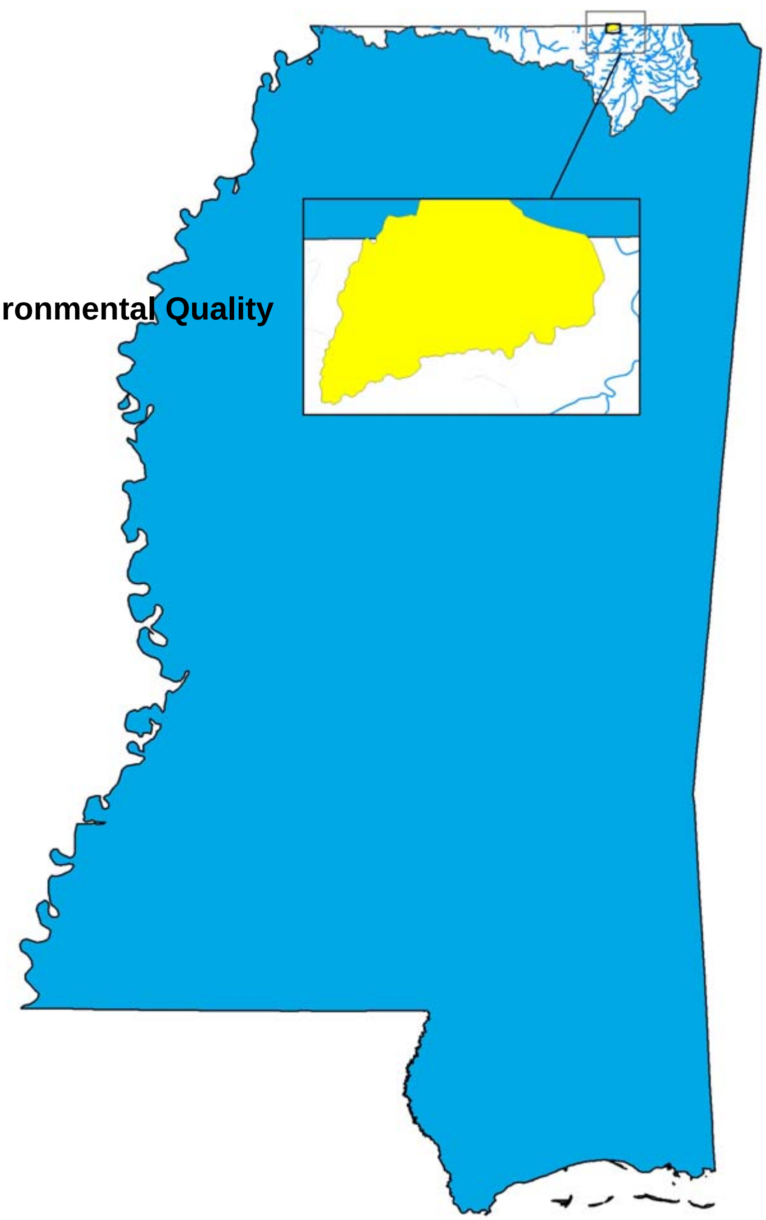
FINAL REPORT
October 2005
ID: 305101401

Fecal Coliform TMDL for Bearman Creek

North Independent Streams Basin

Tippah and Alcorn Counties, Mississippi



Prepared By

Mississippi Department of Environmental Quality
Office of Pollution Control
TMDL/WLA 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 waterbody segments found on Mississippi's 1996 Section 303(d) List of Impaired Waterbodies. 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	0.00156	Days	Seconds	86400
Cubic feet	Cu. Meter	0.02832	Feet	Meters	0.3048
Cubic feet	Gallons	7.4805	Gallons	Cu feet	0.13368
Cubic feet	Liters	28.316	Hectares	Acres	2.4711
cfs	Gal/min	448.83	Miles	Meters	1609.34
cfs	MGD	0.64632	Mg/l	ppm	1
Cubic meters	Gallons	264.173	μg/l * cfs	Gm/day	2.45

CONTENTS

FOREWORD ii

CONTENTS iii

TMDL INFORMATION PAGE v

EXECUTIVE SUMMARY vi

INTRODUCTION 1

1.1 Background 1
1.2 Applicable Waterbody Segment Use 2
1.3 Applicable Waterbody Segment Standard 3

TMDL ENDPOINT AND WATER QUALITY ASSESSMENT 4

2.1 Selection of a TMDL Endpoint and Critical Condition 4
2.1.1 Discussion of the Geometric Mean Test 4
2.1.2 Discussion of the 10% Test 5
2.1.3 Discussion of Combining the Tests 5
2.1.4 Discussion of the Targeted Endpoint 7
2.1.5 Discussion of the Critical Condition for Fecal Coliform 7
2.2 Discussion of Instream Water Quality 7
2.2.1 Inventory of Available Water Quality Monitoring Data 7
2.2.2 Analysis of Instream Water Quality Monitoring Data 8

SOURCE ASSESSMENT 11

3.1 Assessment of Point Sources 11
3.2 Assessment of Nonpoint Sources 11
3.2.1 Failing Septic Systems 12
3.2.2 Wildlife 13
3.2.3 Land Application of Hog Manure 13
3.2.4 Beef and Dairy Cattle 13
3.2.5 Land Application of Poultry Litter 14
3.2.6 Other Direct Inputs 15
3.2.7 Urban Development 15

MASS BALANCE PROCEDURE 16

4.1 Modeling Framework Selection 16
4.2 Calculation of Allowable Load 16
4.3 Calculation of Existing Load 17

ALLOCATION 18

5.1 Wasteload Allocations 18
5.2 Load Allocations 18
5.3 Incorporation of a Margin of Safety (MOS) 18

5.4 Calculation of the TMDL 19
5.5 Seasonality 20
5.6 Reasonable Assurance 20

CONCLUSION 21

6.1 Future Monitoring 21
6.2 Public Participation 21

DEFINITIONS 22

ABBREVIATIONS 25

REFERENCES 26

FIGURES

1. Location of the Bearman Creek Watershed vii
2. Bearman Creek Watershed 303d Listed Segment 1
3. Bearman Creek 303d Listed Segment with Water Quality and Flow Gages 2
4. Theoretical Maximum Allowable Load Curve 6
5. 10% Test Curve for Station 7, Summer 2002 9
6. 10% Test Curve for Station 7, Summer 2003 10
7. Landuse Distribution Map 12

TABLES

1. Theoretical Maximum Allowable Load Data Set 6
2. Fecal Coliform Data at Station 7, Winter 2001 7
3. Fecal Coliform Data at Station 7, Summer 2002 7
4. Fecal Coliform Data at Station 7, Winter 2003 8
5. Fecal Coliform Data at Station 7, Summer 2003 8
6. Landuse Distribution 11
7. Existing Load, Summer 2002 17
8. Existing Load, Summer 2003 17
9. TMDL Summary for Segment MS202E 21

TMDL INFORMATION PAGE

Listing Information

Name	ID	County	HUC	Cause	Mon/Eval
Bearman Creek	MS202E	Tippah and Alcorn	08010207	Pathogens	Evaluated
Near Lone Pine from Headwaters to Tennessee State line					

Water Quality Standard

Parameter	Beneficial use	Water Quality Criteria
Fecal Coliform	Secondary Contact	**May - October**: Fecal coliform colony counts not to exceed a geometric mean of 200 per 100ml based on a minimum of 5 samples taken over a 30-day period with no less than 12 hours between individual samples, nor shall the samples examined during a 30-day period exceed 400 per 100ml more than 10% of the time. **November – April**: Fecal coliform colony counts shall not exceed a geometric mean of 2000 per 100 ml based on a minimum of 5 samples taken over a 30-day period with no less than 12 hours between individual samples, nor shall the samples examined during a 30-day period exceed 4000 per 100 ml more than 10% of the time.

Total Maximum Daily Load for Segment MS202E

Season	WLA (counts per 30 days)	LA (counts per 30 days)	MOS (counts per 30 days)	Total TMDL (counts per 30 days)	TMDL Percent Reduction
Summer	0.00	6.54E+11	7.27E+10	7.27E+11	75
Winter	0.00	2.03E+12	2.25E+11	2.25E+12	0

EXECUTIVE SUMMARY

A fecal coliform TMDL has been developed for an evaluated water body segment of Bearman Creek, MS202E, on the Mississippi 2002 Section 303(d) List of Impaired Water Bodies. The segment was originally listed for pathogens based on anecdotal information, but impairment has been verified through recent monitoring. These recent monitoring data were assessed based on the 2002 *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters*. MDEQ selected fecal coliform as an indicator organism for pathogenic bacteria.

