TOTAL MAXIMUM DAILY LOAD (TMDL)

For

Fecal Coliform

In

Cypress Creek
Big Creek
Two Segments of the Loosahatchie River
Located In The
Loosahatchie Watershed (HUC 08010209)
Shelby, and Fayette Counties, Tennessee

Prepared by:

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BMP	Best Management Practices
CFS	Cubic Feet per Second
DEM	Digital Elevation Model
DMR	Discharge Monitoring Report
DWPC	Division of Water Pollution Control
EPA	Environmental Protection Agency
GIS	Geographic Information System
HSPF	Hydrological Simulation Program - FORTRAN
HUC	Hydrologic Unit Code
LA	Load Allocation
MGD	Million Gallons per Day
MOS	Margin of Safety
MRLC	Multi-Resolution Land Characteristic
NPDES	National Pollutant Discharge Elimination System
NPSM	Non-point Source Model
NRCS	Natural Resources Conservation Service
Rf3	Reach File 3
RM	River Mile
STORET	STORage RETrieval database
TDEC	Tennessee Department of Environment & Conservation
TMDL	Total Maximum Daily Load
TWRA	Tennessee Wildlife Resources Agency
USGS	United States Geological Survey
WCS	Watershed Characterization System
WLA	Waste Load Allocation

SUMMARY SHEET
Total Maximum Daily Load (TMDL)
Loosahatchie River - At Confluence of Mississippi River

1. 303(d) Listed Waterbody Information
State: Tennessee
County: Shelby

Major River Basin: Memphis Area Basin
Watershed: Loosahatchie River (HUC08010209)

Waterbody Name: Loosahatchie River
Waterbody ID: TN08010209001
Location: Mouth to confluence with Big Creek
Impacted Stream Length: 6.3 miles Partially Supporting; 29.6 miles Not Supporting
Watershed Area: 742 square miles
Tributary to: Mississippi River

Constituent(s) of Concern: Fecal Coliform Bacteria

Designated Uses: Fish and Aquatic Life, Recreation, Livestock Watering & Wildlife, Irrigation, and Navigation (main stem only)

Applicable Water Quality Standard for Recreation (most stringent standard):
The concentration of the fecal coliform group shall not exceed 200 per 100 ml as a geometric mean based on a minimum of 10 samples collected from a given sampling site over a period of not more than 30 days with individual samples being collected at intervals of not less than 12 hours. In addition, the concentration of the fecal coliform group in any individual sample shall not exceed 1,000 per 100 ml.

2. TMDL Development
Analysis/Modeling:
The Non-Point Source Model (NPSM) was used to develop this TMDL. An hourly time step was used to simulate hydrologic and water quality conditions with results expressed as daily averages.

Critical Conditions:
A simulation period of 10 years was used to assess the water quality standards for this TMDL representing a range of hydrologic and meteorological conditions.

Seasonal Variation:
A simulation period of 10 years was used to assess the water quality standards for this TMDL. This period includes seasonal variations.

3. Allocation Watershed/Stream Reach:

Wasteload Allocations (WLA): 1.151 x 10^{12} counts/30 days
Note: All future permitted discharges shall meet the water quality standard for fecal coliform bacteria of 200-counts/100 ml.

Load Allocation (LA): 8.49 x 10^{13} counts/30 days

Margin of Safety (MOS): 20 counts/100 ml; conservative modeling assumptions

Total Maximum Daily Load (TMDL): 8.61 x 10^{13} counts/30 days, 180 counts/100 ml

SUMMARY SHEET
Total Maximum Daily Load (TMDL)
Loosahatchie River – At Confluence of Big Creek

1. 303(d) Listed Waterbody Information

State: Tennessee
County: Shelby

Major River Basin: Memphis Area Basin
Watershed: Loosahatchie River (HUC 08010209)

Waterbody Name: Loosahatchie River
Waterbody ID: TN08010209002
Location: Confluence of Big Creek to Cypress Creek
Impacted Stream Length: 48.9 miles Partially Supporting; 79.6 miles Not Supporting
Watershed Area: 571 square miles
Tributary to: Mississippi River

Constituent(s) of Concern: Fecal Coliform Bacteria

Designated Uses: Fish and Aquatic Life, Recreation, Livestock Watering & Wildlife, Irrigation, and Navigation (main stem only)

Applicable Water Quality Standard for Recreation (most stringent standard):

The concentration of the fecal coliform group shall not exceed 200 per 100 ml as a geometric mean based on a minimum of 10 samples collected from a given sampling site over a period of not more than 30 days with individual samples being collected at intervals of not less than 12 hours. In addition, the concentration of the fecal coliform group in any individual sample shall not exceed 1,000 per 100 ml.

2. TMDL Development

Analysis/Modeling:

The Non-Point Source Model (NPSM) was used to develop this TMDL. An hourly time step was used to simulate hydrologic and water quality conditions with results expressed as daily averages.

Critical Conditions:

A simulation period of 10 years was used to assess the water quality standards for this TMDL representing a range of hydrologic and meteorological conditions.

Seasonal Variation:

A simulation period of 10 years was used to assess the water quality standards for this TMDL. This period includes seasonal variations.

3. Allocation Watershed/Stream Reach:

Wasteload Allocations (WLA): 2.93×10^{11} counts/30 days

Note: All future permitted discharges shall meet the water quality standard for fecal coliform bacteria of 200/100 ml.

Load Allocation (LA): 2.38×10^{13} counts/30 days

Margin of Safety (MOS): 20 counts/100 ml; conservative modeling assumptions

Total Maximum Daily Load (TMDL): 2.41×10^{13} counts/30 days, 180 counts/100 ml

SUMMARY SHEET
Total Maximum Daily Load (TMDL)
Big Creek – At Confluence of Loosahatchie River

1. **303(d) Listed Waterbody Information**
   State: Tennessee
   County: Shelby

   Major River Basin: Memphis Area Basin
   Watershed: Loosahatchie River (HUC 08010209)

   Waterbody Name: Big Creek
   Waterbody ID: TN08010209021
   Location: From mouth to Big Crooked Creek
   Impacted Stream Length: 117.5 miles Partially Supporting
   Watershed Area: 159 square miles
   Tributary to: Loosahatchie River

   Constituent(s) of Concern: Fecal Coliform Bacteria

   Designated Uses: Fish and Aquatic Life, Recreation, Livestock Watering & Wildlife, Irrigation, and Navigation (main stem only)

   Applicable Water Quality Standard for Recreation (most stringent standard):
   The concentration of the fecal coliform group shall not exceed 200 per 100 ml as a geometric mean based on a minimum of 10 samples collected from a given sampling site over a period of not more than 30 days with individual samples being collected at intervals of not less than 12 hours. In addition, the concentration of the fecal coliform group in any individual sample shall not exceed 1,000 per 100 ml.

2. **TMDL Development**
   Analysis/Modeling:
   The Non-Point Source Model (NPSM) was used to develop this TMDL. An hourly time step was used to simulate hydrologic and water quality conditions with results expressed as daily averages.

   Critical Conditions:
   A simulation period of 10 years was used to assess the water quality standards for this TMDL representing a range of hydrologic and meteorological conditions.

   Seasonal Variation:
   A simulation period of 10 years was used to assess the water quality standards for this TMDL. This period includes seasonal variations.

3. **Allocation Watershed/Stream Reach:**

   Wasteload Allocations (WLA): 8.43×10^{11} counts/30 days
   Note: All future permitted discharges shall meet the water quality standard for fecal coliform bacteria of 200/100 ml.

   Load Allocation (LA): 2.10×10^{13} counts/30 days

   Margin of Safety (MOS): 20 counts/100 ml; conservative modeling assumptions

   Total Maximum Daily Load (TMDL): 2.18×10^{13} counts/30 days, 180 counts/100 ml

SUMMARY SHEET
Total Maximum Daily Load (TMDL)
Cypress Creek

1. **303(d) Listed Waterbody Information**
   State: Tennessee
   County: Fayette and Shelby

   Major River Basin: Memphis Area Basin
   Watershed: Loosahatchie River (HUC 08010209)

   Waterbody Name: Cypress Creek
   Waterbody ID: TN08010209003
   Location: From mouth to headwaters
   Impacted Stream Length: 128.7 miles Partially Supporting
   Watershed Area: 66 square miles
   Tributary to: Loosahatchie River

   Constituent(s) of Concern: Fecal Coliform Bacteria

   Designated Uses: Fish and Aquatic Life, Recreation, Livestock Watering & Wildlife, and Irrigation

   Applicable Water Quality Standard for Recreation (most stringent standard):
   The concentration of the fecal coliform group shall not exceed 200 per 100 ml as a geometric mean based on a minimum of 10 samples collected from a given sampling site over a period of not more than 30 days with individual samples being collected at intervals of not less than 12 hours. In addition, the concentration of the fecal coliform group in any individual sample shall not exceed 1,000 per 100 ml.

2. **TMDL Development**
   Analysis/Modeling:
   The Non-Point Source Model (NPSM) was used to develop this TMDL. An hourly time step was used to simulate hydrologic and water quality conditions with results expressed as daily averages.

   Critical Conditions:
   A simulation period of 10 years was used to assess the water quality standards for this TMDL representing a range of hydrologic and meteorological conditions.

   Seasonal Variation:
   A simulation period of 10 years was used to assess the water quality standards for this TMDL. This period includes seasonal variations.

3. **Allocation Watershed/Stream Reach:**

   Wasteload Allocations (WLA): 6.59 x 10^9 counts/30 days
   Note: All future permitted discharges shall meet the water quality standard for fecal coliform bacteria of 200/100 ml.

   Load Allocation (LA): 2.62 x 10^{12} counts/30 days

   Margin of Safety (MOS): 20 counts/100 ml; conservative modeling assumptions

   Total Maximum Daily Load (TMDL): 2.63 x 10^{12} counts/30 day, 180 counts/100 ml

FECAL COLIFORM TOTAL MAXIMUM DAILY LOAD (TMDL) LOOSAHATCHIE WATERSHED (HUC 08010209)

Loosahatchie River (TN08010209001)
Loosahatchie River (TN08010209002)
Big Creek (TN08010209021)
Cypress Creek (TN08010209003)

1.0 INTRODUCTION

Section 303(d) of the Clean Water Act requires each state to list those waters within its boundaries for which technology based effluent limitations are not stringent enough to protect any water quality standard applicable to such waters. Listed waters are prioritized with respect to designated use classifications and the severity of pollution. In accordance with this prioritization, states are required to develop Total Maximum Daily Loads (TMDLs) for those water bodies that are not meeting designated uses. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions, so that states can establish water quality based controls to reduce pollution from both point and non-point sources and restore and maintain the quality of their water resources (USEPA, 1991).

2.0 WATERSHED DESCRIPTION

The Loosahatchie River watershed (HUC 08010209) is located in western Tennessee (Figure 1) and primarily falls within the Level III Mississippi Valley Loess Plains (74) ecoregion. The majority of the watershed is located in the Level IV Loess Plains subecoregion (74b). Irregular plains, level to gently rolling, with wide, flat bottomlands and floodplains, characterize the physiography of the region. Streams in this subecoregion are generally low gradient and murky with silt and sand bottoms, and most have been channelized (USEPA, 1997).

The Loosahatchie watershed drains an area of approximately 742 square miles. Big Creek and Cypress Creek are tributaries of the Loosahatchie River and have approximate drainage areas of 159 and 66 square miles respectively. Watershed land use distribution is based on the Multi-Resolution Land Characteristic (MRLC) databases derived from Landsat Thematic Mapper digital images from the period 1990-1993. Land use is summarized in Table 1 and shown in Figure 2. The designated use classifications for surface waters in the Loosahatchie watershed include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation.

Figure 1 Location of the Loosahatchie Watershed

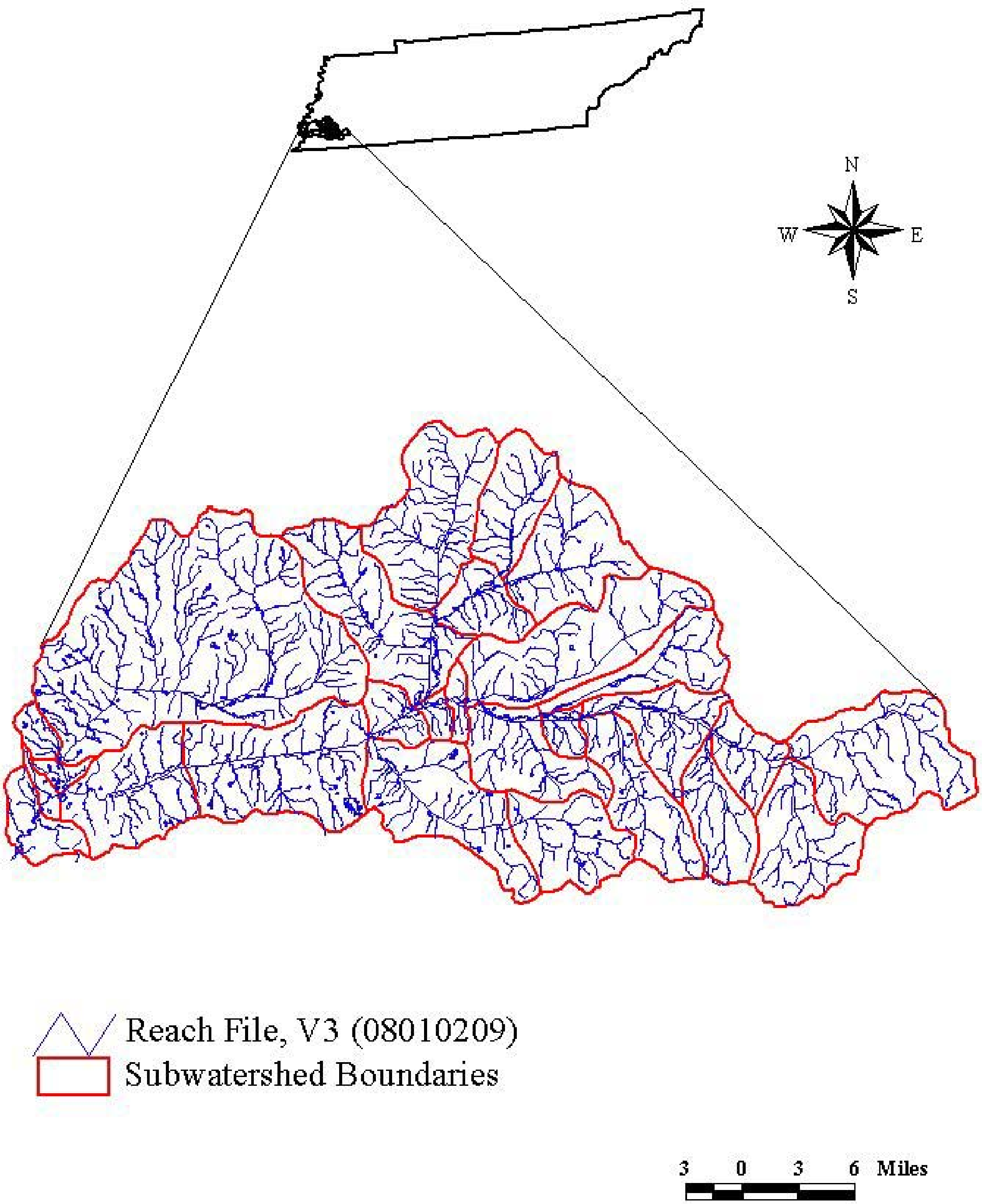
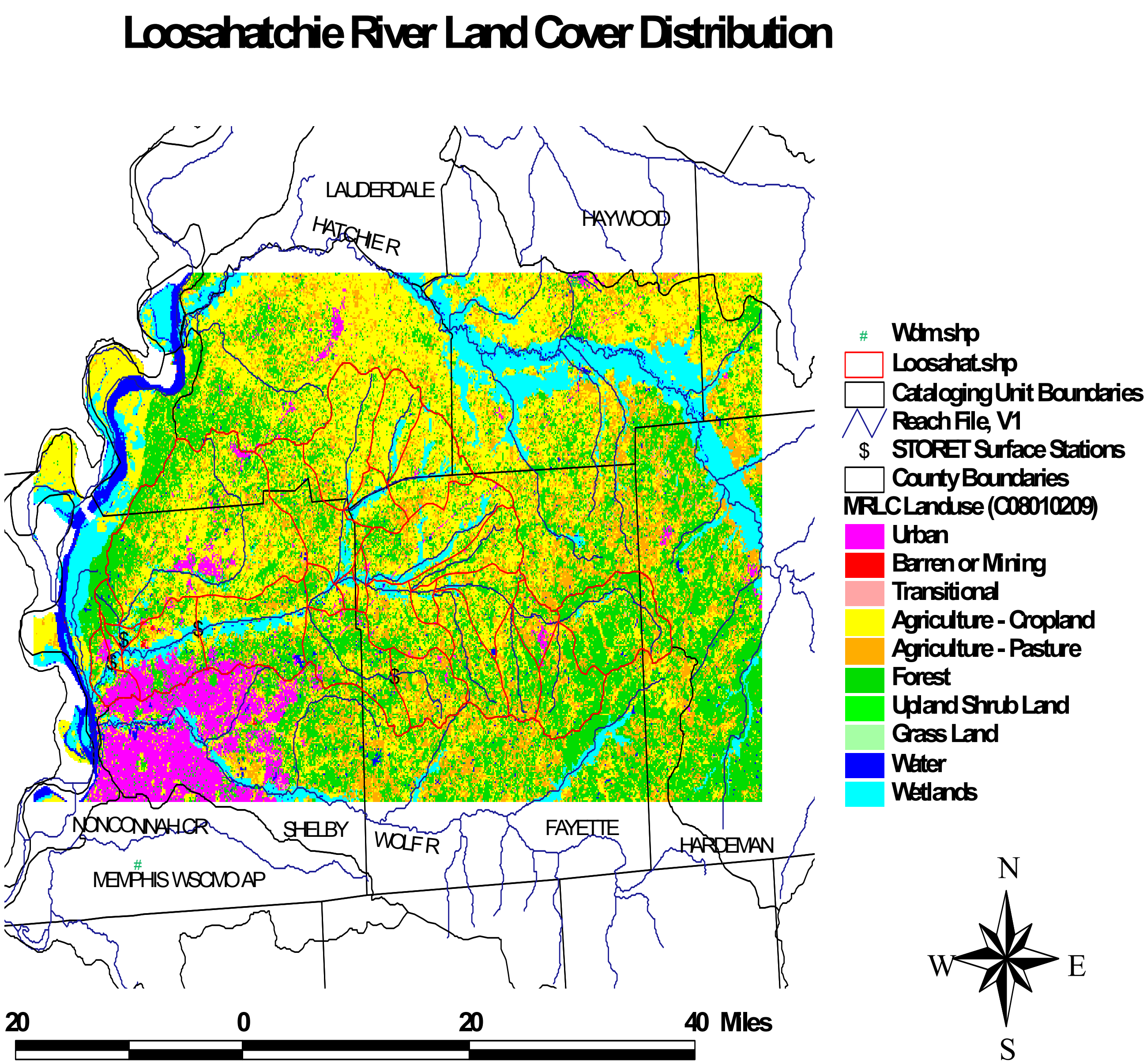


