TOTAL MAXIMUM DAILY LOAD (TMDL)

for

E. Coli

in the

Wolf River Watershed (HUC 08010210)

Fayette, Hardeman, and

Shelby Counties, Tennessee

FINAL

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LIST OF ABBREVIATIONS

AFO	Animal Feeding Operation
BMP	Best Management Practices
BST	Bacteria Source Tracking
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
CFU	Colony Forming Units
DA	Drainage Area
DEM	Digital Elevation Model
E. coli	Escherichia coli
EPA	Environmental Protection Agency
GIS	Geographic Information System
HSPF	Hydrological Simulation Program - Fortran
HUC	Hydrologic Unit Code
LA	Load Allocation
LCS	Leaking Collection System
LDC	Load Duration Curve
LSPC	Loading Simulation Program in C^{++}
MGD	Million Gallons per Day
MOS	Margin of Safety
MRLC	Multi-Resolution Land Characteristic
MS4	Municipal Separate Storm Sewer System
MST	Microbial Source Tracking
NHD	National Hydrography Dataset
NMP	Nutrient Management Plan
NPS	Nonpoint Source
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
PCR	Polymerase Chain Reaction
PDFE	Percent of Days Flow Exceeded
PFGE	Pulsed Field Gel Electrophoresis
PLRG	Percent Load Reduction Goal
RM	River Mile
SSO	Sanitary Sewer Overflow
STP	Sewage Treatment Plant
SWMP	Storm Water Management Plan
TDA	Tennessee Department of Agriculture
TDEC	Tennessee Department of Environment & Conservation
TDOT	Tennessee Department of Transportation
TMDL	Total Maximum Daily Load
TWRA	Tennessee Wildlife Resources Agency
USGS	United States Geological Survey
UCF	Unit Conversion Factor
UTK	University of Tennessee, Knoxville
WCS	Watershed Characterization System
WLA	Waste Load Allocation
WWTF	Wastewater Treatment Facility

SUMMARY SHEET

Total Maximum Daily Load for E. Coli in Selected Waterbodies of the Wolf River Watershed (HUC 08010210)

Impaired Waterbody Information

State: Tennessee
Counties: Fayette, Hardeman, and Shelby
Watershed: Wolf River (HUC 08010210)
Constituents of Concern: E. coli

Impaired Waterbodies Addressed in This Document (from the Final 2006 303(d) List):

Waterbody ID	Waterbody	RM not Fully Supporting
TN08010210001 – 0100	HARRINGTON CREEK	16.5
TN08010210001 – 0300	WORKHOUSE BAYOU	3.7
TN08010210001 – 1000	WOLF RIVER	12.8
TN08010210002 – 1000	WOLF RIVER	6.3
TN08010210002 – 2000	WOLF RIVER	3.8
TN08010210003 – 0100	JOHNSON CREEK	10.4
TN08010210004 – 0100	HURRICANE CREEK	12.5
TN08010210004 – 0400	UNNAMED TRIB TO WOLF RIVER	23.6
TN08010210004 – 0500	RUSSELL CREEK	12.8
TN08010210005 – 0100	TEAGUE BRANCH	17.0
TN08010210005 – 1000	GRISSUM CREEK	17.9
TN08010210009 – 0300	EARLY GROVE CREEK	2.5
TN08010210020 – 0300	MCKINNIE CREEK	35.1
TN08010210020 – 0310	MAY CREEK	27.1
TN08010210020 – 0400	NORTH FORK CREEK	39.0
TN08010210020 – 2000	NORTH FORK WOLF RIVER	10.79
TN08010210021 – 0100	ALEXANDER CREEK	21.8
TN08010210021 – 1000	SHAWS CREEK	20.1
TN08010210022 – 0100	UNNAMED TRIB TO GRAYS CREEK	8.4
TN08010210022 – 0300	MARYS CREEK	17.4
TN08010210022 – 0350	MARYS CREEK	2.5
TN08010210023 – 0100	UNNAMED TRIB TO FLETCHER CREEK	23.1
TN08010210023 – 0200	UNNAMED TRIB TO FLETCHER CREEK	6.5
TN08010210023 – 1000	FLETCHER CREEK	10.7
TN08010210032 – 1000	CYPRESS CREEK	13.6

Designated Uses:

The designated use classifications for all impaired waterbodies in the Wolf River watershed include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. Use classifications for the Wolf River from mile 6.7 to the state line include industrial water supply and navigation.

Water Quality Goal:

Derived from *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, January, 2004* for recreation use classification (most stringent):

> The concentration of the E. coli group shall not exceed 126 colony forming units per 100 ml, as a geometric mean based on a minimum of 5 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. For the purposes of determining the geometric mean, individual samples having an E. coli concentration of less than 1 per 100 ml shall be considered as having a concentration of 1 per 100 ml.
>
> Additionally, the concentration of the E. coli group in any individual sample taken from a lake, reservoir, State Scenic River, or Tier II or III stream (1200-4-3-.06) shall not exceed 487 colony forming units per 100 ml. The concentration of the E. coli group in any individual sample taken from any other waterbody shall not exceed 941 colony forming units per 100 ml.

Note:At the time of this TMDL analysis, high quality waters were designated as Tier II and Tier III streams. The proposed revised water quality standards redefine high quality waters as Exceptional Tennessee Waters. For further information on Tennessee's current general water quality standards, see:

http://www.state.tn.us/sos/rules/1200/1200-04/1200-04-03.pdf.

For further information on the proposed revised general water quality standards and Tennessee's Antidegradation Statement, including the definition of Exceptional Tennessee Waters, see:

http://state.tn.us/environment/wpc/publications/1200_04_03_2nd_draft.pdf.

TMDL Scope:

Waterbodies identified on the Final 2006 303(d) List as impaired due to E. coli. TMDLs were developed for impaired waterbodies on HUC-12 subwatershed or waterbody drainage area basis.

Analysis/Methodology:

The TMDLs for impaired waterbodies in the Wolf River watershed were developed using a load duration curve methodology to assure compliance with the E. coli 126 CFU/100 mL geometric mean and the 487 CFU/100 mL maximum water quality criteria for lakes, reservoirs, State Scenic Rivers, or Tier II or III waterbodies and 941 CFU/100 mL maximum water quality criterion for all other waterbodies. A duration curve is a cumulative frequency graph that represents the percentage of time during which the value of a given parameter is equaled or exceeded. Load duration curves are developed from flow duration curves and can illustrate existing water quality conditions (as represented by loads calculated from monitoring data), how these conditions compare to desired targets, and the region of the waterbody flow zone represented by these existing loads. Load duration curves were also used to determine percent load reduction goals to meet the target maximum loading for E. coli. When sufficient data were available, load reductions were also determined based on the geometric mean criterion.

Critical Conditions:

Water quality data collected over a period of up to nearly seven years for load duration curve analysis were used to assess the water quality standards representing a range of hydrologic and meteorological conditions.

For each impaired waterbody, critical conditions were determined by evaluating the percent load reduction goals, for each hydrologic flow zone, to meet the target (TMDL) loading for E. coli. The percent load reduction goal of the greatest magnitude corresponds with the critical flow zone.

Seasonal Variation:

The 10-year period used for LSPC model simulation and for load duration curve analysis included all seasons and a full range of flow and meteorological conditions.

Margin of Safety (MOS):

Explicit MOS = 10% of the E. coli water quality criteria for each impaired subwatershed or drainage area.

TMDLs, WLAs, & LAs

Summary of TMDLs, WLAs, & LAs for Impaired Waterbodies

HUC-12 Subwatershed (08010210__)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs[a]			LAs
					WWTFs[b]	Leaking Collection Systems	MS4s	
			[CFU/day]	[CFU/day]	[CFU/day]	[CFU /day]	[CFU/day/acre]	[CFU/day/acre]
0105	Early Grove Creek	TN08010210009 – 0300	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	3.24×10^{6} * Q
0201	McKinnie Creek	TN08010210020 – 0300	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	9.74×10^{5} * Q
	May Creek	TN08010210020 – 0310	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	2.29×10^{6} * Q
	North Fork Creek	TN08010210020 – 0400	1.19×10^{10} * Q	1.19×10^{9} * Q	NA	NA	NA	8.28×10^{5} * Q
0202	North Fork Wolf River	TN08010210020 – 2000	1.19×10^{10} * Q	1.19×10^{9} * Q	NA	NA	NA	2.46×10^{5} * Q
0301	Hurricane Creek	TN08010210004 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	4.69×10^{6} * Q
	Unnamed Tributary to Wolf River	TN08010210004 – 0400	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	NA	2.94×10^{6} * Q
	Russell Creek	TN08010210004 – 0500	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	4.23×10^{6} * Q
0302	Teague Branch	TN08010210005 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	3.17×10^{6} * Q
	Grissum Creek	TN08010210005 – 1000	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	8.80×10^{5} * Q
0303	Alexander Creek	TN08010210021 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	2.74×10^{6} * Q
	Shaws Creek	TN08010210021 – 1000	2.30×10^{10} * Q	2.30×10^{9} * Q	7.13×10^{8}	NA	NA	6.79×10^{5} * Q – 2.34×10^{4}
0304	Wolf River	TN08010210002 – 2000	2.30×10^{10} * Q	2.30×10^{9} * Q	4.31×10^{11}	0	4.61×10^{4} * Q – 9.59×10^{5}	4.61×10^{4} * Q – 9.59×10^{5}
	Johnson Creek	TN08010210003 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	5.10×10^{6} * Q	5.10×10^{6} * Q
0305	Unnamed Tributary to Grays Creek	TN08010210022 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	8.88×10^{6} * Q	8.88×10^{6} * Q
	Marys Creek	TN08010210022 – 0300	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	2.03×10^{6} * Q	2.03×10^{6} * Q
	Marys Creek Headwaters	TN08010210022 – 0350	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	8.68×10^{6} * Q	8.68×10^{6} * Q
0306	Harrington Creek	TN08010210001 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	2.79×10^{6} * Q	2.79×10^{6} * Q
	Workhouse Bayou	TN08010210001 – 0300	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.34×10^{7} * Q	1.34×10^{7} * Q

Summary of TMDLs, WLAs, & LAs for Impaired Waterbodies (Cont.)

HUC-12 Subwatershed (08010210__)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs[a]			LAs
					WWTFs[b]	Leaking Collection Systems	MS4s	
			[CFU/day]	[CFU/day]	[CFU /day]	[CFU /day]	[CFU/day/acre]	[CFU/day/acre]
0306 (cont.)	Wolf River	TN08010210001 – 1000	1.19×10^{10} * Q	1.19×10^{9} * Q	4.31×10^{11}	0	2.04×10^{4} * Q – 8.22×10^{5}	2.04×10^{4} * Q – 8.22×10^{5}
	Cypress Creek	TN08010210032 – 1000	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.72×10^{6} * Q	1.72×10^{6} * Q
0307	Wolf River	TN08010210002 – 1000	2.30×10^{10} * Q	2.30×10^{9} * Q	4.31×10^{11}	0	4.47×10^{4} * Q – 1.16×10^{6}	4.47×10^{4} * Q – 1.16×10^{6}
0308	Unnamed Tributary to Fletcher Creek	TN08010210023 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	3.01×10^{6} * Q	3.01×10^{6} * Q
	Unnamed Tributary to Fletcher Creek	TN08010210023 – 0200	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	8.10×10^{6} * Q	8.10×10^{6} * Q
	Fletcher Creek	TN08010210023 – 1000	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.00×10^{6} * Q	1.00×10^{6} * Q

Note: NA = Not applicable.
Q = Mean Daily In-stream Flow (cfs).
a. There are no CAFOs in impaired subwatersheds of the Wolf River watershed.
b. WLAs for WWTFs expressed as E. coli loads (CFU/day). Current and future WWTFs must meet water quality standards at the point of discharge as specified in their NPDES permits. At no time shall concentration exceed appropriate, site-specific (487 CFU/100 mL or 941 CFU/100 mL) water quality criteria.

E. COLI TOTAL MAXIMUM DAILY LOAD (TMDL)
WOLF RIVER WATERSHED (HUC 08010210)

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 waterbodies that are not attaining water quality standards. State water quality standards consist of designated uses for individual waterbodies, appropriate numeric and narrative water quality criteria protective of the designated uses, and an antidegradation statement. The TMDL process establishes the maximum allowable loadings of pollutants for a waterbody that will allow the waterbody to maintain water quality standards. The TMDL may then be used to develop controls for reducing pollution from both point and nonpoint sources in order to restore and maintain the quality of water resources (USEPA, 1991).

2.0 SCOPE OF DOCUMENT

This document presents details of TMDL development for waterbodies in the Wolf River Watershed identified on the Final 2006 303(d) List as not supporting designated uses due to Escherichia coli (E. coli). The majority of the Wolf River Watershed lies in the state of Tennessee with approximately 30% lying in Mississippi. TMDL analyses were performed on a 12-digit hydrologic unit area (HUC-12) subwatershed or waterbody drainage area basis.

3.0 WATERSHED DESCRIPTION

The Wolf River watershed (HUC 08010210) is located primarily in western Tennessee (Figure 1), with a portion in northern Mississippi, and lies within the Level III Southeastern Plains (65), Mississippi Alluvial Plain (73), and Mississippi Valley Loess Plains (74) ecoregions. The impaired subwatersheds lie in the Level IV Southeastern Plains and Hills (65e), Northern Mississippi Alluvial Plain (73a) and Loess Plains (74b) ecoregions as shown in Figure 2 (USEPA, 1997). For detailed information about the Wolf River watershed, including descriptions of Level IV ecoregions, see:

http://state.tn.us/environment/wpc/watershed/wsmplans/wolf/

The Wolf River watershed, located in Fayette, Hardeman, and Shelby Counties, Tennessee, and Benton, Marshall, and Tippah Counties, Mississippi, has a total drainage area of approximately 819 square miles (mi^2). 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. Although changes in the land use of the Wolf River watershed have occurred since 1993 as a result of development, this is the most current land use data readily available for GIS-interfaced hydrologic model input. Land use for the Wolf River watershed is summarized in Table 1 and shown in Figure 3. Predominate land use in the Wolf River watershed is forest (47.3%) followed by agriculture (38.8%). Urban areas represent approximately 11.7% of the total drainage area of the watershed. Details of land use distribution of E. coli-impaired subwatersheds in the Wolf River watershed are presented in Appendix A.

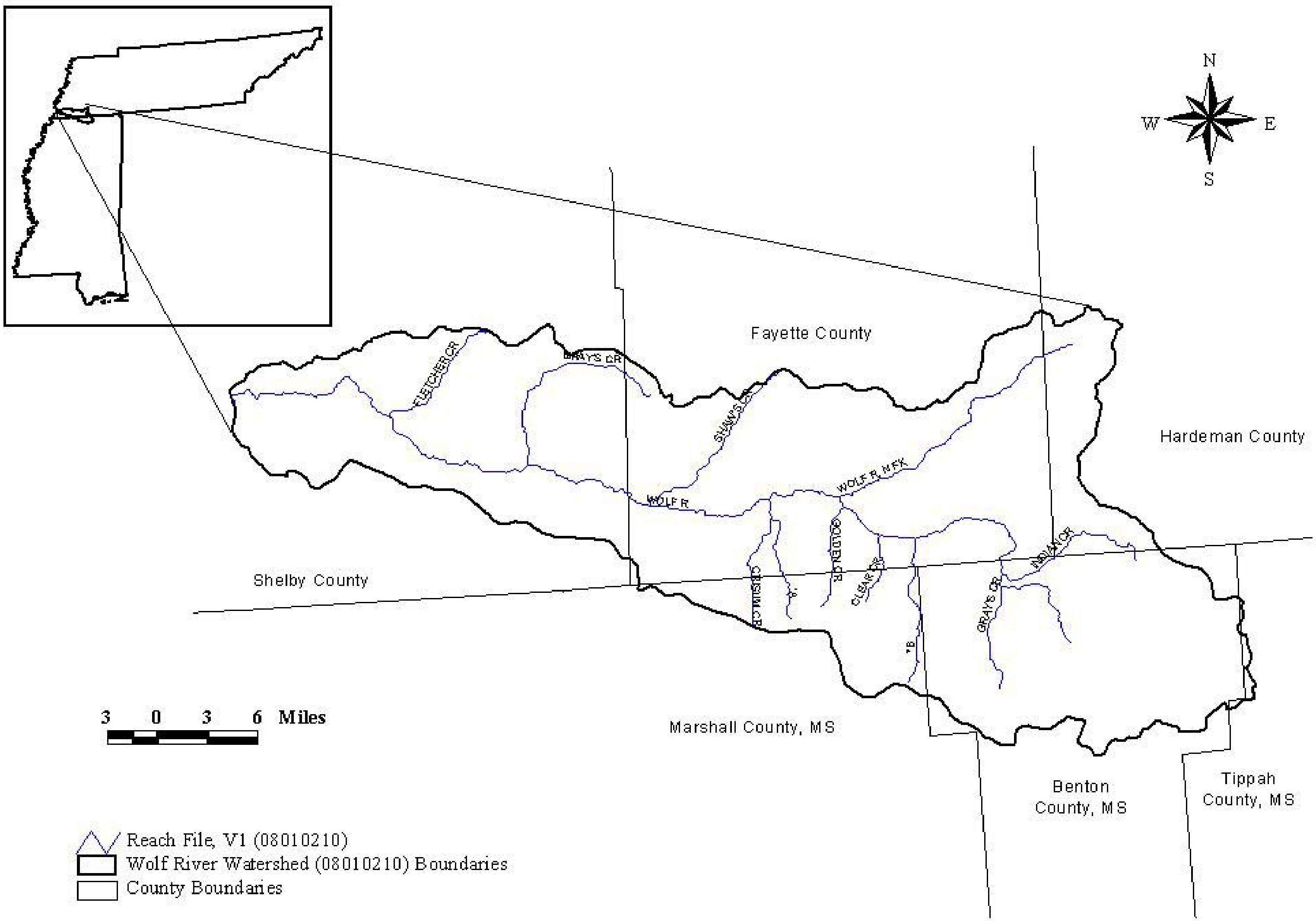

Figure 1. Location of the Wolf River Watershed.

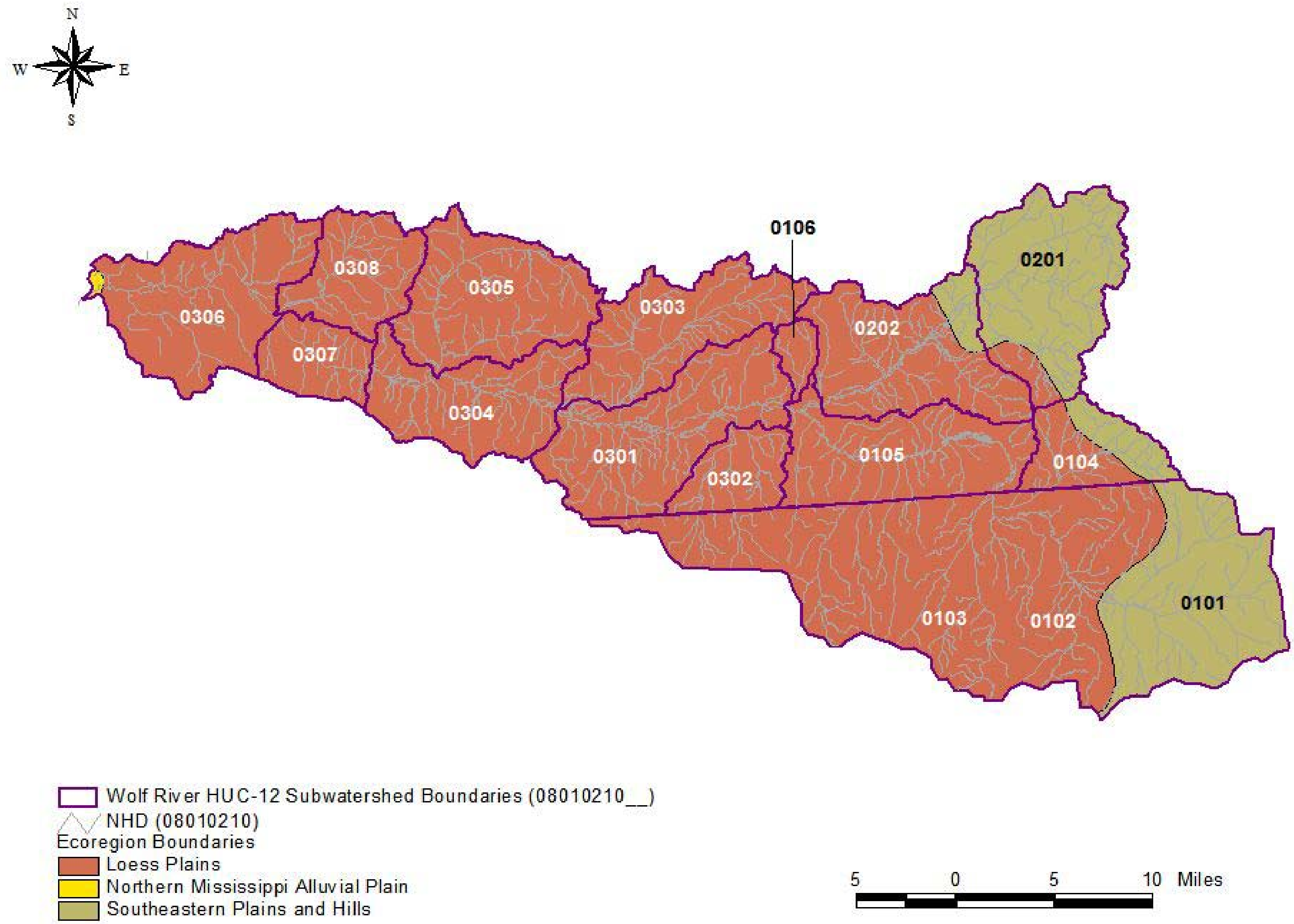

Figure 2. Level IV Ecoregions in the Wolf River Watershed.

Table 1. MRLC Land Use Distribution – Wolf River Watershed

Land Use	Area	
	[acres]	[%]
Bare Rock/Sand/Clay	137	0.0*
Deciduous Forest	145,286	27.7
Emergent Herbaceous Wetlands	245	0.0*
Evergreen Forest	21,953	4.2
High Intensity Commercial/ Industrial/Transportation	7,701	1.5
High Intensity Residential	18,394	3.5
Low Intensity Residential	33,651	6.4
Mixed Forest	35,588	6.8
Open Water	7,182	1.4
Other Grasses (Urban/recreational)	4,187	0.8
Pasture/Hay	107,890	20.6
Quarries/Strip Mines/Gravel Pits	109	0.0*
Row Crops	95,125	18.2
Transitional	1797	0.3
Woody Wetlands	44,756	8.5
Total	**524,002**	**100.0**

* < 0.05%

4.0 PROBLEM DEFINITION

The State of Tennessee's Final 2006 303(d) List (TDEC, 2006), http://state.tn.us/environment/wpc/publications/303d2006.pdf, was approved by the U.S. Environmental Protection Agency (EPA), Region IV in October of 2006. The list identified twenty-five (25) waterbody segments in the Wolf River watershed as not fully supporting designated use classifications due, in part, to E. coli. See Table 2 and Figure 4. The designated use classifications for these waterbodies include industrial water supply, fish and aquatic life, irrigation, livestock watering & wildlife, recreation, and navigation.