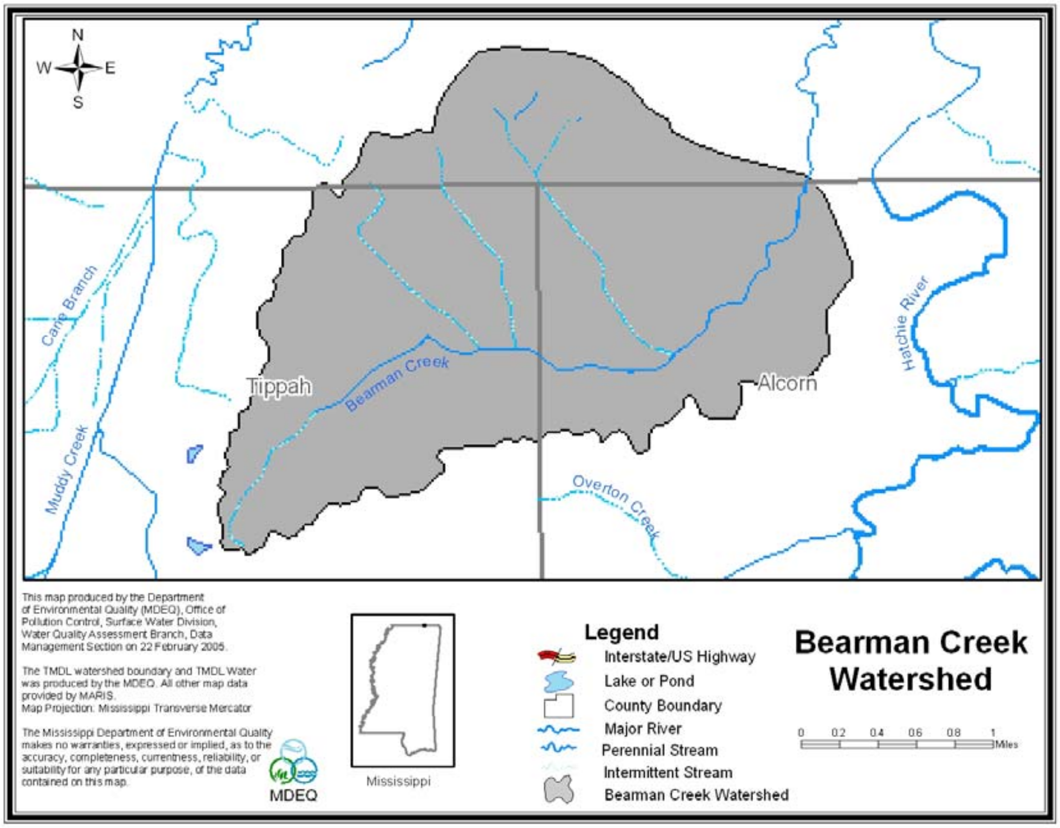
Bearman Creek, Figure 1, flows in a northeasterly direction from its headwaters in north east Tippah County into Alcorn County and across the Tennessee State line to the confluence with the Hatchie River. This TMDL has been developed for the segment of Bearman Creek from the headwaters to the Tennessee State line. Due to data limitations, complex dynamic modeling was inappropriate for performing the TMDL allocations for this study, as were load duration curves. Therefore, a mass balance approach was used to develop the TMDL for segment MS202E.

Although fecal coliform loadings from point and nonpoint sources in the watershed were not explicitly represented with a model, a source assessment was conducted for the Bearman Creek Watershed. Nonpoint sources of fecal coliform include wildlife and agricultural animal populations. Also considered were the nonpoint sources such as failing septic systems and other direct inputs to Bearman Creek. There are no NPDES Permitted discharges included as point sources in the waste load allocation (WLA).

The seasonal variations in hydrology, climatic conditions, and watershed activities are represented through the use of a seasonal TMDL based on seasonal average flows and seasonal monitoring. The critical period was determined to be the summer season. An explicit 10% margin of safety (MOS) was used in the mass balance method to account for uncertainty.

Water quality data indicate violations of the fecal coliform standard in the waterbody. The estimated summer reduction of fecal coliform bacteria for segment MS202E is 75%.

Figure 1. Location of the Bearman Creek Watershed



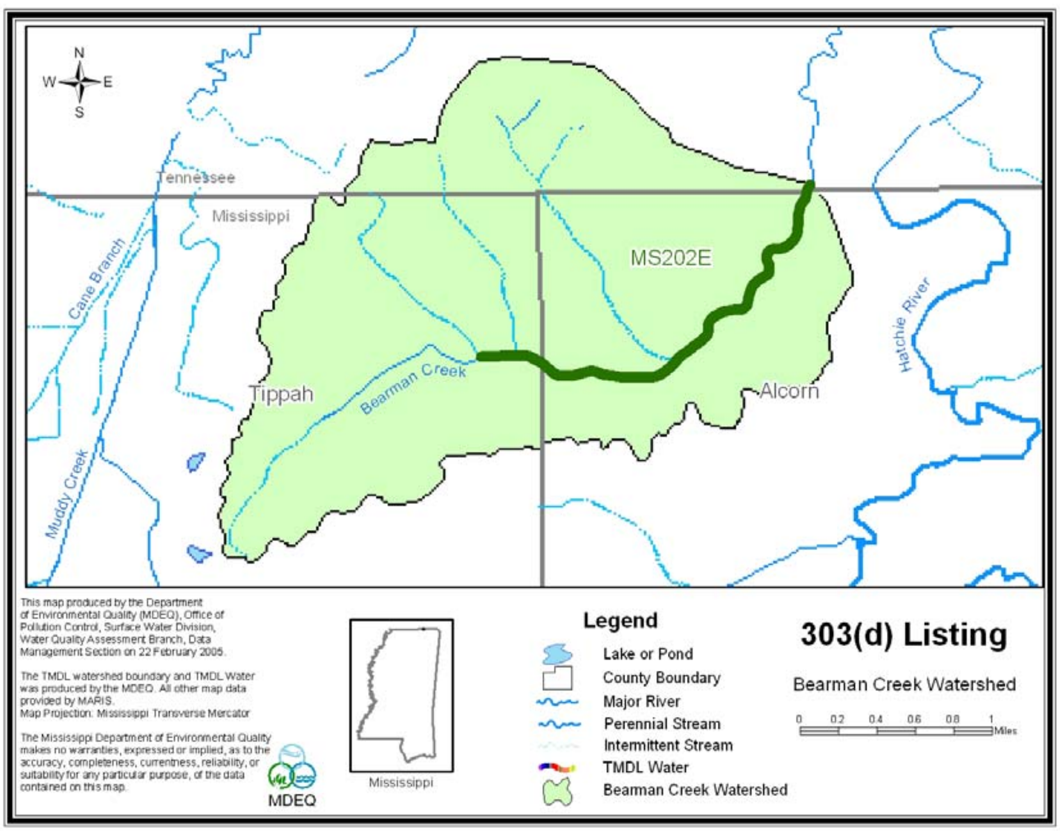
INTRODUCTION

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 pollutant of concern for this TMDL is pathogens as indicated by fecal coliform. Fecal coliform bacteria are used as indicator organisms because they are readily identifiable and indicate the possible presence of other pathogenic organisms in the water body. The TMDL process can be used to establish water quality based controls to reduce pollution from nonpoint sources, maintain permit requirements for point sources, and restore and maintain the quality of water resources.