Table 1 Land Use Distribution in the Loosahatchie Watershed

Land Use	Loosahatchie R (mouth to headwaters)		Loosahatchie R (Big Creek to headwaters)		Big Creek		Cypress Creek	
	Area [acres]	Area [%]	Area [acres]	Area [%]	Area [acres]	Area [%]	Area [acres]	Area [%]
Bare Rock/Sand/Clay	10	0	0	0	10	0	0	0
Deciduous Forest	86765	18.3	66340	18.2	19159	19.2	7340	17.7
Evergreen Forest	8083	1.7	6663	1.8	1388	1.4	1521	3.7
High Intensity Commercial/ Industrial/ Transport.	1769	0.4	1125	0.3	511	0.5	219	0.5
High Intensity Residential	4012	0.8	1965	0.5	1462	1.5	32	0.1
Low Intensity Residential	12035	2.5	7162	2.0	2232	2.2	448	1.1
Mixed Forest	59195	12.5	45762	12.5	12643	12.7	9042	21.8
Open Water	4393	0.9	3366	0.9	846	0.8	523	1.3
Other Grasses Urban/Recreational	1134	0.2	566	0.2	507	0.5	43	0.1
Pasture/Hay	94616	19.9	75879	20.8	17753	17.8	11085	26.7
Quarries/Strip Mines/Gravel Pits	256	0.1	251	0.1	5	0	11	0
Row Crops	175518	37.0	133177	36.5	40972	41.0	11187	27.0
Transitional	366	0.1	275	0.1	83	0.1	12	0
Woody Wetlands	26382	5.6	22706	6.2	2318	2.3	9	0
Total	474534	100	365241	100	99887	100	41472	100

Figure 2 Land Use Distribution in the Loosahatchie Watershed



3.0 PROBLEM DEFINITION

EPA Region IV approved Tennessee's final 1998 303(d) list on September 17, 1998. The list identified the waterbodies shown in Table 2 as not fully supporting designated use classifications due, in part, to pathogens. The fecal coliform group is an indicator of the presence of pathogens in a stream. The objective of this study is to develop fecal coliform TMDLs for 303(d) listed waterbodies in the Loosahatchie watershed.

Table 2 Waterbodies Impacted for Pathogens

Waterbody ID	Impacted Waterbody	Partially Supporting Desig. Uses	Not Supporting Desig. Uses
		[mi.]	[mi.]
TN08010209001	Loosahatchie River – mouth to Big Creek (Todd Branch is partially supporting)	6.3	29.6
TN08010209002	Loosahatchie River – Big Cr. to Cypress Cr. (Oliver Creek is partially supporting)	48.9	79.6
TN08010209021	Big Creek – mouth to Big Crooked Cr	117.5	—
TN08010209003	Cypress Creek	128.7	—

4.0 TARGET IDENTIFICATION

Of the use classifications with numeric criteria for fecal coliform bacteria, the recreation use classification is the most stringent and will be used as the target level for TMDL development. The fecal coliform water quality criteria for protection of the recreation use classification, as established by *State of Tennessee Water Quality Standards, Chapter 1200-4-3 General Water Quality Criteria, October, 1999*. Section 1200-4-3-.03 (4) (f) states, in part, that the concentration of the fecal coliform group shall not exceed 200 per 100 ml as a geometric mean based on a minimum of 10 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. In addition, the concentration of the fecal coliform group in any individual sample shall not exceed 1,000 per 100 ml. The geometric mean standard is the target value for the TMDLs.

The geometric mean standard is the primary target value for the TMDLs since the geometric mean is a better representation of average conditions in the stream. In the TMDL, simulated concentrations are expressed in terms of a 10-year geometric mean plot. Critical conditions are determined from this ten year record. A ten year graph with the proposed reductions is used to show compliance with the geometric mean standard and to illustrate standards have been met for all seasons. To address the uncertainty in the model, a margin of safety of 20 counts/100 ml is included in the TMDLs.

The instantaneous standard is difficult to model and insufficient data are available to calibrate the water quality model for the instantaneous maximum. By meeting the geometric mean standard, compliance with the instantaneous standard is expected to be met during most flow regimes.

5.0 WATER QUALITY ASSESSMENT AND DEVIATION FROM TARGET

With respect to fecal coliform, the existing water quality of 303(d) listed streams in the Loosahatchie River watershed can be characterized by data collected since 1991 at following monitoring sites:

- STORET Station No. 001800 – Loosahatchie River at Watkins Road Crossing
- STORET Station LOOSAHATCH017.2 – Loosahatchie River at Singleton Parkway
- STORET Station No. 000300 – Big Creek at Fite Rd.
- STORET Station No. 001017 – Cypress Creek at Chulahoma Rd.

Although insufficient data were collected to calculate 30-day geometric mean values, individual samples exceeded 1,000-counts/100 ml maximum at all sites (see Table 3). Therefore, two segments of Loosahatchie River, Big Creek, and Cypress Creek were listed as partially supporting designated uses and were scheduled for TMDL evaluation. Two segments of the Loosahatchie River were also listed as not supporting designated uses. Due to limited precipitation data available for use in the model, only data collected through December 1998 were used in the water quality calibration.

6.0 SOURCE ASSESSMENT

An important part of the TMDL analysis is the identification of source categories, source subcategories, or individual sources of fecal coliform bacteria in the watershed and the amount of pollutant loading contributed by each of these sources. Sources are broadly classified as either point or non-point sources.

A point source can be defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. Point source discharges of industrial wastewater and treated sanitary wastewater must be authorized by National Pollutant Discharge Elimination System (NPDES) permits. NPDES permitted facilities discharging treated sanitary wastewater are considered primary point sources of fecal coliform bacteria.

Non-point sources of fecal coliform bacteria are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. These sources generally, but not always, involve accumulation of fecal coliform bacteria on land surfaces and washoff as a result of storm events. Typical non-point sources of fecal coliform bacteria include:

- Wildlife
- Land application of agricultural manure
- Livestock grazing
- Leaking septic systems
- Urban development (including leaking sewer collection lines)
- Animals having access to streams

Table 3 Water Quality Monitoring Data

Sample Date	Monitoring Site			
	Loosahatchie River at Station 001800	Loosahatchie River at Station LOOSAHATCH017.2	Big Creek	Cypress Creek
	[#/100 ml]	[#/100 ml]	[#/100 ml]	[#/100 ml]
4/30/91				760
8/7/91		850		
12/4/91		2000		
3/17/92		160		
6/10/92		4800		
7/8/92			450	
8/4/92		2600		
9/10/92		180		
12/16/92		2400		
3/3/93		1700		
6/2/93		800		
7/20/93			440	
9/21/93	130	210		
12/9/93		1100		
6/9/94	1000	1100		
9/22/94	100	20		
12/22/94	4900	13000		
1/11/95				21000
3/2/95	48	6		
5/23/95	200	300		
7/19/95				5100
8/10/95			3100	
9/27/95	810	30		
12/20/95	2200	800		
1/9/96				620
1/23/96			1200	
2/28/96	9000	8500		
6/26/96	40			
6/24/98	20	250	44	

6.1 Point Sources

There are a number of point sources located in the drainage areas of the 303(d) listed stream segments that possess NPDES permits for discharges of treated sanitary wastewater. The design flow and fecal coliform loading for these facilities are summarized in Table 4. The loading rates are based on the facility design flow and the permit concentration of 200 counts/100 ml for fecal coliform bacteria.

Table 4 NPDES Facilities Discharging Fecal Coliform in the Loosahatchie Watershed

		NPDES Permit	
Facility Name	NPDES Permit No.	Design Flow [MGD]	Fecal Coliform Loading [a] [counts/hr]
Arlington Lagoon #1	TN0021351	0.554	1.127×10^8
Bartlett STP #1	TN0066800	2.2	6.92×10^8
Bartlett WWTP #2	TN0068543	0.5	1.57×10^8
Fayette Co. Central School	TN0023779	0.025	5.085×10^6
Galloway Lagoon	TN0062138	0.165	3.356×10^7
Lakeland Wastewater Lagoon	TN0074012	0.5	1.57×10^8
Mason-STP	TN0026620	0.11	2.237×10^7
Memphis Chapel Hill STP	TN0026361	0.045	9.153×10^6
Millington STP	TN0021067	5.8	11.797×10^8
Oakland Lagoon	TN0026573	0.151	3.071×10^7
Pine Lake Cooperative	TN0061433	0.045	9.153×10^6
Pleasant Ridge Trailer Park	TN0067482	0.05	1.017×10^7
Somerville Lagoon	TN0021652	0.895	1.820×10^8

a Loading based on Monthly Average permit limit (200 counts/ 100 ml) at design flow.

6.2 Non-point Source Assessment

6.2.1 Wildlife

Wildlife deposit fecal coliform bacteria with their feces onto land surfaces where it can be transported during storm events to nearby streams. Deer densities for several counties in the Loosahatchie River watershed, provided by the Tennessee Wildlife Resources Agency (TWRA), range from 18 to 32 animals per square mile. Fecal coliform loading due to deer is estimated by EPA to be 5.0×10^8 counts/animal/day.

6.2.2 Agricultural Animals

Agricultural animals are the source of several types of fecal coliform loading to streams in the Loosahatchie River watershed:

- As with wildlife, agricultural livestock grazing on pastureland or forestland deposit fecal coliform bacteria with their feces onto land surfaces where it can be transported during storm events to nearby streams.

- Processed agricultural manure from confined feeding operations is generally collected in lagoons and applied to land surfaces during the months April through October. In the Loosahatchie watershed, manure is applied only to pastureland since chemical fertilizer is used on cropland. Data sources for confined feeding operations are tabulated by county and include the Census of Agriculture (USDA, 1997) and the Natural Resources Conservation Service (NRCS).

- Agricultural livestock and other unconfined animals (i.e., deer and other wildlife) often have direct access to streams that pass through pastures.

Livestock data from the 1997 Census of Agriculture for the two major counties in the Loosahatchie watershed are listed in Table 5. Cattle and swine are the predominate livestock in the watershed. Fecal coliform loading rates for livestock in the watershed are estimated to be: 1.06×10^{11} counts/day/beef cow, 1.24×10^{10} counts/day/hog, 1.04×10^{11} counts/day/dairy cow, 1.38×10^8 counts/day/layer chicken, 1.22×10^{10} counts/day/sheep, and 4.18×10^8 counts/day/horse (NCSU, 1994).

Table 5 Livestock Distribution By County

Livestock	Shelby Co.	Fayette Co.
Cattle	8628	25437
Beef	4980	13421
Dairy	42	965
Swine	335	25667
Poultry (layers)	515	15
Sheep	148	124
Horses	2720	2195

6.2.3 Failing Septic Systems

Some fecal coliform loading in the Loosahatchie watershed can be attributed to failure of septic systems and illicit discharges of raw sewage. Estimates from 1997 county census data of people in selected subwatersheds utilizing septic systems are shown in Table 6. In western Tennessee, EPA estimates that there are approximately 2.5 people per household on septic systems, some of which can be reasonably assumed to be failing.

Table 6 Estimated Number of Septic Systems at Select Locations in the Loosahatchie Watershed

Subwatershed	No. of Septic Systems
Cypress Creek	2380
Big Creek	12,370
Loosahatchie River (for all subwatersheds above confluence with Big Creek, excluding Cypress Cr. segments)	16,893
Loosahatchie River (for subwatersheds between mouth and confluence of Big Creek)	2400

6.2.4 Urban Development

Fecal coliform loading from urban areas is potentially attributable to multiple sources including storm water runoff, leaks and overflows from sanitary sewer systems, illicit discharges of sanitary waste, runoff from improper disposal of waste materials, leaking septic systems, and domestic animals. Urban runoff and storm water processes are considered to be significant contributors to fecal coliform impairment in the two listed segments of the Loosahatchie River.

7.0 ANALYTICAL APPROACH

Establishing the relationship between in-stream water quality and source loading is an important component of TMDL development. It allows the determination of the relative contribution of sources to total pollutant loading and the evaluation of potential changes to water quality resulting from implementation of various management options. This relationship can be developed using a variety of techniques ranging from qualitative assumptions based on scientific principles to numerical computer modeling. In this section, the numerical modeling techniques developed to simulate fecal coliform bacteria fate and transport in the watershed are discussed.

7.1 Model Selection

A dynamic computer model was selected for fecal coliform analysis in order to: a) simulate the time varying nature of fecal coliform bacteria deposition on land surfaces and transport to receiving waters; b) incorporate seasonal effects on the production and fate of fecal coliform bacteria; and c) identify the critical condition for the TMDL analysis. Several computer-based tools were also utilized to generate input data for the model.

The Non-point Source Model (NPSM) is a watershed model capable of simulating non-point source runoff and associated pollutant loadings, account for point source discharges, and performing flow and water quality routing through stream reaches. NPSM is based on the Hydrologic Simulation Program - Fortran (HSPF). In these TMDLs, NPSM was used to simulate point source discharges, simulate the deposition and transport of fecal coliform bacteria from land surfaces, and compute the resulting water quality response. In-stream decay of fecal coliform bacteria reported in Lombardo (1972) ranges from 0.008 1/hr to 0.13 1/hr, with a median value of 0.048 1/hr. In the model, in-stream decay was conservatively estimated using the median value.

In addition to NPSM, the Watershed Characterization System (WCS), a geographic information system (GIS) tool, was used to display, analyze, and compile available information to support water quality model simulations for the Loosahatchie watershed. This information includes land use categories, point source dischargers, soil types and characteristics, population data (human and livestock), and stream characteristics.

Results of the WCS characterization and revised animal counts provided by the NRCS are input to a spreadsheet developed by Tetra Tech, Inc. to estimate NPSM input parameters associated with fecal coliform buildup (loading rates) and washoff from land surfaces. In addition, the spreadsheet can be used to estimate direct sources of fecal coliform loading to water bodies from leaking septic systems and animals having access to streams. Information from the WCS and spreadsheet tools were used as initial input for variables in the NPSM model. Appendix A illustrates how loads are calculated based on animal population and manure application rates.

7.2 Model Set Up

The Loosahatchie watershed was delineated into 27 subwatersheds in order to characterize relative fecal coliform bacteria contributions from significant contributing drainage areas (see Figure 3). Boundaries were constructed so that subwatershed "pour points" coincided, when possible, with water quality monitoring stations or USGS flow gage. Watershed delineation was based on the Reach File 3 (Rf3) stream coverage and Digital Elevation Model (DEM) data. This discretization allows management and load reduction alternatives to be varied by subwatershed.

An important factor influencing model results is the precipitation data contained in the meteorological data file used in the simulation. The pattern and intensity of rainfall affects the build-up and wash-off of fecal coliform bacteria from the land into the streams, as well as the dilution potential of the stream. Weather data from the Memphis meteorological station were used for simulations in all subwatersheds.

7.3 Model Calibration

Calibration of the watershed model included both hydrology and water quality components. The hydrology calibration was performed first and involved adjustment of the model parameters used to represent the hydrologic cycle until acceptable agreement was achieved between simulated flows and historic stream flow data from a USGS stream gaging station in the watershed for the same period of time. Model parameters adjusted include: evapotranspiration, infiltration, upper and lower zone storage, groundwater storage, recession, losses to the deep groundwater system, and interflow discharge. The USGS gage on the Loosahatchie River near Arlington, TN (USGS Station 07030240) was used for flow calibration.

The model was also calibrated for water quality. Appropriate model parameters were adjusted to obtain acceptable agreement between simulated instream fecal coliform concentrations and observed data collected at sampling stations in Loosahatchie River, Big Creek, and Cypress Creek. Results show that the model adequately simulates peaks in fecal coliform bacteria in response to storm events and base concentrations during low flow events.

After calibration was complete, a sensitivity analysis was performed to evaluate the model response to changes in input water quality and flow parameters. The model was considered sensitive to a parameter if a small change resulted in a large change in simulated flow or concentration. The sensitivity of the model to animal to streams is provided in Appendix B.

The details and results of the hydrologic and water quality calibrations are presented in Appendix B.

8.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOAD

The TMDL process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions. A TMDL can be expressed as the sum of all point source loads (Waste Load Allocations), non-point source loads (Load Allocations), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\text{TMDL} = \Sigma \text{ WLAs} + \Sigma \text{ LAs} + \text{MOS}$$

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) states that TMDLs can be expressed in terms of mass per time (e.g. pounds per day), toxicity, or <u>other appropriate measure</u>.

8.1 Critical Conditions

The critical condition for non-point source fecal coliform loading is an extended dry period followed by a rainfall runoff event. During the dry weather period, fecal coliform bacteria builds up on the land surface, and is washed off by rainfall. The critical condition for point source loading occurs during periods of low stream flow when dilution is minimized. Both conditions are simulated in the water quality model.

The ten-year period from January 1, 1989, to December 31, 1998 was used to simulate a continuous 30-day geometric mean concentration to compare to the target. This 10-year period contained a range of hydrological conditions that included both low and high stream flows from which critical conditions were identified and used to derive the TMDL values.

The ten-year simulated geometric mean concentrations for existing conditions are presented in Appendix C. From these figures, critical conditions can be determined. The 30-day critical period in the model is the period preceding the largest simulated violation of the geometric mean standard (EPA, 1991) during average flow conditions. Meeting water quality standards during this period ensures that water quality standards can be achieved throughout the ten-year period. For the listed segments in the Loosahatchie watershed, this violation occurred on July 18, 1998 when the simulated stream flow was 270 cfs (average flow for the period of record at the USGS gage is about 350 cfs). The critical period then, is June 19, 1998 through July 18, 1998.