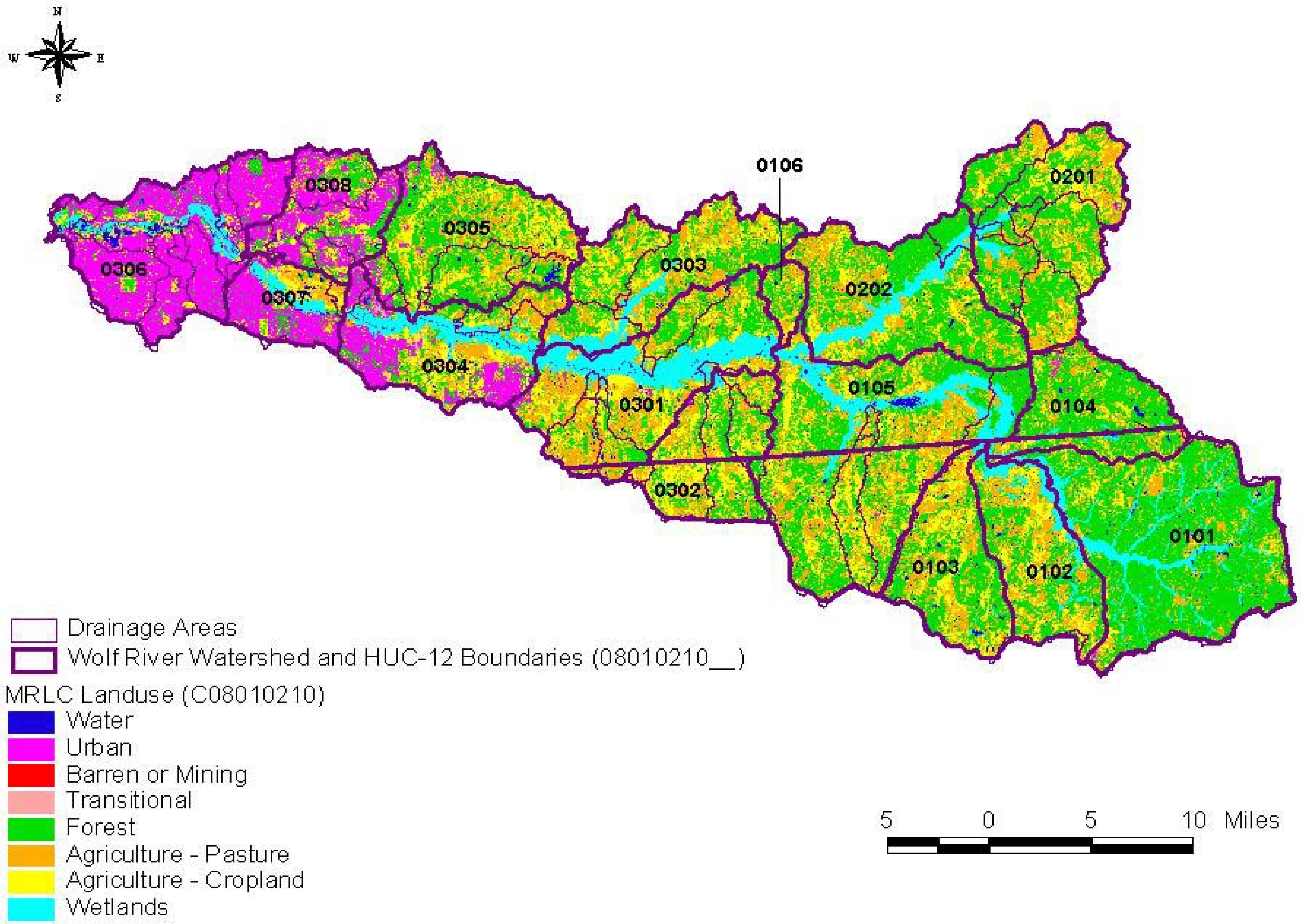

Figure 3. Land Use Characteristics of the Wolf River Watershed.

Table 2. Final 2006 303(d) List for E. coli – Wolf River Watershed

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	CAUSE / TMDL Priority	Pollutant Source
TN08010210001 – 0100	HARRINGTON CREEK	16.5	Arsenic Phosphate Low Dissolved Oxygen Escherichia coli	Discharges from MS4 area
TN08010210001 – 0300	WORKHOUSE BAYOU	3.7	Habitat loss due to alteration in stream-side or littoral vegetative cover Phosphate Escherichia coli	Discharges from MS4 area
TN08010210001 – 1000	WOLF RIVER	12.8	Lead Chlordane PCBs Dioxin Loss of biological integrity due to siltation Escherichia coli	Discharges from MS4 area RCRA Hazardous Waste Site Channelization Contaminated Sediments
TN08010210002 – 1000	WOLF RIVER	6.3	Chlordane PCBs Dioxin Lead Loss of biological integrity due to siltation Escherichia coli	Discharges from MS4 area RCRA Hazardous Waste Site Channelization Contaminated Sediments
TN08010210002 – 2000	WOLF RIVER	3.8	Lead Loss of biological integrity due to siltation Escherichia coli	Discharges from MS4 area RCRA Hazardous Waste Site Channelization
TN08010210003 – 0100	JOHNSON CREEK	10.4	Escherichia coli	Pasture Grazing
TN08010210004 – 0100	HURRICANE CREEK	12.5	Escherichia coli	Pasture Grazing
TN08010210004 – 0400	UNNAMED TRIBUTARY TO WOLF RIVER	23.6	Escherichia coli	Pasture Grazing
TN08010210004 – 0500	RUSSELL CREEK	12.8	Escherichia coli	Pasture Grazing

Table 2. Final 2006 303(d) List for E. coli – Wolf River Watershed (Cont.)

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	CAUSE / TMDL Priority	Pollutant Source
TN08010210005 – 0100	TEAGUE BRANCH	17.0	Loss of biological integrity due to siltation Physical Substrate Habitat Alterations Escherichia coli	Pasture Grazing
TN08010210005 – 1000	GRISSUM CREEK	17.9	Loss of biological integrity due to siltation Low dissolved Oxygen Escherichia coli	Pasture Grazing Channelization
TN08010210009 – 0300	EARLY GROVE CREEK	2.5	Escherichia coli	Pasture Grazing Sources Outside of State
TN08010210020 – 0300	MCKINNIE CREEK	35.1	Low dissolved Oxygen Escherichia coli	Pasture Grazing
TN08010210020 – 0310	MAY CREEK	27.1	Escherichia coli	Pasture Grazing
TN08010210020 – 0400	NORTH FORK CREEK	39.0	Escherichia coli	Pasture Grazing
TN08010210020 – 2000	NORTH FORK WOLF RIVER	10.79	Escherichia coli	Pasture Grazing
TN08010210021 – 0100	ALEXANDER CREEK	21.8	Escherichia coli	Pasture Grazing
TN08010210021 – 1000	SHAWS CREEK	20.1	Lead Low dissolved Oxygen Escherichia coli	Undetermined Source Pasture Grazing
TN08010210022 – 0100	UNNAMED TRIBUTARY TO GRAYS CREEK	8.4	Loss of biological integrity due to siltation Physical Substrate Habitat Alterations Phosphate Low dissolved Oxygen Escherichia coli	Discharges from MS4 area
TN08010210022 – 0300	MARYS CREEK	17.4	Loss of biological integrity due to siltation Phosphate Low dissolved Oxygen Escherichia coli	Discharges from MS4 area Upstream Impoundment

Table 2. Final 2006 303(d) List for E. coli – Wolf River Watershed (Cont.)

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	CAUSE / TMDL Priority	Pollutant Source
TN08010210022 – 0350	MARYS CREEK	2.5	Habitat loss due to stream flow alteration Escherichia coli	Upstream Impoundment Pasture Grazing
TN08010210023 – 0100	UNNAMED TRIBUTARY TO FLETCHER CREEK	23.1	Escherichia coli	Discharges from MS4 area
TN08010210023 – 0200	UNNAMED TRIBUTARY TO FLETCHER CREEK	6.5	Low dissolved Oxygen Phosphate Escherichia coli	Discharges from MS4 area Pasture Grazing Livestock Feeding Operations
TN08010210023 – 1000	FLETCHER CREEK	6.3	Arsenic Lead Low dissolved Oxygen Phosphate Physical Substrate Habitat Alterations Escherichia coli	Pasture Grazing Discharges from MS4 area Channelization
TN08010210032 – 1000	CYPRESS CREEK	13.6	Lead Low dissolved Oxygen Phosphate Physical Substrate Habitat Alterations Escherichia coli	Discharges from MS4 area Channelization

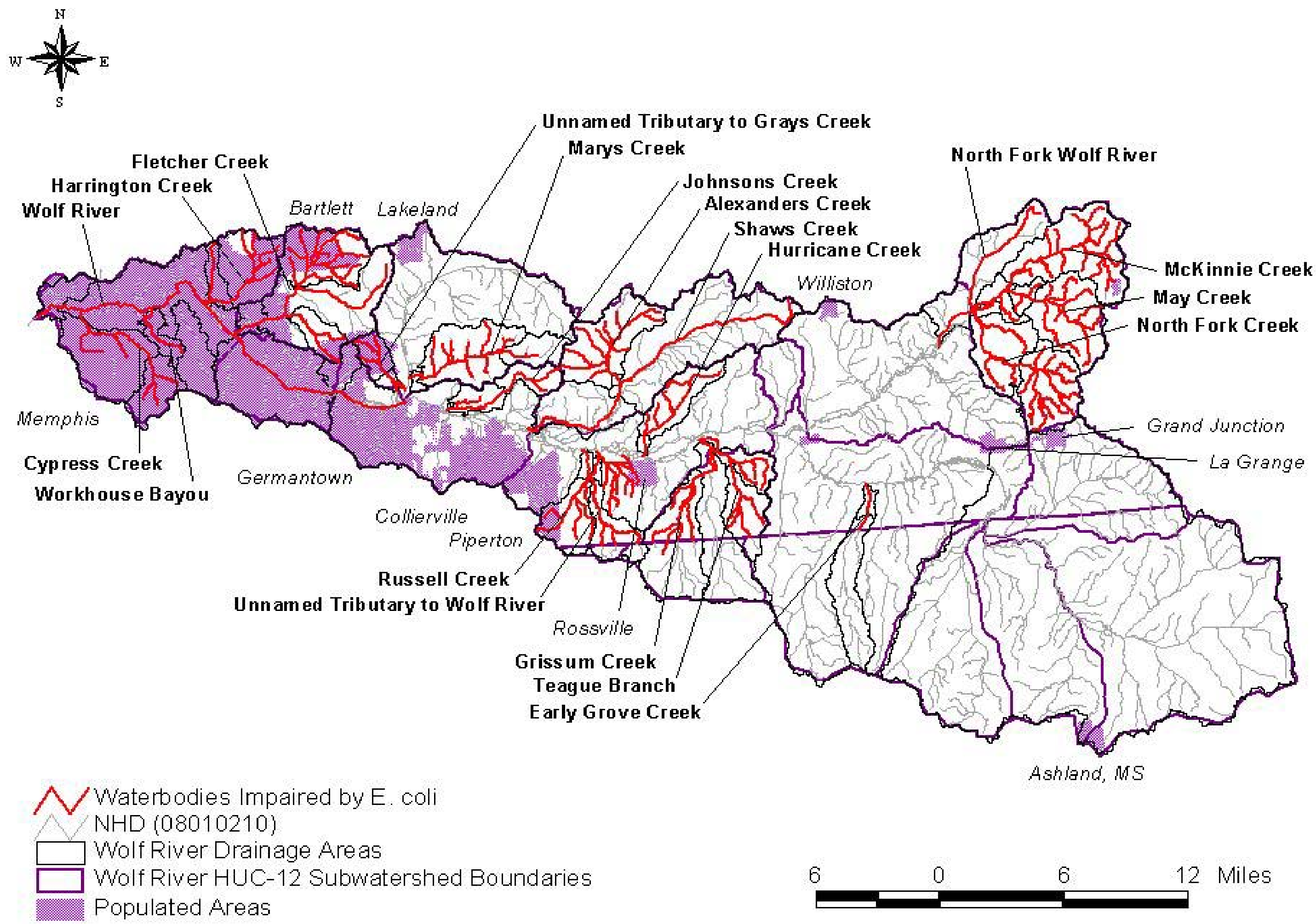

Figure 4. Waterbodies Impaired by E. Coli (as Documented on the Final 2006 303(d) List).

5.0 WATER QUALITY CRITERIA & TMDL TARGET

As previously stated, the designated use classifications for the Wolf River waterbodies include industrial water supply, fish & aquatic life, irrigation, livestock watering & wildlife, recreation, and navigation. Of the use classifications with numeric criteria for E. coli, the recreation use classification is the most stringent and will be used to establish target levels for TMDL development. The coliform water quality criteria, for protection of the recreation use classification, is established by *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, January 2004* (TDEC, 2004a).

A portion of the Wolf River, from the mouth to Fletcher Creek and portions of the North Fork Wolf River and North Fork Creek, in the Ames Plantation Natural Area, have been designated as high quality waters. As of February 2, 2006, none of the other E. coli impaired waterbodies in the Wolf River watershed have been designated as high quality waters.

For further information concerning Tennessee's general water quality criteria and Tennessee's Antidegradation Statement, including the definition of high quality waters, see:

http://www.state.tn.us/sos/rules/1200/1200-04/1200-04-03.pdf.

The geometric mean criterion for the E. coli group of 126 colony forming units per 100 mL (CFU/100 mL) and the sample maximum criterion of 487 CFU/100 mL have been selected as the appropriate numerical targets for TMDL development for impaired waterbodies designated as lakes, reservoirs, State Scenic Rivers, or high quality waters. The geometric mean criterion for the E. coli group of 126 CFU/100 mL and the sample maximum criterion of 941 CFU/100 mL have been selected as the appropriate numerical targets for TMDL development for the other impaired waterbodies.

6.0 WATER QUALITY ASSESSMENT AND DEVIATION FROM TARGET

There are multiple water quality monitoring stations that provide data for waterbodies identified as impaired for E. coli in the Wolf River watershed:

- HUC-12 080102100105:
  - EGROV001.6FA – Early Grove Creek, at Yager Road
- HUC-12 080102100201:
  - MCKIN000.5FA – McKinnie Creek, at Sardis Drive
  - MAY001.4FA – May Creek, at Buford Ellington Road
  - NFORK004.4FA – North Fork Creek, at Buford Ellington Road
- HUC-12 080102100202:
  - NFWOL011.4FA – North Fork Wolf River, at LaGrange Road
- HUC-12 080102100301:
  - HURRI001.1FA – Hurricane Creek, at Hwy. 194
  - WOLF1T1.1FA – Unnamed Tributary to Wolf River, at Hwy. 57
  - RUSSE001.5FA – Russell Creek, at Hwy. 57
- HUC-12 080102100302:
  - TEAGU001.4FA – Teague Branch, at Hwy. 57 East

  - GRISS002.7FA – Grissum Creek, at Route 57

- HUC-12 080102100303:
  - ALEXA000.8FA – Alexander Creek, at Jenkins Drive
  - SHAWS007.2FA – Shaws Creek, at Raleigh-LaGrange Road

- HUC-12 080102100304:
  - JOHNS002.9SH – Johnsons Creek, at Hwy. 205
  - 1W – Wolf River, at Germantown Parkway*

- HUC-12 080102100305:
  - GRAYS1T2.1SH – Unnamed Tributary to Grays Creek, at Raleigh-LaGrange Road
  - MARYS005.8SH – Marys Creek (headwaters), at Hwy. 205
  - MARYS001.0SH – Marys Creek, at Raleigh-LaGrange Road

- HUC-12 080102100306:
  - 4W – Harrington Creek, at Raleigh-LaGrange Road*
  - WORKH000.3SH – Workhouse Bayou, at Pumping Station
  - WOLF001.5SH – Wolf River, Hwy. 51 Bridge
  - CYPRE004.8SH – Cypress Creek, at Summer Avenue

- HUC-12 080102100307:
  - WOLF018.9SH – Wolf River, at Germantown Road

- HUC-12 080102100308:
  - FLETC2T0.2SH – Unnamed Tributary to Fletcher Creek, at Reese Road
  - FLETC1T0.4SH – Unnamed Tributary to Fletcher Creek, at Whitten Road
  - 6W – Fletcher Creek, at North Shelby Oaks*

* City of Memphis Monitoring Stations

The locations of these monitoring stations are shown in Figure 5. Water quality monitoring results for these stations are tabulated in Appendix B. Examination of the data shows exceedances of the 487 CFU/100 mL (Tier II) and 941 CFU /100 mL (all other) mL maximum E. coli criterion at all monitoring stations where E. coli samples were collected. Water quality monitoring results are summarized in Table 3.

Most of the water quality monitoring stations (Table 3 and Appendix B) have at least one E. coli sample value reported as >2419.2. In addition, at many of these sites, the maximum E. coli sample value is >2419.2. For the purpose of calculating summary data statistics, TMDLs, Waste Load Allocations (WLAs), and Load Allocations (LAs), these data values are treated as (equal to) 2419.2. Therefore, the calculated results are considered to be estimates. Future E. coli sample analyses at these sites should follow established protocol. See Section 9.4.

There were not enough data to calculate the geometric mean at any of the monitoring stations. Whenever a minimum of 5 samples is collected at a given monitoring station over a period of not more than 30 consecutive days, a geometric mean analysis is conducted.

Table 3. Summary of Water Quality Monitoring Data

Monitoring Station	E. Coli (Single Sample Max. WQ Target = 941 CFU/100 mL)*					
	Data Pts.	Date Range	[CFU/100 mL] Min.	Avg.	Max.	Exceed WQ Max. Target
EGROV001.6FA	9	3/00-6/04	7.4	841.9	>2419.2	3
MCKIN000.5FA	10	2/00-5/04	20	1115.5	8664	2
MAY001.4FA	13	1/00-6/04	4.1	581.1	>2419.2	3
NFORK004.4FA	*9*	*7/03-6/04*	*23.1*	*763.8*	*>2419.2*	*3*
NFWOL011.4FA	*14*	*2/00-6/04*	*21.3*	*395.5*	*1553.1*	*3*
HURRI001.1FA	11	3/00-6/04	9.8	742.4	>2419.2	3
WOLF1T1.1FA	7	10/03-5/04	173	2189.1	8164	4
RUSSE001.5FA	12	3/00-5/04	30.6	3404.8	24192	7
TEAGU001.4FA	10	8/03-6/04	135	1101.4	>2419.2	4
GRISS002.7FA	14	1/99-6/04	5.2	738.0	>2419.2	4
ALEXA000.8FA	13	3/00-6/04	9.7	987.4	3255	4
SHAWS007.2FA	22	1/99-6/04	3	866.6	9804	4
JOHNS002.9SH	8	7/03-6/04	10	1500.6	3873	4
1W (Wolf River)	71	6/00-6/05	1	1496.6	60000	14
GRAYS1T2.1SH	14	1/00-6/04	22.8	1430.4	11199	4
MARYS005.8SH	7	10/03-5/04	186	1958.8	7270	3
MARYS001.0SH	13	9/99-5/04	8.6	1220.6	9804	3
4W (Harrington Creek)	70	6/00-6/05	1	1404.6	29000	16
WORKH000.3SH	15	4/00-6/04	38.8	854.4	>2419.2	5
WOLF001.5SH	*39*	*1/99-9/05*	*10*	*1739.7*	*19863*	*18*
CYPRE004.8SH	13	3/00-6/04	426	4728.1	24192	8
WOLF018.9SH	24	1/99-6/04	15.6	516.9	>2419.2	4
FLETC2T0.2SH	12	6/03-6/04	43.5	735.0	2489	3
FLETC1T0.4SH	12	6/03-6/04	13.5	929.2	>2419.2	5
6W (Fletcher Creek)	72	6/00-6/05	1	2661.1	73000	17

* Single sample maximum water quality target is 487 CFU/100 mL for Tier II waterbodies and 941 CFU/100 mL for other waterbodies. Tier II waterbodies are italicized.

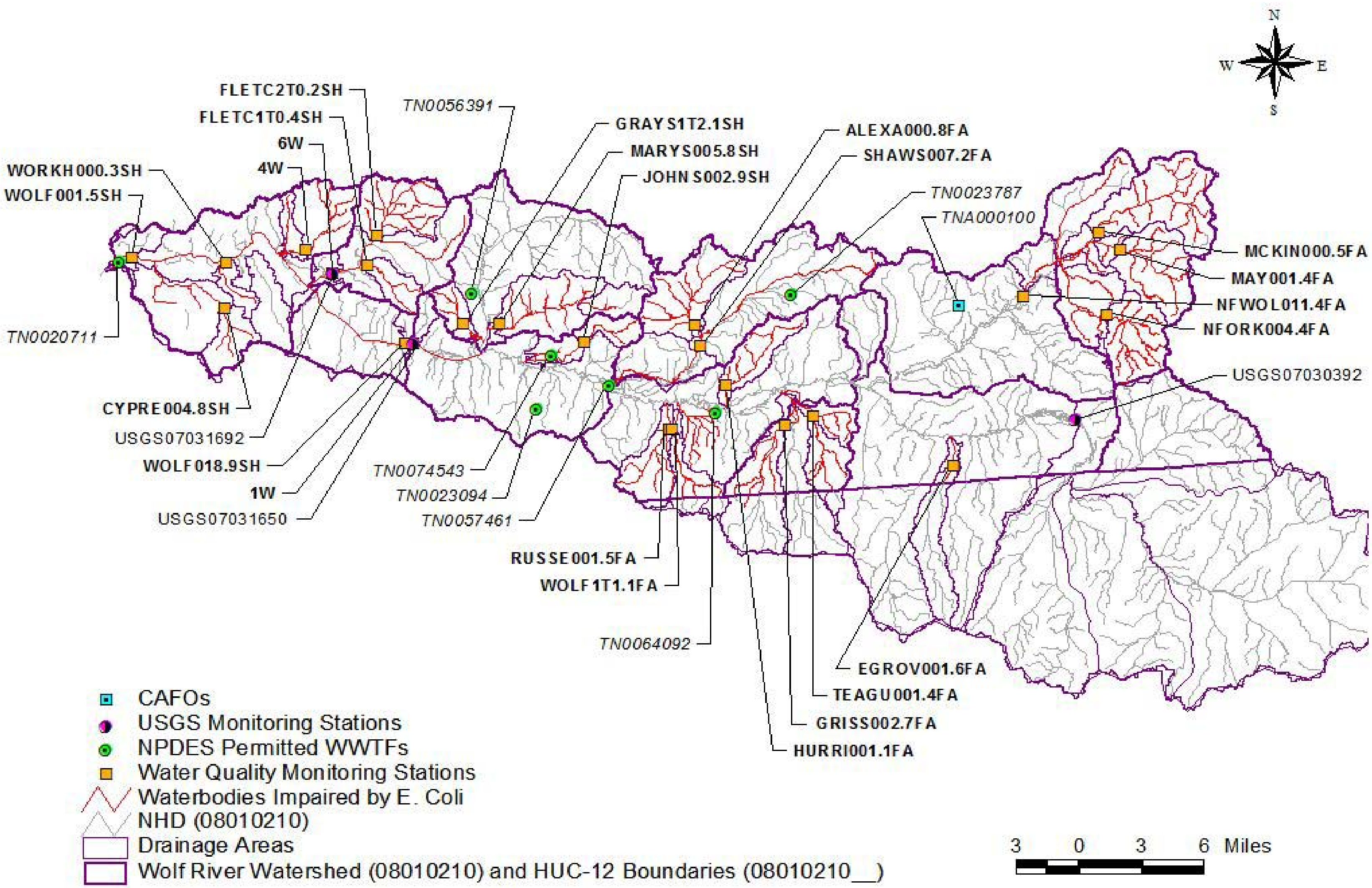

Figure 5. Monitoring Stations and NPDES permitted WWTFs in the Wolf River Watershed.