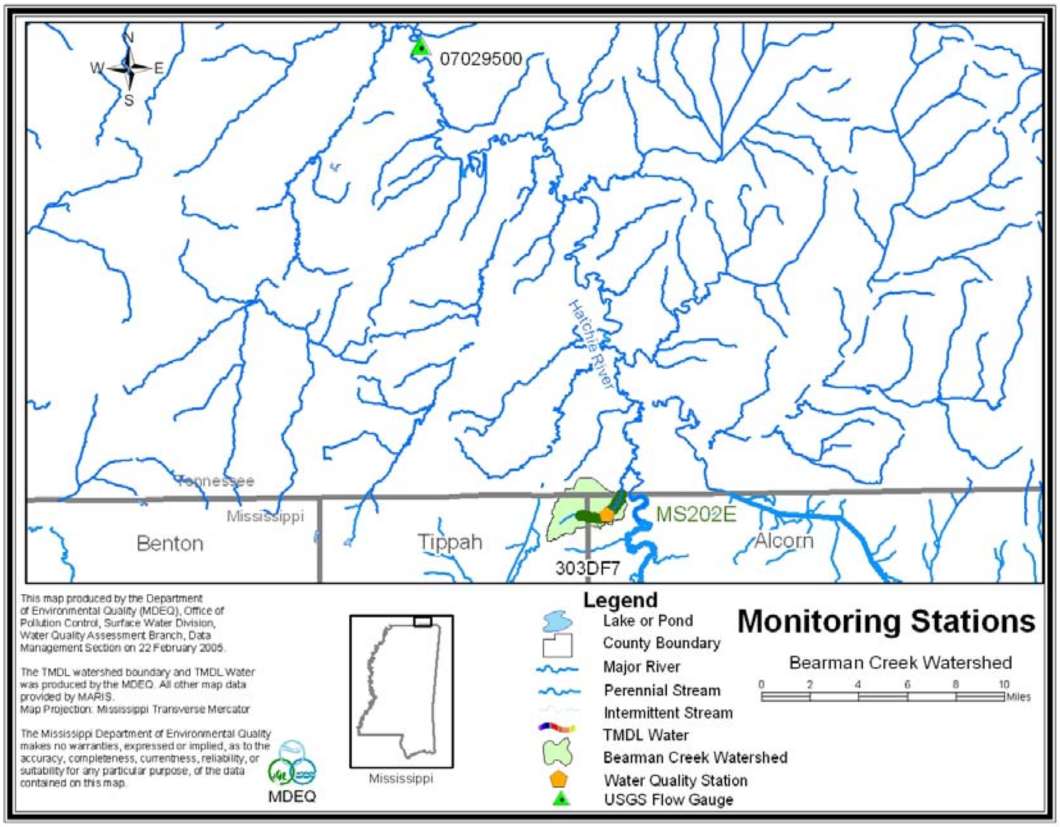
A TMDL has been developed for segment MS202E of Bearman Creek, from the headwaters to the Tennessee State line as shown in Figure 2. Segment MS202E was originally listed based on anecdotal information and is listed on the evaluated section of the Mississippi 2002 Section 303(d) List of Impaired Water Bodies for pathogen impairment. This segment recently had data collected that confirmed impairment. The data are listed in Section 2.2.

Figure 2. Bearman Creek Watershed Segment



The mass balance method is an applicable method for TMDL development when the water quality data are collected in a manner consistent with the water quality standards, that is at least 5 samples collected within a 30 day period. The mass balance method requires water quality data and flow data. The water body segment along with the location of the water quality station and flow gage are shown in Figure 3. The TMDL for segment MS202E was developed using the mass balance method with water quality data from station 7 and flow data from the station 07029500.

Figure 3. Bearman Creek Segment with Water Quality Station and Flow Gage



The Bearman Creek segment is in Hydrologic Unit Code (HUC) 08010207 in northeast Mississippi. The watershed is approximately 3,000 acres. The watershed is primarily rural. Forest is the dominant landuse within the watershed. This fecal coliform TMDL is for the entire Bearman Creek Watershed, a small portion of which is in Tennessee.

1.2 Applicable Waterbody Segment Use

The water use classification for the listed segment of Bearman Creek, 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 Bearman Creek are Secondary Contact and Aquatic Life Support. Secondary Contact is defined as incidental contact with the water during activities such as wading, fishing and boating, that are not likely to result in full body immersion.

1.3 Applicable Waterbody 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* (2002). The standard for fecal coliform is different for summer and winter for a secondary contact use, where summer is defined as the months of May through October and winter is defined as the months of November through April. For the summer months the fecal coliform colony counts shall not exceed a geometric mean of 200 per 100 ml, based on a minimum of 5 samples taken over a 30-day period with no less than 12 hours between individual samples, nor shall the samples examined during a 30-day period exceed 400 per 100 ml more than 10% of the time. For the winter months, the maximum allowable level of fecal coliform shall not exceed a geometric mean of 2000 colonies per 100 ml, based on a minimum of 5 samples taken over a 30-day period with no less than 12 hours between individual samples, nor shall the samples examined during a 30-day period exceed 4000 per 100 ml more than 10% of the time. The water quality standard was used to assess the data to determine impairment in the water body.

TMDL ENDPOINT AND WATER QUALITY ASSESSMENT

2.1 Selection of a TMDL Endpoint and Critical Condition

One of the major components of a TMDL is the establishment of instream numeric endpoints, which are used to evaluate the attainment of acceptable water quality. Instream numeric endpoints, therefore, represent the water quality goals that are to be achieved by implementing the load and waste load reductions specified in the TMDL. The endpoints allow for a comparison between observed instream conditions and conditions that are expected to restore designated uses. The fecal coliform standard allows for a statistical review of any fecal coliform data set. There are two tests, the geometric mean test and the 10% test, that the data set must pass to show acceptable water quality.

The geometric mean test states that for the summer the fecal coliform colony count shall not exceed a geometric mean of 200 per 100 ml based on a minimum of 5 samples taken over a 30-day period with no less than 12 hours between individual samples and for the winter the fecal coliform colony count shall not exceed a geometric mean of 2000 per 100 ml based on a minimum of 5 samples taken over a 30-day period with no less than 12 hours between individual samples. The 10% test states that for the summer the samples examined during a 30-day period shall not exceed a count of 400 per 100 ml more than 10% of the time and for the winter the samples examined during a 30-day period shall not exceed a count of 4000 per 100 ml more than 10% of the time.

2.1.1 Discussion of the Geometric Mean Test

The level of fecal coliform found in a natural water body varies greatly depending on several independent factors such as temperature, flow, or distance from the source. This variability is accentuated by the standard laboratory analysis method used to measure fecal coliform levels in the water. The membrane filtration (MF) method uses a direct count of bacteria colonies on a nutrient medium to estimate the fecal level. The fecal coliform colony count per 100 ml is determined using an equation that incorporates the dilution and volume to the sample filtered.

The geometric mean test is used to dampen the impact of the large numbers when there are smaller numbers in the data set. The geometric mean is calculated by multiplying all of the data values together and taking the root of that number based on the number of samples in the data set.

$$G = \sqrt[n]{s1 * s2 * s3 * s4 * s5 * sn}$$

The water quality standard requires a minimum of 5 samples be used to determine the geometric mean. MDEQ routinely gathers 6 samples within a 30-day period in case there is a problem with one of the samples. It is conceivable that there would be more samples available in an intensive survey, but typically each data set will contain 6 samples therefore, n would equal 6. For the data set to indicate no impairment, the result must be less than or equal to 200 in summer and 2000 in winter.

2.1.2 Discussion of the 10% Test

The 10% test looks at the data set as representing the 30 days for 100% of the time. The data points are sorted from the lowest to the highest and each value then represents a point on the curve from 0% to 100% or from day 1 to day 30. The lowest value becomes the 1st data point and the highest data point becomes the nth data point. The water quality standard requires that 90% of the time, the counts of fecal coliform in the stream be less than or equal to 400 counts per 100 ml in summer and 4000 counts per 100 ml in winter.

By calculating a concentration of fecal coliform for every percentile point based on the data set, it is possible to determine a curve that represents the percentile ranking of the data set. Once the 90th percentile of the data set has been determined, it may be compared to the standard of 400 counts per 100 ml. If the 90th percentile of the data is greater than 400, then the stream will be considered impaired. This can be used not only to assess actual water quality data, but also computer generated daily average model results. Actual water quality data will typically have 5 or 6 values in the data set, and computer generated model results would have 30 daily values.

2.1.3 Discussion of Combining the Tests

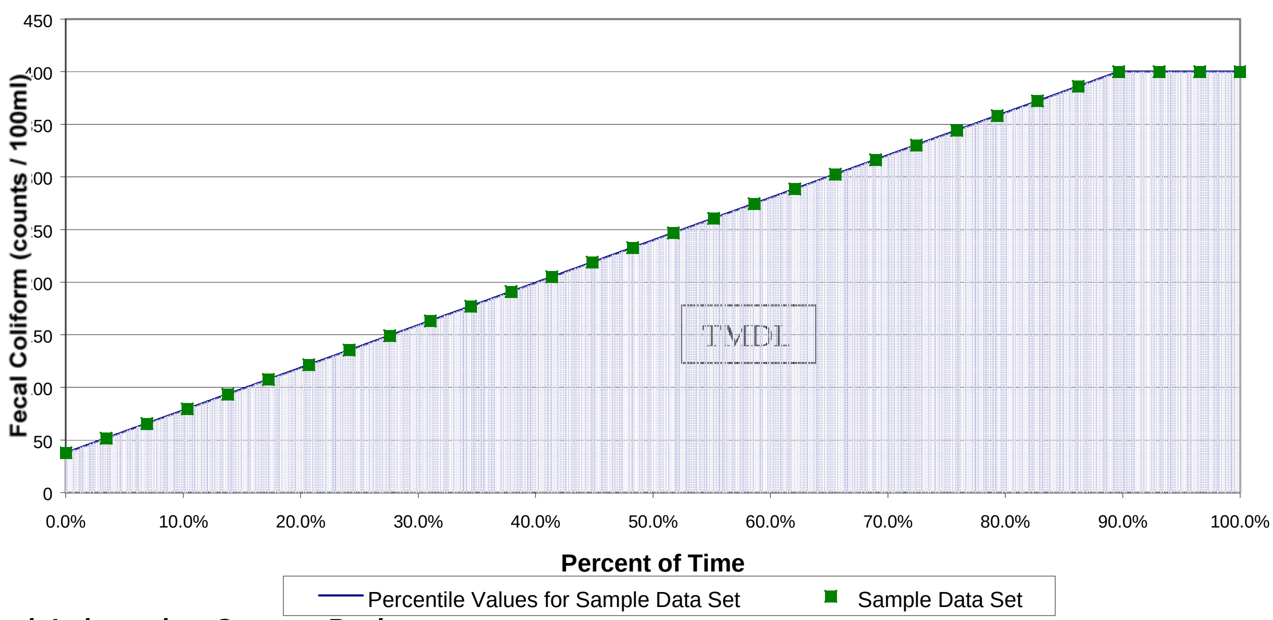
MDEQ determined a theoretical maximum allowable load data set that meets both portions of the water quality standard and is indicative of possible water quality conditions. This theoretical maximum allowable load data set is shown in Table 1. The theoretical maximum allowable load data set was constructed to represent the maximum amount of fecal coliform per day that will still meet both portions of the water quality standard. The theoretical maximum allowable load data set was then plotted, generating a theoretical maximum allowable load data set curve. This curve can be seen in Figure 4. The integral of the theoretical maximum allowable load data set curve is used for mass balance TMDL calculations. By multiplying the integral of the theoretical maximum allowable load data set curve by the flow in a given water body, the mass balance TMDL is calculated.