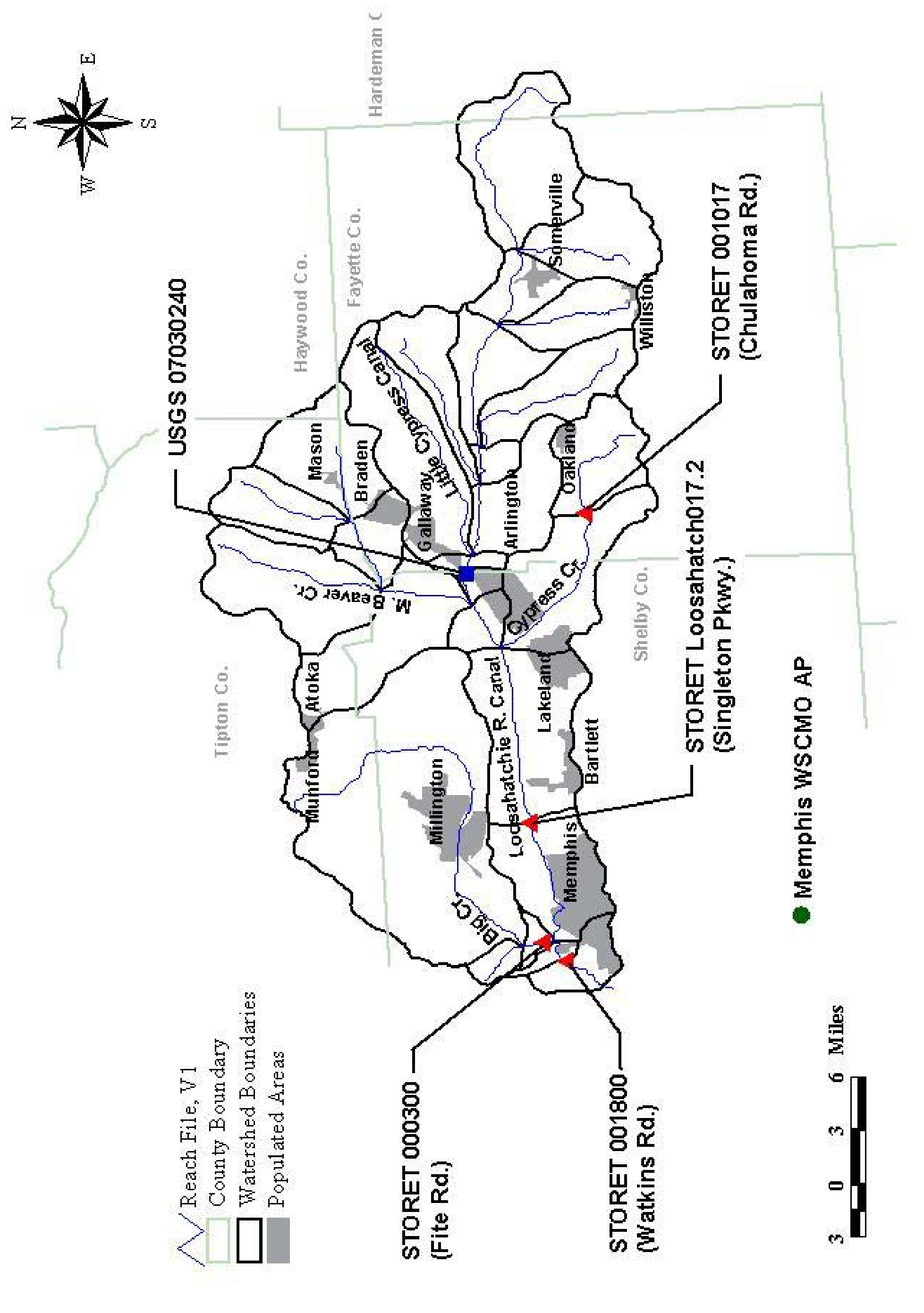


Figure 3 Loosahatchie River Watershed

8.2 Existing Conditions

The existing fecal coliform load for each of the 303(d) listed waterbodies in the Loosahatchie watershed was determined in the following manner:

- The calibrated model, corresponding to the portion of the Loosahatchie watershed that is upstream of the pour point of the listed waterbody segment was run for a time period that included the critical condition (6/19/98 – 7/18/98).
- The daily fecal coliform load indirectly going to surface waters from all land uses was added to the direct daily discharge load of modeled point sources and the result summed for the 30 day critical period. This value represents the existing load.

Model results indicate that non-point sources related to agricultural and urban land uses are the largest sources of fecal coliform bacteria loading in the Loosahatchie watershed. Direct inputs of fecal coliform bacteria from "other sources" (i.e., animal access to streams, illicit discharges of fecal coliform bacteria, failing septic systems, and leaking sewer collection lines) are also shown to have an impact on bacteria loading in the watershed. Reductions in these loading rates reduce the in-stream fecal coliform bacteria levels. Non-point source loading rates and the geometric mean in-stream concentration simulated during the critical period, representing existing conditions in the model are shown in Table 7.

In general, point source loads from NPDES facilities do not significantly contribute to the impairment of the listed stream segments since discharges from these facilities are required to be treated to levels corresponding to instream water quality criteria. Table 4 provides point source loads from NPDES facilities based on facility design flows and permit limits.

Table 7 Non-point Source Loading Rates and In-stream Fecal Coliform Bacteria Concentrations for Existing Conditions

Subwatershed	Runoff from All Lands	Other Direct Sources	In-Stream Fecal Coliform Bacteria Concentration[1]
	[Counts / 30 days]	[Counts / 30 days]	[Counts / 100 ml]
Loosahatchie River at mouth (includes all modeled areas)	7.71×10^{14}	1.88×10^{13}	657.45
Loosahatchie River @ confluence of Big Cr.	1.01×10^{14}	1.17×10^{13}	436.13
Big Creek	3.75×10^{13}	4.94×10^{12}	416.61
Cypress Creek	4.15×10^{12}	1.94×10^{12}	358.92

1. Fecal coliform bacteria concentrations represent the maximum simulated geometric mean concentration during the critical period (see Section 8.1).

8.3 Margin of Safety

There are two methods for incorporating an MOS in the analysis: a) implicitly incorporate the MOS using conservative model assumptions to develop allocations; or b) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations. In these TMDLs, both and explicit and implicit MOS were used. The explicit MOS is 20 counts/100 ml below the in-stream target concentration on all reaches. The implicit MOS includes the use of conservative modeling assumptions and a 10-year continuous simulation that incorporates a range of meteorological events. Conservative modeling assumptions used include: septic systems discharging directly into the streams; development of the TMDL using loads based on the design flow and fecal coliform permit limits of NPDES facilities; all land uses connected directly to streams; decay of fecal coliform bacteria was assumed negligible once manure was applied to the land; and a conservative value was used to estimate the in-stream decay of fecal coliform in the waterbodies.

8.4 Determination of TMDL, WLAs, & LAs

The TMDL is the total amount of pollutant that can be assimilated by a water body while maintaining water quality standards. Fecal coliform bacteria TMDLs are expressed as counts per 30 day period since this is how the water quality standard is expressed. The TMDL, therefore, represents the maximum fecal coliform bacteria load that can be assimilated by a stream during the critical 30-day period while maintaining the fecal coliform bacteria water quality standard (including explicit MOS) of 180 counts/100 ml. The TMDL components were estimated according to the following procedure:

- The calibrated model, corresponding to the portion of the Loosahatchie watershed that is upstream of the pour point of the listed waterbody segment was run for a time period that included the critical condition (6/19/98 – 7/18/98).

- Existing NPDES permitted facilities were assumed to discharge at design flows and the fecal coliform permit limit of 200 counts/100 ml

- Fecal coliform land loading variables and the magnitude of loading from sources modeled as “other direct sources” were adjusted within reasonable range of known values until the resulting fecal coliform concentration at the pour point of the listed water body segment is less than 180 counts/100ml (includes explicit MOS).

- The $\sum$WLAs is the load associated with the daily discharge loads of all modeled NPDES permitted facilities summed over the 30 day critical period. The discharge load for each facility represents the design flow at a fecal coliform concentration of 200 counts/100 ml.

- The $\sum$LAs is the daily fecal coliform load indirectly going to surface waters from all modeled land use areas as a result of buildup/washoff processes plus the daily discharge load sources modeled as “other direct sources” and the result summed over the 30 day critical period. (Note: For loading resulting from buildup/washoff processes, there is no distinction in the model between point source discharges covered by an MS4 permit and non-point source discharges. Therefore, storm water discharges covered by the Memphis MS4 are included in the calculation for ∑LAs).

- The percent reduction is based on the maximum simulated geometric mean concentration for the 30-day critical period for existing and TMDL conditions. The maximum simulated concentrations for the TMDL scenario were less than 180 counts/100 ml.

The TMDL components for the listed water bodies are summarized in Table 8.

Table 8 TMDL Components

Watershed	∑WLAs [counts/30 day]	∑LAs [counts/30 day]	MOS	TMDL [counts/30 day]
Loosahatchie River at mouth (includes all areas)	1.151×10^{12}	8.49×10^{13}	Explicit[1] & Implicit	8.61×10^{13}
Loosahatchie River at confluence of Big Cr.	2.93×10^{11}	2.38×10^{13}	Explicit[1] & Implicit	2.41×10^{13}
Big Creek	8.43×10^{11}	2.10×10^{13}	Explicit[1] & Implicit	2.18×10^{13}
Cypress Creek	6.59×10^{9}	2.62×10^{12}	Explicit[1] & Implicit	2.63×10^{12}

1 Explicit MOS = 20 counts/30 day.

8.4.1 Waste Load Allocations

There are 13 NPDES permitted that discharge fecal coliform bacteria in the Loosahatchie River watershed. Future facility permits will require end-of-pipe limits equivalent to the water quality standard of 200-counts/100 ml. Future facilities discharging at concentrations less than the water quality standard will not cause or contribute fecal coliform bacteria impairment in the watershed.

8.4.2 Load Allocations

There are two modes of transport for non-point source fecal coliform bacteria loading in the model. First, loading from failing septic systems, animals in the stream, and leaking sewer system collection lines are modeled as “other direct sources” to the stream and are independent of precipitation. The second mode involves loading resulting from fecal coliform accumulation on land surfaces and wash-off during storm events. Fecal coliform applied to land is subject to a die-off rate and an absorption rate before it is transported to the stream. In the model, once the fecal coliform was applied to the land it was not subject to a die-off rate and is considered a conservative assumption.

Model results indicate that non-point sources related to agricultural and urban runoff and direct inputs have the greatest impact on the fecal coliform bacteria loadings in the Loosahatchie watershed. One possible allocation scenario that would meet instream water quality standards for the listed streams in the Loosahatchie watershed includes (Note: in-stream fecal coliform reductions include the effects of dilution and decay):

- Loosahatchie River at mouth: 89% load reduction from runoff and 75% load reduction from "other direct sources" of fecal coliform bacteria in the stream, resulting in an in-stream fecal coliform reduction of 73 percent.

- Loosahatchie River at confluence of Big Creek: 80% load reduction from runoff and a 72% load reduction from "other direct sources" of fecal coliform bacteria in the stream, resulting in an in-stream fecal coliform reduction of 59 percent.

- Big Creek: 46% load reduction from runoff and 85% load reduction from "other direct sources" of fecal coliform bacteria in the stream, resulting in an in-stream fecal coliform reduction of 57 percent.

- Cypress Creek: 47% load reduction from runoff and an 79% load reduction from "other direct sources" of fecal coliform bacteria in the stream, resulting in an in-stream fecal coliform reduction of 50 percent.

Best management practices (BMPs) that could be used to implement this TMDL include controlling pollution from agriculture and urban runoff, identification and elimination of illicit discharges and other unknown "direct sources" of fecal coliform bacteria to the streams, and repair of leaking sewer collection lines and failing septic systems. Loading from agricultural sources should be minimized by adoption of NRCS resource management practices. NRCS practices include measures such as covering manure stacks exposed to the environment; reducing animal access to streams; and applying manure to croplands (if applicable) at agronomic rates. Fecal coliform loading rates and the percent reduction of in-stream fecal coliform bacteria concentrations required to achieve water quality standards for this allocation scenario are shown in Table 9. Additional monitoring and characterization of the watershed should be conducted to verify the various other direct sources of fecal coliform bacteria in the watershed.

Table 9. Load Allocations in the Loosahatchie Watershed

Watershed	Runoff Load	"Other Direct Sources"	Overall In-stream Reduction (Existing to Allocated Conditions)[1]
	[counts/30 days]	[counts/30 days]	[%]
Loosahatchie River at mouth	8.02×10^{13}	4.71×10^{12}	73
Loosahatchie River @ confluence of Big Cr.	2.05×10^{13}	3.292×10^{12}	59
Big Creek	2.03×10^{13}	7.414×10^{11}	57
Cypress Creek	2.22×10^{12}	4.02×10^{11}	50

1. The percent reduction of in-stream fecal coliform bacteria concentrations based on the simulated geometric mean concentration for existing conditions and the target concentration of 180 counts/100 ml.

8.4.3 Seasonal Variation

Seasonal variation was incorporated in the continuous simulation water quality model by using varying monthly loading rates and daily meteorological data.

9.0 IMPLEMENTATION PLAN

The TMDL analysis was performed using the best data available to specify WLAs & LAs that will meet the water quality criteria for pathogens (fecal coliform) in Loosahatchie watershed so as to support its Recreation use classification. The following recommendations and strategies are targeted toward source identification, collection of data to support additional modeling and evaluation, and subsequent reduction in sources that are causing impairment of water quality.

9.1 Point Source Facilities

All discharges from industrial and municipal point source facilities are required to be in compliance with the conditions of their NPDES permit at all times.

9.2 Urban Sources of Fecal Coliform Loading

9.2.1 Municipal Entities Covered Under Phase 1 Storm Water Regulations

The Memphis MS4 permit became effective on June 1, 1996 and authorizes existing or new storm water induced, point source discharges to surface waters from the Municipal Separate Storm Sewer System and covers all areas located within the corporate boundary of the City of Memphis. The City is in the fifth year of the existing permit term and is proceeding according to the schedule specified by the permit. Annual reports have been submitted detailing implementation of the SWMP and the results of sampling activities.

In accordance with the load allocations developed in this TMDL, the Memphis MS4 permit should be modified to require the review and revision, as necessary, of the Memphis SWMP to accomplish the following:

a) A reduction of fecal coliform loading in point and non-point source storm water runoff discharges to the Loosahatchie watershed in accordance with the Load Allocations specified in Table 9. (For the purposes of this TMDL, the Waste Load Allocations for point source discharges covered under the Memphis MS4 permit were calculated as a part of the Load Allocations – see Section 8.4)

b) Reduction of fecal coliform loading, to the maximum extent practicable, due to failing septic systems and miscellaneous sources located within the city limits. Miscellaneous sources include, but are not limited to, leaking collection systems, illicit discharges, and unidentified sources.

c) Appropriate discharge and stream monitoring to verify the effectiveness of pollution reduction measures.

In addition, the City of Memphis should be encouraged to develop and calibrate a dynamic water quality model, such as the Storm Water Management Model (SWMM), to evaluate urban storm water loading/transport processes and facilitate planning and additional pollution control strategies.

9.2.2 Municipal Entities Covered Under Phase 2 Storm Water Regulations

The City of Millington and Shelby County will be issued NPDES Municipal Separate Storm Sewer System (MS4) permits under the Phase 2 storm water regulations. Applications are due by March 10, 2003. Each permitted entity will be required to develop a Storm Water Management Program (SWMP). The SWMP covers the duration of the permit (5-year renewable) and comprises a comprehensive planning process which involves public participation and intergovernmental coordination to reduce the discharge of pollutants to the maximum extent practicable using management practices, control techniques, public education, and other appropriate methods and provisions. With respect to fecal coliform pollution reduction, additional activities and programs conducted by city, county, and state agencies are recommended to support the SWMP:

- Field screening and monitoring programs to identify the types and extent of fecal coliform water quality problems, relative degradation or improvement over time, areas of concern, and source identification.

- Requirements that all new and replacement sanitary sewage systems are designed to minimize discharges from the system into the storm sewer system.

- Mechanisms for reporting and correcting illicit connections, breaks, surcharges, and general sanitary sewer system problems with potential to release to the municipal separate storm sewer system.

- Require NPDES facilities to comply with permit limits.

9.3 Agricultural Sources of Fecal Coliform Loading

The Tennessee Department of Environment & Conservation (TDEC) should coordinate with the Tennessee Department of Agriculture (TDA) and the Natural Resources Conservation Service (NRCS) to address issues concerning fecal coliform loading from agricultural land uses in the Loosahatchie watershed. It is recommended that additional information (such as livestock populations by subwatershed, animal access to streams, manure application practices, etc.) be evaluated to better identify and quantify agricultural sources of fecal coliform loading in order to minimize uncertainty in future modeling efforts. It is further recommended that BMPs be utilized to reduce the amount of fecal coliform bacteria transported to surface waters from agricultural sources to the maximum extent practicable.

9.4 Stream Monitoring

Tennessee's watershed management approach specifies a five-year cycle for planning and assessment. Each watershed will be examined (or re-examined) on a rotating basis. Generally, in years two and three of the five-year cycle, water quality data are collected in support of water quality assessment (including TMDL development) and planning activities. Therefore, a watershed TMDL is developed one to two years prior to commencement of the next cycle's monitoring period.

Continued monitoring of the fecal coliform concentration at multiple water quality sampling points in the watershed is critical in characterizing sources of fecal coliform contamination and documenting future reduction of loading. In the next watershed cycle, monitoring should be expanded to provide water quality information to characterize seasonal trends and refined source identification and delineation. Recommended monitoring for the Loosahatchie watershed includes monthly grab samples and intensive sampling for one month during the wet season (January-March). In addition, monitoring efforts should be refined and enhanced in order to characterize dry and wet season base flow conditions (concentrations) and promote selective storm response (hydrograph) characterization. Lastly, stream discharge should be measured or estimated with the collection of each fecal coliform sample to characterize the dynamics of fecal coliform transport within the surface-water system.