7.0 SOURCE ASSESSMENT

An important part of TMDL analysis is the identification of individual sources, or source categories of pollutants in the watershed that affect E. coli loading and the amount of loading contributed by each of these sources.

Under the Clean Water Act, sources are classified as either point or nonpoint sources. Under 40 CFR §122.2 (http://www.epa.gov/epacfr40/chapt-I.info/chi-toc.htm), a point source is defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. The National Pollutant Discharge Elimination System (NPDES) program (http://cfpub1.epa.gov/npdes/index.cfm) regulates point source discharges. Point sources can be described by three broad categories: 1) NPDES regulated municipal (http://cfpub1.epa.gov/npdes/home.cfm?program_id=13) and industrial (http://cfpub1.epa.gov/npdes/home.cfm?program_id=14) wastewater treatment facilities (WWTFs); 2) NPDES regulated industrial and municipal storm water discharges (http://cfpub1.epa.gov/npdes/home.cfm?program_id=6); and 3) NPDES regulated Concentrated Animal Feeding Operations (CAFOs) (http://cfpub1.epa.gov/npdes/home.cfm?program_id=7). A TMDL must provide WLAs for all NPDES regulated point sources. Nonpoint sources are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. For the purposes of this TMDL, all sources of pollutant loading not regulated by NPDES permits are considered nonpoint sources. The TMDL must provide a LA for these sources.

7.1 Point Sources

7.1.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

Both treated and untreated sanitary wastewater contain coliform bacteria. There were seven (7) NPDES permitted WWTFs in the impaired subwatersheds of the Wolf River watershed authorized to discharge treated sanitary wastewater during the TMDL analysis period. These facilities are tabulated in Table 4 and the locations are shown in Figure 5. Four of the facilities are sewage treatment plants (STPs) serving municipalities and all four (Memphis-Maynard C. Stiles STP [TN0020711], Collierville STP [TN0057461], Rossville STP [TN0064092], and the Collierville Northwest STP [TN0074543]) are major facilities with design capacities equal to or greater than 1.0 million gallons per day (MGD). However, two of the facilities (TN0020711 and TN0064092) are located in impaired watersheds but discharge to unimpaired waterbodies. The permit limits for discharges from these WWTFs are in accordance with the coliform criteria specified in Tennessee Water Quality Standards for protection of the recreation use classification.

The permits for two facilities, Ridgeway Country Club (TN0023094) and Rocky Woods Estates (TN0056391) were each terminated in 2003.

Non-permitted point sources of (potential) E. coli contamination of surface waters associated with STP collection systems include leaking collection systems (LCSs) and sanitary sewer overflows (SSOs).

Note: As stated in Section 5.0, the current coliform criteria are expressed in terms of E. coli concentration, whereas previous criteria were expressed in terms of fecal coliform and E. coli concentration. Due to differences in permit issuance dates, some permits still have fecal coliform limits instead of E. coli. As permits are reissued, limits for fecal coliform will be replaced by E. coli limits.

7.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

Municipal Separate Storm Sewer Systems (MS4s) are considered to be point sources of E. coli. Discharges from MS4s occur in response to storm events through road drainage systems, curb and gutter systems, ditches, and storm drains. Phase I of the EPA storm water program (http://cfpub.epa.gov/npdes/stormwater/swphases.cfm#phase1) requires large and medium MS4s to obtain NPDES storm water permits. Large and medium MS4s are those located in incorporated places or counties serving populations greater than 100,000 people. At present, the City of Memphis is the only large or medium (Phase I) MS4 in the Wolf River watershed.

Table 4. WWTFs Permitted to Discharge Treated Sanitary Wastewater, located in the Wolf River Watershed Impaired Subwatersheds

NPDES Permit No.	Facility Name	Receiving Stream
TN0020711	Memphis - Maynard C. Stiles STP	Mississippi River, mile 738.8
TN0023094	Ridgeway Country Club	Unnamed tributary to an unnamed tributary to the Wolf River (mile 26.3)
TN0023787	Southwest School	Unnamed tributary to Shaws Creek (mile 13.1)
TN0056391	Rocky Woods Estates	Unnamed tributary to Grays Creek (mile 3.1)
TN0057461	Collierville STP	Wolf River, mile 30.9
TN0064092	Rossville STP	Wolf River, mile 43.7
TN0074543	Collierville Northwest STP	Wolf River, mile 25.3

As of March 2003, regulated small MS4s in Tennessee must also obtain NPDES permits in accordance with the Phase II storm water program (http://cfpub.epa.gov/npdes/stormwater/swphases.cfm#phase2). A small MS4 is designated as *regulated* if: a) it is located within the boundaries of a defined urbanized area that has a residential population of at least 50,000 people and an overall population density of 1,000 people per square mile; b) it is located outside of an urbanized area but within a jurisdiction with a population of at least 10,000 people, a population density of 1,000 people per square mile, and has the potential to cause an adverse impact on water quality; or c) it is located outside of an urbanized area but contributes substantially to the pollutant loadings of a physically interconnected MS4 regulated by the NPDES storm water program. Most regulated small MS4s in Tennessee obtain coverage under the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (http://state.tn.us/environment/wpc/ppo/TN%20Small%20MS4%20Modified%20General%20Permit%202003.pdf), (TDEC, 2003). There are 5 permitted Phase II MS4s located in the drainage areas of (E. coli) 303(d)-listed waterbodies in the Wolf River Watershed:

NPDES Permit Number	Phase	Permittee Name
TNS075230	II	Collierville
TNS075337	II	Germantown
TNS075526	II	City of Lakeland
TNS075663	II	Shelby County
TNS075698	II	Bartlett

The Tennessee Department of Transportation (TDOT) has been issued an individual MS4 permit (TNS077585) that authorizes discharges of storm water runoff from State road and interstate highway right-of-ways that TDOT owns or maintains, discharges of storm water runoff from TDOT owned or operated facilities, and certain specified non-storm water discharges. This permit covers all eligible TDOT discharges statewide, including those located outside of urbanized areas. TDOT's individual MS4 permit may be obtained from the Tennessee Department of Environment and Conservation (TDEC) website: http://state.tn.us/environment/wpc/stormh2o/TNS077585.pdf.

For information regarding storm water permitting in Tennessee, see the TDEC website: http://www.state.tn.us/environment/wpc/stormh2o/.

7.1.3 NPDES Concentrated Animal Feeding Operations (CAFOs)

Animal feeding operations (AFOs) are agricultural enterprises where animals are kept and raised in confined situations. AFOs congregate animals, feed, manure and urine, dead animals, and production operations on a small land area. Feed is brought to the animals rather than the animals grazing or otherwise seeking feed in pastures, fields, or on rangeland (USEPA, 2002a). Concentrated Animal Feeding Operations (CAFOs) are AFOs that meet certain criteria with respect to animal type, number of animals, and type of manure management system. CAFOs are considered to be potential point sources of E. coli loading and are required to obtain an NPDES permit. Most CAFOs in Tennessee obtain coverage under TNA000000, *Class II Concentrated Animal Feeding Operation General Permit* (http://state.tn.us/environment/wpc/ppo/CAFO%20Final%20PDF%20Modified.pdf), while larger, Class I CAFOs are required to obtain an individual NPDES permit.

There was one Class II CAFO (TNA000100) in the Wolf River watershed with coverage under the general NPDES permit during the TMDL analysis period. This CAFO permit has been terminated. In addition, this CAFO was not located in the drainage area of a (E. coli) 303(d)-listed waterbody. There were no Class I CAFOs with individual permits located in the watershed.

7.2 Nonpoint Sources

Nonpoint sources of 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 coliform bacteria on land surfaces and wash off as a result of storm events. Nonpoint sources of E. coli loading are primarily associated with agricultural and urban land uses. The vast majority of waterbodies identified on the Final 2006 303(d) List as impaired due to E. coli are attributed to nonpoint agricultural or urban sources.

7.2.1 Wildlife

Wildlife deposit coliform bacteria, with their feces, onto land surfaces where it can be transported during storm events to nearby streams. The overall deer density for Tennessee was estimated by the Tennessee Wildlife Resources Agency (TWRA) to be 23 animals per square mile.

7.2.2 Agricultural Animals

Agricultural activities can be a significant source of coliform bacteria loading to surface waters. The activities of greatest concern are typically those associated with livestock operations:

- Agricultural livestock grazing in pastures deposit manure containing coliform bacteria onto land surfaces. This material accumulates during periods of dry weather and is available for washoff and transport to surface waters during storm events. The number of animals in pasture and the time spent grazing are important factors in determining the loading contribution.
- Processed agricultural manure from confined feeding operations is often applied to land surfaces and can provide a significant source of coliform bacteria loading. Guidance for issues relating to manure application is available through the University of Tennessee Agricultural Extension Service and the Natural Resources Conservation Service (NRCS).
- Agricultural livestock and other unconfined animals (i.e., deer and other wildlife) often have direct access to waterbodies and can provide a concentrated source of coliform bacteria loading directly to a stream.

Data sources related to livestock operations include the 2002 Census of Agriculture (http://www.nass.usda.gov/census/census02/volume1/tn/index2.htm). Livestock data, for counties containing E. coli-impaired subwatersheds, are summarized in Table 5. Note that, due to confidentiality issues, any tabulated item that identifies data reported by a respondent or allows a respondent's data to be accurately estimated or derived is suppressed and coded with a 'D' (USDA, 2004).

Table 5. Livestock Distribution in the Wolf River Watershed

County Name	Livestock Population (2002 Census of Agriculture)*						
	Beef Cow	Milk Cow	Hogs	Sheep	Poultry (Layers)	Poultry (Broilers)	Horses
Fayette	10,754	732	11,378	132	541	64	2,226
Hardeman	7,310	6	496	318	834	102	1,247
Shelby	3,755	20	340	265	570	(D)	2,344

* In keeping with the provisions of Title 7 of the United States Code, no data are published in the 2002 Census of Agriculture that would disclose information about the operations of an individual farm or ranch. Any tabulated item that identifies data reported by a respondent or allows a respondent's data to be accurately estimated or derived is suppressed and coded with a 'D' (USDA, 2004).

7.2.3 Failing Septic Systems

Some coliform loading in the Wolf River watershed can be attributed to failure of septic systems and illicit discharges of raw sewage. Estimates from 2000 county census data of people in E. coli-impaired subwatersheds of the Wolf River watershed utilizing septic systems were compiled using the WCS and are summarized in Table 6. In western Tennessee, it is estimated that there are approximately 2.37 people per household on septic systems, some of which can be reasonably assumed to be failing. As with livestock in streams, discharges of raw sewage provide a concentrated source of coliform bacteria directly to waterbodies.

Table 6. Population on Septic Systems in the Wolf River Watershed

County Name	Population on Septic Systems
Fayette	1035
Hardeman	177
Shelby	3531

7.2.4 Urban Development

Nonpoint source loading of coliform bacteria from urban land use areas is attributable to multiple sources. These include: stormwater runoff, illicit discharges of sanitary waste, runoff from improper disposal of waste materials, leaking septic systems, and domestic animals. Impervious surfaces in urban areas allow runoff to be conveyed to streams quickly, without interaction with soils and groundwater. The Wolf River HUC-12 subwatershed 080102100306 (Memphis area) has the highest percentage of urban land area for impaired subwatersheds in the Wolf River watershed, with 73.9%. Land use for the Wolf River impaired HUC-12 subwatersheds and drainage areas is summarized in Figures 6-13 and tabulated in Appendix A.

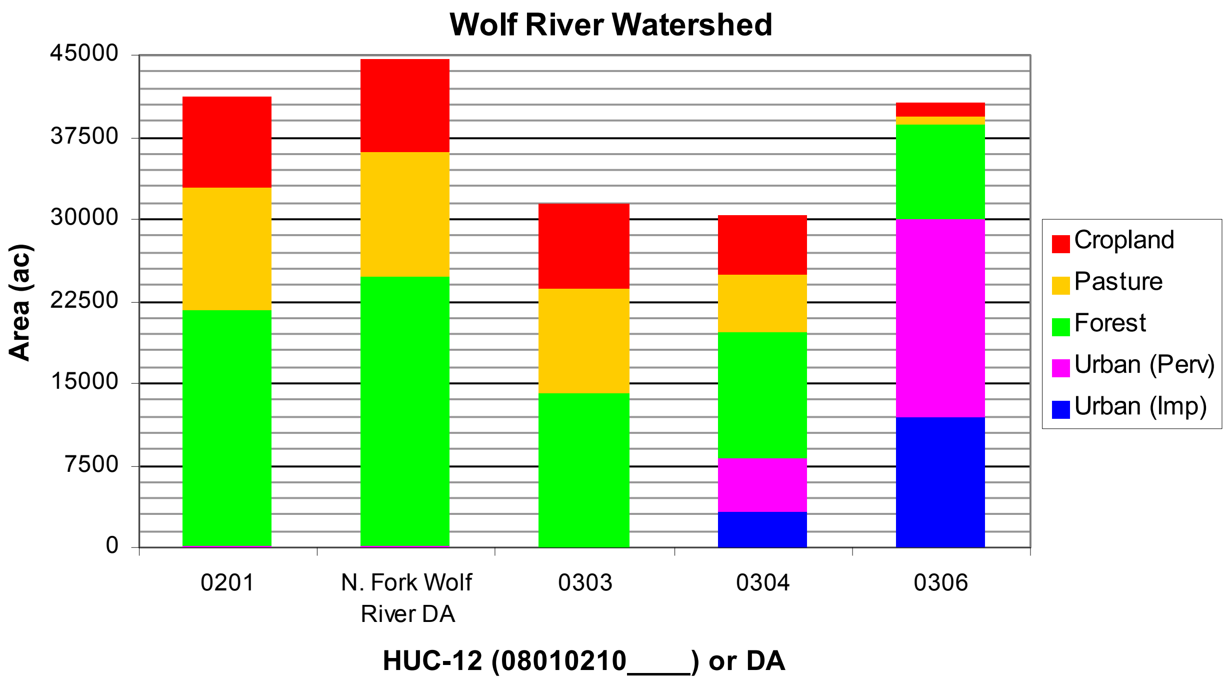

Figure 6. **Land Use Area of Wolf River HUC-12 Subwatersheds 0201, 0303, 0304, and 0306, and Drainage Area North Fork of the Wolf River.**

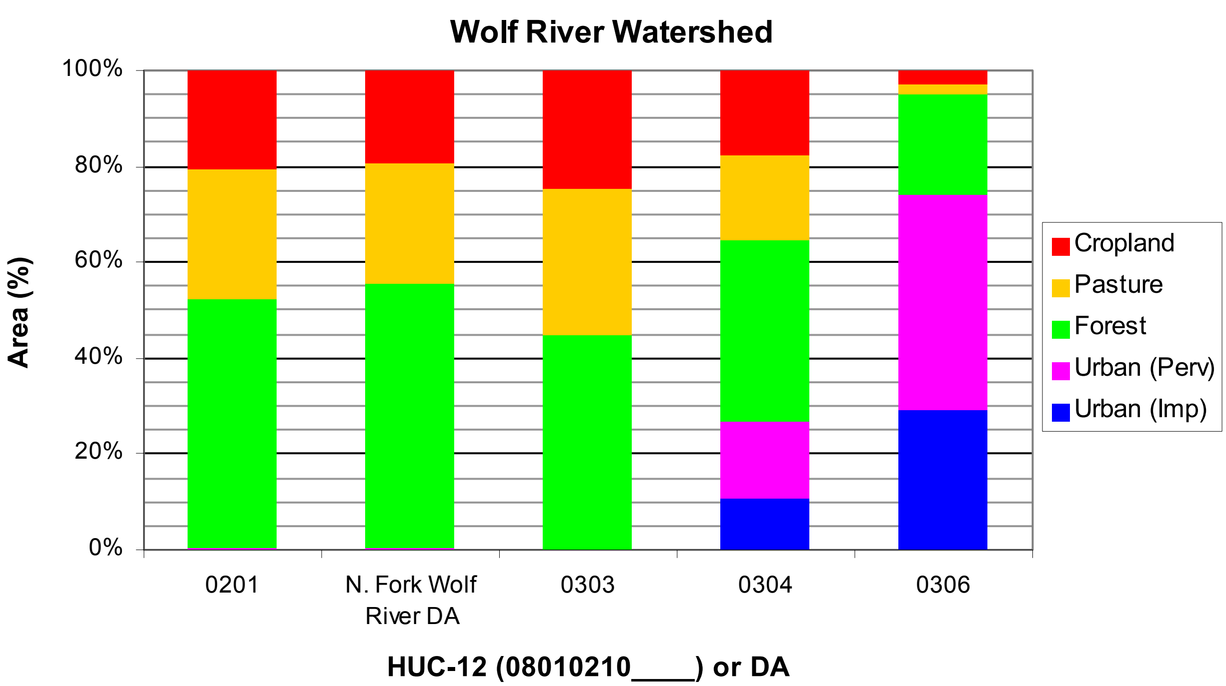

Figure 7. **Land Use Percent of Wolf River HUC-12 Subwatersheds 0201, 0303, 0304, 0306, and Drainage Area North Fork of the Wolf River.**

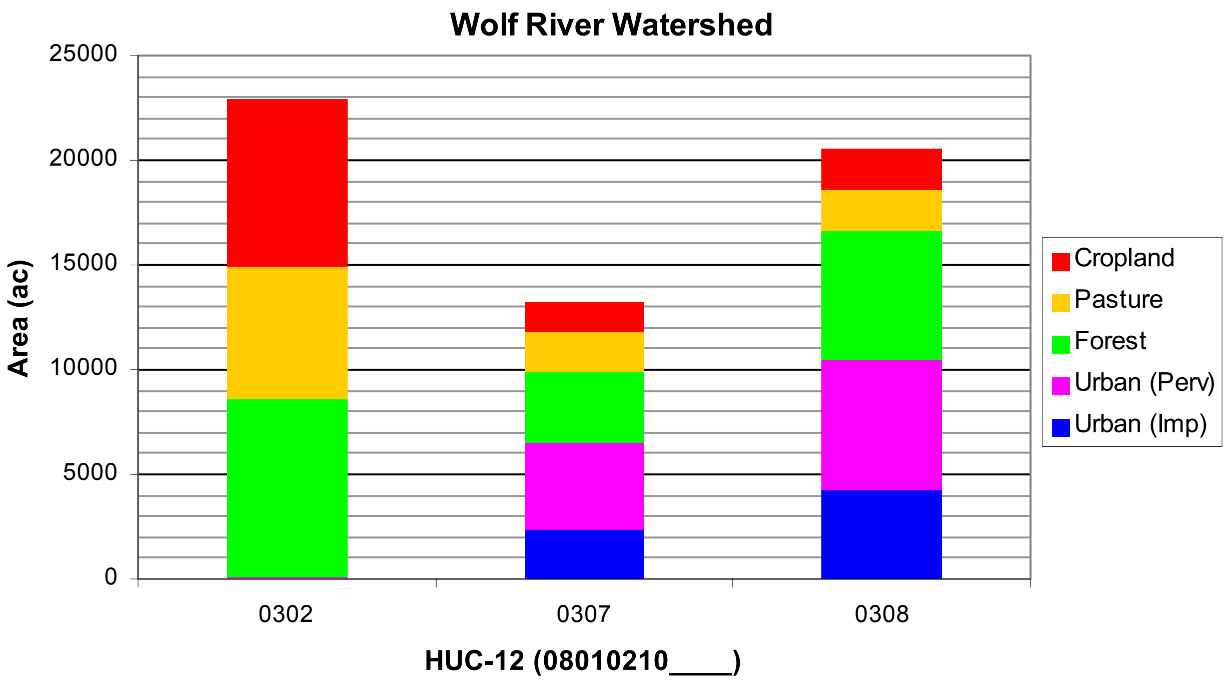

Figure 8. Land Use Area of Wolf River HUC-12 Subwatersheds 0302, 0307, and 0308.