When actual data are collected from a water body, and the data are plotted in a similar way, an existing load can be calculated based on the integral of the existing load curve as explained in section 4.3. The existing load can be compared to the TMDL calculated using the theoretical maximum allowable load data set curve to determine the percent reduction of fecal coliform necessary for the water body to meet both portions of the water quality standard, the geometric mean test and the 10% test.

Table 1. Theoretical Maximum Allowable Load Data Set

Fecal Coliform (counts/100ml)	Percentile Ranking
37.82	0.0%
51.75	3.4%
65.68	6.9%
79.61	10.3%
93.54	13.8%
107.47	17.2%
121.4	20.7%
135.33	24.1%
149.26	27.6%
163.19	31.0%
177.12	34.5%
191.05	37.9%
204.98	41.4%
218.91	44.8%
232.84	48.3%
246.77	51.7%
260.7	55.2%
274.63	58.6%
288.56	62.1%
302.49	65.5%
316.42	69.0%
330.35	72.4%
344.28	75.9%
358.21	79.3%
372.14	82.8%
386.07	86.2%
400	89.7%
400	93.1%
400	96.6%
400	100.0%

Figure 4. Theoretical Maximum Allowable Load Data Set Curve



2.1.4 Discussion of the Targeted Endpoint

While the endpoint of a TMDL calculation is similar to a standard for a pollutant, the endpoint is not the standard. For a mass balance TMDL, the endpoint selected is both portions of the standard, that is the geometric mean test and the 10% test. Meeting the geometric mean test and applying the 10% test to the data sets applies both parts of the standard to an actual data set or when considering a computer generated data set. It is therefore appropriate to select both portions of the standard as the targeted endpoint for the mass balance TMDL.

2.1.5 Discussion of the Critical Condition for Fecal Coliform

Critical conditions for waters impaired by nonpoint sources generally occur during periods of wet-weather and high surface runoff. But, critical conditions for point source dominated systems generally occur during periods of low-flow, low-dilution conditions. Therefore, a careful examination of the data is needed to determine the critical 30-day period to be used for the TMDL.

2.2 Discussion of Instream Water Quality

Monitoring was performed in a manner consistent with the water quality standards. At least 5 samples were collected in a 30-day period, at station 7 in segment MS202E during two summer seasons and two winter seasons in 2001, 2002, and 2003.

2.2.1 Inventory of Available Water Quality Monitoring Data

The data collected at station 7 is provided in Tables 2 through 5.

Table 2. Fecal Coliform Data reported in Bearman Creek, Station 7
Winter 2001

Date and Time	Fecal Coliform (counts/100ml)	Geometric Mean	Geometric Mean Test Violation	90th Percentile	10% Test Violation
12/4/01 11:35	185	123.3	No, geometric mean is less than 2000	169	No, 90th percentile is less than 4000
12/6/01 10:25	85				
12/11/01 10:25	100				
12/21/01 10:10	125				
12/26/01 10:00	145				

Table 3. Fecal Coliform Data reported in Bearman Creek, Station 7
Summer 2002

Date and Time	Fecal Coliform (counts/100ml)	Geometric Mean	Geometric Mean Test Violation	90th Percentile	10% Test Violation
5/8/02 11:00	> 360	292.3	Yes, geometric mean is greater than 200	1130	Yes, 90th percentile is greater than 400
5/14/02 10:45	270				
5/17/02 10:40	> 1900				
5/21/02 10:15	125				
5/23/02 10:45	260				
6/4/02 10:10	104				

Table 4. Fecal Coliform Data reported in Bearman Creek, Station 7
Winter 2003

Date and Time	Fecal Coliform (counts/100ml)	Geometric Mean	Geometric Mean Test Violation	90th Percentile	10% Test Violation
3/14/03 10:25	175	219.4	No, geometric mean is less than 2000	430	No, 90th percentile is less than 4000
3/21/03 10:15	150				
3/25/03 9:55	77				
4/1/03 10:00	460				
4/3/03 9:50	300				
4/10/03 10:05	400				

Table 5. Fecal Coliform Data reported in Bearman Creek, Station 7
Summer 2003

Date and Time	Fecal Coliform (counts/100ml)	Geometric Mean	Geometric Mean Test Violation	90th Percentile	10% Test Violation
9/9/03 11:00	175	228.6	Yes, geometric mean is greater than 200	897.5	Yes, 90th percentile is greater than 400
9/11/03 11:00	100				
9/15/03 11:45	295				
9/17/03 11:30	155				
9/19/03 11:30	119				
9/23/03 11:00	> 1500				

2.2.2 Analysis of Instream Water Quality Monitoring Data

For segment MS202E, the data collected at station 7 during the two summer season monitoring periods in 2002 and 2003 indicate violation of the geometric mean portion of the standard and the percent of time in exceedence portion of the standard. A graphical representation can be seen in Figures 5 and 6 below. A line has been added to the graph representing 400 counts/100 ml and showing that this occurs less than 90% of the time, meaning that the counts of fecal coliform in the stream is greater than 400 more than 10% of the time. However, the data collected during the two winter monitoring periods of 2001 and 2003 indicated no violations of either portion of the standard. Since the violations occurred during the summer seasons, it is considered the critical period for Bearman Creek.