9.5 Future Efforts

This TMDL represents the first phase of a long-term restoration project to reduce fecal coliform loading to acceptable levels (meeting water quality standards) in the Loosahatchie watershed. TDEC, coordinating with the TDA, will evaluate the progress of implementation strategies and refine the TMDL as necessary in the next phase (next five-year cycle). This will include recommending specific implementation plans for identified problem areas with as yet undefined sources and causes of pollution. Cooperation will be maintained with TDA (for possible 319 non-point source grants) and NRCS for developing BMPs. The dynamic loading model may be upgraded and refined in the next phase to more effectively link sources (including background and agricultural) to impacts and characterize the processes (loading, transport, decay, etc.) contributing to exceedances of fecal coliform concentrations (loading) in impacted water bodies. The phased approach will assure progress toward water quality standards attainment in the future.

10.0 PUBLIC PARTICIPATION

In accordance with 40 CFR §130.7, announcement of the availability of proposed fecal coliform TMDLs for two sections of the Loosahatchie River (mouth to Big Creek and Big Creek to Cypress Creek), Cypress Creek, and Big Creek was made to the public, effected dischargers, and other concerned parties and comments solicited. Steps taken in this regard include:

1) Notice of the proposed TMDLs was posted on the Tennessee Department of Environment and Conservation website on June 5, 2001 (see Appendix D). The announcement invited public comment until July 19, 2001. As of July 15, the Public Notice announcement was downloaded 81 times and the TMDL document 199 times.

2) Notice of the availability of the proposed TMDLs (similar to the website announcement) was included in one of the NPDES permit Public Notice mailings which are sent to approximately 90 interested persons or groups who have requested this information.

3) A letter was sent to point source facilities in the Loosahatchie River study area that are permitted to discharge treated sanitary wastewater advising them of the proposed fecal coliform TMDLs and their availability on the TDEC website. The letter also stated that a written copy of the draft TMDL document would be provided on request. Letters were sent to the following facilities:

   Pleasant Ridge Trailer Park (TN0067482)
   Millington STP (TN0021067)
   Memphis Chapel Hill STP (TN0026361)
   Arlington Lagoon #1 (TN0021351)
   Pine Lake Cooperative (TN0061433)
   Galloway Lagoon (TN0062138)
   Mason STP (TN0026620)
   Somerville Lagoon (TN0021652)
   Oakland Lagoon (TN0026573)
   Fayette Co. Central School (TN0023779)

4) A draft copy of the proposed fecal coliform TMDLs was sent to the City of Memphis, City of Millington, and Shelby County. The City of Memphis is covered under Municipal Separate Storm Sewer System (MS4) permit TNS068276. Both of the latter two entities will be issued MS4 permits under the Phase II storm water regulations.

Written comments were received from one party during the public comment period. These comments are included in Appendix E and the Division of Water Pollution Control responses are contained in Appendix F. No requests to hold public meetings were received regarding the proposed TMDLs as of close of business on July 19, 2001.

11.0 FURTHER INFORMATION

Further information concerning Tennessee's TMDL program can be found on the Internet at the Tennessee Department of Environment and Conservation website:

www.state.tn.us/environment/wpc/tmdl.htm

Technical questions regarding this TMDL should be directed to the following members of the Division of Water Pollution Control staff:

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REFERENCES

ASAE Standards, 45th Edition, Standards Engineering Practices Data. American Society of Agricultural Engineers (ASAE), 1998.

Horner. *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, Washington, 1992.

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

Lombardo, P.S., 1972. *Mathematical Model of Water Quality in Rivers and Impoundments,* Technical Report, Hydrocomp, Inc. Cited in *Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling (Second Edition)*, EPA/600/3-85/040, June 1985.

Metcalf & Eddy, 1991. *Wastewater Engineering: Treatment, disposal, Reuse,* Third Edition, McGraw-Hill, Inc., New York.

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.

TDEC. 1998. *Final 1998 303(d) List, June 1998 (Revised July and September 1998).* State of Tennessee, Department of Environment and Conservation, Division of Water Pollution Control.

TDEC. 1999. *State of Tennessee Water Quality Standards, Chapter 1200-4-3 General Water Quality Criteria, October 1999.* State of Tennessee, Department of Environment and Conservation, Division of Water Pollution Control.

USDA, 1997. *1997 Census of Agriculture, Volume 1, Geographic Area Series, Part 42*, U.S. Department of Agriculture, National Agricultural Statistics Service. AC97-A-42, March 1999.

USDA, 1999. *A Tennessee tradition, Equine '99*, U.S. Department of Agriculture, National Agricultural Statistics Service and Tennessee Department of Agriculture.

USEPA, 1991. *Guidance for Water Quality –based Decisions: The TMDL Process.* U.S. Environmental Protection Agency, Office of Water, Washington, DC. EPA-440/4-91-001, April 1991.

USEPA. 1997. *Ecoregions of Tennessee*. U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Corvallis, Oregon. EPA/600/R-97/022.

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

USEPA, 2001. *Protocols for Pathogen TMDLs,* U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

APPENDIX A

Example of Runoff Load Calculation Spreadsheet

EXAMPLE CALCULATION OF RUNOFF LOAD (example shown for runoff from pastureland in Fayette Co)

COUNTY	AGRICULTURAL ANIMALS (NRCS and WWW.NASS.GOV for horses)								
	CATTLE	BEEF	DAIRY	SWINE	SHEEP	BROILERS	LAYERS	HORSES	cattle access to stream
Shelby	8628	4980	42	335	148	0	515	2720	yes
Fayette	25437	13421	965	25667	124	0	15	2195	yes

LOAD ESTIMATES BASED ON ANIMAL POPULATION AND LAND APPLICATION OF MANURE
Runoff from pastureland (COUNTS/DAY) = Number animals * Fecal concentration (counts/animal/day) * Fecal content multiplier * Runoff rate * monthly application rate
Model units are in terms of counts/acre-day and are calculated by dividing the load by the area of pasture land in the county (calculation not shown)

Hog Manure Available for Wash-off

Fecal concentration	1.24E+10	counts/animal/day (NCSU, 1994)
Manure fecal content multiplier	0.75	(assume 25% dies-off in lagoon - EPA conservative assumption)
Fraction available for runoff	0.63	(EPA assumption)

Hog manure application rates (NRCS):

	January	February	March	April	May	June	July	August	September	October	November	December
Fraction of manure applied each month	0	0	0.075	0.1575	0.1335	0.1335	0.1335	0.1335	0.1585	0.075	0	0

Hog manure runoff from pastureland (counts/day):

Fayette Co	0.00E+00	0.00E+00	1.79E+13	3.76E+13	3.19E+13	3.19E+13	3.19E+13	3.19E+13	3.78E+13	1.79E+13	0.00E+00	0.00E+00

Beef Cattle Manure Available for Wash-off

Fecal concentration	1.06E+11	counts/animal/day (NCSU, 1994)
Manure fecal content multiplier	1	(a value of 1 assumes fresh application - worse case scenario)
Fraction available for runoff	0.6	(EPA assumption)

Beef cattle manure application rates (NRCS):

	January	February	March	April	May	June	July	August	September	October	November	December
Fraction of manure applied each month	0.0833	0.0833	0.0833	0.0833	0.0833	0.0834	0.0834	0.0834	0.0834	0.0833	0.0833	0.0833

Beef manure runoff from pastureland (counts/day):

Fayette Co	7.11E+13	7.11E+13	7.11E+13	7.11E+13	7.11E+13	7.12E+13	7.12E+13	7.12E+13	7.12E+13	7.11E+13	7.11E+13	7.11E+13

Dairy Cattle Manure Available for Wash-off

Fecal concentration	1.04E+11	counts/animal/day (NCSU, 1994)
Manure fecal content multiplier	1	(a value of 1 assumes fresh application - worse case scenario)
Fraction available for runoff	0.63	(EPA assumption)

Dairy cattle manure application rates (NRCS):

	January	February	March	April	May	June	July	August	September	October	November	December
Fraction of manure applied each month	0	0.0835	0.075	0.1585	0.05	0.1335	0.05	0.1335	0.075	0.1585	0	0.0825

Dairy manure runoff from pastureland (counts/day):

Fayette Co.	0.00E+00	5.28E+12	4.74E+12	1.00E+13	3.16E+12	8.44E+12	3.16E+12	8.44E+12	4.74E+12	1.00E+13	0.00E+00	5.22E+12

Poultry Litter Available for Wash-off (from layers)

Fecal concentration	1.38E+08	counts/animal/day (NCSU, 1994)
Manure fecal content multiplier	1	(a value of 1 assumes fresh application - worse case scenario)
Fraction available for runoff	0.2029	(EPA assumption)

Poultry litter application rates (NRCS):

	January	February	March	April	May	June	July	August	September	October	November	December
Fraction of litter applied each month	0	0	0.075	0.1575	0.1335	0.1335	0.1335	0.1335	0.1585	0.075	0	0

Poultry litter runoff from pastureland (counts/day):

Fayette Co.	0.00E+00	0.00E+00	3.15E+07	6.62E+07	5.61E+07	5.61E+07	5.61E+07	5.61E+07	6.66E+07	3.15E+07	0.00E+00	0.00E+00

Horse Manure Available for Wash-off

Fecal concentration	4.18E+08	counts/animal/day (NCSU, 1994)
Manure fecal content multiplier	0.75	(a value of 1 assumes fresh application - worse case scenario)
Fraction available for runoff	0.63	(EPA assumption)

Horse manure application rates (NRCS):

	January	February	March	April	May	June	July	August	September	October	November	December
Fraction of manure applied each month	0.0833	0.0833	0.0833	0.0833	0.0833	0.0834	0.0834	0.0834	0.0834	0.0833	0.0833	0.0833

Horse manure runoff from pastureland (counts/day):

Fayette Co	3.61E+10	3.61E+10	3.61E+10	3.61E+10	3.61E+10	3.62E+10	3.62E+10	3.62E+10	3.62E+10	3.61E+10	3.61E+10	3.61E+10

Runoff load from pastureland (counts/day)	January	February	March	April	May	June	July	August	September	October	November	December
from all animals - Fayette Co.	7.11E+13	7.64E+13	9.38E+13	1.19E+14	1.06E+14	1.12E+14	1.06E+14	1.12E+14	1.14E+14	9.91E+13	7.11E+13	7.64E+13

Estimation of load from animal access to streams (for calculation purposes assume only beef cattle have access to streams)
assume 50 % of beef cattle in the watershed have access to streams and of those 25% defecate in or near the stream banks about 3 minutes per day
(resulting stream access is 0.00025 (i.e., 0.5 x 0.25 x 3min/(24*60))

Total load from cattle in stream =number beef cows in watershed * fecal concentration * 0.00025

APPENDIX B

Model Development and Calibration

B.1 Model Set Up

The Loosahatchie watershed was delineated into 27 subwatersheds in order to characterize relative fecal coliform bacteria contributions from significant contributing drainage areas (see Figure 3). Boundaries were constructed so that subwatershed "pour points" coincided, when possible, with water quality monitoring stations or USGS flow gages. Watershed delineation was based on the Rf3 stream coverage and Digital Elevation Model (DEM) data. This discretization allows management and load reduction alternatives to be varied by subwatershed. Initial input for model variables was developed using WCS and the associated spreadsheet tools.

An important factor influencing model results is the precipitation data contained in the meteorological data file used in the simulation. The pattern and intensity of rainfall affects the build-up and wash-off of fecal coliform bacteria from the land into the streams, as well as the dilution potential of the stream. Weather data from the Memphis meteorological station were available for the time period from January 1970 through December 1998 and were used for all simulations. The model was allowed to stabilize for one year (1988) before results from the 10-year simulation were analyzed.

B.2 Model Calibration

The calibration of the NPSM watershed model involves both hydrology and water quality components. The model must be calibrated to appropriately represent hydrologic response in the watershed before subsequent calibrations and reasonable water quality simulations can be performed. A sensitivity analysis is part of the calibration process to evaluate the impact model parameters have on the simulated results.

B.2.1 Hydrologic Calibration

The hydrology calibration of the watershed model involves comparing simulated stream flows to historic stream flow data from a USGS stream gaging station for the same period of time. The hydrology portion of the model was calibrated using the continuous USGS flow gage on the Loosahatchie River at Station No. 07030240 near Arlington, Tennessee during the period from January 1, 1989 through September 30, 1996. The portion of the watershed modeled for the calibration simulations corresponds to the drainage area upstream of the USGS station.

Initial values for hydrological variables were taken from an EPA developed default data set. During the calibration process, model parameters were adjusted within reasonable constraints until acceptable agreement was achieved between simulated and observed stream flow. Model parameters adjusted include: evapotranspiration, infiltration, upper and lower zone storage, groundwater storage, recession, losses to the deep groundwater system, and interflow discharge. Results of the hydrology calibration for selected years are shown in Figures B-1 to B-4.

B.2.2 Water Quality Calibration

Loosahatchie River watershed data, generated by WCS, was processed through the spreadsheet applications developed by Tetra Tech, Inc. to generate fecal coliform loading data for use as <u>initial</u> input to the NPSM model. The sensitivity of the model to changes in non-point source loading rates is a critical element of the calibration process. The model is very sensitive to loads applied directly into the stream (e.g., leaking septic systems, animal access to streams, etc.) and if the loads are too high, then the model will not accurately simulate the response to rainfall runoff.

B.2.2.1 Point Sources

For existing conditions, NPDES facilities located in modeled subwatersheds are represented as point sources of constant flow and concentration based on the facility's design flow and permit effluent fecal coliform concentration (see Table 4).

B.2.2.2 Non-point Sources

A number of non-point source categories are not associated with land loading processes and are represented as direct, instream source contributions in the model. These may include, but are not limited to, failing septic systems, leaking sewer lines, animals in streams, direct discharge of raw sewage, and undefined sources. All other non-point sources involve land loading of fecal coliform bacteria and washoff as a result of storm events. Only a portion of the load from these sources are actually delivered to streams due to the mechanisms of washoff (efficiency), decay, and incorporation into soil (adsorption, absorption, filtering) before being transported to the stream. Therefore, land loading non-point sources are represented as indirect contributions to the stream. Buildup, washoff, and die-off rates are dependent on seasonal and hydrologic processes.

Initial input for non-point sources of fecal coliform loading in the water quality model was developed using watershed information generated with WCS and the Tetra Tech loading calculation spreadsheets.

B.2.2.2.1 Wildlife

Fecal coliform loading from wildlife is considered to be uniformly distributed to forest, pasture, cropland, and wetland areas in the modeled subwatersheds. A loading rate of 5.0×10^8 counts/animal/day for deer is based on best professional judgment (BPJ) of EPA. An animal density of 45 animals/square mile is used to account for deer and all other wildlife. The resulting fecal coliform loading is 2.5×10^6 counts/acre/day and is considered background.

B.2.2.2.2 Land Application of Agricultural Manure

In the water quality model, county livestock populations (see Table 5) are distributed to subwatersheds based on the percentage of agricultural area in each subwatershed classified as pasture/hay. Fecal coliform loading rates were calculated from livestock populations based on manure application rates, literature values for bacteria concentrations in livestock manure, and the following assumptions:

- Fecal content in manure was adjusted to account for die-off due to known treatment/storage methods.

- Manure application rates from the various animal sources vary monthly according to management practices. Hog manure is applied from March through September; beef cattle manure is applied throughout the year.

- The fraction of manure available for runoff is dependent on the method of manure application. In the water quality model, the fraction available is estimated based on incorporation into the soil.

- In the Loosahatchie watershed, manure is not applied to cropland, only pastureland.

- Fecal coliform production rates used in the model for cattle, hogs, poultry, sheep, and horses are: 1.06×10^{11} counts/day/beef cow, 1.24×10^{10} counts/day/hog, 1.04×10^{11} counts/day/dairy cow, 1.38×10^{8} counts/day/layer chicken, 1.22×10^{10} counts/day/sheep, and 4.18×10^{8} counts/day/horse (NCSU, 1994).

Since manure is not applied to cropland in the Loosahatchie watershed, the only source of fecal coliform bacteria from cropland is from wildlife that deposits feces on the land surface. The in-stream loading from cropland is considered background.

B.2.2.2.3 Grazing Animals

Cattle spend time grazing on pastureland and deposit feces onto the land. During storm events, a portion of this material containing fecal coliform bacteria is transported to streams. Beef cattle are assumed to spend all their time in pasture. The percentage of feces deposited during grazing time is used to estimate fecal coliform loading rates from pastureland. Because there is no assumed monthly variation in animal access to pastures in western Tennessee, the fecal loading rate does not vary significantly throughout the year. Therefore, the loading rate to pastureland used in the model is assumed to be constant. This rate varies from about 7.03×10^{9} counts/acre-day for subwatersheds in Shelby County to 1.09×10^{10} counts/acre-day for subwatersheds in Fayette County. Contributions of fecal coliform from wildlife (as noted in Section B.2.2.2.1) are also included in these rates.

B.2.2.2.4 Urban Development

Urban land use represented in the MRLC database includes areas classified as: high intensity commercial, industrial, transportation, low intensity residential, high intensity residential, and transitional. Associated with each of these classifications is a percent of the land area that is impervious. A single, area-weighted loading rate from urban areas is used in the model and is based on the percentage of each urban land use type in the watershed and build-up and accumulation rates referenced in Horner (1992). In the water quality calibrated model, this rate is assumed to vary from 7.16×10^{8} to 1.16×10^{9} counts/acre-day and is assumed constant throughout the year.

B.2.2.2.5 Other Sources

As previously stated, there are a number of non-point sources of fecal coliform bacteria that are not associated with land loading and washoff processes. These include animal access to streams, failing septic systems, leaking sewer lines, illicit discharges, and other undefined sources. In each subwatershed, all of these miscellaneous sources have been grouped together and modeled as a point source of constant flow and fecal coliform concentration. The <u>initial</u> baseline values of flow and concentration were estimated using the Tetra Tech, Inc. developed spreadsheets and the following assumptions:

- The load attributed to animals having access to streams is initially based on the beef cow population in the watershed. It was assumed that 50 % have access to streams and, of those, 25% defecate in or near the stream banks during a portion of the day. The resulting percentage of time fecal coliform bacteria is discharged into the streams from grazing animals is 0.025 percent. Literature values were used to estimate the fecal coliform bacteria concentration in beef cow manure.

- The initial baseline loads attributable to leaking septic systems is based on an assumed failure rate of 20 percent.

These flow and concentration variables were adjusted during water quality calibration to alter simulated instream fecal concentrations during dry weather conditions.