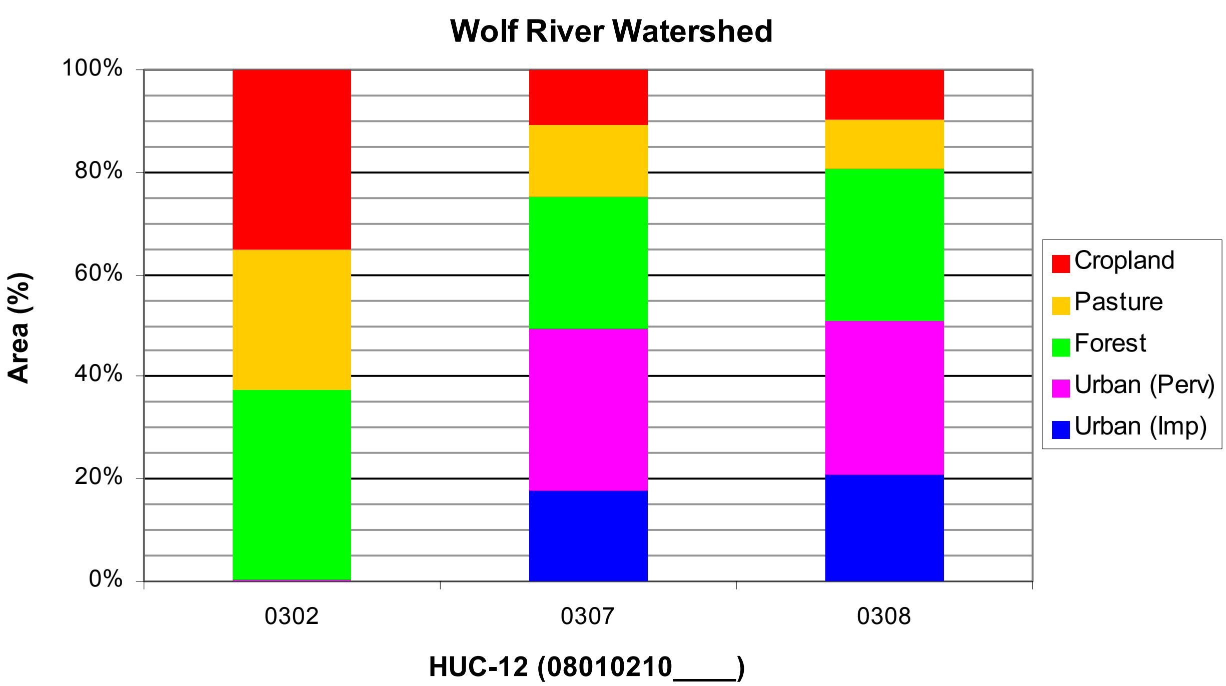

Figure 9. Land Use Percent of Wolf River HUC-12 Subwatersheds 0302, 0307, and 0308.

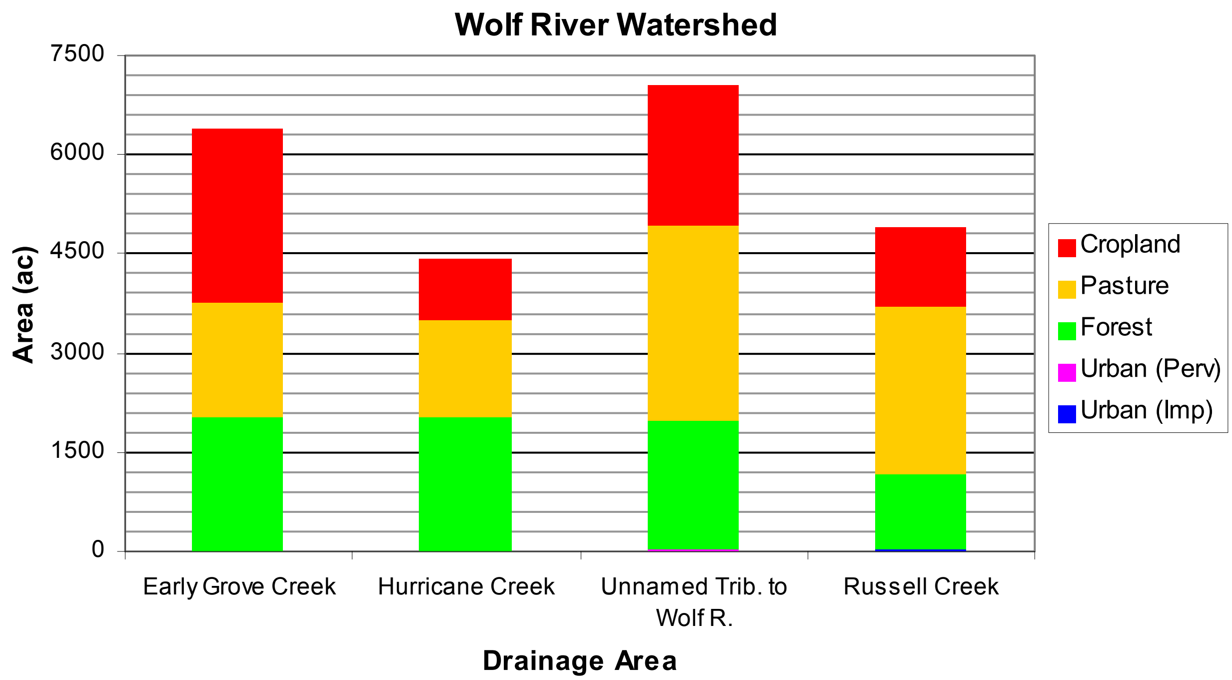

Figure 10. Land Use Area of Wolf River Watershed Drainage Areas Early Grove Creek, Hurricane Creek, Unnamed Tributary to Wolf River, and Russell Creek.

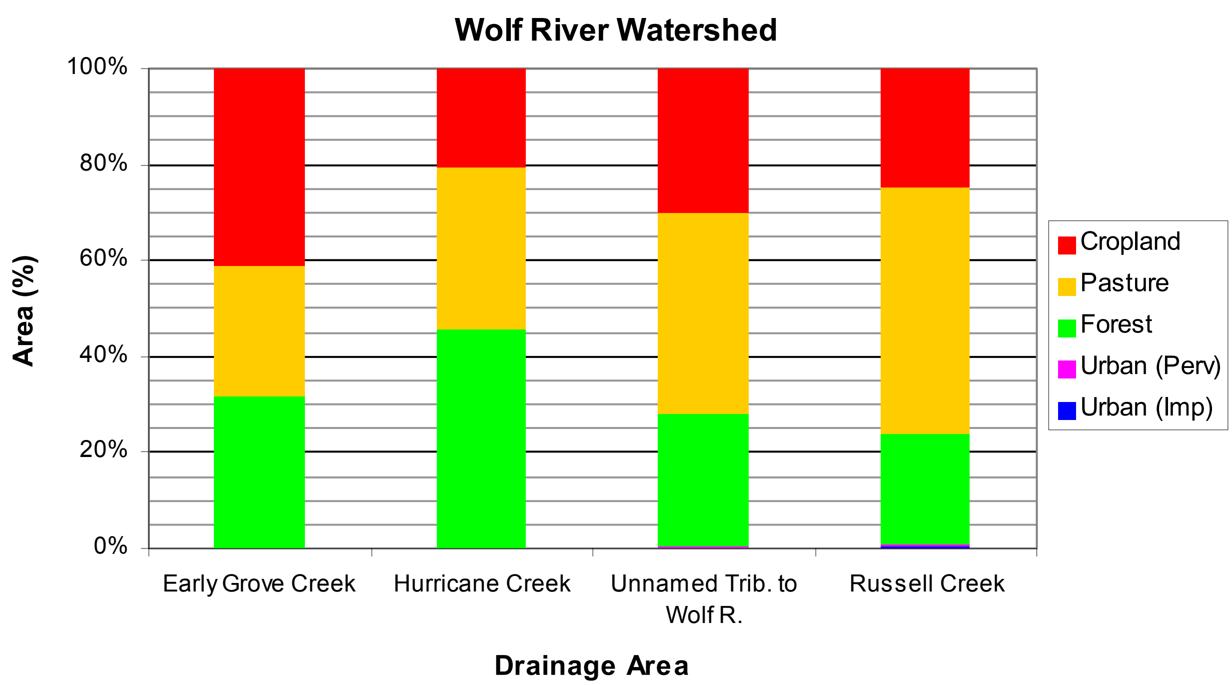

Figure 11. Land Use Percent of Wolf River Watershed Drainage Areas Early Grove Creek, Hurricane Creek, Unnamed Tributary to Wolf River, and Russell Creek.

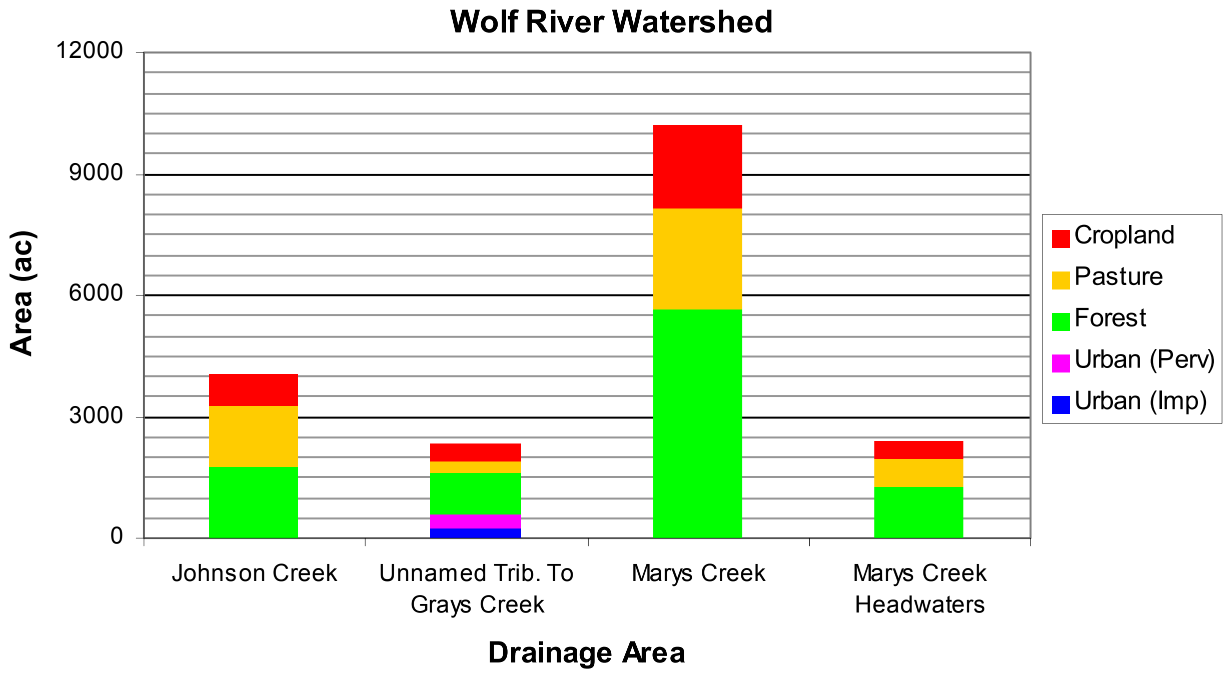

Figure 12. Land Use Area of Wolf River Watershed Drainage Areas Johnson Creek, Unnamed Tributary to Grays Creek, Marys Creek, and Marys Creek Headwaters.

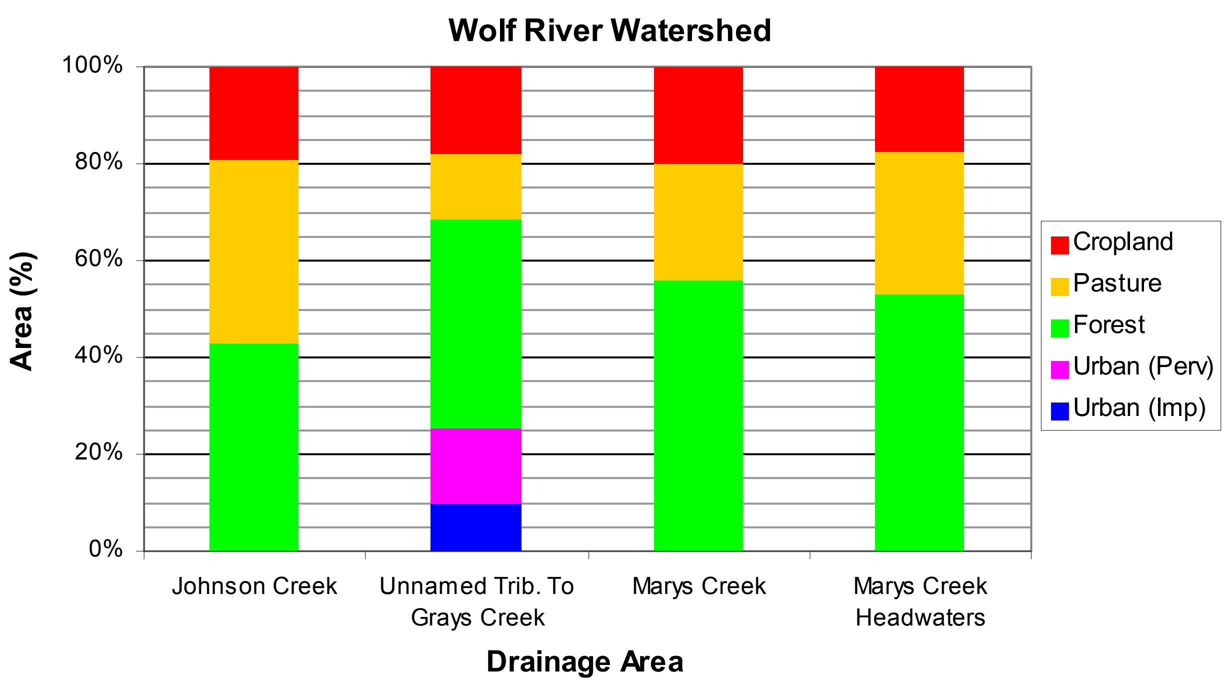

Figure 13. Land Use Percent of Wolf River Watershed Drainage Areas Johnson Creek, Unnamed Tributary to Grays Creek, Marys Creek, and Marys Creek Headwaters.

8.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOAD

The Total Maximum Daily Load (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) that takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$TMDL = \Sigma\ WLAs + \Sigma\ LAs + MOS$$

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) (http://www.epa.gov/epacfr40/chapt-I.info/chi-toc.htm) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measure.

This document describes TMDL, Waste Load Allocation (WLA), Load Allocation (LA), and Margin of Safety (MOS) development for waterbodies identified as impaired due to E. coli on the Final 2006 303(d) List.

8.1 Expression of TMDLs, WLAs, & LAs

In this document, the E. coli TMDL is a daily load expressed as a function of mean daily flow (daily loading function). For implementation purposes, corresponding percent load reduction goals (PLRGs) to decrease E. coli loads to TMDL target levels, within each respective flow zone, are also expressed. WLAs & LAs for precipitation-induced loading sources are also expressed as daily loading functions in CFU/day/acre. Allocations for loading that is independent of precipitation (WLAs for WWTFs and LAs for “other direct sources”) are expressed as CFU/day.

8.2 Area Basis for TMDL Analysis

The primary area unit of analysis for TMDL development is the HUC-12 subwatershed containing one or more waterbodies assessed as impaired due to E. coli (as documented on the Final 2006 303(d) List). In some cases, however, TMDLs were developed for an impaired waterbody drainage area only. Determination of the appropriate area to use for analysis (see Table 7) was based on a careful consideration of a number of relevant factors, including: 1) location of impaired waterbodies in the HUC-12 subwatershed; 2) land use type and distribution; 3) water quality monitoring data; and 4) the assessment status of other waterbodies in the HUC-12 subwatershed.

8.3 TMDL Analysis Methodology

TMDLs for the Wolf River Watershed were developed using load duration curves for analysis of impaired HUC-12 subwatersheds or specific waterbody drainage areas. A load duration curve (LDC) is a cumulative frequency graph that illustrates existing water quality conditions (as represented by loads calculated from monitoring data), how these conditions compare to desired targets, and the portion of the waterbody flow zone represented by these existing loads. Load duration curves are considered to be well suited for analysis of periodic monitoring data collected by grab sample. LDCs were developed at monitoring site locations in impaired waterbodies and daily loading functions were expressed for TMDLs, WLAs, LAs, and MOS. In addition, load reductions (PLRGs) for each flow zone were calculated for prioritization of implementation measures according

Table 7. Determination of Analysis Areas for TMDL Development

HUC-12 Subwatershed (08010210)	Impaired Waterbody	Area
0105	Early Grove Creek	DA*
0201	McKinnie Creek	HUC-12
	May Creek	
	North Fork Creek	
0202	North Fork Wolf River	DA*
0301	Hurricane Creek	DA*
	Unnamed Tributary to Wolf River	DA*
	Russell Creek	DA*
0302	Teague Branch	HUC-12
	Grissum Creek	
0303	Alexander Creek	HUC-12
	Shaws Creek	
0304	Wolf River	DA*
	Johnson Creek	DA*
0305	Unnamed Tributary to Grays Creek	DA*
	Marys Creek	DA*
	Marys Creek Headwaters	DA*
0306	Harrington Creek	HUC-12
	Workhouse Bayou	
	Wolf River	
	Cypress Creek	
0307	Wolf River	HUC-12
0308	Unnamed Tributary to Fletcher Creek	HUC-12
	Unnamed Tributary to Fletcher Creek	
	Fletcher Creek	

* Drainage Area

to the methods described in Appendix E.

8.4 Critical Conditions and Seasonal Variation

The critical condition for non-point source E. coli loading is an extended dry period followed by a rainfall runoff event. During the dry weather period, E. coli 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 streamflow when dilution is minimized. Both conditions are represented in the TMDL analyses.

The ten-year period from January 1, 1996 to December 31, 2005 was used to simulate flow. This 10-year period contained a range of hydrologic conditions that included both low and high streamflows. Critical conditions are accounted for in the load duration curve analyses by using the entire period of flow and water quality data available for the impaired waterbodies.

In most subwatersheds, water quality data have been collected during most flow ranges. For each subwatershed, the critical flow zone has been identified based on the incremental levels of impairment relative to the target loads. Based on the location of the water quality exceedances on the load duration curves and the distribution of critical flow zones, no one delivery mode for E. coli appears to be dominant for waterbodies in the Wolf River watershed (see Sections 9.1.2 and 9.1.3 and Appendix E).

Seasonal variation was incorporated in the load duration curves by using the entire 10-year simulation period and all water quality data collected at the monitoring stations. Water quality data were collected during all seasons.

8.5 Margin of Safety

There are two methods for incorporating an MOS in the analysis: a) implicitly incorporate the MOS using conservative model assumptions; or b) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations. For development of E. coli TMDLs in the Wolf River Watershed, an explicit MOS, equal to 10% of the E. coli water quality targets (ref.: Section 5.0), was utilized for determination of WLAs and LAs:

Instantaneous Maximum (lake, reservoir, State Scenic River, Tier II, Tier III):

	MOS = 49 CFU/100 ml
Instantaneous Maximum (other):	MOS = 94 CFU/100 ml
30-Day Geometric Mean:	MOS = 13 CFU/100 ml

8.6 Determination of TMDLs

E. coli daily loading functions were calculated for impaired segments in the Wolf River watershed using LDCs to evaluate compliance with the single sample maximum target concentrations according to the procedure in Appendix C. These TMDL loading functions for impaired segments and subsequent subwatersheds are shown in Table 8.

8.7 Determination of WLAs & LAs

WLAs for MS4s and LAs for precipitation induced sources of E. coli loading were determined according to the procedures in Appendix C. These allocations represent the available loading after application of the explicit MOS. WLAs for existing WWTFs are equal to their existing NPDES permit limits. Since WWTF permit limits require that E. coli concentrations must comply with water quality criteria (TMDL targets) at the point of discharge and recognition that loading from these facilities is generally small in comparison to other loading sources, further reductions were not considered to be warranted. WLAs for CAFOs and LAs for "other direct sources" (non-precipitation induced) are equal to zero. WLAs & LAs are summarized in Table 8.

Table 8. WLAs & LAs for Wolf River, Tennessee

HUC-12 Subwatershed (08010210__)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs[a]			LAs
					WWTFs[b]	Leaking Collection Systems	MS4s	
			[CFU/day]	[CFU/day]	[CFU/day]	[CFU /day]	[CFU/day/acre]	[CFU/day/acre]
0105	Early Grove Creek	TN08010210009 – 0300	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	3.24×10^{6} * Q
0201	McKinnie Creek	TN08010210020 – 0300	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	9.74×10^{5} * Q
	May Creek	TN08010210020 – 0310	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	2.29×10^{6} * Q
	North Fork Creek	TN08010210020 – 0400	1.19×10^{10} * Q	1.19×10^{9} * Q	NA	NA	NA	8.28×10^{5} * Q
0202	North Fork Wolf River	TN08010210020 – 2000	1.19×10^{10} * Q	1.19×10^{9} * Q	NA	NA	NA	2.46×10^{5} * Q
0301	Hurricane Creek	TN08010210004 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	4.69×10^{6} * Q
	Unnamed Tributary to Wolf River	TN08010210004 – 0400	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	NA	2.94×10^{6} * Q
	Russell Creek	TN08010210004 – 0500	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	4.23×10^{6} * Q
0302	Teague Branch	TN08010210005 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	3.17×10^{6} * Q
	Grissum Creek	TN08010210005 – 1000	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	8.80×10^{5} * Q
0303	Alexander Creek	TN08010210021 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	2.74×10^{6} * Q
	Shaws Creek	TN08010210021 – 1000	2.30×10^{10} * Q	2.30×10^{9} * Q	7.13×10^{8}	NA	NA	6.79×10^{5} * Q – 2.34×10^{4}
0304	Wolf River	TN08010210002 – 2000	2.30×10^{10} * Q	2.30×10^{9} * Q	4.31×10^{11}	0	4.61×10^{4} * Q – 9.59×10^{5}	4.61×10^{4} * Q – 9.59×10^{5}
	Johnson Creek	TN08010210003 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	5.10×10^{6} * Q	5.10×10^{6} * Q
0305	Unnamed Tributary to Grays Creek	TN08010210022 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	8.88×10^{6} * Q	8.88×10^{6} * Q
	Marys Creek	TN08010210022 – 0300	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	2.03×10^{6} * Q	2.03×10^{6} * Q
	Marys Creek Headwaters	TN08010210022 – 0350	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	8.68×10^{6} * Q	8.68×10^{6} * Q
0306	Harrington Creek	TN08010210001 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	2.79×10^{6} * Q	2.79×10^{6} * Q
	Workhouse Bayou	TN08010210001 – 0300	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.34×10^{7} * Q	1.34×10^{7} * Q

Table 8. WLAs & LAs for Wolf River, Tennessee (Cont.)