Figure 5. 10% Test Curve for Station 7, Summer 2002

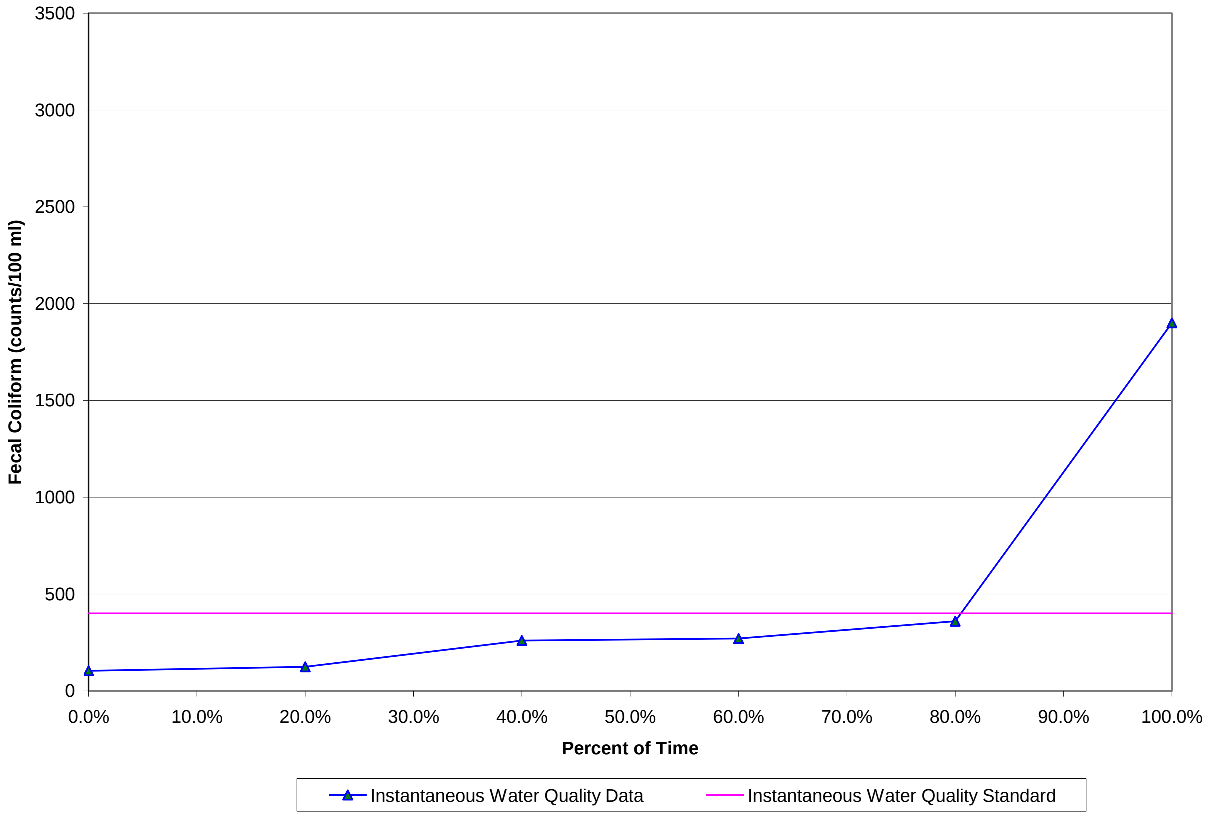
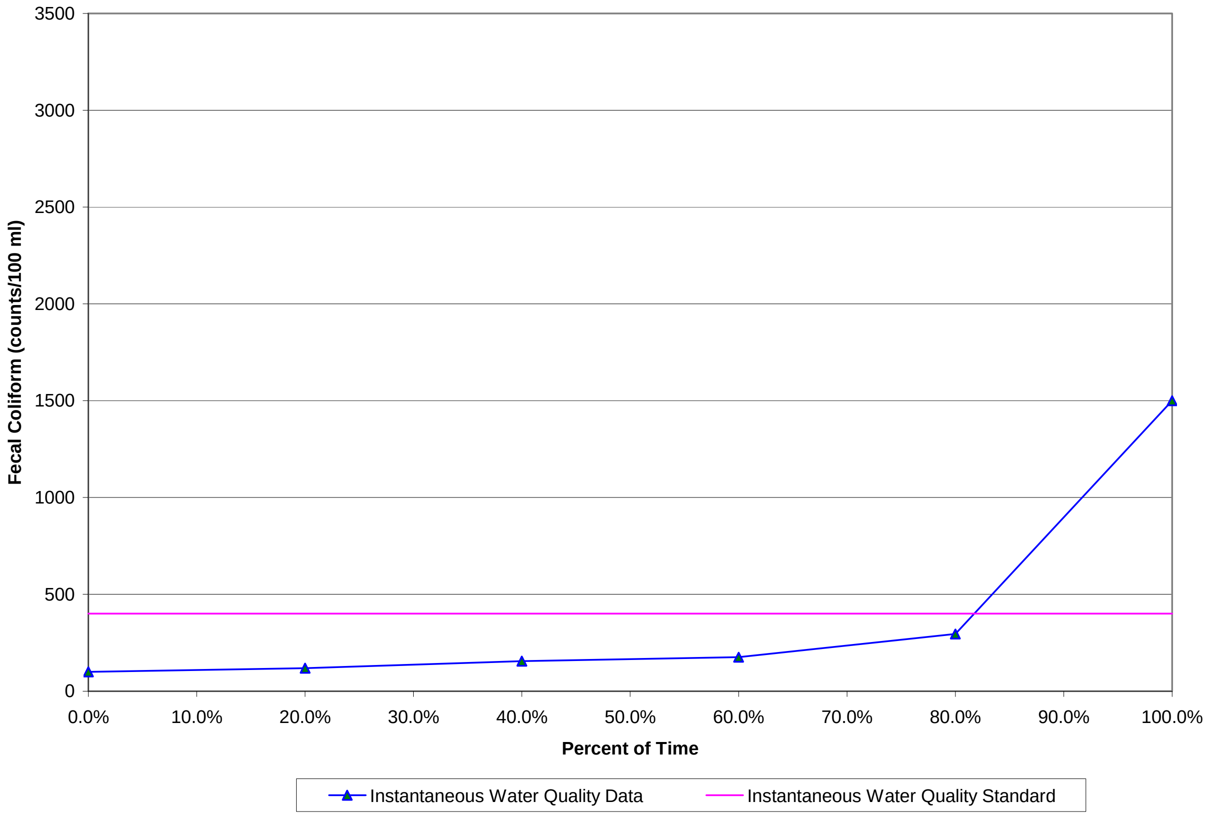


Figure 6. 10% Test Curve for Station 7, Summer 2003



SOURCE ASSESSMENT

The TMDL evaluation summarized in this report examined all known potential fecal coliform sources in the Bearman Creek Watershed. In evaluation of the sources, loads were characterized by the best available information, monitoring data, literature values, and local management activities. This section documents the available information and interpretation for the analysis.

3.1 Assessment of Point Sources

Point sources of fecal coliform bacteria have their greatest potential impact on water quality during periods of low flow. No NPDES permitted dischargers are currently located within the Bearman Creek Watershed.

3.2 Assessment of Nonpoint Sources

There are many potential nonpoint sources of fecal coliform bacteria for Bearman Creek, including:

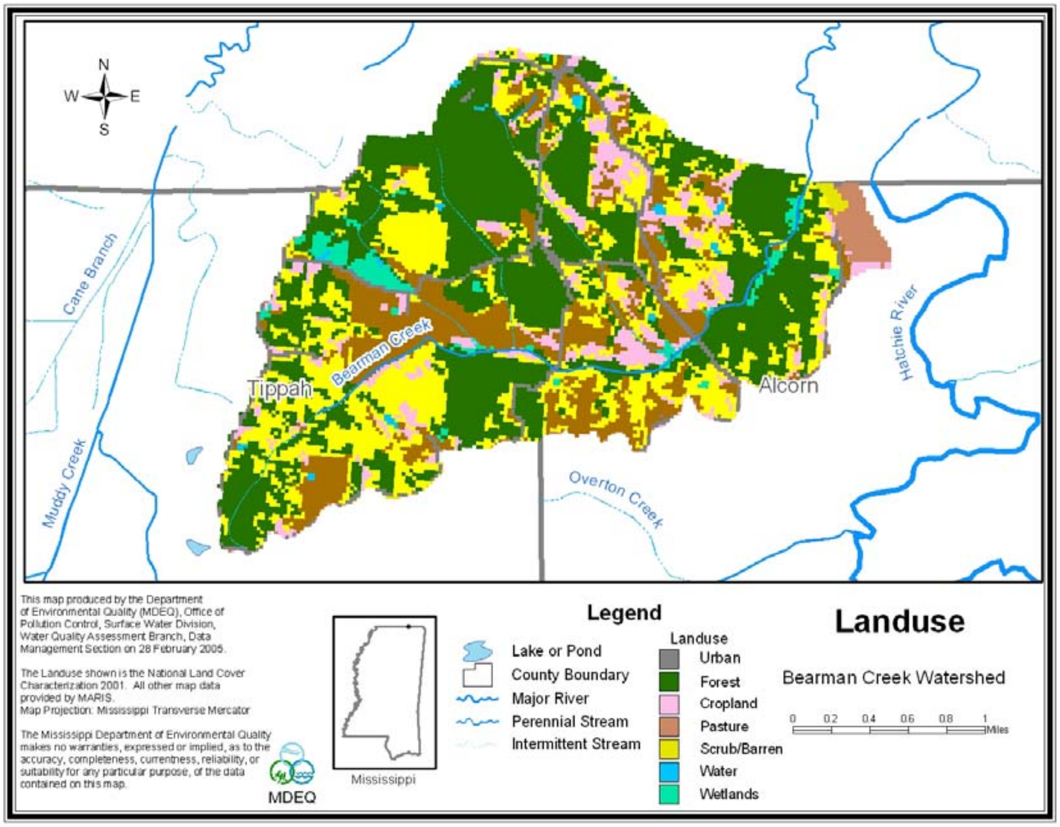
- Failing septic systems
- Wildlife
- Land application of hog and cattle manure
- Grazing animals
- Land application of poultry litter
- Other Direct Inputs
- Urban development

The approximately 3,000 acre drainage area of Bearman Creek contains many different landuse types, including urban, forest, cropland, pasture, scrub/barren, and wetlands. The watershed is predominantly forest. The landuse distribution for the watershed is provided in Table 6 and displayed in Figure 7. The landuse information for the entire watershed is based on the National Land Cover Data Set 2001 (NLCD) Multi-Resolution Land Characteristic (MRLC) data. The landuse categories were grouped into the landuses of urban, forest, cropland, pasture, scrub/barren, wetlands, and water.