B.2.2.3 Water Quality Calibration Results

During water quality calibration, model parameters were adjusted within reasonable limits until acceptable agreement between simulation output and instream observed data was achieved. Model variables adjusted include:

- Rate of fecal coliform bacteria accumulation
- Maximum storage of fecal coliform bacteria
- Rate of surface runoff that will remove 90% of stored fecal coliform bacteria
- Concentration of fecal coliform bacteria in interflow
- Concentration of fecal coliform bacteria in groundwater
- Concentration of fecal coliform bacteria and rate of flow of “other direct sources” described in B.2.2.2.5

Fecal coliform grab samples, collected monthly by TDEC at sampling stations in Loosahatchie River, Big Creek, and Cypress Creek were used for comparison with the simulated daily model results. Only the data collected at Station LOOSAHATCH017.2 on the Loosahatchie River is it possible to identify seasonal trends.

Comparisons of simulated and observed daily fecal coliform concentrations at sampling stations in the listed streams are shown in Figures B-5 to B-9. Results show that the model adequately simulates peaks in fecal coliform bacteria in response to rainfall events. Often a high observed value is not simulated in the model due to lack of rainfall at the meteorological station as compared to the rainfall occurring in the watershed, or is the result of an unknown source that is not included in the model.

The sensitivity of the model using the existing conditions scenario to animal access to streams at select locations in the watershed is shown in Figure B-10 and B-11. In the Cypress Creek watershed, the model simulates reduced fecal coliform concentrations when animals are not allowed access to streams. In the main stem of the Loosahatchie River the difference in simulated concentrations with and without animal access to streams is negligible. However, for all of the listed streams, the simulated fecal coliform concentrations exceed the geometric mean standard when animal access to the streams is removed.

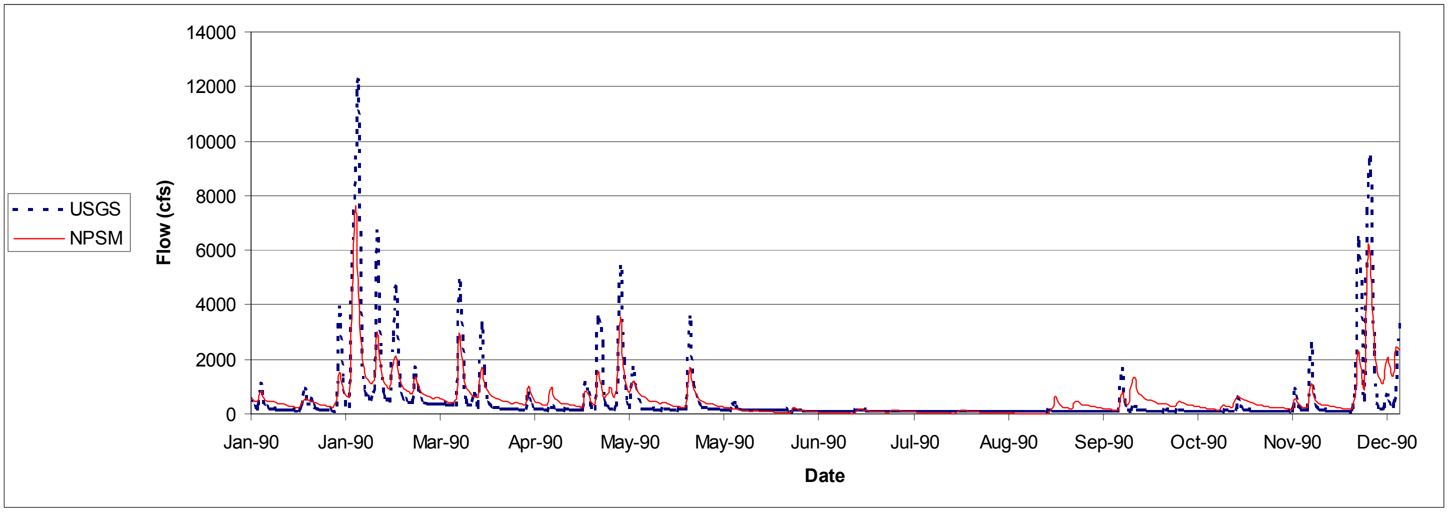


Figure B-1 Hydrology Calibration At USGS 07030240 (1990)

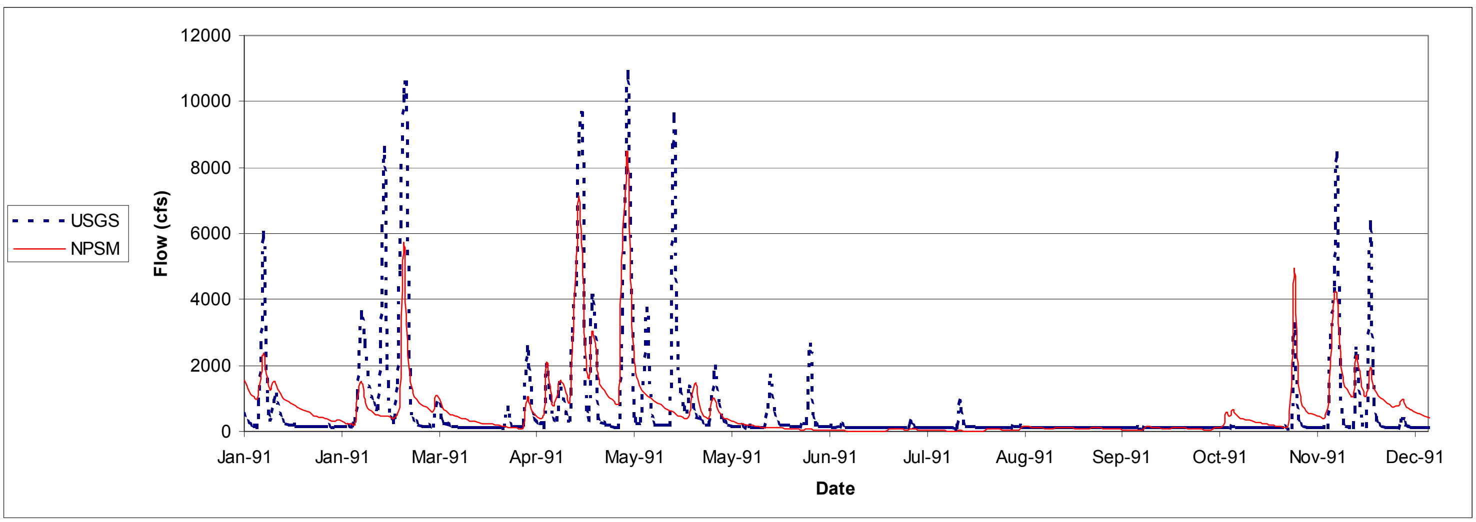


Figure B-2 Hydrology Calibration At USGS 07030240 (1991)

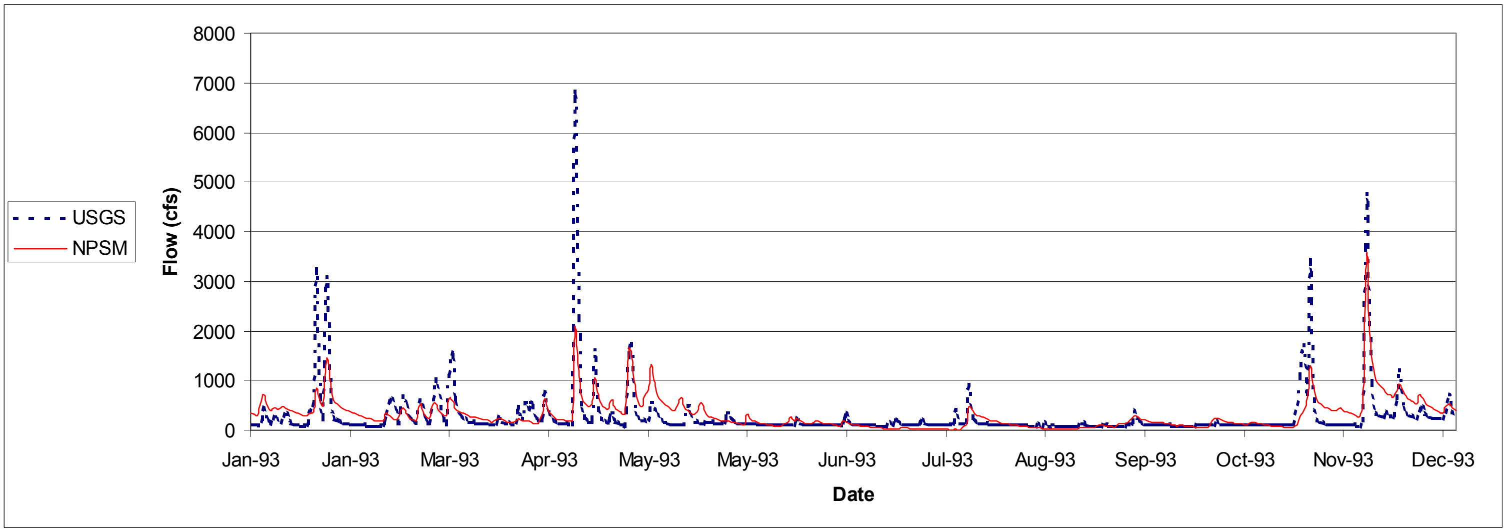


Figure B-3 Hydrology Calibration At USGS 07030240 (1993)

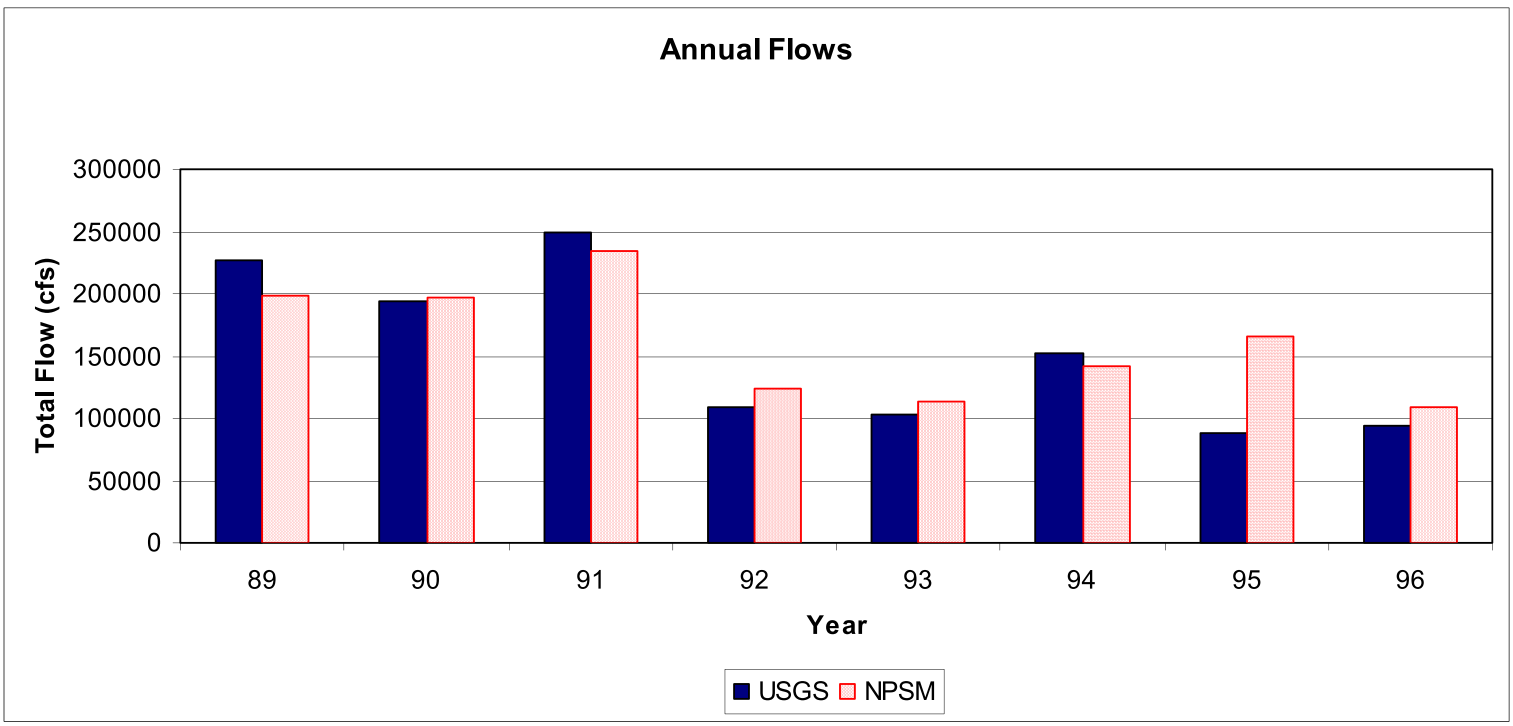


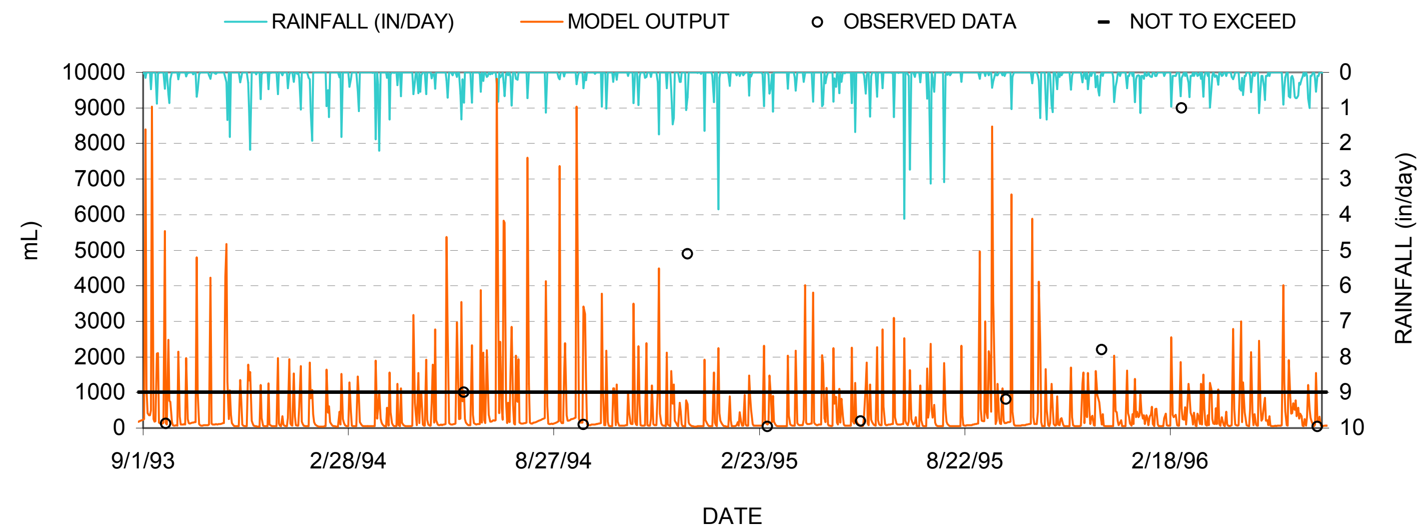
Figure B-4 Comparison of Simulated and Observed Annual Flows at USGS 07030240 (1989-1996)

MULTI-YEAR TIMESERIES MODEL VS DATA

STATION: **Loosahatchie R @ Station 001800**

MODEL RUN: **1**

1 = EXISTING
2 = ALLOCATION 1
3 = ALLOCATION 2



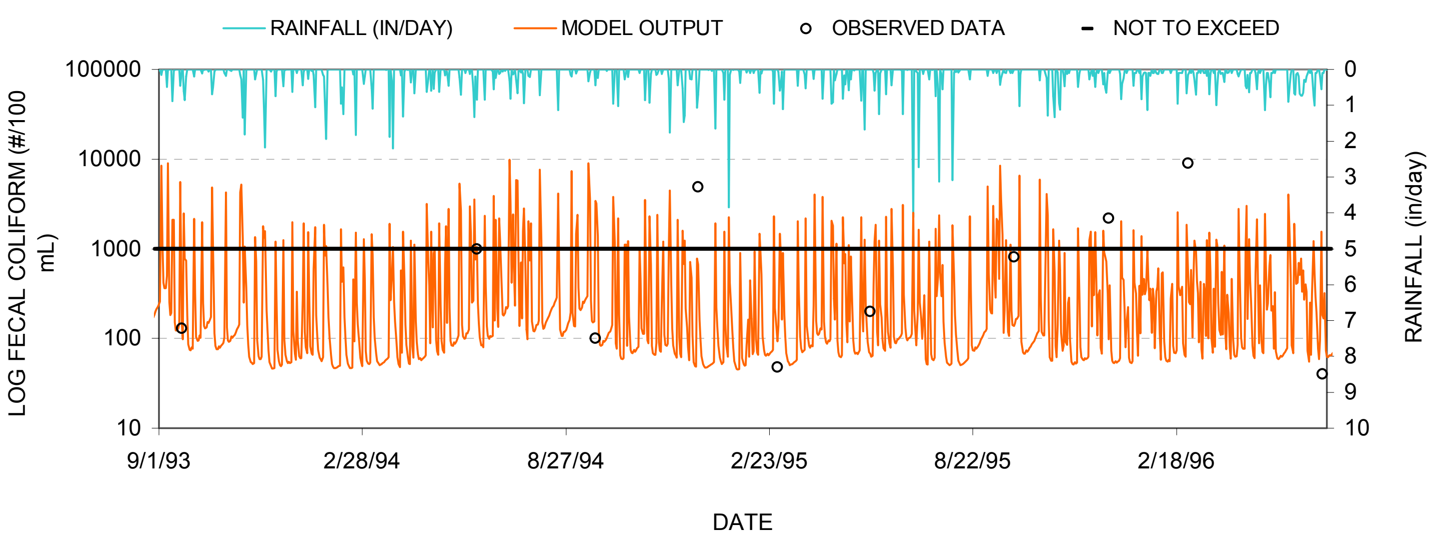


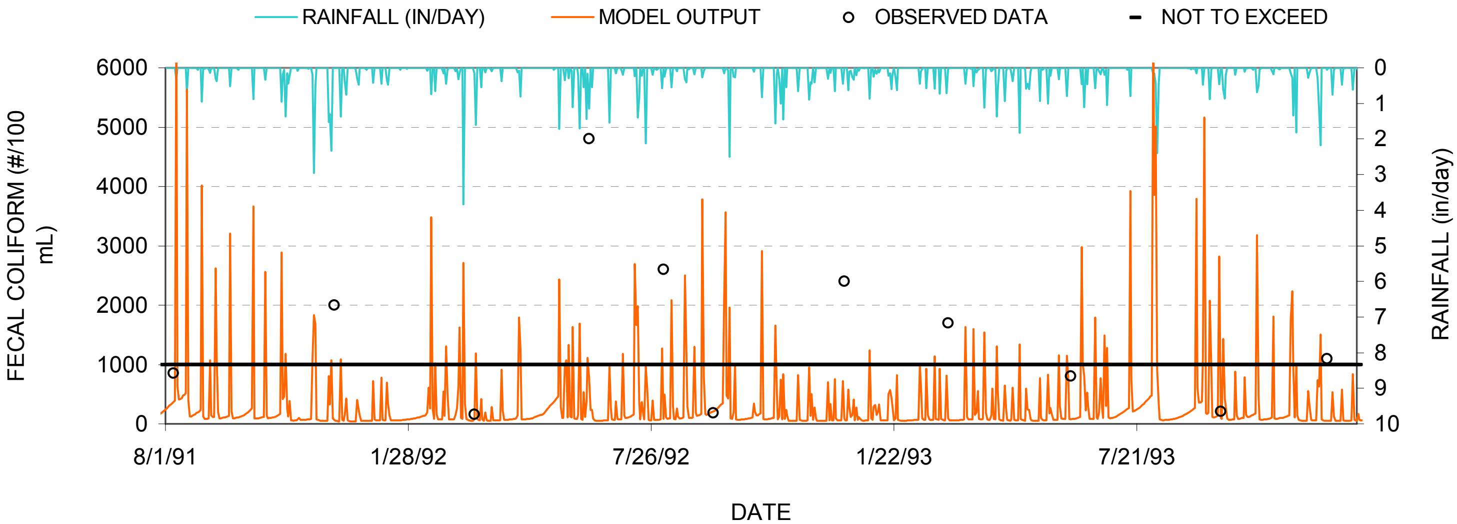
Figure B-5 Water Quality Calibration – Loosahatchie River at Station 001800 (1993-1996)