HUC-12 Subwatershed (08010210__)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs[a]			LAs
					WWTFs[b]	Leaking Collection Systems	MS4s	
			[CFU/day]	[CFU/day]	[CFU /day]	[CFU /day]	[CFU/day/acre]	[CFU/day/acre]
0306 (cont.)	Wolf River	TN08010210001 – 1000	$1.19 \times 10^{10} * Q$	$1.19 \times 10^{9} * Q$	4.31×10^{11}	0	$2.04 \times 10^{4} * Q – 8.22 \times 10^{5}$	$2.04 \times 10^{4} * Q – 8.22 \times 10^{5}$
	Cypress Creek	TN08010210032 – 1000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$1.72 \times 10^{6} * Q$	$1.72 \times 10^{6} * Q$
0307	Wolf River	TN08010210002 – 1000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	4.31×10^{11}	0	$4.47 \times 10^{4} * Q – 1.16 \times 10^{6}$	$4.47 \times 10^{4} * Q – 1.16 \times 10^{6}$
0308	Unnamed Tributary to Fletcher Creek	TN08010210023 – 0100	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$3.01 \times 10^{6} * Q$	$3.01 \times 10^{6} * Q$
	Unnamed Tributary to Fletcher Creek	TN08010210023 – 0200	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$8.10 \times 10^{6} * Q$	$8.10 \times 10^{6} * Q$
	Fletcher Creek	TN08010210023 – 1000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$1.00 \times 10^{6} * Q$	$1.00 \times 10^{6} * Q$

Note: NA = Not applicable.
Q = Mean Daily In-stream Flow (cfs).
a. There are no CAFOs in impaired subwatersheds of the Wolf River watershed.
b. WLAs for WWTFs expressed as E. coli loads (CFU/day). Current and future WWTFs must meet water quality standards at the point of discharge as specified in their NPDES permits. At no time shall concentration exceed appropriate, site-specific (487 CFU/100 mL or 941 CFU/100 mL) water quality criteria.

9.0 IMPLEMENTATION PLAN

The TMDLs, WLAs, and LAs developed in Section 8 are intended to be the first phase of a long-term effort to restore the water quality of impaired waterbodies in the Wolf River watershed through reduction of excessive E. coli loading. Adaptive management methods, within the context of the State's rotating watershed management approach, will be used to modify TMDLs, WLAs, and LAs as required to meet water quality goals.

TMDL implementation activities will be accomplished within the framework of Tennessee's Watershed Approach (ref: http://www.state.tn.us/environment/wpc/watershed/). The Watershed Approach is based on a five-year cycle and encompasses planning, monitoring, assessment, TMDLs, WLAs/LAs, and permit issuance. It relies on participation at the federal, state, local and non-governmental levels to be successful.

9.1 Application of Load Duration Curves for Implementation Planning

The Load Duration Curve (LDC) methodology (Appendix C) is a form of water quality analysis and presentation of data that aids in guiding implementation by targeting management strategies for appropriate flow conditions. One of the strengths of this method is that it can be used to interpret possible delivery mechanisms of E. coli by differentiating between point and non-point source problems. The load duration curve analysis can be utilized for implementation planning. See Cleland (2003) for further information on duration curves and TMDL development, and: http://www.tmdls.net/tipstools/docs/TMDLsCleland.pdf

9.1.1 Flow Zone Analysis for Implementation Planning

A major advantage of the duration curve framework in TMDL development is the ability to provide meaningful connections between allocations and implementation efforts (USEPA, 2006). Because the flow duration interval serves as a general indicator of hydrologic condition (i.e., wet versus dry and to what degree), allocations and reduction goals can be linked to source areas, delivery mechanisms, and the appropriate set of management practices. The use of duration curve zones (e.g., high flow, moist, mid-range, dry, and low flow) allows the development of allocation tables (USEPA, 2006) (Appendix E), which can be used to guide potential implementation actions to most effectively address water quality concerns.

For the purposes of implementation strategy development, available E. coli data are grouped according to flow zones, with the number of flow zones determined by the HUC-12 subwatershed or drainage area size, the total contributing area (for non-headwater HUC-12s), and/or the baseflow characteristics of the waterbody. In general, for drainage areas greater than 40 square miles, the duration curves will be divided into five zones (Figure 14): high flows (exceeded 0-10% of the time), moist conditions (10-40%), median or mid-range flows (40-60%), dry conditions (60-90%), and low flows (90-100%). For smaller drainage areas, flows occurring in the low flow zone (baseflow conditions) are often extremely low and difficult to measure accurately. In many small drainage areas, extreme dry conditions are characterized by zero flow for a significant percentage of time. For this reason, the low flow zone is best characterized as a broader range of conditions (or percent time) with subsequently fewer flow zones. Therefore, for most HUC-12 subwatershed drainage areas less than 40 square miles, the duration curves will be divided into four zones: high flows (exceeded 0-10% of the time), moist conditions (10-40%), median or mid-range flows (40-70%), and low flows (70-100%). Some small (<40 mi^2) waterbody drainage areas have sustained baseflow (no

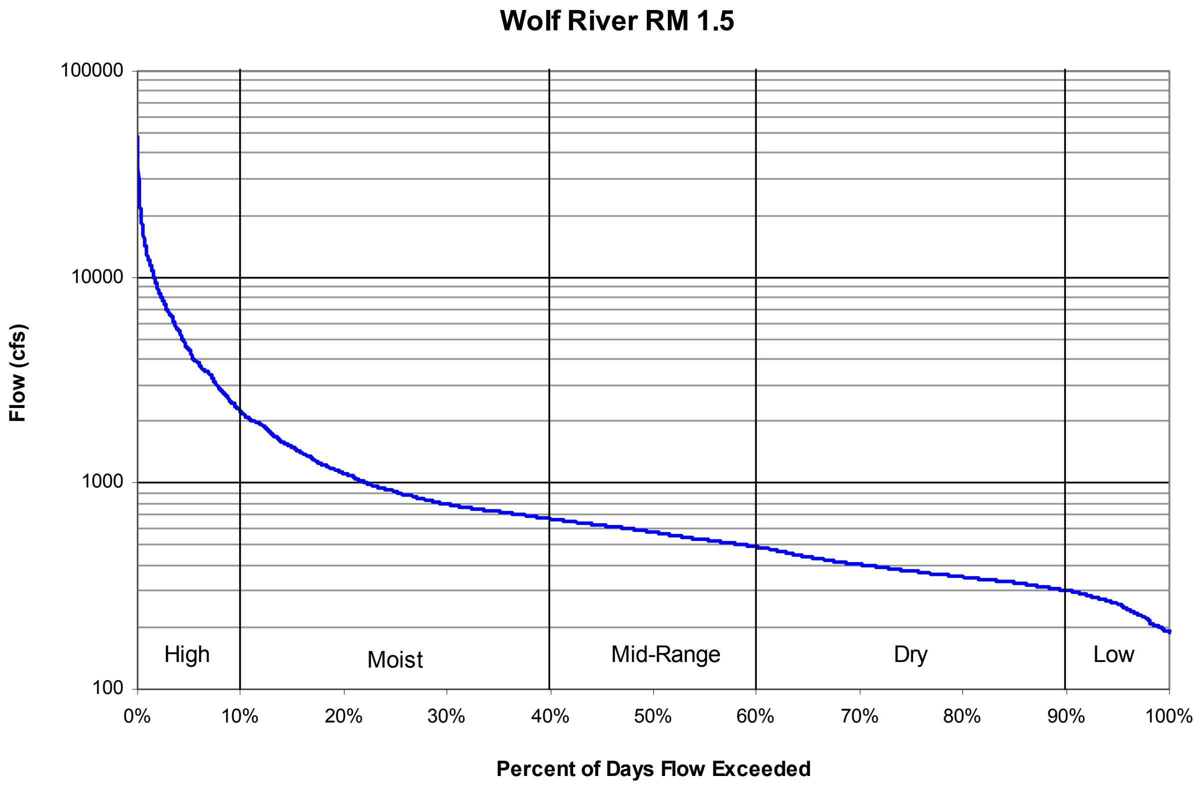

Figure 14. Five-Zone Flow Duration Curve for Wolf River at RM 1.5.

zero flows) throughout their period of record. For these waterbodies (e.g., Early Grove Creek), the duration curves will be divided into five zones.

Given adequate data, results (allocations and percent load reduction goals) will be calculated for all flow zones; however, less emphasis is placed on the upper 10% flow range for pathogen (E. coli) TMDLs and implementation plans. The highest 10 percent flows, representing flood conditions, are considered non-recreational conditions: unsafe for wading and swimming. Humans are not expected to enter the water due to the inherent hazard from high depths and velocities during these flow conditions. As a rule of thumb, the *USGS Field Manual for the Collection of Water Quality Data* (Lane, 1997) advises its personnel not to attempt to wade a stream for which values of depth (ft) multiplied by velocity (ft/s) equal or exceed 10 ft^2/s to collect a water sample. Few observations are typically available to estimate loads under these adverse conditions due to the difficulty and danger of sample collection. Therefore, in general, the 0-10% flow range is beyond the scope of pathogen TMDLs and subsequent implementation strategies.

9.1.2 Existing Loads and Percent Load Reductions

Each impaired waterbody has a characteristic set of pollutant sources and existing loading conditions that vary according to flow conditions. In addition, maximum allowable loading (assimilative capacity) of a waterbody varies with flow. Therefore, existing loading, allowable loading, and percent load reduction expressed at a single location on the LDC (for a single flow condition) do not appropriately represent the TMDL in order to address all sources under all flow conditions (i.e., at all times) to satisfy implementation objectives. The LDC approach provides a methodology for determination of assimilative capacity and existing loading conditions of a waterbody for each flow zone. Subsequently, each flow zone, and the sources contributing to impairment under the corresponding flow conditions, can be evaluated independently. Lastly, the critical flow zone (with the highest percent load reduction goal) can be identified for prioritization of implementation actions.

Existing loading is calculated for each individual water quality sample as the product of the sample flow (cfs) times the single sample E. coli concentration (times a conversion factor). A percent load reduction is calculated for each water quality sample as that required to reduce the existing loading to the product of the sample flow (cfs) times the single sample maximum water quality standard (times a conversion factor). For samples with negative percent load reductions (non-exceedance: concentration below the single sample maximum water quality criterion), the percent reduction is assumed to be zero. The percent load reduction goal (PLRG) for a given flow zone is calculated as the mean of all the percent load reductions for a given flow zone. See Appendix E.

9.1.3 Critical Conditions

The critical condition for each impaired waterbody is defined as the flow zone with the largest PLRG, excluding the “high flow” zone because these extremely high flows are not representative of recreational flow conditions, as described in Section 9.1.1. If the PLRG in this zone is greater than all the other zones, the zone with the second highest PLRG will be considerd the critical flow zone. The critical conditions are such that if water quality standards were met under those conditions, they would likely be met overall.

9.2 Point Sources

9.2.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

All present and future discharges from industrial and municipal wastewater treatment facilities are required to be in compliance with the conditions of their NPDES permits at all times, including elimination of bypasses and overflows. In Tennessee, permit limits for treated sanitary wastewater require compliance with coliform water quality standards (ref: Section 5.0) prior to discharge. No additional reduction is required. WLAs for WWTFs are derived from facility design flows and permitted E. coli limits and are expressed as average loads in CFU per day.

9.2.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

For present and future regulated discharges from municipal separate storm sewer systems (MS4s), WLAs are and will be implemented through Phase I & II MS4 permits. These permits will require the development and implementation of a Storm Water Management Plan (SWMP) that will reduce the discharge of pollutants to the "maximum extent practicable" and not cause or contribute to violations of State water quality standards. Both the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (TDEC, 2003) and the TDOT individual MS4 permit (TNS077585) require SWMPs to include minimum control measures. The permits also contain requirements regarding control of discharges of pollutants of concern into impaired waterbodies, implementation of provisions of approved TMDLs, and descriptions of methods to evaluate whether storm water controls are adequate to meet the requirements of approved TMDLs.

For guidance on the six minimum control measures for MS4s regulated under Phase I or Phase II, a series of fact sheets are available at: http://cfpub1.epa.gov/npdes/stormwater/swfinal.cfm?program_id=6

For further information on Tennessee's *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems*, see: http://state.tn.us/environment/wpc/ppo/TN%20Small%20MS4%20Modified%20General%20Permit%202003.pdf

In order to evaluate SWMP effectiveness and demonstrate compliance with specified WLAs, MS4s must develop and implement appropriate monitoring programs. An effective monitoring program could include:

- Effluent monitoring at selected outfalls that are representative of particular land uses or geographical areas that contribute to pollutant loading before and after implementation of pollutant control measures.

- Analytical monitoring of pollutants of concern (e.g., monthly) in receiving waterbodies, both upstream and downstream of MS4 discharges, over an extended period of time. In addition, intensive collection of pollutant monitoring data during the recreation season (June – September) at sufficient frequency to support calculation of the geometric mean.

When applicable, the appropriate Division of Water Pollution Control Environmental Field Office should be consulted for assistance in the determination of monitoring strategies, locations, frequency, and methods within 12 months after the approval date of TMDLs or designation as a regulated MS4. Details of monitoring plans and monitoring data should be included in annual reports required by MS4 permits.

9.2.3 NPDES Regulated Concentrated Animal Feeding Operations (CAFOs)

WLAs provided to most CAFOs will be implemented through NPDES Permit No. TNA000000, General NPDES Permit for *Class II Concentrated Animal Feeding Operation* or the facility's individual permit. Provisions of the general permit include development and implementation of Nutrient Management Plan (NMPs), requirements regarding land application BMPs, and requirements for CAFO liquid waste management systems. For further information, see: http://state.tn.us/environment/wpc/ppo/CAFO%20Final%20PDF%20Modified.pdf

Provisions of individual CAFO permits are similar.

9.3 Nonpoint Sources

The Tennessee Department of Environment & Conservation has no direct regulatory authority over most nonpoint source (NPS) discharges. Reductions of E. coli loading from nonpoint sources will be achieved using a phased approach. Voluntary, incentive-based mechanisms will be used to implement NPS management measures in order to assure that measurable reductions in pollutant loadings can be achieved for the targeted impaired waters. Cooperation and active participation by the general public and various industry, business, and environmental groups is critical to successful implementation of TMDLs. There are links to a number of publications and information resources on EPA's Nonpoint Source Pollution web page (http://www.epa.gov/owow/nps/pubs.html) relating to the implementation and evaluation of nonpoint source pollution control measures.

Local citizen-led and implemented management measures have the potential to provide the most efficient and comprehensive avenue for reduction of loading rates from nonpoint sources. The Wolf River Watershed Water Quality Management Plan (TDEC, 2005) describes local initiatives and partnerships in the Tennessee portion of the Wolf River watershed. For additional information, visit: http://state.tn.us/environment/wpc/watershed/wsmplans/wolf/.

9.3.1 Urban Nonpoint Sources

Management measures to reduce pathogen loading from urban nonpoint sources are similar to those recommended for MS4s (Sect. 9.2.2). Specific categories of urban nonpoint sources include stormwater, illicit discharges, septic systems, pet waste, and wildlife:

Stormwater: Most mitigation measures for stormwater are not designed specifically to reduce bacteria concentrations (ENSR, 2005). Instead, BMPs are typically designed to remove sediment and other pollutants. Bacteria in stormwater runoff are, however, often attached to particulate matter. Therefore, treatment systems that remove sediment may also provide reductions in bacteria concentrations.

Illicit discharges: Removal of illicit discharges to storm sewer systems, particularly of sanitary wastes, is an effective means of reducing pathogen loading to receiving waters (ENSR, 2005). These include intentional illegal connections from commercial or residential buildings, failing septic systems, and improper disposal of sewage from campers and boats.

Septic systems: When properly installed, operated, and maintained, septic systems effectively reduce pathogen concentrations in sewage. To reduce the release of pathogens, practices can be employed to maximize the life of existing systems, identify failed systems, and replace or remove failed systems (USEPA, 2005a). Alternatively, the installation of public sewers may be appropriate.

Pet waste: If the waste is not properly disposed of, these bacteria can wash into storm drains or directly into water bodies and contribute to pathogen impairment. Encouraging pet owners to properly collect and dispose of pet waste is the primary means for reducing the impact of pet waste (USEPA 2002b).

Wildlife: Reducing the impact of wildlife on pathogen concentrations in waterbodies generally requires either reducing the concentration of wildlife in an area or reducing their proximity to the waterbody (ENSR, 2005). The primary means for doing this is to eliminate human inducements for congregation. In addition, in some instances population control measures may be appropriate.

Two additional urban nonpoint source resource documents provided by EPA are:

National Management Measures to Control Nonpoint Source Pollution from Urban Areas (http://www.epa.gov/owow/nps/urbanmm/index.html) helps citizens and municipalities in urban areas protect bodies of water from polluted runoff that can result from everyday activities. The scientifically sound techniques it presents are among the best practices known today. The guidance will also help states to implement their nonpoint source control programs and municipalities to implement their Phase II Storm Water Permit Programs (Publication Number EPA 841-B-05-004, November 2005).

The Use of Best Management Practices (BMPs) in Urban Watersheds (http://www.epa.gov/nrmrl/pubs/600r04184/600r04184chap1.pdf) is a comprehensive literature review on commonly used urban watershed Best Management Practices (BMPs) that heretofore was not consolidated. The purpose of this document is to serve as an information source to individuals and agencies/municipalities/watershed management groups/etc. on the existing state of BMPs in urban stormwater management (Publication Number EPA/600/R-04/184, September 2004).

9.3.2 Agricultural Nonpoint Sources

BMPs have been utilized in the Wolf River watershed to reduce the amount of coliform bacteria transported to surface waters from agricultural sources. These BMPs (e.g., pasture and hayland planting, pasture establishment, cropland conversion, diversion, pond, etc.) may have contributed to reductions in in-stream concentrations of coliform bacteria in one or more Wolf River watershed E. coli-impaired subwatersheds during the TMDL evaluation period. The Tennessee Department of Agriculture (TDA) keeps a database of BMPs implemented in Tennessee. Those listed in the Wolf River watershed are shown in Figure 15. It is recommended that additional information (e.g., livestock access to streams, manure application practices, etc.) be provided and evaluated to better identify and quantify agricultural sources of coliform bacteria loading in order to minimize uncertainty in future TMDL analysis efforts.

It is further recommended that additional BMPs be implemented and monitored to document performance in reducing coliform bacteria loading to surface waters from agricultural sources. Demonstration sites for various types of BMPs should be established and maintained and their performance (in source reduction) evaluated over a period of at least two years prior to recommendations for utilization for subsequent implementation. E. coli sampling and monitoring are recommended during low-flow (baseflow) and storm periods at sites with and without BMPs and/or before and after implementation of BMPs.

For additional information on agricultural BMPs in Tennessee, see: http://state.tn.us/agriculture/nps/bmpa.html

An additional agricultural nonpoint source resource provided by EPA is *National Management Measures to Control Nonpoint Source Pollution from Agriculture* (http://www.epa.gov/owow/nps/agmm/index.html): a technical guidance and reference document for use by State, local, and tribal managers in the implementation of nonpoint source pollution management programs. It contains information on the best available, economically achievable means of reducing pollution of surface and ground water from agriculture (EPA 841-B-03-004, July 2003).

9.3.3 Other Nonpoint Sources

Additional nonpoint source references (not specifically addressing urban and/or agricultural sources) provided by EPA include:

National Management Measures to Control Nonpoint Source Pollution from Forestry (http://www.epa.gov/owow/nps/forestrymgmt/) helps forest owners protect lakes and streams from polluted runoff that can result from forestry activities. These scientifically sound techniques are the best practices known today. The report will also help states to implement their nonpoint source

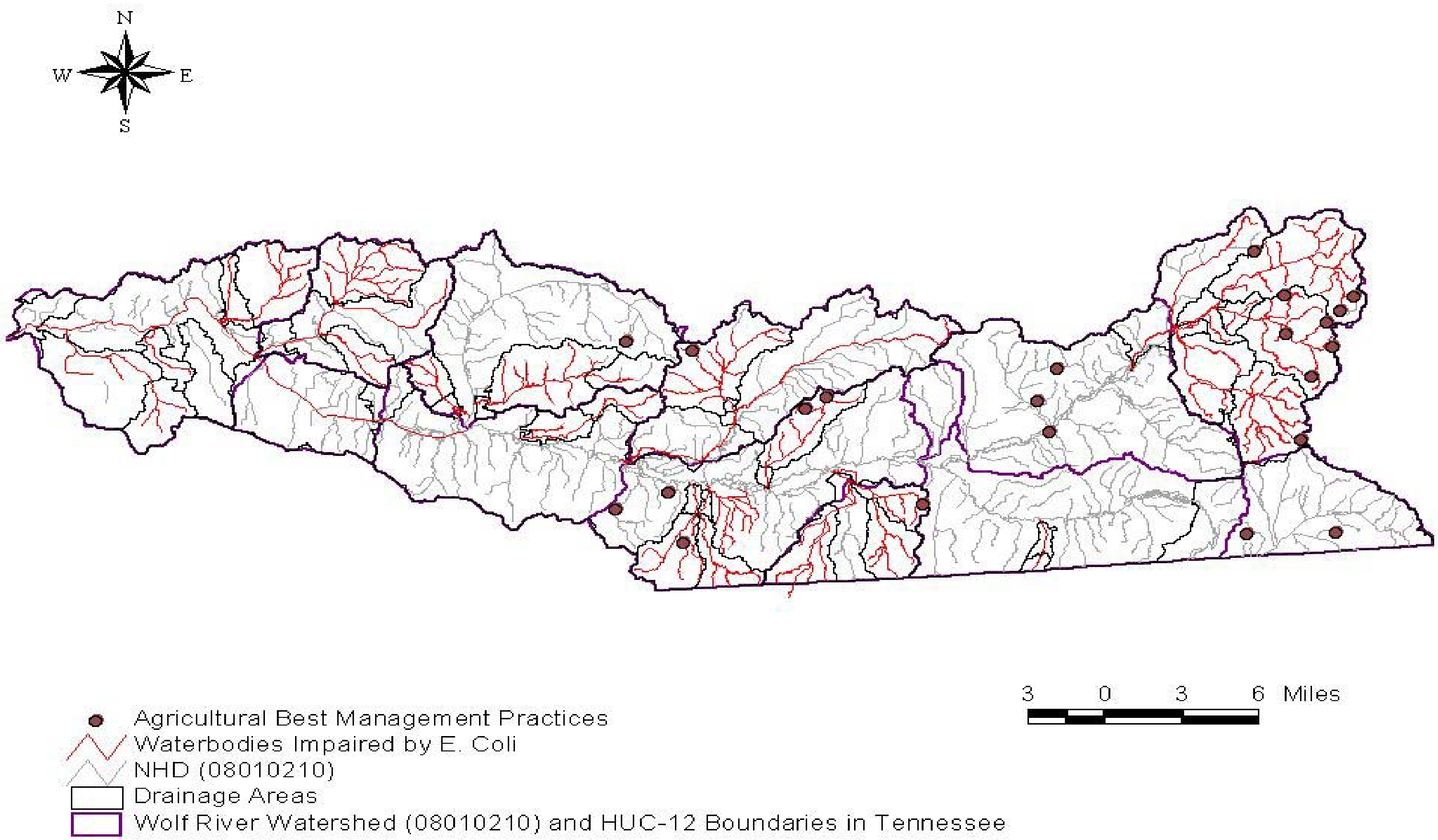

Figure 15. Tennessee Department of Agriculture Best Management Practices in the Wolf River Watershed.

control programs (EPA 841-B-05-001, May 2005).