Table 6. Landuse Distribution (acres)

	Urban	Forest	Cropland	Pasture	Scrub/Barren	Wetland	Water	Total
Area (acres)	160	1,397	242	515	816	75	16	3,221
% Area	5%	43%	8%	16%	25%	2%	1%	100%

Figure 7. Landuse Distribution Map for the Bearman Creek Watershed



MDE
Q contacted several agencies to refine the information concerning nonpoint sources of fecal coliform bacteria. The Mississippi Department of Wildlife, Fisheries, and Parks provided information of wildlife density in the Bearman Creek Watershed. The Mississippi State Department of Health was contacted regarding the failure rate of septic tank systems in this portion of the state. Mississippi State University researchers provided information on manure application practices for hog farms, poultry farms, and beef and dairy operations. The Natural Resources Conservation Service gave MDEQ information on agricultural manure treatment practices and land application of manure. The Natural Resources Conservation Service also gave MDEQ information on possible nonpoint sources of fecal coliform bacteria specific to the watershed. The 2002 Census of Agriculture produced by the National Agriculture Statistics Service was used to estimate agricultural animal populations in the watershed.

3.2.1 Failing Septic Systems

Septic systems have a potential to deliver fecal coliform bacteria loads to surface waters due to malfunctions, failures, and direct pipe discharges. Properly operating septic systems treat wastewater and dispose of the water through a series of underground field lines. The water is applied through these lines into a rock substrate, thence into underground absorption. The systems can fail when the field lines are broken, or when the underground substrate is clogged or flooded. A failing septic system's discharge can reach the surface, where it becomes available for wash-off into the stream. Another potential problem is a direct bypass from the system to a stream. In an effort to keep the water off the land, pipes are occasionally placed from the septic tank or the field lines directly to the creek.

Another consideration is the use of individual onsite wastewater treatment plants. These treatment systems are in wide use in Mississippi. They can adequately treat wastewater when properly maintained. However, these systems may not receive the maintenance needed for proper, long-term operation. These systems require some sort of disinfection to properly operate. When this expense is ignored, the water does not receive adequate disinfection prior to release.

Septic systems have an impact on nonpoint source fecal coliform impairment in the North Independent Streams Basin. The best management practices needed to reduce this pollutant load need to prioritize eliminating septic tank failures and improving maintenance and proper use of individual onsite treatment systems.

The Mississippi portion of the Bearman Creek Watershed is located in Tippah and Alcorn Counties, neither of which have a wastewater ordinance. A wastewater ordinance requires that the wastewater treatment and disposal system used be certified as sufficient. It also ensures that electricity, water, or natural gas will not be made available without written approval from the county Health Department or the Mississippi Department of Environmental Quality that the wastewater treatment and disposal system used is sufficient. The lack of a wastewater ordinance could allow some of the rural areas not connected to a sewer system to have only modest wastewater treatment, if any treatment before discharge.

3.2.2 Wildlife

Wildlife present in the Bearman Creek Watershed contributes to fecal coliform bacteria on the land surface which is then available for wash-off and delivery to receiving water bodies. Some form of wildlife may be present on all land uses within the watershed. Also, wildlife is present throughout the year.

3.2.3 Land Application of Hog Manure

In the North Independent Streams Basin processed manure from confined hog operations is collected in lagoons and routinely applied to pastureland during April through October. This manure is a potential contributor of bacteria to receiving water bodies due to runoff produced during a rain event. Hog farms in the North Independent Streams Basin operate by keeping the animals confined at all times. The hog waste is collected in a lagoon and periodically sprayed on forage or cropland. The amount of the manure application is determined by the nitrogen uptake of the plant being sprayed. The frequency is determined by rain events so that the waste is not sprayed on saturated ground or just prior to a rain event to minimize runoff. Another factor in the application of the manure is pumping the lagoons often enough to avoid a lagoon overflow. Also, the waste is not land applied during the winter months when there is no forage or crop being grown.

There are very few hogs and pigs in Alcorn and Tippah Counties. All of the hogs and pigs in the watershed are on small farms with less than 50 hogs and pigs.

3.2.4 Beef and Dairy Cattle

Large dairy farms, over 200 head, typically confine the milking herd at all times. Smaller dairy farms confine the lactating cattle for a limited time during the day for milking and feeding. The manure collected during confinement is applied to the available pastureland in the watershed.

Application rates of dairy cow manure to pastureland vary monthly according to management practices currently used in this area.

Grazing cattle deposit manure on pastureland where it is available for wash-off and delivery to receiving water bodies. Beef cattle have access to pastureland for grazing all of the time. For dairy cattle, the dry cattle and heifers have access to pastureland for grazing all of the time. The small dairy farms, less than 200 head, in the North Independent Streams Basin confine the lactating cattle for a limited time during the day. During all other times, the lactating cattle at small dairies have access to pastureland for grazing. The milking herd makes up approximately 80% of the total herd. Manure produced by grazing beef and dairy cows is directly deposited onto pastureland and is available for wash off.

The manure produced by confined dairy cows is collected in lagoons and spray applied to available pastureland in the watershed. Large dairy farms, more than 200 head, typically confine the milking herd at all times. Smaller dairy farms confine the lactating cattle for a limited time during the day for milking and feeding.

Cattle are few and spread throughout the whole Bearman Creek watershed. These cattle are primarily beef cattle, heifers, steers, and bulls. There are no dairy cattle in Alcorn County and very few in Tippah County. All of the dairy cattle in Tippah County are on small farms with less than 200 head of cattle.

3.2.5 Land Application of Poultry Litter

Predominantly, two kinds of chickens are raised on farms in the North Independent Streams Basin, broilers and layers. For the broiler chickens, the amount of growth time from when the chicken is born to when it is sold off the farm is approximately 48 days or 1.6 months. Broiler chickens are confined in poultry houses all of the time. Typically, the dry waste accumulated in the poultry houses is “de-caked” between flocks unless a disease situation warrants clean-out before the change of flocks. During “de-caking”, approximately the top two inches of litter is removed. Every year or two, the middle third of the poultry house is removed and the remaining litter is spread evenly in the house. The majority of the litter is used as a fertilizer on hay and row crops and may be used in areas of the state other than the location of the poultry houses. The litter is applied in the spring, summer, and early fall and rates are determined by a phosphorous index.

Layer chickens are confined at all times and remain on farms for ten months or longer. Large scale layer operations collect the chicken waste in a lagoon and periodically spray apply the waste to corn fields. The application rates vary monthly from the spring through the early fall.

Poultry populations within the Bearman Creek Watershed are vary low. There are no broiler chickens and very few layer chickens. The layer chickens are in small layer operations with less than 50 birds.

3.2.6 Other Direct Inputs

Other direct inputs of fecal coliform bacteria to water bodies in the Bearman Creek Watershed include illicit disharges, human recreation, leaking sewer collection lines, and access of both domestic and wild animals to the stream. Due to the general topography in the Bearman Creek Watershed, land slopes in the watershed are such that unconfined animals are able to access some intermittent streams in the watershed.

3.2.7 Urban Development

Urban areas include land classified as urban and barren. Even though a small percentage of the entire watershed is classified as urban, there are no significant urban areas within the Bearman Creek Watershed. Fecal coliform contributions from urban areas may come from storm water runoff and runoff contribution from improper disposal of materials such as pet waste and litter.

MASS BALANCE PROCEDURE

Establishing the relationship between the instream water quality target and the source loading is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired source load reductions. Ideally, the linkage will be supported by monitoring data that allow the TMDL developer to associate certain waterbody 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 mass balance approach was used to calculate the TMDL for segment MS202E. This method of analysis was selected because data limitations precluded the use of more complex methods. The mass balance approach is suitable for this TMDL

4.2 Calculation of Allowable Load

The mass balance approach utilizes the conservation of mass principle. Loads can be calculated by multiplying the fecal coliform concentration in the water body for a 30-day period by the flow. The principle of the conservation of mass allows for the addition and subtraction of those loads to determine the appropriate numbers necessary for the TMDL. The loads can be calculated using the following relationship:

Load (counts/30days) = [**Concentration for 30 days** (30 days*counts/ 100 ml)] * [**Flow** (cfs)] * (Conversion Factor)

where (Conversion Factor) = [(28316.8 ml/1 ft^3)*(1 (100 ml)/100 (1 ml))*(60 s/1 min)* (60 min/1 hour)*(24 hour/1 day)*(30 days/1 (30 days)/30 days]
= 2.45 E+07 ((100 ml * s)/(ft^3 *30 days*30days))

For the calculation of this TMDL, the concentration for 30 days used was the integral of the theoretical maximum allowable load curve as shown in section 2.1.3. This value is 7129.4 (30days*counts/100 ml). USGS flow gage 07029500 was used to estimate the flow for segment MS202E. The average summer discharge at the flow gage was calculated by averaging the USGS monthly mean stream flows for the summer period (May through October) for the period of record of the gage. The average winter discharge at the flow gage was calculated accordingly. The average summer flow for segment 202E was estimated to be 4 cfs based on the average summer discharge at station 07029500 on the Hatchie River at Bolivar, Tennessee (Telis). This method was also used to calculate the average winter discharge of 13 cfs.