MULTI-YEAR TIMESERIES MODEL VS DATA

STATION: **Loosahatchie R @ GAGE017.2**

MODEL RUN: **1**

1 = EXISTING
2 = ALLOCATION 1
3 = ALLOCATION 2



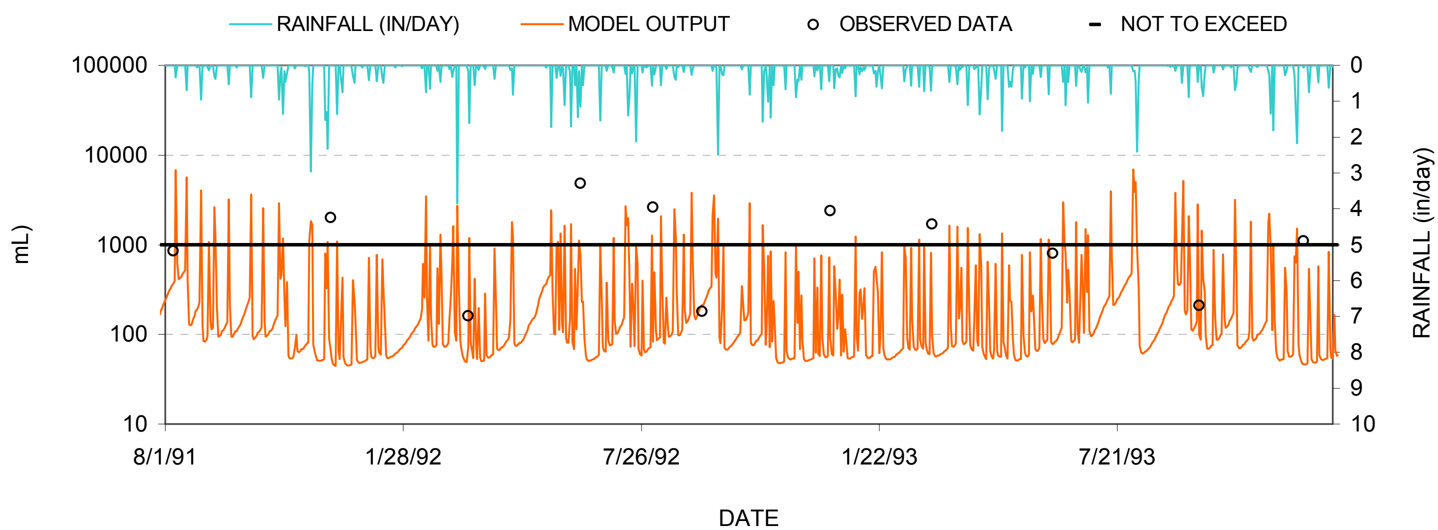


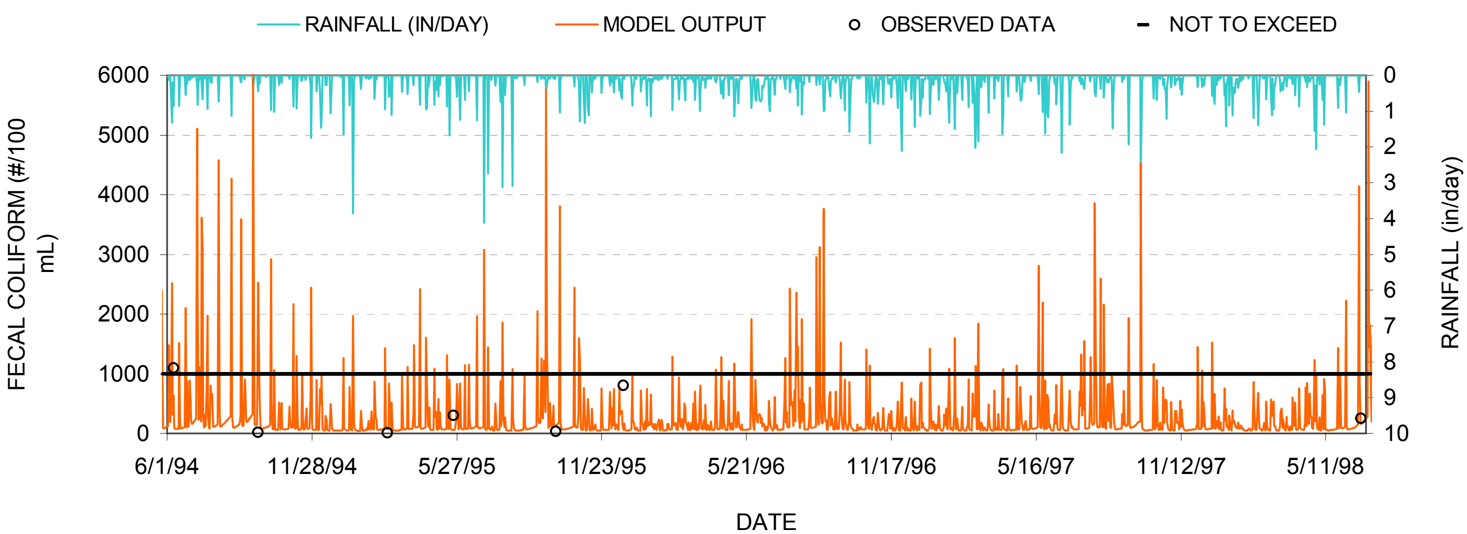
Figure B-6 Water Quality Calibration – Loosahatchie River at Station LOOSAHATCH017.2 (1991-1993)

MULTI-YEAR TIMESERIES MODEL VS DATA

STATION:
Loosahatchie R @ Gage017.2

MODEL RUN: **1**

1 = EXISTING
2 = ALLOCATION 1
3 = ALLOCATION 2



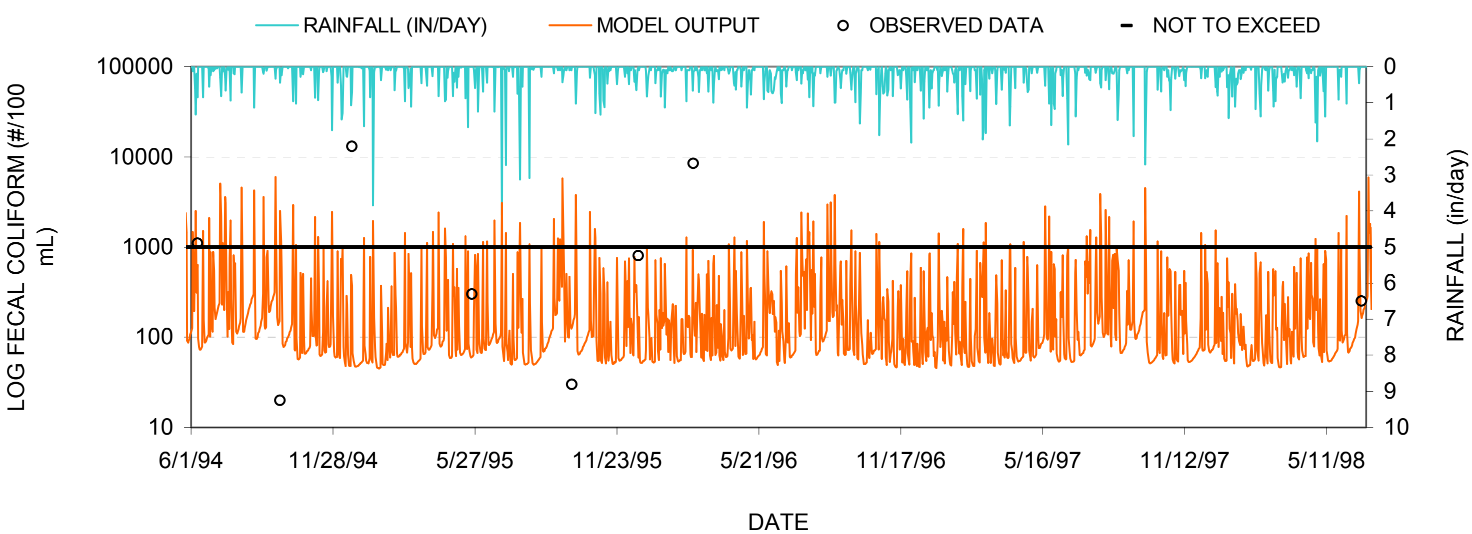


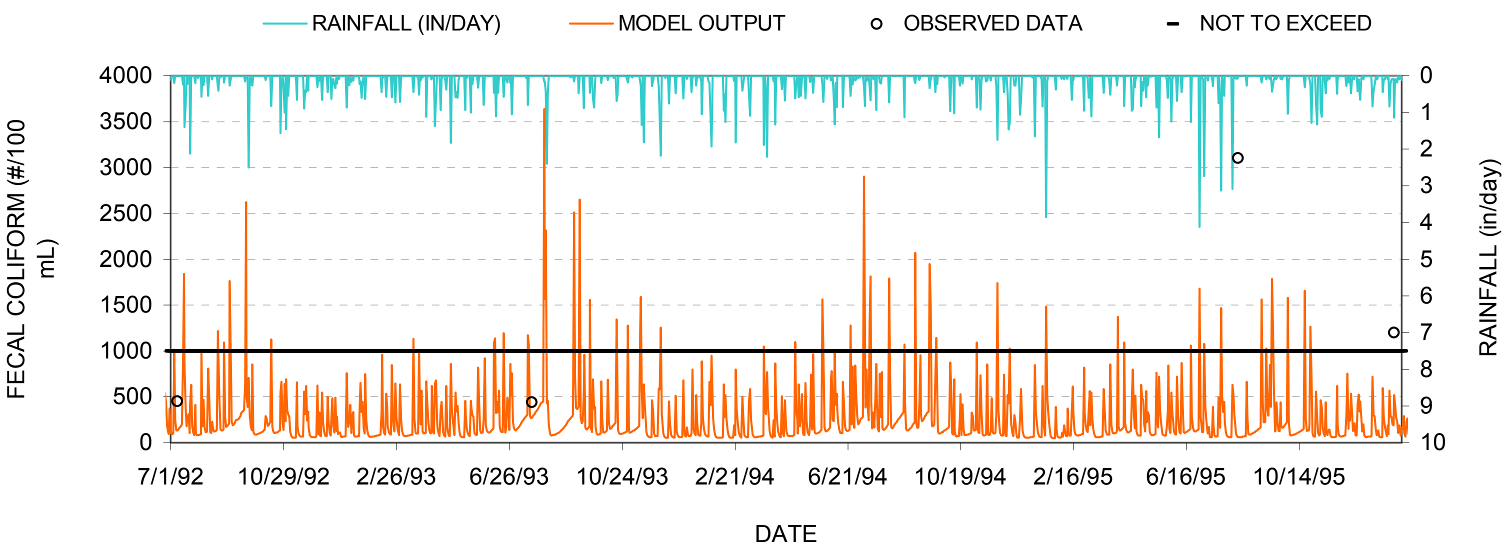
Figure B-7 Water Quality Calibration – Loosahatchie River at Station LOOSAHATCH017.2 (1994-1996)

MULTI-YEAR TIMESERIES MODEL VS DATA

STATION: **Big Creek**

MODEL RUN: 1

1 = EXISTING
2 = ALLOCATION 1
3 = ALLOCATION 2



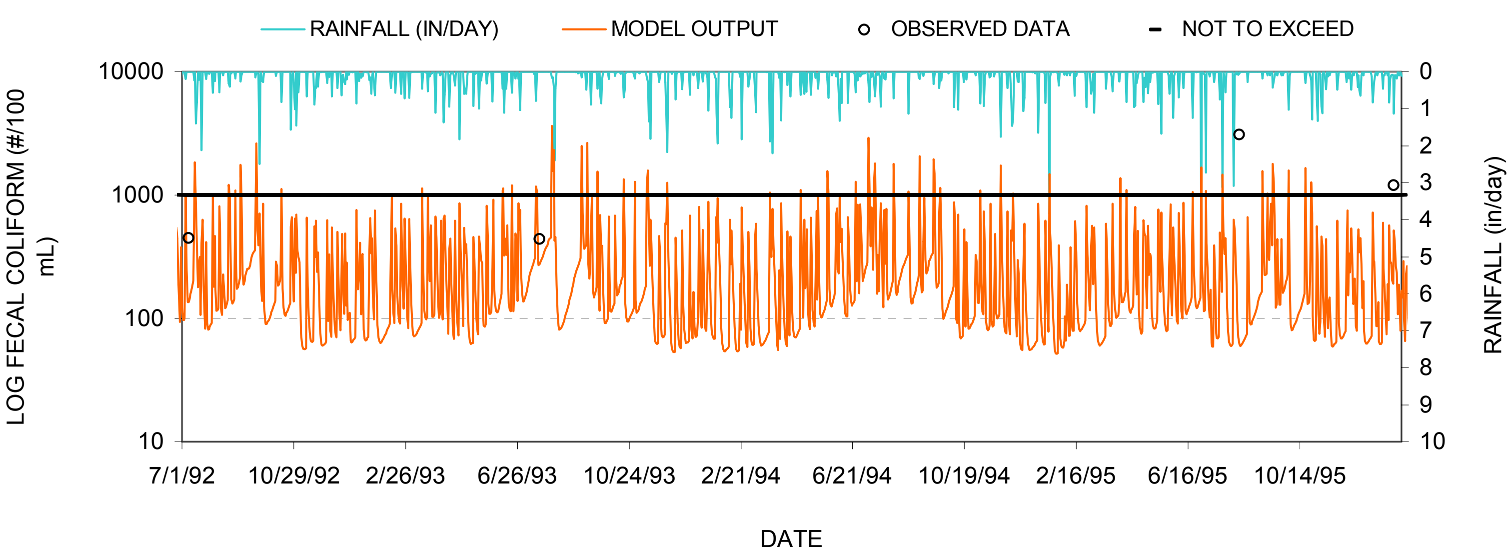


Figure B-8 Water Quality Calibration – Big Creek (1992-1996)

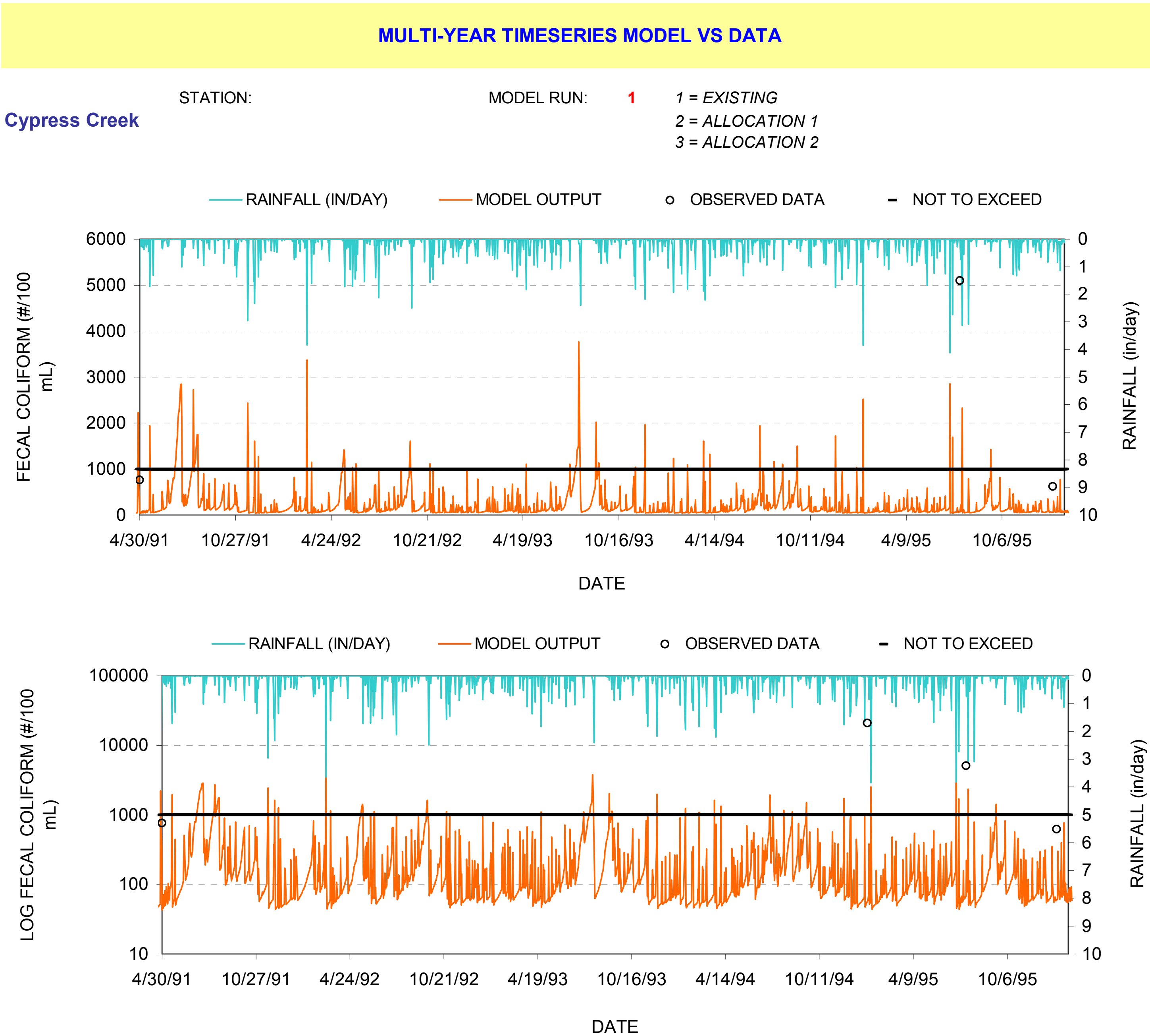


Figure B-9 Water Quality Calibration – Cypress Creek (1991-1996)

