6.8
Scenic Hollow MHP	2.5	2.2	1.1	0.2
Wall WWTP	38.7	34.7	17.5	3.7
Twin Lakes #1	17.0	15.3	7.3	1.5
Twin Lakes #2	17.0	15.3	7.3	1.5
Total	**150.9**	**135.4**	**65.5**	**13.8**

It is noted that the Desoto County Regional Utility Authority (DCRUA) has devised a draft implementation plan that will through a phased approach remove all of the significant point sources from Johnson Creek. All dischargers with the exception of Scenic Hollow MHP will be relocated to the Mississippi River. Please refer to section 4.5 for complete details regarding this implementation plan.

4.2 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 BOD_u concentration of 1.33 mg/l and an NH_3-N concentration of 0.1 mg/l. This TMDL does not require a reduction of the load allocation. In Table 18, the load allocation is shown as the non-point sources (the spatially distributed flow entering each reach in the model).

Table 18. Load Allocation, Maximum Scenario

	CBODu (lbs/day)	NBODu (lbs/day)	TBODu (lbs/day)
Background	0.11	0.02	0.13
Non-Point Source	6.13	1.40	7.53
	6.24	**1.42**	**7.66**

Although, reductions are not required for the TBODu non-point source loads, best management practices (BMPs) should be encouraged in the watershed. The watershed should be considered a priority for riparian buffer zone restoration and any nutrient reduction BMPs. For land disturbing activities related to silviculture, construction, and agriculture, it is recommended that practices, as outlined in “Mississippi’s BMPs: Best Management Practices for Forestry in Mississippi” (MFC, 2000), “Planning and Design Manual for the Control of Erosion, Sediment, and Stormwater” (MDEQ, et. al, 1994), and “Field Office Technical Guide” (NRCS, 2000), be followed, respectively. Table 19 shows the load allocation for TN and TP. The overall TN reduction is 10.3%, and the overall TP reduction is 78.9%. These reductions are reflected in the nutrient load allocation in the table below.

Table 19. Load Allocation for Estimated TN and TP

Nutrient	Estimated Nutrient Nonpoint Source Load (lbs/day)	Allocated Nutrient Nonpoint Source Load (lbs/day)	Percent Reduction %
TN	207.3	186.0	10.3
TP	152.1	32.1	78.9

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 for this TMDL 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 represented by the low-flow, high-temperature condition when Sardis spillway is closed for inspections. Modeling the water body at this flow provides protection during the worst-case scenario.

4.4 Seasonality

Seasonal variation may be addressed in the TMDL by using seasonal water quality standards or developing model scenarios 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. This model was set up to simulate dissolved oxygen during the critical condition period, which occurs during the hot, dry summer period. 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 Western Division Implementation Plan

The proposed plan for the Western Division of Desoto County is a phased approach to allow for design, land acquisition, funding and construction to be provided in a reasonable and logical manner. Currently, the plan is in draft form. Through this phased approach, all of the significant point sources will be removed from Johnson Creek. All dischargers with the exception of Scenic Hollow MHP will be relocated first to Johnson Creek and ultimately to the Mississippi River. The detailed engineering is now on-going and land acquisition will follow accordingly. At present, the draft implementation plan is phased through 2011, but may change as the project proceeds. The proposed phased approach to this implementation is outlined as follows:

Phase II-A

1. Johnson Creek WWTF Site Package - Given the site conditions of the treatment plant area, a site package for the treatment facility will be constructed first. This will allow areas that will face significant settlement to be pre-loaded and surcharged to account for future structure loadings, thereby, allowing settlement to occur prior to the construction of the permanent structures.

2. Johnson Creek Interceptor (Segment #1) – Since the treatment plant site will need time to consolidate, construction of pipeline elements will proceed during this time of consolidation. It is proposed to construct a gravity line to the Walls lagoon that will allow it to be taken out of service. For this reason, an initial segment, approximately 3,000 feet, will be constructed to a point where the Walls Interceptor will be connected. The design and land acquisition process of the Johnson Creek Interceptor to its terminus near the Lake Forest is currently underway. The downstream end of the Johnson Creek Interceptor will be stubbed out and capped for future connection to the Johnson Creek Influent Pump Station. This upstream end of this interceptor will also be stubbed and capped from the manhole at the Walls Interceptor connection to allow for future extension of the Johnson Creek Interceptor.

3. Walls Interceptor – Likely, the Walls Interceptor pipeline and Johnson Creek Interceptor will be included in the same bid package and be constructed as one project. This interceptor will connect to the influent pump station at the Walls Lagoon but valved off until the treatment plant is ready to receive flow. The downstream end will be connected to the Johnson Creek Interceptor.

Phase II-B

4. Twin Lakes Pump Station and Force Main – The Twin Lakes Pump Station and Force Main will be used as a temporary solution to allow the removal of the Twin Lakes facility in a timely manner. This would also allow the critical mass of flow to be accumulated to operate the new regional treatment facility. The pump station will be constructed adjacent to the existing treatment facility and will intercept the incoming flow to this facility. The force main will be constructed adjacent to Nail Road and connected to the Walls Interceptor near the Walls lagoon. It may be possible to temporarily pump some flow from the Twin Lakes and/or Lake Forest facility to the Walls Lagoon if necessitated.