Avg Seasonal Discharge (cfs)={[**07029500 Avg Seasonal Discharge** (cfs)]/[**07029500 Drainage Area** (acres)]}*[**MS202E Drainage Area** (acres)]

Avg Summer Discharge (cfs)= {[1,222 (cfs)]/[947,196.2 (acres)]}*[3221 (acres)]
= 4 cfs

4.3 Calculation of Existing Load

For the calculation of the existing load, the daily streamflow was multiplied by the fecal coliform concentration for the dates the water quality samples were taken to get a daily load. These daily loads were then plotted to generate an existing load curve. The integral of this existing load curve over 30 days was then multiplied by the conversion factor to get the existing load. The percent reduction was based on the Summer 2002 existing load curve because it was the most critical.

Table 7. Existing Load
Summer 2002

Date and Time	Fecal Coliform (counts/100ml)	Flow (cfs)	Existing Load (counts/day)	Existing Load (counts/30days)
5/8/02 11:00	360	13.45	1.19E+11	2.95E+12
5/14/02 10:45	270	13.01	8.61E+10	
5/17/02 10:40	1900	10.32	4.80E+11	
5/21/02 10:15	125	5.18	1.59E+10	
5/23/02 10:45	260	3.44	2.19E+10	
6/4/02 10:10	104	6.91	1.76E+10	

Table 8. Existing Load
Summer 2003

Date and Time	Fecal Coliform (counts/100ml)	Flow (cfs)	Existing Load (counts/day)	Existing Load (counts/30days)
9/11/03 11:00	100	1.95	4.78E+09	8.31E+11
9/9/03 11:00	175	1.71	7.33E+09	
9/15/03 11:45	295	1.56	1.13E+10	
9/17/03 11:30	155	1.46	5.54E+09	
9/19/03 11:30	119	1.34	3.91E+09	
9/23/03 11:00	1500	5.86	2.15E+11	

ALLOCATION

The allocation for this TMDL includes a wasteload allocation (WLA) for point sources, a load allocation (LA) for nonpoint sources, and a margin of safety (MOS).

5.1 Wasteload Allocations

There are no point sources currently within the Bearman Creek Watershed.

5.2 Load Allocations

The load allocation for segment MS202E is calculated using the water quality criteria and the estimated critical flow. The load allocation is assumed to represent nonpoint sources as described in section 3.2. In calculating the LA component, the total TMDL for the water body is reduced by a 10% MOS. For this TMDL, the summer load is based on a fecal coliform concentration for 30 days determined by the integral of the theoretical maximum allowable load curve and the average summer flow of 4 cfs. The resulting summer LA is estimated to be 6.54E+11 counts/30 days. The resulting winter LA is estimated to be 2.03E+12 counts/30 days using the average winter flow of 13 cfs.

<u>Summer</u>

LA = 0.9*7129.4(30 days*counts/100ml)* 4 (cfs) * 2.45E+07[(100ml*s)/(ft^3 *30 days*30 days)] – 0(counts for 30 days)
LA = 6.54E+11 (counts for 30 days)

<u>Winter</u>

LA = 0.9*7129.4 (30 days*counts/100ml)* 13(cfs) * 2.45E+07[(100ml*s)/(ft^3 *30 days*30 days)] – 0(counts for 30 days)
LA = 2.03E+12 (counts for 30 days)

5.3 Incorporation of a Margin of Safety (MOS)

The two types of MOS development are to implicitly incorporate the MOS using conservative assumptions or to explicitly specify a portion of the total TMDL as the MOS. For segment MS202E, reducing the TMDL by 10% explicitly specifies the MOS. Assuming the average summer flow, the resulting load attributed to the MOS for the critical condition of summer is 7.27E+10 counts/30 days.

<u>Summer</u>

MOS = 0.1*7129.4(30 days*counts/100ml)* 4 (cfs) * 2.45E+07[(100ml*s)/(ft^3*30 days*30 days)]
MOS = 7.27E+10 (counts for 30 days)

Winter

MOS = 0.1*7129.4 (30 days*counts/100ml)* 13(cfs) * 2.45E+07[(100ml*s)/(ft^3*30 days*30 days)]
MOS = 2.25E+11 (counts for 30 days)

5.4 Calculation of the TMDL

The TMDL for segment MS202E is calculated based on the following equation:

TMDL = WLA + LA + MOS

where WLA is the Waste Load Allocation, LA is the Load Allocation, and MOS is the Margin of Safety.

WLA = NPDES Permitted Facilities

LA = Surface Runoff + Other Direct Inputs

MOS = 10% explicit

The summer TMDL for segment MS202E was calculated based on the average summer flow of the watershed, and a fecal coliform concentration for 30 days determined by the integral of the theoretical maximum allowable load curve. The fecal coliform percent reductions calculated for the two violating summer seasons are 75% and 13%. The resulting summer percent reduction of fecal coliform to segment MS202E is the maximum of 75% for the summer of 2002. The winter TMDL was calculated based on the average winter flow of the watershed, and a fecal coliform concentration for 30 days determined by the integral of the theoretical maximum allowable load curve.

Summer

TMDL = 7129.4(30 days*counts/100ml)* 4 (cfs) * 2.45E+07[(100ml*s)/(ft^3*30 days*30 days)]
TMDL = 7.27E+11 (counts for 30 days)

Winter

TMDL = 7129.4 (30 days*counts/100ml)* 13(cfs) * 2.45E+07[(100ml*s)/(ft^3*30 days*30 days)]
TMDL = 2.25E+12 (counts for 30 days)

Table 10. TMDL Summary for Segment MS202E (counts/30 days)

	Summer	Winter
WLA	0.00	0.00
LA	6.54E+11	2.03E+12
MOS	7.27E+10	2.25E+11
TMDL = WLA + LA +MOS	**7.27E+11**	**2.25E+12**

5.5 Seasonality

For many streams in the state, fecal coliform limits vary according to the seasons. This stream is designated for the use of secondary contact. For this use, the fecal coliform standard is seasonal. The criteria for the most critical season, which is the summer for Bearman Creek, was used as the target for this TMDL.

MDEQ used the average summer flow for calculating the summer TMDL and the average winter flow for calculating the winter TMDL; therefore, the season differences are incorporated in the seasonal average flow values.

5.6 Reasonable Assurance

This component of TMDL development does not apply to this TMDL Report. There is no WLA reduction request based on promised LA components and reductions. This TMDL will recommend that all point sources discharge treated and disinfected effluent that will be below the 200 colony counts per 100ml target at the end of their discharge pipe.

CONCLUSION

The TMDL will not impact future NPDES Permits as long as the effluent is disinfected to meet water quality standards for fecal coliform. Education projects that teach best management practices should be used as a tool for reducing nonpoint source contributions. These projects may be funded by CWA Section 319 Nonpoint Source (NPS) Grants.

6.1 Future Monitoring

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 resources for water quality monitoring will be focused on one of the basin groups. During the next monitoring phase in the North Independent Streams Basin, Bearman Creek will receive additional monitoring to identify any change in water quality. MDEQ produced guidance for future Section 319 project funding will encourage NPS restoration projects that attempt to address TMDL related issues within Section 303(d)/TMDL watersheds in Mississippi.

6.2 Public Participation

This TMDL will be published for a 30-day public notice. During this time, the public will be notified by publication in the statewide newspaper and a newspaper in the area of the watershed. The public will be given an opportunity to review the TMDL and submit comments. MDEQ also distributes all TMDLs prior to the beginning of the public notice to those members of the public who have requested to be included on a TMDL email list. Anyone wishing to be included on the TMDL email list should contact Greg Jackson at (601) 961-5098 or Greg_Jackson@deq.state.ms.us. All written comments should also be sent to Greg Jackson. 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 meeting. All written comments received during the public notice period and at any public meeting become a part of the record of this TMDL. All comments will be considered in the ultimate completion of this TMDL for submission of this TMDL to EPA Region 4 for final approval.

DEFINITIONS

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 natural body of water to receive wastewaters or toxic materials without deleterious effects and without damage to aquatic life or humans who use the water.

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.

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.

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

Daily discharge: the discharge of a pollutant measured during a 24-hour period that reasonably represents the 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 discharge is calculated as the average measurement of the pollutant over the day.