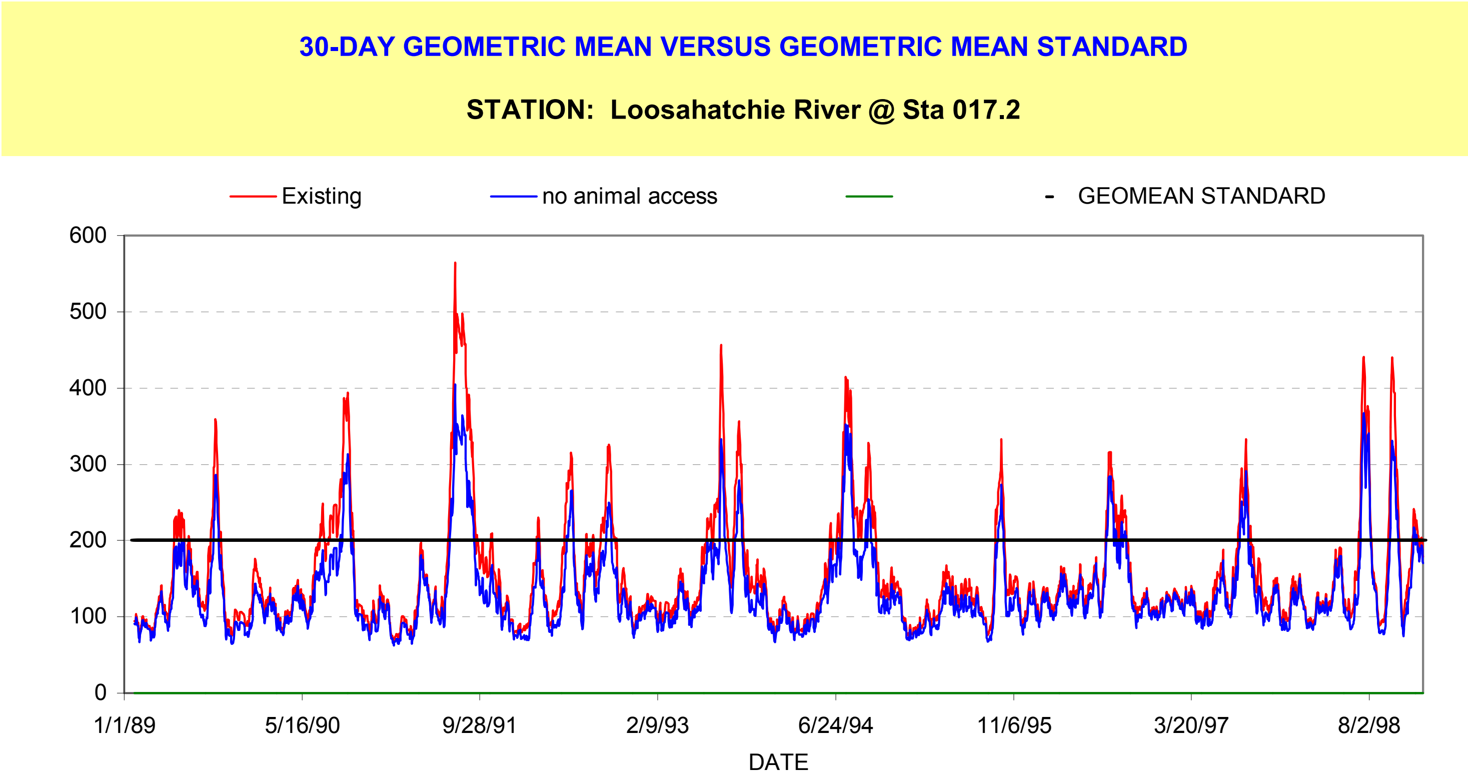


Figure B-10 Model Sensitivity to Animal Access in Loosahatchie River – Existing Conditions

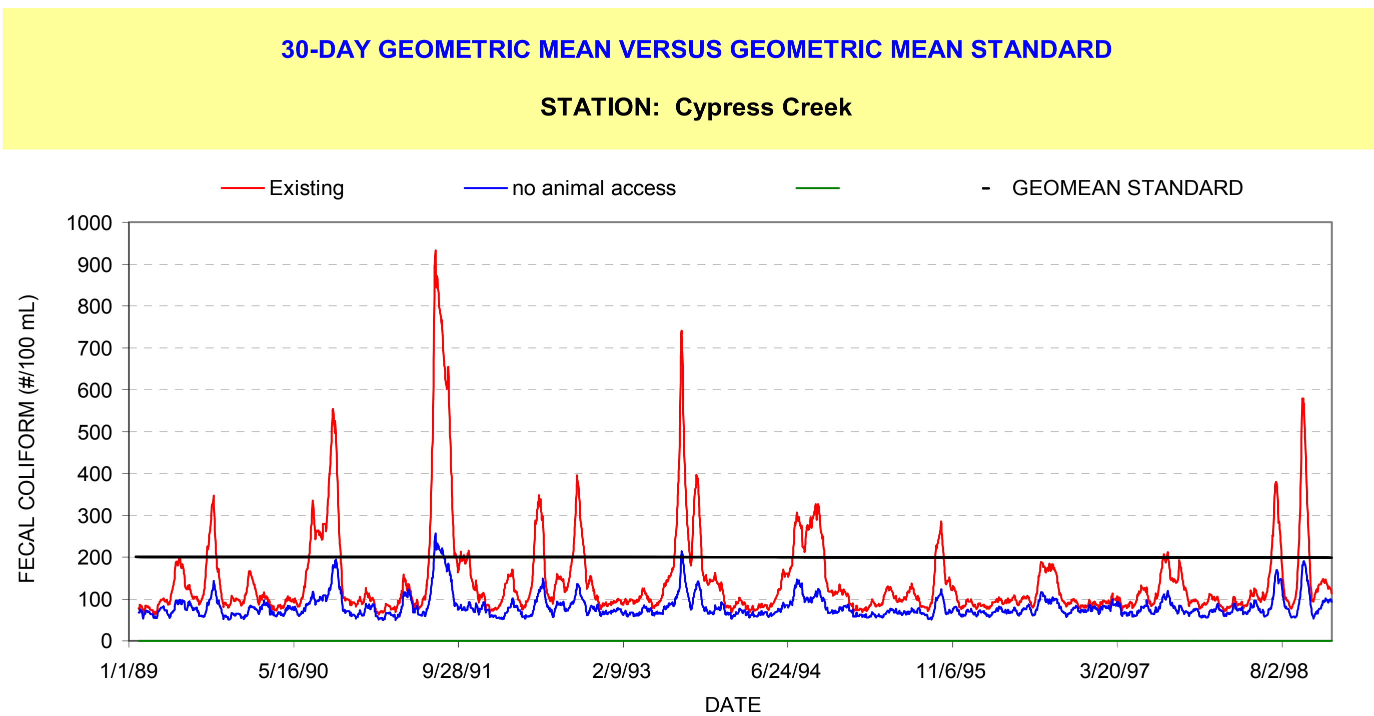


Figure B-11 Model Sensitivity to Animals Access in Cypress Creek – Existing Conditions

APPENDIX C

Determination of Critical Conditions

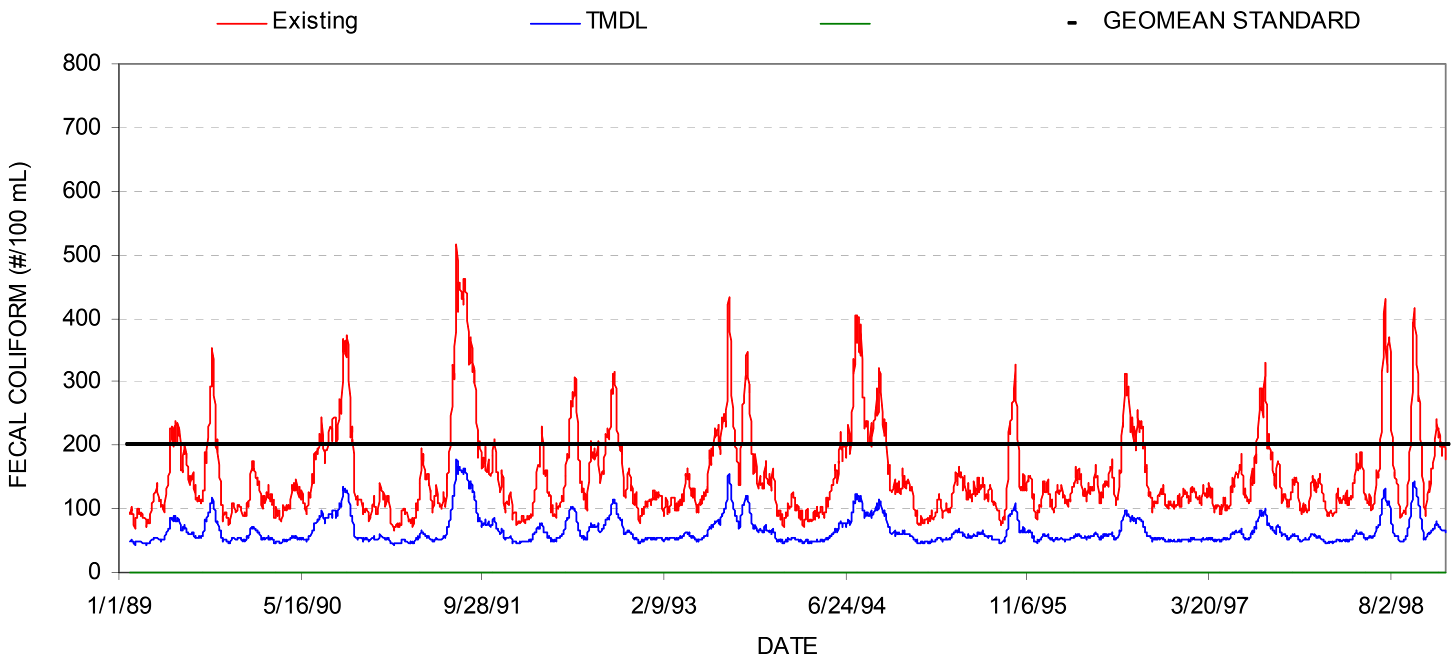


Figure C-1 Simulated 30-DayGeometric Mean for Loosahatchie River at Station LOOSAHATCH017.2

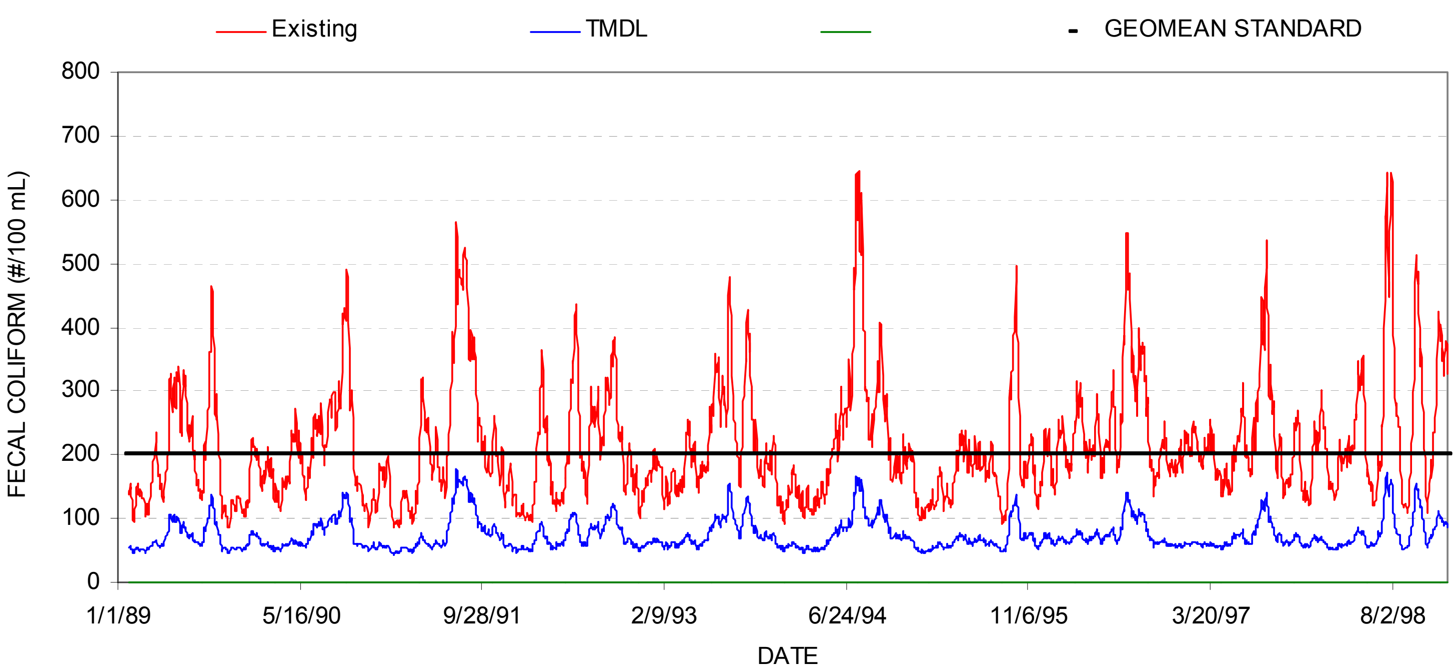


Figure C-2 Simulated 30-Day Geometric Mean for Loosahatchie River at Station 001800