In addition, the EPA website, http://www.epa.gov/owow/nps/bestnpsdocs.html, contains a list of guidance documents endorsed by the Nonpoint Source Control Branch at EPA headquarters. The list includes documents addressing urban, agriculture, forestry, marinas, stream restoration, nonpoint source monitoring, and funding.

9.4 Additional Monitoring

Additional monitoring and assessment activities are recommended to determine whether implementation of TMDLs, WLAs, & LAs in tributaries and upstream reaches will result in achievement of in-stream water quality targets for E. coli.

9.4.1 Water Quality Monitoring

Activities recommended for the Wolf River watershed:

Verify the assessment status of stream reaches identified on the Final 2006 303(d) List as impaired due to E. coli. If it is determined that these stream reaches are still not fully supporting designated uses, then sufficient data to enable development of TMDLs should be acquired. TMDLs will be revisited on 5-year watershed cycle as described above.

Evaluate the effectiveness of implementation measures (see Sect. 9.6). Includes BMP performance analysis and monitoring by permitees and stakeholders. Where required TMDL loading reduction has been fully achieved, adequate data to support delisting should be collected.

Provide additional data to clarify status of ambiguous sites (e.g., geometric mean data) for potential listing. Analyses of existing data at several monitoring sites on unlisted waterbodies in the Wolf River watershed suggest levels of impairment. Therefore, additional data are required for listing determination.

Continue ambient (long-term) monitoring at appropriate sites and key locations.

Comprehensive water quality monitoring activities include sampling during all seasons and a broad range of flow and meteorological conditions. In addition, collection of E. coli data at sufficient frequency to support calculation of the geometric mean, as described in Tennessee's General Water Quality Criteria (TDEC, 2004a), is encouraged. Finally, for individual monitoring locations, where historical E. coli data are greater than 1000 colonies/100 mL (or future samples are anticipated to be), a 1:100 dilution should be performed as described in Protocol A of the *Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water* (TDEC, 2004b).

9.4.2 Source Identification

An important aspect of E. coli load reduction activities is the accurate identification of the actual sources of pollution. In cases where the sources of E. coli impairment are not readily apparent, Microbial Source Tracking (MST) is one approach to determining the sources of fecal pollution and E. coli affecting a waterbody. Those methods that use bacteria as target organisms are also known as Bacterial Source Tracking (BST) methods. This technology is recommended for source identification in E. coli impaired waterbodies.

Bacterial Source Tracking is a collective term used for various biochemical, chemical, and molecular methods that have been developed to distinguish sources of human and non-human fecal pollution in environmental samples (Shah, 2004). In general, these methods rely on genotypic (also known as "genetic fingerprinting"), or phenotypic (relating to the physical characteristics of an organism) distinctions between the bacteria of different sources. Three primary genotypic techniques are available for BST: ribotyping, pulsed field gel electrophoresis (PFGE), and polymerase chain reaction (PCR). Phenotypic techniques generally involve an antibiotic resistance analysis (Hyer, 2004).

The USEPA has published a fact sheet that discusses BST methods and presents examples of BST application to TMDL development and implementation (USEPA, 2002). Various BST projects and descriptions of the application of BST techniques used to guide implementation of effective BMPs to remove or reduce fecal contamination are presented. The fact sheet can be found on the following EPA website: http://www.epa.gov/owm/mtb/bacsortk.pdf.

A multi-disciplinary group of researchers at the University of Tennessee, Knoxville (UTK) has developed and tested a series of different microbial assay methods based on real-time PCR to detect fecal bacterial concentrations and host sources in water samples (McKay, 2005). The assays have been used in a study of fecal contamination and have proven useful in identification of areas where cattle represent a significant fecal input and in development of BMPs. It is expected that these types of assays could have broad applications in monitoring fecal impacts from Animal Feeding Operations, as well as from wildlife and human sources. Additional information can be found on the following UTK website: http://web.utk.edu/~hydro/Research/McKayAGU2004Abstract.pdf.

A good example of this in west Tennessee: the City of Memphis conducted a Microbial Source Tracking Study for South Cypress Creek, in the Nonconnah Creek watershed (Lawrence, 2003), to identify fecal sources in an urban watershed. The Institute for Environmental Health (IEH), in Seattle, WA, assisted with the project and conducted ribotyping on E. coli strains from fecal coliform samples. In addition, a library of known sources was supplemented with local data by the collection of scat samples for better matching of bacteria sources. The results indicated that human sources (including raw sewage) accounted for less than 20% of the total occurrences of E. coli from fecal samples. Avian and wild animal sources were the primary sources of fecal contributions to South Cypress Creek. The report can be found at the following websites: http://www.cityofmemphis.org/pdf_forms/MicrobialSourceTrackingStudy.pdf and http://www.cityofmemphis.org/pdf_forms/MicrobialSourceTrackingStudyFigures.pdf.

9.5 Source Area Implementation Strategy

Implementation strategies are organized according to the dominant landuse type and the sources associated with each (Table 9 and Appendix E). Each HUC-12 subwatershed is grouped and targeted for implementation based on this source area organization. Three primary categories are identified: predominantly urban, predominantly agricultural, and mixed urban/agricultural. See Appendix A for information regarding landuse distribution of impaired subwatersheds. For the purpose of implementation evaluation, urban is defined as residential, commercial, and industrial landuse areas with predominate source categories such as point sources (WWTFs), collection systems/septic systems (including SSOs and CSOs), and urban stormwater runoff associated with MS4s. Agricultural is defined as cropland and pasture, with predominate source categories associated with livestock and manure management activities. A fourth category (infrequent) is associated with forested (including non-agricultural undeveloped and unaltered [by humans]) landuse areas with the predominate source category being wildlife.

Table 9. Source area types for waterbody drainage area analyses.

Waterbody ID	Source Area Type*			
	Urban	Agricultural	Mixed	Forested
Early Grove Creek		ò		
McKinnie Creek		ò		
May Creek		ò		
North Fork Creek		ò		
North Fork Wolf River		ò		
Hurricane Creek		ò		
UT to Wolf River		ò		
Russell Creek		ò		
Teague Branch		ò		
Grissum Creek		ò		
Alexander Creek		ò		
Shaws Creek		ò		
Wolf River #1			ò	
Johnson Creek		ò		
UT to Grays Creek	ò			
Marys Creek			ò	
Marys Creek Headwaters		ò		
Harrington Creek	ò			
Workhouse Bayou	ò			
Wolf River #2			ò	
Cypress Creek	ò			
Wolf River #3			ò	
UT #1 to Fletcher Creek	ò			
UT #2 to Fletcher Creek			ò	
Fletcher Creek			ò	

* All waterbodies potentially have significant source contributions from other source type/landuse areas.

All impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas have been classified according to their respective source area types in Table 9. The implementation for each area will be prioritized according to the guidance provided in Sections 9.5.1 and 9.5.2, below. For all impaired waterbodies, the determination of source area types serves to identify the predominant sources contributing to impairment (i.e., those that should be targeted initially for implementation). However, it is not intended to imply that sources in other landuse areas are not contributors to impairment and/or to grant an exemption from addressing other source area contributions with implementation strategies and corresponding load reduction. For mixed use areas, implementation will follow the guidance established for both urban and agricultural areas, at a minimum.

Appendix E provides source area implementation examples for urban and agricultural subwatersheds, development of percent load reduction goals, and determination of critical flow zones (for implementation prioritization) for E. coli impaired waterbodies. Load duration curve analyses (TMDLs, WLAs, LAs, and MOS) and percent load reduction goals for all flow zones for all E. coli impaired waterbodies in the Wolf River watershed are summarized in Table E-4.

9.5.1 Urban Source Areas

For impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas classified as predominantly urban, implementation strategies for E. coli load reduction will initially and primarily target source categories similar to those listed in Table 10 (USEPA, 2006). Table 10 presents example urban area management practices and the corresponding potential relative effectiveness under each of the hydrologic flow zones. Each implementation strategy addresses a range of flow conditions and targets point sources, non-point sources, or a combination of each. For each waterbody, the existing loads and corresponding PLRG for each flow zone are calculated according to the method described in Section E.4. The resulting determination of the critical flow zone further focuses the types of urban management practices appropriate for development of an effective load reduction strategy for a particular waterbody.

9.5.2 Agricultural Source Areas

For impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas classified as predominantly agricultural, implementation strategies for E. coli load reduction will initially and primarily target source categories similar to those listed in Table 11 (USDA, 1988). Table 11 presents example agricultural area management practices and the corresponding potential relative effectiveness under each of the hydrologic flow zones. Each implementation strategy addresses a range of flow conditions and targets point sources, non-point sources, or a combination of each. For each waterbody, the existing loads and corresponding PLRG for each flow zone are calculated according to the method described in Section E.4. The resulting determination of the critical flow zone further focuses the types of agricultural management practices appropriate for development of an effective load reduction strategy for a particular waterbody.

9.5.3 Forestry Source Areas

There are no impaired waterbodies with corresponding HUC-12 subwatersheds or drainage areas classified as source area type predominantly forested, with the predominate source category being wildlife, in the Wolf River watershed.

Table 10. Example Urban Area Management Practice/Hydrologic Flow Zone Considerations.

Management Practice	Duration Curve Zone (Flow Zone)				
	High	Moist	Mid-Range	Dry	Low
Bacteria source reduction					
Remove illicit discharges			L	M	H
Address pet & wildlife waste		H	M	M	L
Combined sewer overflow management					
Combined sewer separation		H	M	L	
CSO prevention practices		H	M	L	
Sanitary sewer system					
Infiltration/Inflow mitigation	H	M	L	L	
Inspection, maintenance, and repair		L	M	H	H
SSO repair/abatement	H	M	L		
Illegal cross-connections					
Septic system management					
Managing private systems		L	M	H	M
Replacing failed systems		L	M	H	M
Installing public sewers		L	M	H	M
Storm water infiltration/retention					
Infiltration basin		L	M	H	
Infiltration trench		L	M	H	
Infiltration/Biofilter swale		L	M	H	
Storm Water detention					
Created wetland		H	M	L	
Low impact development					
Disconnecting impervious areas		L	M	H	
Bioretention	L	M	H	H	
Pervious pavement		L	M	H	
Green Roof		L	M	H	
Buffers		H	H	H	
New/existing on-site wastewater treatment systems					
Permitting & installation programs		L	M	H	M
Operation & maintenance programs		L	M	H	M
Other					
Point source controls		L	M	H	H
Landfill control		L	M	H	
Riparian buffers		H	H	H	
Pet waste education & ordinances		M	H	H	L
Wildlife management		M	H	H	L
Inspection & maintenance of BMPs	L	M	H	H	L

__Note__: Potential relative importance of management practice effectiveness under given hydrologic condition (*H: High, M: Medium, L: Low*)

Table 11. Example Agricultural Area Management Practice/Hydrologic Flow Zone Considerations.

Flow Condition	High	Moist	Mid-range	Dry	Low
% Time Flow Exceeded	0-10	10-40	40-60	60-90	90-100
Grazing Management					
Prescribed Grazing (528A)	**H**	**H**	**M**	**L**	
Pasture & Hayland Mgmt (510)	**H**	**H**	**M**	**L**	
Deferred Grazing (352)	**H**	**H**	**M**	**L**	
Planned Grazing System (556)	**H**	**H**	**M**	**L**	
Proper Grazing Use (528)	**H**	**H**	**M**	**L**	
Proper Woodland Grazing (530)	**H**	**H**	**M**	**L**	
Livestock Access Limitation					
Livestock Exclusion (472)			**M**	**H**	**H**
Fencing (382)			**M**	**H**	**H**
Stream Crossing			**M**	**H**	**H**
Alternate Water Supply					
Pipeline (516)			**M**	**H**	**H**
Pond (378)			**M**	**H**	**H**
Trough or Tank (614)			**M**	**H**	**H**
Well (642)			**M**	**H**	**H**
Spring Development (574)			**M**	**H**	**H**
Manure Management					
Managing Barnyards	**H**	**H**	**M**	**L**	
Manure Transfer (634)	**H**	**H**	**M**	**L**	
Land Application of Manure	**H**	**H**	**M**	**L**	
Composting Facility (317)	**H**	**H**	**M**	**L**	
Vegetative Stabilization					
Pasture & Hayland Planting (512)	**H**	**H**	**M**	**L**	
Range Seeding (550)	**H**	**H**	**M**	**L**	
Channel Vegetation (322)	**H**	**H**	**M**	**L**	
Brush (& Weed) Mgmt (314)	**H**	**H**	**M**	**L**	

Table 11. Example Agricultural Area Management Practice/Hydrologic Flow Zone Considerations (Cont.)

Flow Condition	High	Moist	Mid-range	Dry	Low
% Time Flow Exceeded	0-10	10-40	40-60	60-90	90-100
Vegetative Stabilization (cont'd)					
Conservation Cover (327)		**H**	**H**	**H**	
Riparian Buffers (391)		**H**	**H**	**H**	
Critical Area Planting (342)		**H**	**H**	**H**	
Wetland restoration (657)		**H**	**H**	**H**	
CAFO Management					
Waste Management System (312)	**H**	**H**	**M**		
Waste Storage Structure (313)	**H**	**H**	**M**		
Waste Storage Pond (425)	**H**	**H**	**M**		
Waste Treatment Lagoon (359)	**H**	**H**	**M**		
Mulching (484)	**H**	**H**	**M**		
Waste Utilization (633)	**H**	**H**	**M**		
Water & Sediment Control Basin (638)	**H**	**H**	**M**		
Filter Strip (393)	**H**	**H**	**M**		
Sediment Basin (350)	**H**	**H**	**M**		
Grassed Waterway (412)	**H**	**H**	**M**		
Diversion (362)	**H**	**H**	**M**		
Heavy Use Area Protection (561)					
Constructed Wetland (656)					
Dikes (356)	**H**	**H**	**M**		
Lined Waterway or Outlet (468)	**H**	**H**	**M**		
Roof Runoff Mgmt (558)	**H**	**H**	**M**		
Floodwater Diversion (400)	**H**	**H**	**M**		
Terrace (600)	**H**	**H**	**M**		
Potential for source area contribution under given hydrologic condition (H: High; M: Medium; L: Low)					

Note: Numbers in parentheses are the U.S. Soil Conservation Service practice number.

9.6 Evaluation of TMDL Implementation Effectiveness

Evaluation of the effectiveness of TMDL implementation strategies should be conducted on multiple levels, as appropriate:

- HUC-12 or waterbody drainage area (i.e., TMDL analysis location)
- Subwatersheds or intermediate sampling locations
- Specific landuse areas (urban, pasture, etc.)
- Specific facilities (WWTF, CAFO, uniquely identified portion of MS4, etc.)
- Individual BMPs

In order to conduct an implementation effectiveness analysis on measures to reduce E. coli source loading, monitoring results should be evaluated in one of several ways. Sampling results can be compared to water quality standards (e.g., load duration curve analysis) for determination of impairment status, results can be compared on a before and after basis (temporal), or results can be evaluated both upstream and downstream of source reduction measures or source input (spatial). Considerations include period of record, data collection frequency, representativeness of data, and sampling locations.

In general, periods of record greater than 5 years (given adequate sampling frequency) can be evaluated for determination of relative change (trend analysis). For watersheds in second or successive TMDL cycles, data collected from multiple cycles can be compared. If implementation efforts have been initiated to reduce loading, evaluation of routine monitoring data may indicate improving or worsening conditions over time and corresponding effectiveness of implementation efforts.

Water quality data for implementation effectiveness analysis can be presented in multiple ways. For example, Figure 16 shows fecal coliform concentration data statistics for Oostanaula Creek at mile 28.4 (Hiwassee River watershed) for a historical (2002) TMDL analysis period versus a recent post-implementation period of sampling data (revised TMDL). The individual flow zone analyses are presented in a box and whisker plot of recent [2] versus historical [1] data. Figure 17 shows a load duration curve analysis (of recent versus historical data) of fecal coliform loading statistics for Oostanaula Creek. Lastly, Figure 18 shows best fit curve analyses of flow (percent time exceeded) versus fecal coliform loading relationships (regressions) plotted against the LDC of the single sample maximum water quality standard. Note that Figures 16-18 present the same data, from approved TMDLs (2 cycles), each clearly illustrating improving conditions between historical and recent periods.

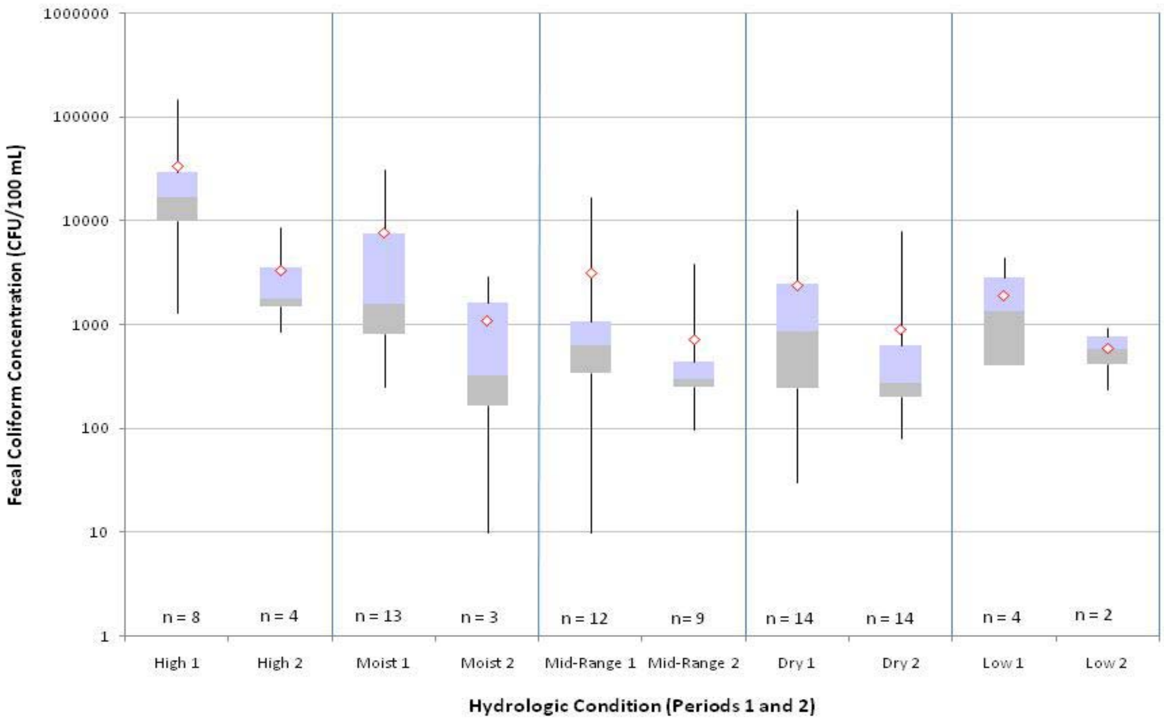

Figure 16. Oostanaula Creek TMDL implementation effectiveness (box and whisker plot).

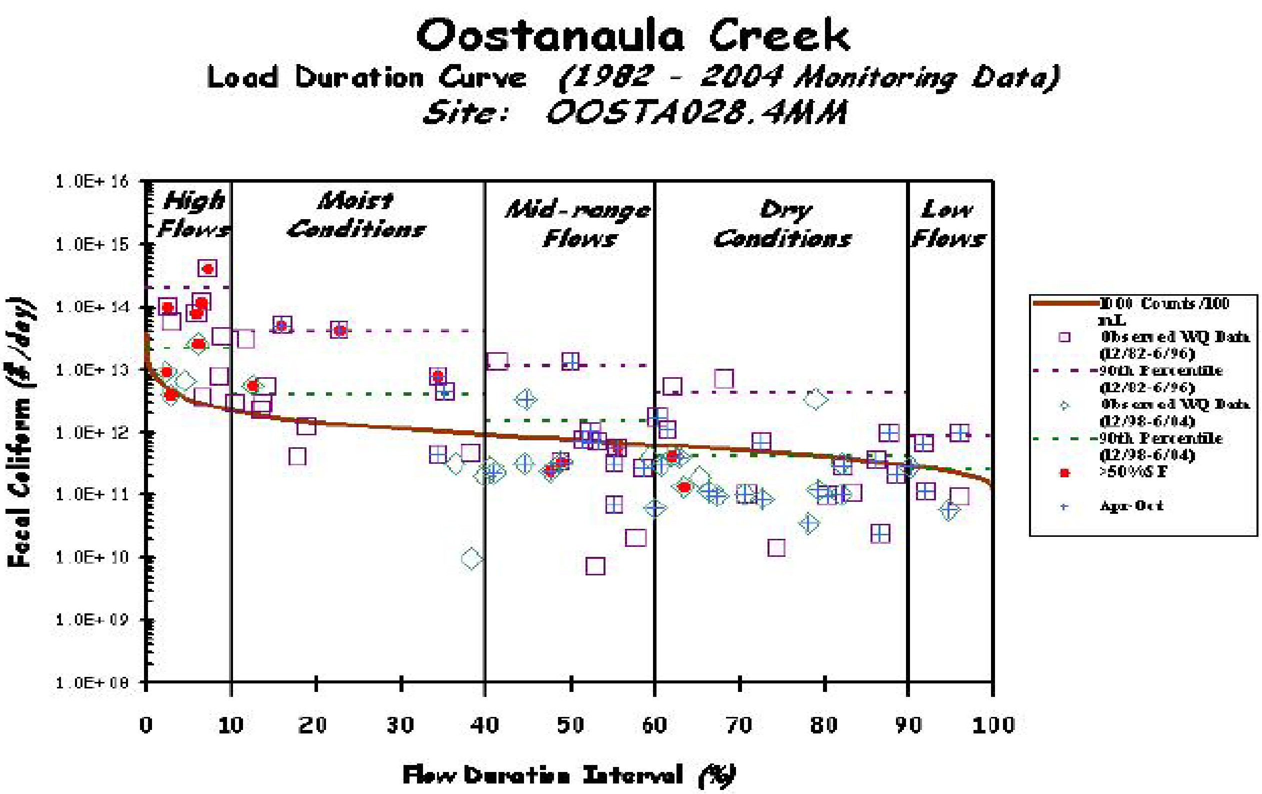

Figure 17. Oostanaula Creek TMDL implementation effectiveness (LDC analysis).