Designated Uses: (1) those uses specified in the water quality standards for each water body or segment whether or not they are being attained. (2) those water uses identified in state water quality standards which must be achieved and maintained as required under the Clean Water Act. Uses can include public water supply, recreation, etc.

Discharge monitoring report (DMR): the EPA uniform national form, including any subsequent additions, revisions, or modifications for the reporting of self-monitoring results by permittees.

Effluent: wastewater – treated or untreated – that flows out of a treatment plant or industrial outfall. Generally refers to wastes discharged into surface waters.

Effluent limitation: (1) any restriction established by a State or the Administrator on quantities, rates, and concentrations of chemical, physical, biological, and other constituents which are discharged from point sources into navigable waters, the waters of the contiguous zone, or the ocean, including schedules of compliance. (2) restrictions established by a State or EPA on quantities, rates, and concentrations in wastewater discharges.

Effluent standard: any effluent standard or limitation, which may include a prohibition of any discharge, established or proposed to be established for any toxic pollutant under section 307(a) of the Act.

Fecal Coliform Bacteria: (1) those organisms associated with the intestines of warm-blooded animals that are commonly used to indicate the presence of fecal material and the potential presence of organisms capable of causing human disease. (2) bacteria found in the intestinal tracts of mammals. Their presence in water or sludge is an indicator of pollution and possible contamination by pathogens.

Geometric mean: the *n*th root of the production of n factors. A 30-day geometric mean is the 30^{th} root of the product of 30 numbers.

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 that is attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished.

Loading: the introduction of waste into a waste management unit but not necessarily to complete capacity.

Mass Balance: a concept based on a fundamental law of physical science (conservation of mass) which says that matter can not be created or destroyed. It is used to calculate all input and output streams of a given substance in a system.

Model: a quantitative or mathematical representation or computer simulation which attempts to describe the characteristics or relationships of physical events.

National pollutant discharge elimination system (NPDES): the national program for issuing, modifying, revoking and reissuing, terminating, monitoring and enforcing permits, and imposing and enforcing pretreatment requirements, under section 307, 402, 318, and 405 of the Clean Water Act.

Nonpoint Source: the pollution sources which generally are not controlled by establishing effluent limitations under section 301, 302, and 402 of the Clean Water Act. Nonpoint source pollutants are not traceable to a discrete identifiable origin, but generally result from land runoff, precipitation, drainage, or seepage.

Outfall: the point where an effluent is discharges into receiving waters

Point Source: a stationery location or fixed facility from which pollutants are discharges or emitted. Also, any single identifiable source of pollution, e.g., a pipe, ditch, ship, ore pit, factory smokestack.

Pollution: generally, the presence of matter or energy whose nature, location or quanitity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, and radiological integrity of water.

Publicly Owned Treatment Works (POTW): the treatment works treating domestic sewage that is owned by a municipality or State.

Regression: a relationship of y and x in a finction of y = f(x), where: y is the expected value of an independent random variable x. The parameters in the function f(x) are determined by the method of least squares. When f(x) is a linear function of x, the term linear regression is used.

Regression Coefficient: a quantity that describes the slope and intercept of a regression line.

Scientific Notation (Exponential Notation): mathematical method in which very large numbers or very small numbers are expressed in a more concise form. The notation is based on powers of ten. Numbers in scientific notation are expressed as the following: *4.16 x 10^(+b)* and *4.16 x 10^(-b) [same as 4.16E4 or4.16E-4]*. In this case, *b* is always a positive, real number. The *10^(+b)* tells us that the decimal point is *b* places to the right of where it is shown. The *10^(-b)* tells us that the decimal point is *b* places to the left of where it is shown.
For example: $2.7X10^{4}$ = 2.7E+4 =27000 and $2.7X10^{-4}$ = 2.7E-4=0.00027.

Sigma (Σ): shorthand way to express taking the sum of a series of numbers. For example, the sum or total of three amounts 24, 123, 16, ($\mathbf{d_1}$, $\mathbf{d_2}$, $\mathbf{d_3}$) respectively could be shown as:

$$\sum_{i=1}^{3} d_i = d_1+d_2+d_3 = 24 + 123 + 16 = 163$$

Total Maximum Daily Load or TMDL: (1) the calculated maximum permissible pollutant loading introduced to a water body such that any additional loading will produce a violation of water quality standards. (2) the sum of the individual waste load allocations and load allocations. A margin of safety is included with the two types of allocations so that any additional loading, regardless of source, would not produce a violation of water quality standards.

Waste: (1) useless, unwanted or discarded material resulting form (agricultural, commercial, community and industrial) activities. Wastes include solids, liquids, and gases. (2) any liquid resulting from industrial, commercial, mining, or agricultural operations, or from community activities that is discarded or is being accumulated, stored, or physically, chemically, or biologically treated prior to being discarded or recycled.

Wasteload allocation (WLA): (1) the portion of a receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality based effluent limitation. (2) the portion of a receiving water's total maximum daily load that is allocated to one of its existing or future point source of pollution. (3) the maximum load of pollutants each discharger of waste is allowed to release into a particulat waterway. Discharge limits are usually required for each specific water quality criterion being, or expected to be, violated. The portion of a stream's total assimilative capacity assigned to an individual discharge.

Water Quality Standards: State-adopted and EPA-approved regulations mandated by the Clean Water Act and specified in 40 CFR 131 that describe the designated uses of a water body, the numeric and narrative water quality criteria designed to protect those uses, and an antidegredation statement to protect existing levels of water quality. Standards are designed to safeguard the public health and welfare, enhance the quality of water and serve the purposes of the Clean Water Act.

Water quality criteria: numeric water quality values and narrative statements which are derived to protect designated uses. Numeric criteria are scientifically-derived ambient concentrations developed by EPA or States for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal. Ambient waters that meet applicable water quality criteria are considered to support their designated 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: (1) the land area that drains (contributes runoff) into a stream. (2) the land area that drains into a stream; the watershed for a major river may encompass a number of smaller watersheds that ultimately combine at a common delivery point.

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

CWA .... Clean Water Act

DMR...Discharge Monitoring Report

EPA ....Environmental Protection Agency

GIS ....Geographic Information System

HUC ....Hydrologic Unit Code

LA ....Load Allocation

MARIS ....State of Mississippi Automated Information System

MDEQ ....Mississippi Department of Environmental Quality

MOS ....Margin of Safety

NRCS .... National Resource Conservation Service

NPDES ....National Pollution Discharge Elimination System

NPSM..Nonpoint Source Model

RF3..Reach File 3

USACOE...United States Army Corps of Engineers

USGS...United States Geological Survey

WLA...Waste Load Allocation

REFERENCES

Horner, 1992. Water Quality Criteria/Pollutant Loading Estimation/Treatment Effectiveness Estimation. In R.W. Beck and Associates. Covington Master Drainage Plan. King County Surface Water Management Division, Seattle, WA.

Horsley & Whitten, Inc. 1996. Identification and Evaluation of Nutrient Bacterial Loadings to Maquoit Bay, Brunswick, and Freeport, Maine. Casco Bay Estuary Project.

Lee, C.C.. 1998. *Environmental Engineering Dictionary*. 3rd Edition. Government Institutes, Inc., Rockville, Maryland.

Metccalf and Eddy. 1991. *Wastewater Engineering: Treatment, Disposal, Reuse*. 3rd Edition. McGraw-Hill, Inc., New York.

MDEQ. 2001. *Wastewater Regulations for National Pollutant Discharge Elimination System (NPDES) Permits, Underground Injection Control (UIC) Permits, State Permits, Water Quality Based Effluent Limitations and Water Quality Certification.* Office of Pollution Control.

MDEQ. 2002. *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters*. Office of Pollution Control.

MDEQ. 2002. *Mississippi List of Water Bodies, Pursuant to Section 303(d) of the Clean Water Act*. Office of Pollution Control.

MDEQ. 2000. *Mississippi 2000 Water Quality Assessment, Pursuant to Section 305(b) of the Clean Water Act. Pascagoula River Supplement*. Office of Pollution Control.

NCSU, 1994. *Livestock Manure Production and Characterization in North Carolina*, North Carolina Cooperative Extension Service, North Carolina State University (NCSU) College of Agriculture and Life Sciences, Raleigh, January 1994.

Sheely. 2002. *Load Duration Curves: Development and Application to Data Analysis for Streams in the Yazoo River Basin, MS*. Special Project, Summer 2002, Jackson Engineering Graduate Program.

USDA. 2004. *2002 Census of Agriculture*. U.S. Department of Agriculture, National Agricultural Statistics Service, Washington, D.C.

USEPA. 1998. *Better Assessment Science Integrating Point and Nonpoint Sources, BASINS, Version 2.0 User's Manual*. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.