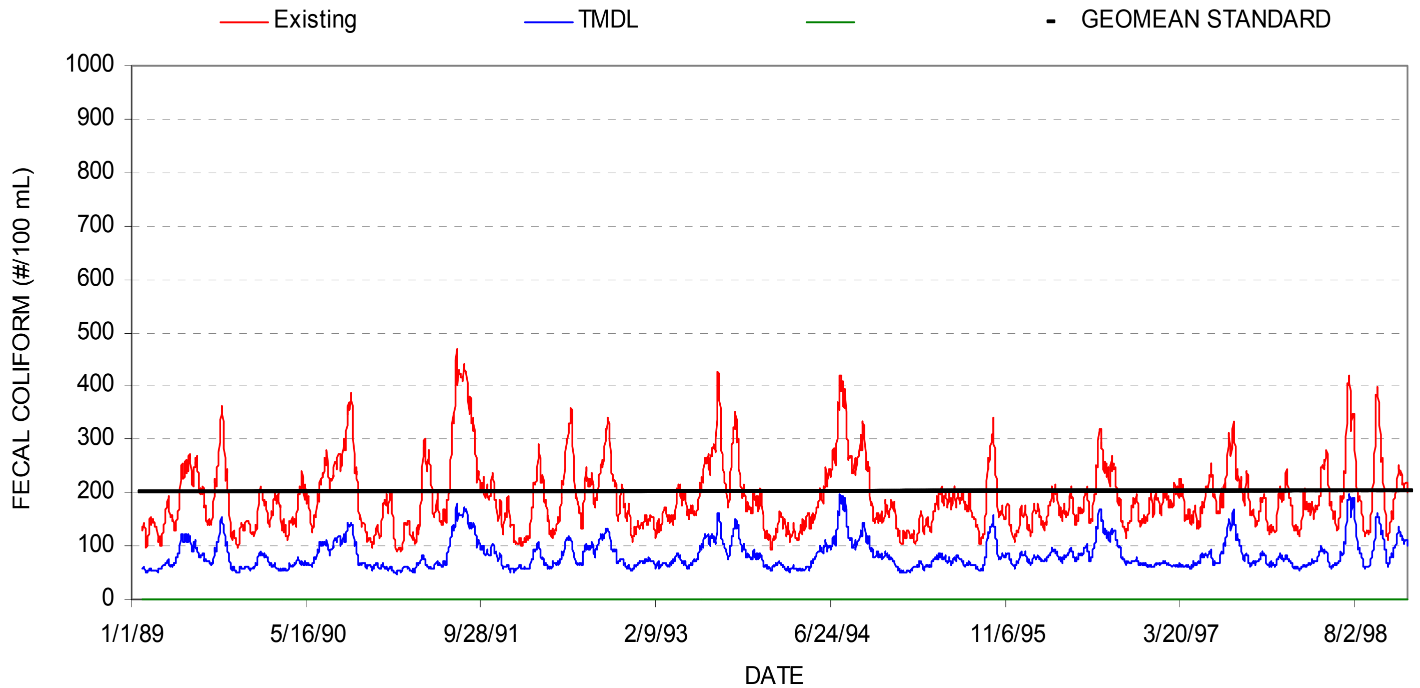


Figure C-3 Simulated 30-Day Geometric Mean for Big Creek

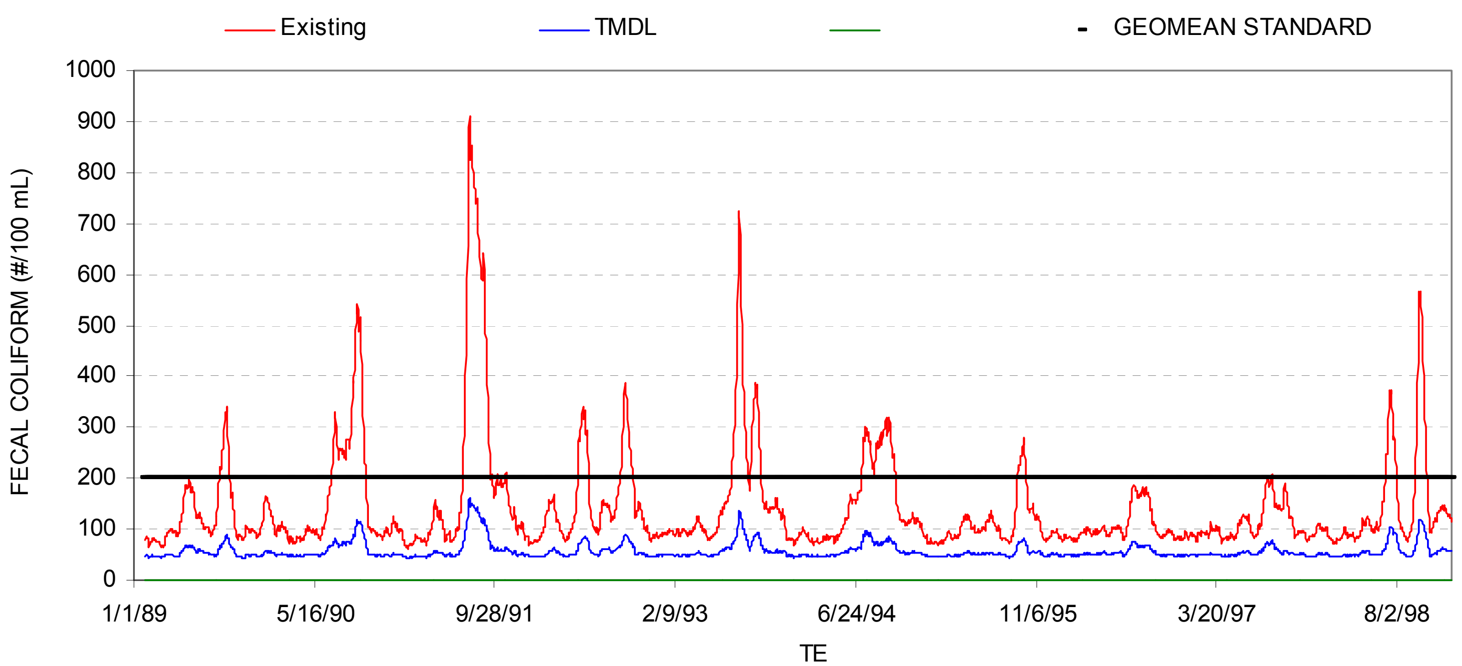


Figure C-4 Simulated 30-Day Geometric Mean for Cypress Creek

APPENDIX D

Public Notice Announcement

STATE OF TENNESSEE
DEPARTMENT OF ENVIRONMENT AND CONSERVATION
DIVISION OF WATER POLLUTION CONTROL

PUBLIC NOTICE OF AVAILABILITY OF PROPOSED TOTAL MAXIMUM DAILY LOAD (TMDL) FOR FECAL COLIFORM IN LOOSAHATCHIE RIVER (Mouth to Big Cr.) LOOSAHATCHIE RIVER (Big Cr. to Cypress Cr.) BIG CREEK CYPRESS CREEK LOOSAHATCHIE WATERSHED (HUC 08010209), TENNESSEE

Announcement is hereby given of the availability of Tennessee's proposed Total Maximum Daily Loads (TMDLs) for fecal coliform in Loosahatchie River watershed located in western Tennessee. Section 303(d) of the Clean Water Act requires states to develop TMDLs for waters on their impaired waters list. TMDLs must determine the allowable pollutant load that the water can assimilate, allocate that load among the various point and nonpoint sources, include a margin of safety, and address seasonality.

Cypress Creek, Big Creek, and two segments of the Loosahatchie River (mouth to Big Cr. and Big Cr. to Cypress Cr.) are listed on Tennessee's final 1998 303(d) list as not supporting designated use classifications due, in part, to pathogens associated with urban storm water runoff, collection system failure, and agriculture. The TMDLs utilize Tennessee's general water quality criteria, USGS continuous record station flow data, in-stream water quality monitoring data, a calibrated dynamic water quality model, and an appropriate Margin of Safety (MOS) to establish allowable loadings of fecal coliform which will result in reduced in-stream concentrations and the attainment of water quality standards. The TMDLs require reductions in in-stream fecal coliform loading of approximately 50% to 73% in the four listed waterbodies.

The proposed fecal coliform TMDLs may be downloaded from the Department of Environment and Conservation website:

http://www.state.tn.us/environment/wpc/tmdl.htm

Technical questions regarding this TMDL should be directed to the following members of the Division of Water Pollution Control staff:

Bruce R. Evans, P.E., Watershed Management Section
Telephone: 615-532-0668

Sherry H. Wang, Ph.D., Watershed Management Section
Telephone: 615-532-0656

Persons wishing to comment on the TMDLs are invited to submit their comments in writing no later than July 19, 2001 to:

Division of Water Pollution Control
Watershed Management Section
6th Floor, L & C Annex
401 Church Street
Nashville, TN 37243-1534

All comments received prior to that date will be considered when revising the TMDL for final submittal to the U.S. Environmental Protection Agency.

The TMDL and supporting information are on file at the Division of Water Pollution Control, 6th Floor, L & C Annex, 401 Church Street, Nashville, Tennessee. They may be inspected during normal office hours. Copies of the information on file are available on request.

APPENDIX E

Public Comments Received

Comments from the City of Memphis

July 6, 2001

Sherry H. Wang
Tennessee Department of Environment and Conservation
Division of Water Pollution Control
6th Floor L & C Annex
401 Church Street
Nashville, TN 37243-1534

Dear Ms. Wang:

Thank you for allowing the City of Memphis the opportunity to review and comment on the "Proposed Total Maximum Daily Load (TMDL) for Fecal Coliform in Cypress Creek, Big Creek and Two Segments of the Loosahatchie River." We have reviewed the document and offer the following comments:

1) Section 4.0 states that a margin of safety of 20 counts/100 ml is included in the TMDL to address uncertainty in the model. Margins of safety are already built into the water quality standards and into the model design, thus this additional margin of safety seems excessive. In order to be consistent with the "Draft TMDL for Fecal Coliform in the Nonconnah Creek Watershed, "which had an implicit margin of safety, the margin of safety for this TMDL should also be implicit. Additional margins of safety already incorporated into the process are listed in Section 8.3.

2) Section 6.1 give the loading to the River from point sources as being calculated based on the design flow and the facility's permit limit. For evaluating the conditions in the River and for model calibration, the actual flow and the actual fecal coliform loading should be used. Design flow and the facility's permit limit may be used for load allocation once the model has been calibrated using existing conditions and collected data.

3) Section 6.1 states that point sources have a permit concentration of 200 counts/100ml, yet Section 9.1 of the Implementation Plan states that the discharges from point sources "are required to be in compliance with the conditions of their NPDES permit at all times." In order to maintain consistency with the margin of safety discussed in Section 4.0, the Permit concentration should be lowered to 180 counts/100 ml, unless an implicit margin of safety is employed.

4) Section 6.1, Table 4 is missing the sewage treatment facilities for the Cities of Bartlett and Lakeland. These facilities need to be added and their impact included in the TMDL analysis.

5) Section 7.1 gives a fecal coliform in-stream decay and a source of "Lombardo 1972." Indicate where the study conducted by Lombardo occurred and what types of stream conditions were studied. Fecal coliform in the slow moving rivers of this area of the country may actually reproduce or may decay much less than in other parts of the country, particularly during the summer.

6) Section 8.2 states that the model results indicated that "agricultural and urban land uses are the largest sources of fecal coliform bacteria loading," yet there is no data to support this conclusion. There are no sampling points immediately downstream of the various cities and towns in the watershed, except for the site downstream of the City of Memphis, which has lower average coliform values than the more upstream sampling point.

7) Section 8.2, table 7 shows high "simulated" in-stream concentrations, yet there is no data to support this simulation, since the upstream station at Singleton Parkway had much higher results than the downstream station. The data shows higher fecal coliform levels in the River, which diminish as the flow is diluted downstream. The model arrives at a conclusion opposite of that shown both by the data included in the TMDL and by the data that we've collected and submitted to the State in our Annual Storm Water NPDES Permit Reports. The model needs to be recalibrated to be in line with the collected data.

8) Section 8.4.2 in the second paragraph, the words "and urban runoff" need to be removed from the sentence, as well as elsewhere that they appear in the TMDL document, as the statement is contradictory to the information shown by the data collected and used in the analysis. It appears that the model may have a bias toward including urban loading, where such loading does not exist, regardless of the information collected and put into the model.

9) Section 9.2.1 should be modified or deleted, since the fecal coliform levels in the River downstream of the City of Memphis urban area are lower than upstream of the City, thus the water flowing into the River from the City is cleaner on average than the water approaching the City from upstream. If Section 9.2.1 is to be modified instead of deleted, all paragraphs should be deleted, except the existing first paragraph of the section. The second paragraph should read as follows:

" In accordance with the findings of the data collected and evaluated for this TMDL, the City of Memphis has done an excellent job of implementing practices to keep fecal coliform from its urban activities from impacting the waters of the Loosahatchie River. The City should continue with existing practices, while implementing any new practices that it feels are warranted, to keep fecal coliform from polluting the Loosahatchie River while upstream sources are being addressed."

10) Section 9.2.2 should list the City of Bartlett as a municipality covered under the Phase 2 storm water regulations, as it is shown in the watershed in the map in Figure 3.

11) The graphs in Section C are unclear, since the lines for "Existing" and "TMDL" are both solid lines although one appears to be slightly darker than the other. There is a line between "TMDL" and "GEOMEAN STANDARD" that has no label. Also, the graphs in figures B-10 and B-11 are unclear.

12) The TMDL document needs to describe the process that will be used to identify when the Creek has met water quality objectives. I suggest that two years of data showing the geometric mean of fecal coliform levels (or e. Coli levels) of less than the standard of 200 counts/100 ml should be adequate for considering that the water quality objectives have been met. When implementing the EPA's requirement that the State consider "all existing and readily available" information when determining the list of polluted waters, the data used

should accurately represent the conditions in the creek. Data used for the determination of water quality in streams that are being actively tested for the parameter, should be no older than the listing cycle for submission of the impaired waters to the EPA, thus, a reasonable time frame is two years. My understanding of the current TMDL rule is that the listing cycle will be extended to 4 years, beginning April 1, 2002, at which time you may want to consider a longer time frame.

13) The data collected by the City of Memphis and provided to TDEC in our Annual Reports was not considered in the evaluation. Although you may not have rain data to use this data in the model, this data should be included in the TMDL, as it is representative of water conditions in the watershed. Also, if the most recent rain data that is available that can be used in the model is nearly 3 years old, then the use of a different model that can use commonly available rain data should be considered rather than the model currently being used. Use of the current model projects data into the future, which no longer may represent conditions in the stream. This leads to important decisions being made based on faulty projections.

If you have any questions or wish to further discuss this issue, please feel free to contact me at (901) 576-7122.

Sincerely,

Thomas B. Lawrence, P. E.
City of Memphis Storm Water Program

APPENDIX F

Response to Public Comments

<u>Responses to City of Memphis Comments</u>

Note: responses correspond to numbered comments (see Appendix E)

1) Margin of Safety (MOS) is required in TMDLs to account for uncertainties in data or analysis. The MOS used for this TMDL is comprised of both an implicit element, due to conservative modeling assumptions, and an explicit element of 20 counts/100 ml (reference Section 8.3). The explicit MOS was included based on comments received on previous fecal coliform TMDLs. Overall, the MOS described in Section 8.3 is considered to be appropriate.

2) In a strict sense, daily discharge flow and pollutant concentration values should be used for point source discharges for the entire time span of model calibration simulations. This information is time consuming to collect and sometimes is not available. As a matter of convenience and in view of the fact that fecal coliform loading from point sources is only from 0.3% to 3.9% of the total loading (depending on subwatershed), the design flow and permit limits of the various facilities was used. The error introduced into the analysis was considered to be minimal.

3) It is not standard practice in Tennessee to specify water quality based limits in NPDES permits that are more stringent than instream criteria. As part of the overall MOS, the explicit MOS of 20 counts/100 ml is included to account for uncertainties in the analysis. Since fecal coliform loading due to point sources is conservative (design flows & permit limits), of small magnitude, and relatively certain compared to loading from non-point sources, the limit of 200 counts/100 ml was considered to be appropriate.

4) The TMDL analysis has been revised to include the discharges of Bartlett STP #1 (TN0066800), Bartlett WWTP #2 (TN0068543), and Lakeland Wastewater Lagoon (TN0074012). The Summary Sheets, Table 4, Table 8, and Figures B-5, B-6, B-7, C-1,& C-2 have also been updated. The inclusion of the discharges from these facilities has a negligible effect on calculated WLAs and TMDLs for the two Loosahatchie River segments.

5) The fecal coliform decay rate utilized in the model was reported by Lombardo (see References) and cited in *Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling (Second Edition)* (EPA/600/3-85/040, June 1985). The median value used is reasonable when compared to decay rates reported in other studies referenced in the EPA document. The Reference page of the TMDL has been revised to clarify the citation.

6) As stated in Appendix B, the model was calibrated by adjusting parameters within appropriate ranges until acceptable agreement between simulation output and instream observed data was achieved. The calibrated model was used to determine the 30 day "critical period" (Section 8.1) and then to evaluate existing fecal coliform loading during the critical period (Section 8.2). The results of the existing loading simulation indicated that non-point sources related to agricultural and urban land uses were the largest sources of fecal coliform loading in the Loosahatchie watershed. In the model, the fecal coliform loading from other non-point sources, such as forest land, are relatively minor in comparison. The monitoring recommended in the Implementation Plan (Section 9.0) will validate the model results and document changes in water quality resulting from TMDL implementation. With additional monitoring data, this TMDL will be revised as required.

7) See Item 6 above. The ambient monitoring data presented in Table 3 shows that on common sampling dates, the fecal coliform concentrations at the downstream Loosahatchie station (STORET 001800 at North Watkins Street) were higher than those at the upstream station (STORET LOOSAHATCH017.2 at Singleton Parkway) 50% of the time. In addition, the data collected by the City of Memphis as part of their MS4 monitoring in the Loosahatchie watershed show fecal coliform concentrations that exceed the 1,000 counts/100 ml standard in 28% of the samples and exceed the 200 counts/ 100 ml standard in 66% of the samples. This monitoring data was collected monthly (1/20/99 – 5/18/00) at two stations on the Loosahatchie River and four stations on tributaries to the Loosahatchie River. For the Loosahatchie River stations, higher fecal coliform concentrations were reported at the downstream station in 9 of 17 samples. This data has been included in Appendix G and indicates that significant fecal coliform loading is contributed by urban sources This is further supported by language in the "Discussion of Ambient Monitoring Results" section of the *Storm Water Program Annual Report* submitted by the City of Memphis for the period 6/1/99 – 5/31/00:

> For Fecal Coliform results between 1,000 and 10,000 cfu/100 mls, obvious sources generally could not be found and the results in this range tended to persist for several months before dropping down. This finding indicates that sources of Fecal Coliforms in this range are probably more likely to be related to nonpoint sources, including agricultural and urban activities, as well as wildlife and Fecal Coliform persistence in the water of the storm drain system.

The City of Memphis data was not included in the modeling effort due to limitations imposed by the availability of weather data (1/1/70 through 12/31/98). This data will be used, however, for model validation during subsequent TMDL phases. The Non-Point Source Model (NPSM), which is based on the Hydrologic Simulation Program – Fortran (HSPF), has been selected by EPA Region 4 as the model of choice for fecal coliform TMDL analysis.

8) See Items 6 & 7 above.

9) See Items 6 & 7 above.

10) Section 9.2.2 has been revised to include the City of Bartlett as a municipal entity that will be issued an NPDES Municipal Separate Storm Sewer System (MS4) permit under the Phase 2 storm water regulations.

11) The graphs in Appendix C were constructed to show existing fecal coliform concentrations in red and reduced concentrations after implementation of the TMDL in blue. This is clear if the document is viewed in electronic format or printed using a color printer. Since the graphs are of daily mean data for a ten year period, the use of dashed lines does not provide clarity.

12) This TMDL was developed in response to the listing of two segments of the Loosahatchie River, Cypress Creek, and Big Creek on the 1998 303(d) list as not meeting all of their designated use classifications due, in part, to pathogens. The 303(d) list is required to be

updated every two years. Surface waters in Tennessee are monitored on a continuous, rotating basis as part of the State's watershed management approach. This monitoring data, as well as any other new and relevant information, is used to assess the water quality of streams in Tennessee. Waters that are determined to be not supporting classified uses are included in the 303(d) list. Conversely, previously listed streams that are determined to be supporting all designated uses are removed from the list and are no longer considered to be impaired.

13) See Items 6 & 7 above.

APPENDIX G

Ambient Monitoring Data for the Loosahatchie Watershed Submitted by the City Of Memphis

Ambient Monitoring Data Submitted by the City of Memphis in
Storm Water Program Annual Reports for the Periods 6/1/98 – 5/31/99 & 6/1/99 – 5/31/00

Date	Ambient Monitoring Data - Fecal Coliform [cfu/100 mls]					
	Loosahatchie R. at Singleton Pkwy.	Unnamed Trib. at Bolen Huse Rd.	Unnamed Trib. at Egypt Central Rd.	Unnamed Trib. at Hawkins Mill Rd.	Loosahatchie R. at N. Watkins St.	Todd Creek at Millington St.
01/20/99	370	410	174,000	690	1,200	13,000
02/15/99	280	283,000	5,400	3,000	1,335	262,000
03/23/99	70	750	39,000	1,000	470	26,000
04/22/99	80	320	760	170	40	76,000
05/19/99	780	5,600	7,200	4,400	3,100	2,800
06/22/99	20	90	3,000	2,900	10	590
07/20/99	680	5,000	1,300	2,500	230	340
08/26/99	60	80	2,100	2,400	110	1,900
09/23/99	50	330	270	520	20	No Sample
10/21/99	20	40	430	690	30	5,300
11/17/99	40	380	200	210	10	No Sample
12/16/99	880	870	850	320	730	710
01/13/00	60	240	20	190	<10	110
02/22/00	110	2,000	200	25,000	370	120
03/22/00	320	180	580	230	600	360
04/17/00	70	180	740	870	50	20
05/18/00	110	90	>80,000	480	160	270