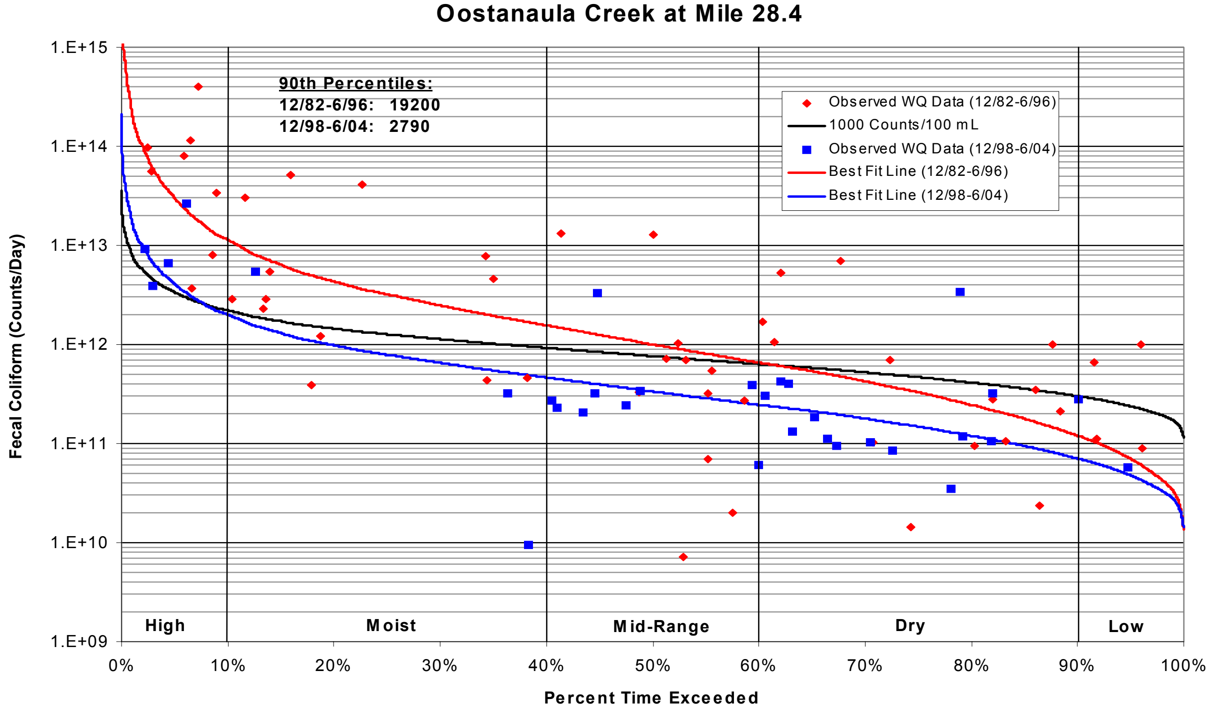

Figure 18. Oostanaula Creek TMDL implementation effectiveness (LDC regression analysis).

10.0 PUBLIC PARTICIPATION

In accordance with 40 CFR §130.7 (http://www.epa.gov/epacfr40/chapt-I.info/chi-toc.htm), the proposed E. coli TMDLs for the Wolf River watershed were placed on Public Notice for a 35-day period and comments solicited. Steps that were taken in this regard included:

1) Notice of the proposed TMDLs was posted on the TDEC website. The announcement invited public and stakeholder comment and provided a link to a downloadable version of the TMDL document.

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 was sent to approximately 90 interested persons or groups who have requested this information.

3) Draft copies of the proposed TMDLs were sent to the cities of Memphis, Collierville, Germantown, Lakeland, and Bartlett; Shelby County; and the Tennessee Department of Transportation.

4) Letters were sent to WWTFs located in E. coli-impaired subwatersheds in the Wolf River watershed, permitted to discharge treated effluent containing E. coli, advising them of the proposed TMDLs and their availability on the TDEC website. The letters also stated that a copy of the draft TMDL document would be provided on request. Letters were sent to the following facilities:

   Memphis – Maynard C. Stiles STP (TN0020711)
   Southwest School (TN0023787)
   Collierville STP (TN0057461)
   Rossville STP (TN0064092)
   Collierville Northwest STP (TN0074543)

   Note: Letters were not sent to Ridgeway Country Club (TN0023094) or Rocky Woods Estates (TN0056391) because each permit has been terminated.

5) Letters were sent to local stakeholder groups in the Wolf River Watershed advising them of the proposed E. coli TMDLs and their availability on the TDEC website. The letters also stated that copies of the draft TMDL document would be provided upon request. Letters were sent to the following local stakeholder groups:

   Wolf River Conservancy
   Tennessee Water Sentinels

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:

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

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

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APPENDIX A

Land Use Distribution in the Wolf River Watershed

Table A-1. MRLC Land Use Distribution of Wolf River Subwatersheds

Land Use	HUC-12 Subwatershed (08010210____) or Drainage Area (DA)					
	0201		0302		0303	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Bare Rock/Sand/Clay	14	0.0*	0	0.0	0	0.0
Deciduous Forest	16,136	39.1	7212	31.5	7090	22.5
Evergreen Forest	1380	3.3	189	0.8	788	2.5
High Intensity Commercial/Industrial/Transportation	16	0.0*	18	0.1	11	0.0*
High Intensity Residential	8	0.0*	1	0.0*	0	0.0
Low Intensity Residential	64	0.2	27	0.1	14	0.0*
Mixed Forest	2560	6.2	649	2.8	3269	10.4
Open Water	270	0.7	280	1.2	277	0.9
Other Grasses	0	0.0	0	0.0	1	0.0*
Pasture/Hay	11,204	27.1	6275	27.4	9609	30.5
Row Crops	8440	20.5	8029	35.0	7756	24.6
Transitional	31	0.1	25	0.1	23	0.1
Woody Wetlands	1144	2.8	224	1.0	2677	8.5
Total	41,273	100	22,927	100	31,516	100

* <0.05

Table A-1. MRLC Land Use Distribution of Wolf River Subwatersheds (Cont.)

Land Use	HUC-12 Subwatershed (08010210____) or Drainage Area (DA)					
	0306		0307		0308	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Bare Rock/Sand/Clay	0	0.0	0	0.0	84	0.2
Deciduous Forest	1538	3.8	745	5.6	2463	9.5
Evergreen Forest	211	0.5	149	1.1	459	1.8
High Intensity Commercial/Indus-trial/Transportation	4088	10.1	567	4.3	955	4.5
High Intensity Residential	8185	20.2	1658	12.6	3803	16.2
Low Intensity Residential	17,521	43.2	4073	30.8	5254	27.6
Mixed Forest	1429	3.5	491	3.7	1694	8.2
Open Water	993	2.4	317	2.4	175	0.9
Other Grasses	1858	4.6	399	3.0	1235	6.0
Pasture/Hay	751	1.8	1831	13.9	1993	9.7
Quarries/Strip Mines/Gravel Pits	0	0.0	0	0.0	28	0.1
Row Crops	1197	2.9	1443	10.9	1948	9.5
Transitional	195	0.5	225	1.7	435	2.1
Woody Wetlands	2628	6.5	1312	9.9	32	0.2
Total	40,594	100	13,210	100	20,558	100

Table A-1. MRLC Land Use Distribution of Wolf River Subwatersheds (Cont.)

Land Use	HUC-12 Subwatershed (08010210____) or Drainage Area (DA)									
	Early Grove Creek DA		North Fork Wolf River DA		Hurricane Creek DA		Unnamed Tributary to Wolf River DA		Russell Creek DA	
	[acres]	[%]	[acres]	[%]	[acres]	[%]	[acres]	[%]	[acres]	[%]
Deciduous Forest	1753	27.4	1228	36.2	1577	35.7	1444	20.5	655	13.4
Evergreen Forest	42	0.7	841	24.8	22	0.5	48	0.7	52	1.1
High Intensity Commercial/Indus-trial/Transportation	0	0.0	0	0.0	0	0.0	8	0.1	15	0.3
High Intensity Residential	0	0.0	0	0.0	1	0.0*	0	0.0	0	0.0
Low Intensity Residential	2	0.0*	0	0.0	1	0.0*	14	0.2	26	0.5
Mixed Forest	179	2.8	245	7.2	333	7.5	224	3.2	142	2.9
Open Water	52	0.8	4	0.1	42	1.0	113	1.6	51	1.0
Pasture/Hay	1720	26.9	155	4.6	1490	33.7	2963	42.1	2525	51.5
Row Crops	2632	41.2	103	3.0	904	20.5	2128	30.2	1204	24.5
Transitional	5	0.1	4	0.1	4	0.1	5	0.1	1	0.0*
Woody Wetlands	4	0.1	813	24.0	37	0.8	105	1.5	225	4.6
Total	6390	100	3394	100	4411	100	7052	100	4898	100

* <0.05

Table A-1. MRLC Land Use Distribution of Wolf River Subwatersheds (Cont.)

Land Use	HUC-12 Subwatershed (08010210____) or Drainage Area (DA)									
	Wolf River DA		Johnson Creek DA		Unnamed Tributary to Grays Creek DA		Marys Creek DA		Marys Creek Headwaters DA	
	[acres]	[%]	[acres]	[%]	[acres]	[%]	[acres]	[%]	[acres]	[%]
Deciduous Forest	3135	10.3	854	21.1	713	30.6	2845	28.0	622	26.1
Evergreen Forest	350	1.2	41	1.0	13	0.6	727	7.1	148	6.2
High Intensity Commercial/Industrial/Transportation	464	1.5	2	0.1	10	0.4	4	0.0*	0	0.0
High Intensity Residential	3261	10.7	0	0.0	252	10.8	0	0.0	0	0.0
Low Intensity Residential	3844	12.7	0	0.0	286	12.3	5	0.1	0	0.0
Mixed Forest	1709	5.6	389	9.6	223	9.6	1680	16.5	242	10.1
Open Water	562	1.9	56	1.4	19	0.8	408	4.0	254	10.7
Other Grasses	386	1.3	0	0.0	14	0.6	0	0.0	0	0.0
Pasture/Hay	5370	17.7	1544	38.1	321	13.8	2469	24.3	700	29.3
Quarries/Strip Mines/Gravel Pits	81	0.3	0	0.0	0	0.0	0	0.0	0	0.0
Row Crops	5330	17.6	778	19.2	416	17.9	2034	20.0	416	17.4
Transitional	593	2.0	0	0.0	46	2.0	0	0.0	0	0.0
Woody Wetlands	5275	17.4	395	9.8	17	0.7	3	0.0*	3	0.1
Total	30,359	100	4058	100	2330	100	10,175	100	2386	100

* <0.05

APPENDIX B

Water Quality Monitoring Data

There are a number of water quality monitoring stations that provide data for waterbodies identified as impaired for E. coli in the Wolf River watershed. The location of these monitoring stations is shown in Figure 5. Monitoring data recorded at these stations for E. coli are tabulated in Table B-1.

Table B-1. Water Quality Monitoring Data – Wolf River Watershed

Monitoring Station	Date	E. Coli [CFU/100 mL]
EGROV001.6FA	3/28/00	15.6
	7/30/03	**>2419.2**
	10/27/03	**>2419.2**
	1/27/04	19.9
	2/23/04	7.4
	3/31/04	28.2
	4/28/04	116.9
	5/24/04	131.7
	6/23/04	**>2419.2**
MCKIN000.5FA	2/24/00	124.2
	10/18/99	23.5
	7/30/03	**1732.9**
	11/24/03	**8664**
	12/17/03	20
	1/27/04	231
	2/23/04	10.9
	3/31/04	111.2
	4/28/04	38.8
	5/24/04	198.9
MAY001.4FA	1/18/00	4.1
	7/30/03	770.1
	8/27/03	87.8
	9/24/03	224.7
	10/27/03	**1299.7**
	11/24/03	**>2419.2**
	12/17/03	41
	1/27/04	63
	2/23/04	18.7
	3/31/04	51.2
	4/28/04	53.8
	5/24/04	101.7
	6/23/04	**>2419.2**

Table B-1. Water Quality Monitoring Data – Wolf River Watershed (Cont.)

Monitoring Station	Date	E. Coli [CFU/100 mL]
NFORK004.4FA	7/30/03	**2419.2**
	11/24/03	**>2419.2**
	12/17/03	209
	1/27/04	213
	2/23/04	23.1
	3/31/04	66.9
	4/28/04	39.7
	5/24/04	184.2
	6/23/04	**1299.7**
NFWOL011.4FA	2/24/00	147
	10/18/99	59.2
	7/30/03	**1413.6**
	8/27/03	77.6
	9/24/03	127.4
	10/27/03	396.8
	11/24/03	**1413.6**
	12/17/03	52
	1/27/04	52.8
	2/23/04	21.3
	3/31/04	33.1
	4/28/04	105.4
	5/24/04	83.9
	6/23/04	**1553.1**
HURRI001.1FA	3/28/00	35.4
	5/23/00	9.8
	8/20/03	66.9
	11/19/03	**>2419.2**
	12/15/03	**1198**
	1/21/04	472
	2/18/04	218
	3/16/04	920.8
	4/27/04	108.6
	5/19/04	298.7
	6/16/04	**>2419.2**
WOLF1T1.1FA	10/8/03	**>2419.2**
	12/10/03	**8164**
	1/14/04	**>2419.2**

Table B-1. Water Quality Monitoring Data – Wolf River Watershed (Cont.)

Monitoring Station	Date	E. Coli [CFU/100 mL]
WOLF1T1.1FA	2/10/04	173
	3/9/04	248.9
	4/14/04	**1732.9**
	5/12/04	166.4
RUSSE001.5FA	3/28/00	325.5
	7/9/03	**1553.1**
	8/18/03	30.6
	9/10/03	**>2419.2**
	10/8/03	**24192**
	11/5/03	**>2419.2**
	12/10/03	**5794**
	1/14/04	350
	2/10/04	70.3
	3/9/04	86
	4/14/04	**>2419.2**
	5/12/04	**1198**
TEAGU001.4FA	8/20/03	298.7
	10/15/03	**1732.9**
	11/19/03	**>2419.2**
	12/15/03	**1789**
	1/21/04	691
	2/18/04	135
	3/16/04	201.4
	4/27/04	461.1
	5/19/04	866.4
	6/16/04	**>2419.2**
GRISS002.7FA	1/20/99	280.9
	2/17/99	109.5
	3/17/99	118.2
	4/15/99	**>2419.2**
	5/13/99	23.8
	6/16/99	5.2
	12/15/99	**1119.9**
	10/15/03	235.9
	11/19/03	**>2419.2**
	12/15/03	857
	2/18/04	24

Table B-1. Water Quality Monitoring Data – Wolf River Watershed (Cont.)

Monitoring Station	Date	E. Coli [CFU/100 mL]
GRISS002.7FA	3/16/04	39.3
	4/27/04	260.2
	6/16/04	**>2419.2**
ALEXA000.8FA	3/28/00	9.7
	7/16/03	**2419.2**
	8/20/03	613.1
	9/17/03	613.1
	10/15/03	**>2419.2**
	11/19/03	**3255**
	12/15/03	262
	1/21/04	34.5
	2/18/04	18.3
	3/16/04	727
	4/27/04	133.4
	5/19/04	344.8
	6/16/04	**1986.3**
SHAWS007.2FA	1/20/99	32.8
	2/17/99	8.5
	3/17/99	6.1
	4/15/99	**>2419.2**
	5/13/99	64
	6/16/99	127.4
	7/21/99	3
	8/18/99	172.6
	9/15/99	6.3
	10/13/99	11
	12/15/99	547.5
	8/20/03	12.1
	9/17/03	325.5
	10/15/03	**>2419.2**
	11/19/03	**9804**
	12/15/03	364
	1/21/04	62
	2/18/04	9.7
	3/16/04	41.1
	4/27/04	117.8
	5/19/04	93.2
	6/16/04	**>2419.2**

Table B-1. Water Quality Monitoring Data – Wolf River Watershed (Cont.)

Monitoring Station	Date	E. Coli [CFU/100 mL]
JOHNS002.9SH	7/9/03	272.3
	10/8/03	**>2419.2**
	1/14/04	579.4
	2/10/04	**2419.2**
	3/9/04	12.2
	4/14/04	**>2419.2**
	5/12/04	**3873**
	6/9/04	10
1W (Wolf River)	6/20/00	50
	7/19/00	10
	8/25/00	200
	9/18/00	10
	10/13/00	220
	10/23/00	20
	11/7/00	**5400**
	11/15/00	50
	12/5/00	40
	12/19/00	90
	1/19/01	10
	1/22/01	10
	2/5/01	10
	2/20/01	40
	3/7/01	20
	3/20/01	40
	4/2/01	10
	4/26/01	350
	5/8/01	130
	5/24/01	270
	6/5/01	50
	6/19/01	90
	7/18/01	90
	8/20/01	10
	9/20/01	10
	10/18/01	**60000**
	11/6/01	90
	12/3/01	110

Table B-1. Water Quality Monitoring Data – Wolf River Watershed (Cont.)

Monitoring Station	Date	E. Coli [CFU/100 mL]
1W (Wolf River)	1/10/02	10
	2/13/02	40
	3/7/02	10
	4/3/02	10
	5/13/02	110
	6/13/02	20
	7/25/02	1
	8/13/02	1
	9/17/02	6
	10/7/02	20
	11/7/02	360
	12/16/02	200
	1/7/03	10
	2/12/03	**1500**
	3/5/03	**4200**
	4/3/03	**1100**
	5/5/03	**6000**
	6/10/03	**6000**
	7/8/03	**3400**
	8/8/03	600
	9/10/03	10
	10/7/03	100
	11/3/03	10
	12/8/03	200
	1/21/04	200
	2/23/04	100
	3/16/04	2
	4/15/04	37
	5/13/04	5
	6/16/04	**3400**
	7/6/04	177
	8/12/04	2
	9/20/04	20
	10/18/04	300
	11/4/04	30
	12/2/04	540
	1/20/05	**1600**

Table B-1. Water Quality Monitoring Data – Wolf River Watershed (Cont.)

Monitoring Station	Date	E. Coli [CFU/100 mL]
1W (Wolf River)	2/1/05	**3000**
	3/1/05	**1000**
	4/19/05	**2600**
	4/21/05	**1000**
	5/16/05	600
	6/8/05	300
GRAYS1T2.1SH	9/7/99	33.6
	1/13/00	23.5
	7/9/03	110.6
	8/18/03	129.6
	9/10/03	36.4
	10/8/03	**>2419.2**
	11/5/03	22.8
	12/10/03	**11199**
	1/14/04	65
	2/10/04	686.7
	3/9/04	243
	4/14/04	**>2419.2**
	5/12/04	**2481**
	6/9/04	156
MARYS001.0SH	9/7/99	8.6
	1/13/00	38.4
	7/9/03	41.9
	8/18/03	57.1
	9/10/03	410
	10/8/03	**2419.2**
	11/5/03	33.6
	12/10/03	**9804**
	1/14/04	83.6
	2/10/04	228.2
	3/9/04	65
	4/14/04	**2419.2**
	5/12/04	259
MARYS005.8SH	10/8/03	**>2419.2**
	12/10/03	**7270**
	1/14/04	**2419.2**

Table B-1. Water Quality Monitoring Data – Wolf River Watershed (Cont.)

Monitoring Station	Date	E. Coli [CFU/100 mL]
MARYS005.8SH	2/10/04	213
	3/9/04	186
	4/14/04	686.7
	5/12/04	517.2
4W (Harrington Creek)	6/20/00	**1900**
	7/19/00	**29000**
	8/25/00	900
	9/18/00	520
	10/13/00	**8000**
	10/23/00	100
	11/7/00	**4100**
	11/15/00	10
	12/5/00	50
	12/19/00	10
	1/19/01	10
	1/22/01	20
	2/5/01	110
	2/20/01	90
	3/7/01	10
	3/20/01	60
	4/2/01	120
	4/26/01	**1100**
	5/8/01	190
	5/24/01	170
	6/5/01	150
	6/19/01	100
	7/18/01	120
	8/20/01	30
	9/20/01	10
	10/18/01	10
	11/6/01	40
	1/10/02	**4200**
	2/13/02	170
	3/7/02	90
	4/3/02	30
	5/13/02	50
	6/13/02	90

Table B-1. Water Quality Monitoring Data – Wolf River Watershed (Cont.)

Monitoring Station	Date	E. Coli [CFU/100 mL]
4W (Harrington Creek)	7/25/02	1
	8/13/02	1
	9/17/02	29
	10/7/02	80
	11/7/02	350
	12/16/02	160
	1/7/03	30
	2/12/03	300
	3/5/03	800
	4/3/03	90
	5/5/03	**6000**
	6/10/03	**6000**
	7/8/03	**5500**
	8/8/03	340
	9/10/03	220
	10/7/03	10
	11/3/03	200
	12/8/03	400
	1/21/04	250
	2/23/04	2
	3/16/04	180
	4/15/04	300
	5/13/04	211
	6/16/04	**10300**
	7/6/04	340
	8/12/04	209
	9/20/04	209
	10/18/04	29
	11/4/04	120
	12/2/04	**1100**
	1/20/05	**1400**
	2/1/05	**3600**
	3/1/05	**4000**
	4/19/05	**1100**
	4/21/05	**1900**
	5/16/05	400
	6/8/05	600

Table B-1. Water Quality Monitoring Data – Wolf River Watershed (Cont.)

Monitoring Station	Date	E. Coli [CFU/100 mL]
WORKH000.3SH	4/18/00	547.5
	3/3/99	**>2419.2**
	10/21/99	816.4
	6/30/03	344.8
	8/4/03	**>2419.2**
	9/3/03	301
	10/1/03	133.3
	11/3/03	38.8
	12/3/03	344.1
	1/7/04	238.2
	2/4/04	261.3
	3/2/04	**1299.7**
	4/7/04	139.6
	5/5/04	**>2419.2**
	6/2/04	**1094**
WOLF001.5SH	1/20/99	**770.1**
	2/17/99	46.4
	3/17/99	372.5
	4/15/99	**>2419.2**
	5/13/99	88.4
	6/16/99	**>2419.2**
	7/21/99	**980.4**
	8/18/99	257.2
	8/26/99	436
	9/15/99	**579.4**
	10/13/99	307.6
	11/17/99	137
	12/15/99	**>2419.2**
	3/14/01	125
	6/13/01	104.2
	8/14/01	**1986.3**
	11/20/01	**>2419.2**
	2/20/02	**9804**
	5/22/02	10
	8/20/02	**798**
	11/7/02	**<2419.2**
	2/11/03	238

Table B-1. Water Quality Monitoring Data – Wolf River Watershed (Cont.)