5. Lake Forest Pump Station and Force Main – The Lake Forest pump station and force main will also be used as a temporary solution to allow the removal of the Lake Forest treatment facility in a timely manner. It is proposed that this pump station will be located at the end of a short segment of gravity line to be constructed south from the facility and would end near Nail Road. A short segment of force main would connect to the Twin Lakes force main that would allow this flow to be combined with the Twin Lakes flow and carried to the Walls Interceptor, thence to the new treatment facility.

6. Lake Forest Interceptor (Segment #1) – This short segment of gravity interceptor will be constructed south from the Lake Forest treatment facility to the proposed Lake Forest pump station. It will be continued in the future (subsequent phase) to the Johnson Creek Interceptor and the Lake Forest pump station will be taken out of service once this connecting segment is constructed.

Phase II-C

7. Johnson Creek WWTF – The Johnson Creek treatment facility and influent pump station will be constructed under the same construction package. It is anticipated that the influent pump station will likely require preloading the site to accommodate settlement. Since the treatment plant site will require the removal of surcharge material it is planned to use some of this material as fill material and surcharge material at the influent pump station site. It is planned to initially construct a 2 mgd treatment facility with expansion capability to 4 mgd with discharge to the Mississippi River when the discharge exceeds 2 mgd. The initial 2 mgd discharge will be to Johnson Creek. Once the facility is constructed the existing facilities (Walls, Twin Lakes and Lake Forest) will be removed from service.

8. Subsequent Improvements – After the Johnson Creek Facility is put into service, subsequent pipelines and phases will be constructed as funding allows and as demand requires. An

evaluation of the regional system as a whole will be reviewed to determine the most critical need.

4.6 Calculation of the TMDL

The TMDL was calculated based on Equation 6.

$$\text{TMDL} = \text{WLA} + \text{LA} + \text{MOS} \quad \text{(Eq. 6)}$$

The TMDL for TBODu was calculated based on the current loading of pollutant in Johnson Creek, according to the model. The TMDL calculations are shown in Tables 20 and 21. As shown in Table 20, the TBODu is the sum of CBODu and NBODu. The wasteload allocations incorporate the CBODu contributions from identified NPDES Permitted facilities. The load allocations include the background and non-point sources of TBODu 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.

Equation 5 was used to calculate the TMDL for TP and TN. The TMDLs given in Table 21 were then compared to the estimated existing load presented in Sections 3.6. The estimated existing TP concentration indicates needed reductions of 78.9%. The estimated existing total nitrogen concentration indicates needed reductions of 10.3%.

Table 20. TMDL for TBODu in Johnson Creek Watershed

	WLA (lbs/day)	LA (lbs/day)	MOS (lbs/day)	TMDL (lbs/day)
CBODu	**135.32**	**6.24**	Implicit	**141.56**
NBODu	**89.74**	**1.42**	Implicit	**91.16**
TBODu	**225.06**	**7.66**	Implicit	**232.72**

Table 21. TMDL for Nutrients in Johnson Creek Watershed

	WLA (lbs/day)	LA (lbs/day)	MOS (lbs/day)	TMDL (lbs/day)
TN	**135.4**	**186.0**	Implicit	**321.4**
TP	**13.8**	**32.1**	Implicit	**45.9**

The TMDL presented in this report represents the current load of a pollutant allowed in the water body. Although it has been developed for critical conditions in the water body, the allowable load is not tied to any particular combination of point and non-point source loads. The LA given in the TMDL applies to all non-point sources, and does not assign loads to specific sources.

CONCLUSION

This 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 that Johnson Creek is not meeting water quality standards for dissolved oxygen at the present loading of TBODu. 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 no increases in loads for Johnson Creek or issuance of new permits in the watershed. This TMDL recommends an overall TBODu reduction of 70.6% from the current loads to eliminate the DO standards violation in the stream. This TMDL also recommends a 10.3% reduction in the estimated existing TN concentration, and a 78.9% reduction in the estimated existing TP concentration to reduce nutrient impairment in the watershed. At present, DCRUA has a phased draft implementation plan in progress to remove all of the significant point sources from the water body and relocate them to the Mississippi River. It is noted that this implementation plan is phased through 2011, but may change as the project proceeds. With the elimination of the point sources, MDEQ believes that a significant reduction in TN, TP, and organic enrichment in the watershed will return the stream to meeting water quality standards.

It is recommended that the Johnson Creek watershed be considered as a priority watershed for riparian buffer zone restoration and any nutrient reduction BMPs. The implementation of these BMP activities should reduce the nutrient load entering the creeks. This will provide improved water quality for the support of aquatic life in the water bodies and will result in the attainment of the applicable water quality standards.

5.1 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 TMDLs and submit comments. MDEQ also distributes all TMDLs at the beginning of the public notice to those members of the public who have requested to be included on a TMDL mailing list. Anyone wishing to become a member of the TMDL mailing list should contact Kay Whittington at Kay_Whittington@deq.state.ms.us.

All comments should be directed to Kay Whittington at Kay_Whittington@deq.state.ms.us or Kay Whittington, MDEQ, PO Box 10385, Jackson, MS 39289. All comments received during the public notice period and at any public hearings become a part of the record of this TMDL and will be considered in the submission of this TMDL to EPA Region 4 for final approval.

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