Monitoring Station	Date	E. Coli [CFU/100 mL]
WOLF001.5SH	5/27/03	63.8
	6/30/03	260.2
	8/4/03	**>2419.2**
	9/3/03	**9804**
	10/1/03	148
	11/3/03	131.3
	12/3/03	80.1
	1/7/04	185
	2/4/04	90.7
	3/2/04	**>2419.2**
	4/7/04	74
	5/5/04	203
	6/2/04	**579.4**
	10/25/04	**1203.3**
	2/8/05	**19863**
	6/29/05	**1081**
	9/21/05	106.7
CYPRE004.8SH	3/22/00	488.4
	10/7/99	**1413.6**
	6/30/03	**1413.6**
	8/4/03	**>2419.2**
	9/3/03	933
	10/1/03	426
	11/3/03	**980.4**
	12/3/03	**>2419.2**
	1/7/04	571
	3/2/04	**24192**
	4/7/04	697
	5/5/04	**>24192**
	6/2/04	**1320**
WOLF018.9SH	1/20/99	191.8
	2/17/99	133.4
	3/17/99	816.4
	4/15/99	**1986.3**
	5/13/99	104.3
	6/16/99	410.6
	7/21/99	57.3
	8/18/99	18.7

Table B-1. Water Quality Monitoring Data – Wolf River Watershed (Cont.)

Monitoring Station	Date	E. Coli [CFU/100 mL]
WOLF018.9SH	9/15/99	15.6
	10/13/99	104.3
	11/17/99	30.9
	12/15/99	613.1
	7/9/03	51.2
	8/18/03	62
	9/10/03	70.8
	10/8/03	**>2419.2**
	11/5/03	58.3
	12/10/03	**2143**
	1/14/04	20.1
	2/10/04	461.1
	3/9/04	29.5
	4/14/04	**>2419.2**
	5/12/04	86
	6/9/04	101.7
FLETC2T0.2SH	6/30/03	117.8
	8/4/03	**>2419.2**
	9/3/03	**2489**
	10/1/03	86
	11/3/03	517.2
	12/3/03	238.2
	1/7/04	727
	2/4/04	101
	3/2/04	**1732.9**
	4/7/04	43.5
	5/5/04	57.3
	6/2/04	290.9
FLETC1T0.4SH	6/30/03	**1299.7**
	8/4/03	**>2419.2**
	9/3/03	**1935**
	10/1/03	146
	11/3/03	48.8
	12/3/03	387.3
	1/7/04	**1732.9**
	2/4/04	488.4
	3/2/04	**1413.6**
	4/7/04	13.5

Table B-1. Water Quality Monitoring Data – Wolf River Watershed (Cont.)

Monitoring Station	Date	E. Coli [CFU/100 mL]
FLETC1T0.4SH	5/5/04	344.8
	6/2/04	920.8
6W (Fletcher Creek)	6/20/00	**2600**
	7/19/00	200
	8/25/00	**73000**
	9/18/00	**37000**
	10/13/00	250
	10/23/00	20
	11/7/00	**41000**
	11/15/00	290
	12/5/00	10
	12/19/00	30
	1/19/01	**1400**
	1/22/01	80
	2/5/01	60
	2/20/01	30
	3/7/01	130
	3/20/01	120
	4/2/01	180
	4/26/01	**1400**
	5/8/01	160
	5/24/01	290
	6/5/01	210
	6/19/01	40
	7/18/01	250
	8/20/01	30
	9/20/01	10
	10/18/01	60
	11/6/01	60
	12/3/01	400
	1/10/02	30
	2/13/02	60
	3/7/02	40
	4/3/02	10
	5/13/02	10
	6/13/02	20
	7/25/02	1
	8/13/02	1

Table B-1. Water Quality Monitoring Data – Wolf River Watershed (Cont.)

Monitoring Station	Date	E. Coli [CFU/100 mL]
6W (Fletcher Creek)	9/17/02	28
	10/7/02	30
	11/7/02	300
	12/16/02	320
	1/7/03	10
	2/12/03	900
	3/5/03	900
	4/3/03	50
	5/5/03	**2800**
	6/10/03	**2500**
	7/8/03	**3400**
	8/8/03	250
	9/10/03	100
	10/7/03	10
	11/3/03	**1000**
	12/8/03	100
	1/21/04	290
	2/23/04	2
	3/16/04	2
	4/15/04	10
	5/13/04	8
	6/16/04	**5400**
	7/6/04	320
	8/12/04	2
	9/20/04	1
	10/18/04	540
	11/4/04	**1100**
	11/17/04	40
	12/2/04	**1200**
	1/20/05	**2200**
	2/1/05	**3700**
	3/1/05	1
	4/19/05	**1200**
	4/21/05	**2500**
	5/16/05	700
	6/8/05	200

APPENDIX C

Load Duration Curve Development and Determination of Daily Loading

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) that takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

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

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) (http://www.epa.gov/epacfr40/chapt-I.info/chi-toc.htm) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measure.

C.1 Development of TMDLs and Load Reductions

E. coli TMDLs, WLAs, and LAs were developed for impaired subwatersheds in the Wolf River watershed using load duration curves (LDCs). Daily loads for TMDLs, WLAs, and LAs are expressed as a function of daily mean in-stream flow (daily loading function).

C.1.1 Development of Flow Duration Curves

A flow duration curve is a cumulative frequency graph, constructed from historic flow data at a particular location, that represents the percentage of time a particular flow rate is equaled or exceeded. Flow duration curves are developed for a waterbody from daily flows over an extended period of record. In general, there is a higher level of confidence that curves derived from data over a long period of record correctly represent the entire range of flow. The preferred method of flow duration curve computation uses daily mean data from U.S. Geological Survey (USGS) continuous-record stations (http://waterdata.usgs.gov/tn/nwis/sw) located on the waterbody of interest. For ungaged streams, alternative methods must be used to estimate daily mean flow. These include: 1) regression equations (using drainage area as the independent variable) developed from continuous record stations in the same ecoregion; 2) drainage area extrapolation of data from a nearby continuous-record station of similar size and topography; and 3) calculation of daily mean flow using a dynamic computer model, such as the Loading Simulation Program C++ (LSPC).

Flow duration curves for impaired waterbodies in the Wolf River watershed were derived from LSPC hydrologic simulations based on parameters derived from calibration at three USGS monitoring stations (07031692, Fletcher Creek at Sycamore View Road; 07031650, Wolf River at Germantown; and 07030392, Wolf River at LaGrange). See Appendix D for details of calibration. The data used included the period of record from 1/1/96 – 12/31/05. For example, a flow-duration curve for Wolf River at mile 1.5 was constructed using simulated daily mean flow for the period from 1/1/96 through 12/31/05 (mile 1.5 corresponds to the location of monitoring station WOLF001.5SH). This flow duration curve is shown in Figure C-1 and represents the cumulative distribution of daily discharges arranged to show percentage of time specific flows were exceeded during the period of record (the highest daily mean flow during this period is exceeded 0% of the time and the lowest daily mean flow is equaled or exceeded 100% of the time). Flow duration curves for other impaired waterbodies were derived using a similar procedure.

C.1.2 Development of Load Duration Curves and TMDLs

When a water quality target concentration is applied to the flow duration curve, the resulting load duration curve (LDC) represents the allowable pollutant loading in a waterbody over the entire range of flow. Pollutant monitoring data, plotted on the LDC, provides a visual depiction of stream water quality as well as the frequency and magnitude of any exceedances. Load duration curve intervals can be grouped into several broad categories or zones, in order to provide additional insight about conditions and patterns associated with the impairment. For example, the duration curve could be divided into five zones: high flows (exceeded 0-10% of the time), moist conditions (10-40%), median or mid-range flows (40-60%), dry conditions (60-90%), and low flows (90-100%). Impairments observed in the low flow zone typically indicate the influence of point sources, while those further left on the LDC (representing zones of higher flow) generally reflect potential nonpoint source contributions (Stiles, 2003).

E. coli load duration curves for impaired waterbodies in the Wolf River watershed were developed from the flow duration curves developed in Section C.1.1, E. coli target concentrations, and available water quality monitoring data. LDCs and daily loading functions were developed using the following procedure (Fletcher Creek, station 6W is shown as an example):

1. A target LDC was generated for Fletcher Creek 6W by applying the E. coli target concentration of 941 CFU/100 mL to each of the ranked flows used to generate the flow duration curve (ref.: Section C.1.1) and plotting the results. The E. coli target maximum load corresponding to each ranked daily mean flow is:

   $(\text{Target Load})_{6W}$ = (941 CFU/100 mL) x (Q) x (UCF)

   where: Target Load = TMDL (CFU/day)
   Q = daily mean in-stream flow (cfs)
   UCF = the required unit conversion factor

   TMDL = 2.30 x 10^{10} x Q

2. Daily loads were calculated for each of the water quality samples collected at monitoring station 6W (ref.: Table B-1) by multiplying the sample concentration by the daily mean flow for the sampling date and the required unit conversion factor. Fletcher Creek 6W was selected for LDC analysis because it has numerous sampling points, well distributed across the full range of flow conditions, and multiple exceedances of the target concentration.

   Note: In order to be consistent for all analyses, the derived daily mean flow was used to compute sampling data loads, even if measured ("instantaneous") flow data were available for some sampling dates.

   Example (6/20/00 sampling event):
   Modeled Flow = 1.33 cfs
   Concentration = 2600 CFU/100 mL
   Daily Load = 8.43 x 10^{10} CFU/day

3. Using the flow duration curves developed in Section C.1.1, the "percent of days the flow was exceeded" (PDFE) was determined for each sampling event. Each sample load was then plotted on the LDCs developed in Step 1 according to the PDFE. The resulting E. coli LDC for Fletcher Creek 6W is shown in Figure C-2.

LDCs of other impaired waterbodies were derived in a similar manner and are shown in Appendix E.

C.2 Development of WLAs, LAs, and MOS

As previously discussed, a TMDL can be expressed as the sum of all point source loads (WLAs), nonpoint source loads (LAs), and an appropriate margin of safety (MOS) that takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$TMDL = \Sigma\ WLAs + \Sigma\ LAs + MOS$$

Expanding the terms:

$$TMDL = [\Sigma WLAs]_{WWTF} + [\Sigma WLAs]_{MS4} + [\Sigma WLAs]_{CAFO} + [\Sigma LAs]_{DS} + [\Sigma LAs]_{SW} + MOS$$

For E. coli TMDLs in each impaired subwatershed, WLA terms include:

- $[\Sigma WLAs]_{WWTF}$ is the allowable load associated with discharges of NPDES permitted WWTFs located in impaired subwatersheds. Since NPDES permits for these facilities specify that treated wastewater must meet in-stream water quality standards at the point of discharge, no additional load reduction is required. WLAs for WWTFs are calculated from the facility design flow and the Monthly Average permit limit.

- $[\Sigma WLAs]_{CAFO}$ is the allowable E. coli load for all CAFOs in an impaired subwatershed. All wastewater discharges from a CAFO to waters of the state of Tennessee are prohibited, except when either chronic or catastrophic rainfall events cause an overflow of process wastewater from a facility properly designed, constructed, maintained, and operated to contain:
  - All process wastewater resulting from the operation of the CAFO (such as wash water, parlor water, watering system overflow, etc.); plus,
  - All runoff from a 25-year, 24-hour rainfall event for the existing CAFO or new dairy or cattle CAFOs; or all runoff from a 100-year, 24-hour rainfall event for a new swine or poultry CAFO.

  Therefore, a WLA of zero has been assigned to this class of facilities.

- $[\Sigma WLAs]_{MS4}$ is the allowable E. coli load for discharges from MS4s. E. coli loading from MS4s is the result of buildup/wash-off processes associated with storm events.

LA terms include:

- $[\Sigma LAs]_{DS}$ is the allowable E. coli load from "other direct sources". These sources include leaking septic systems, illicit discharges, and animals access to streams. The LA specified for all sources of this type is zero CFU/day (or to the maximum extent feasible).

- $[\Sigma LAs]_{SW}$ is the allowable E. coli load from nonpoint sources indirectly going to surface waters from all land use areas (except areas covered by a MS4 permit) as a result of the buildup/wash-off processes associated with storm events (i.e., precipitation induced).

Since $[WLAs]_{CAFO} = 0$ and $[LAs]_{DS} = 0$, the expression relating TMDLs to precipitation-based point and nonpoint sources may be simplified to:

$$TMDL - MOS = [WLAs]_{WWTF} + [WLAs]_{MS4} + [\Sigma LAs]_{SW}$$

As stated in Section 8.5, an explicit MOS, equal to 10% of the E. coli water quality targets (ref.: Section 5.0), was utilized for determination of the percent load reductions necessary to achieve the WLAs and LAs:

Instantaneous Maximum (lake, reservoir, State Scenic River, Tier II, and Tier III):

Target – MOS = (487 CFU/100 ml) – 0.1(487 CFU/100 ml)

Target – MOS = 438 CFU/100 ml

Instantaneous Maximum (other):

Target – MOS = (941 CFU/100 ml) – 0.1(941 CFU/100 ml)

Target – MOS = 847 CFU/100 ml

30-Day Geometric Mean:

Target – MOS = (126 CFU/100 ml) – 0.1(126 CFU/100 ml)

Target – MOS = 113 CFU/100 ml

C.2.1 Daily Load Calculation

Since WWTFs discharge must comply with instream water quality criteria (TMDL target) at the point of discharge, WLAs for WWTFs are expressed as a constant term. In addition, WLAs for MS4s and LAs for precipitation-based nonpoint sources are equal on a per unit area basis and may be expressed as the daily allowable load per unit area (acre) resulting from a decrease in in-stream E. coli concentrations to TMDL target values minus MOS:

$[\text{WLAs}]_{\text{MS4}}$ = LA = (TMDL – MOS – $[\text{WLAs}]_{\text{WWTF}}$) / DA

where: DA = waterbody drainage area (acres)

Using Fletcher Creek 6W as an example:

TMDL_{6W} = (941 CFU/100 mL) x (Q) x (UCF)

= 2.30×10^{10} x Q

MOS_{6W} = TMDL x 0.10

MOS = 2.30×10^{9} x Q

WLA[MS4] $_{6W}$ = LA_{6W}

= {TMDL – MOS – WLA[WWTFs]} / DA

= {(2.30×10^{10} x Q) – (2.30×10^{9} x Q) – (0)} / (20,671)

WLA[MS4] = LA = 1.00×10^{6} x Q

TMDLs, WLAs, LAs, and MOS for other impaired subwatersheds and drainage areas were derived in a similar manner and are summarized in Table C-1.

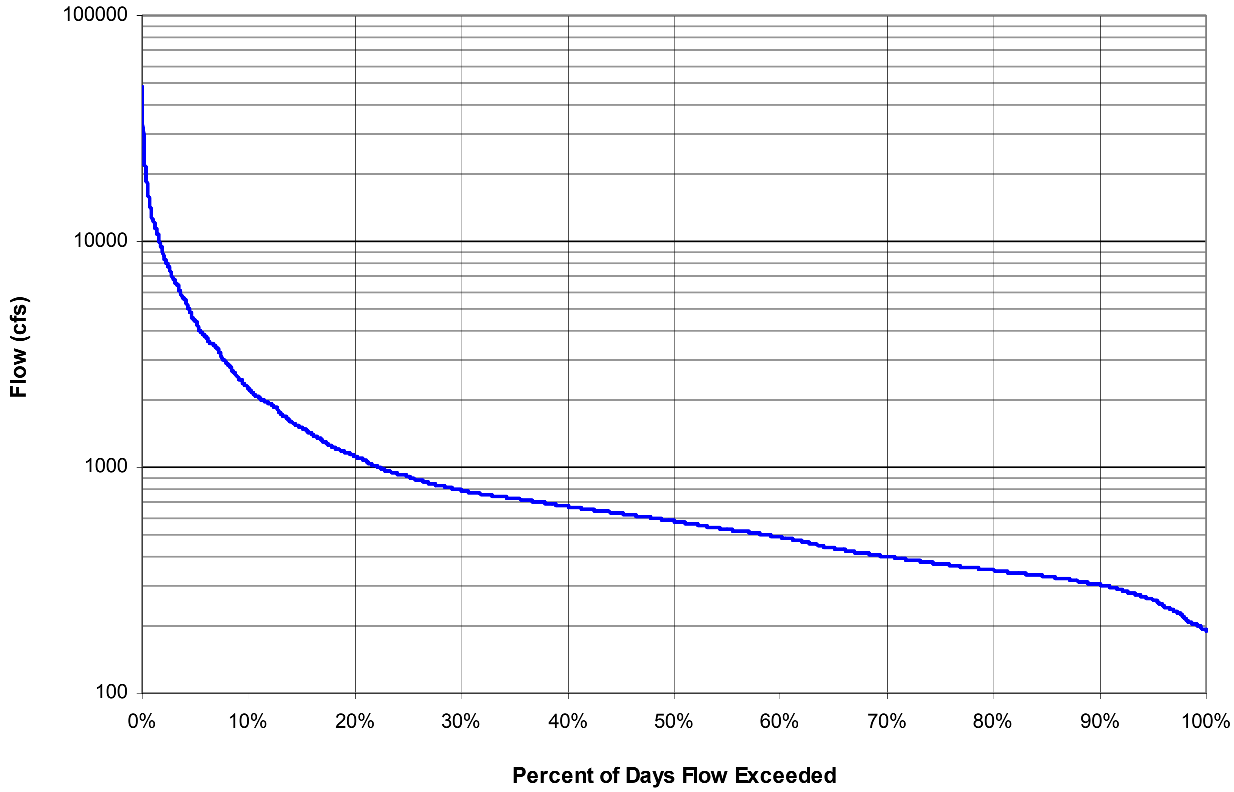


Figure C-1. Flow Duration Curve for Wolf River at Mile 1.5

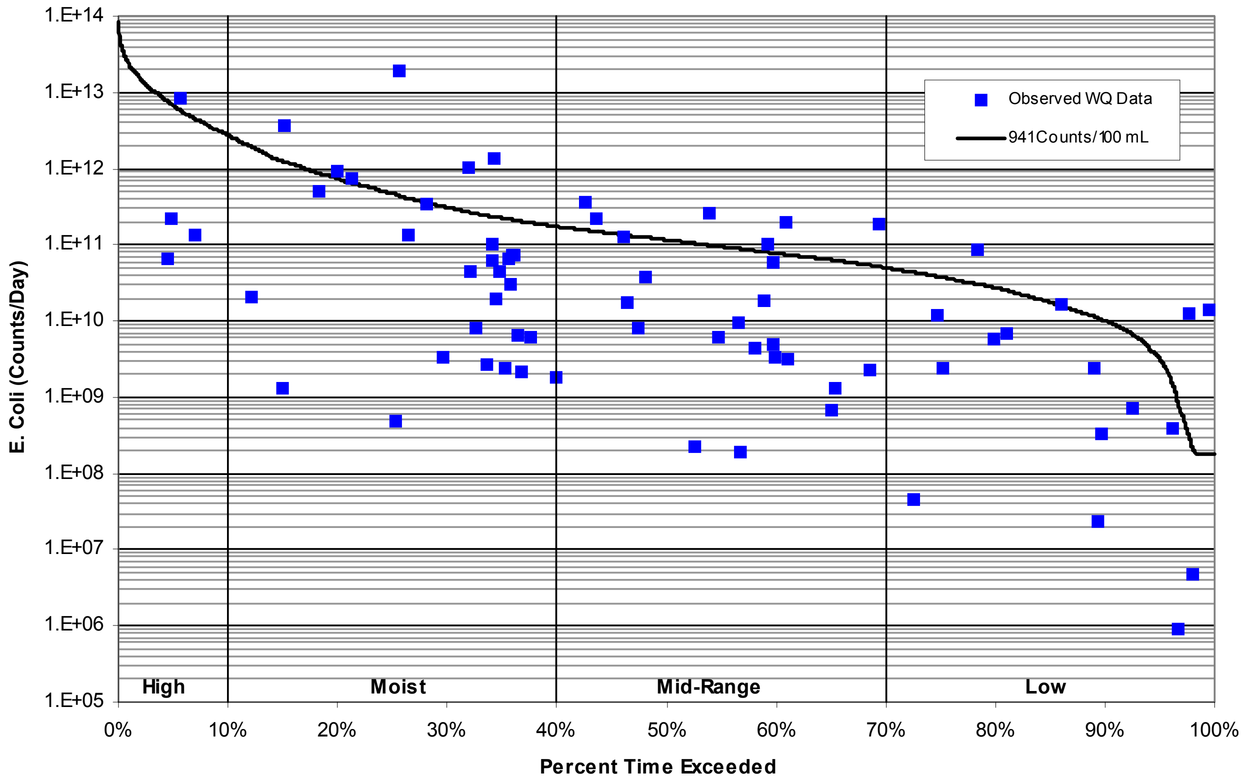


Figure C-2. E. Coli Load Duration Curve for Fletcher Creek at North Shelby Oaks (6W)

Table C-1. TMDLs, WLAs, & LAs for the Wolf River Watershed

HUC-12 Subwatershed (08010210__)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs[a]			LAs
					WWTFs[b]	Leaking Collection Systems	MS4s	
			[CFU/day]	[CFU/day]	[CFU/day]	[CFU /day]	[CFU/day/acre]	[CFU/day/acre]
0105	Early Grove Creek	TN08010210009 – 0300	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	3.24×10^{6} * Q
0201	McKinnie Creek	TN08010210020 – 0300	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	9.74×10^{5} * Q
	May Creek	TN08010210020 – 0310	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	2.29×10^{6} * Q
	North Fork Creek	TN08010210020 – 0400	1.19×10^{10} * Q	1.19×10^{9} * Q	NA	NA	NA	8.28×10^{5} * Q
0202	North Fork Wolf River	TN08010210020 – 2000	1.19×10^{10} * Q	1.19×10^{9} * Q	NA	NA	NA	2.46×10^{5} * Q
0301	Hurricane Creek	TN08010210004 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	4.69×10^{6} * Q
	Unnamed Tributary to Wolf River	TN08010210004 – 0400	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	NA	2.94×10^{6} * Q
	Russell Creek	TN08010210004 – 0500	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	4.23×10^{6} * Q
0302	Teague Branch	TN08010210005 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	3.17×10^{6} * Q
	Grissum Creek	TN08010210005 – 1000	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	8.80×10^{5} * Q
0303	Alexander Creek	TN08010210021 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	2.74×10^{6} * Q
	Shaws Creek	TN08010210021 – 1000	2.30×10^{10} * Q	2.30×10^{9} * Q	7.13×10^{8}	NA	NA	6.79×10^{5} * Q – 2.34×10^{4}
0304	Wolf River	TN08010210002 – 2000	2.30×10^{10} * Q	2.30×10^{9} * Q	4.31×10^{11}	0	4.61×10^{4} * Q – 9.59×10^{5}	4.61×10^{4} * Q – 9.59×10^{5}
	Johnson Creek	TN08010210003 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	5.10×10^{6} * Q	5.10×10^{6} * Q
0305	Unnamed Tributary to Grays Creek	TN08010210022 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	8.88×10^{6} * Q	8.88×10^{6} * Q
	Marys Creek	TN08010210022 – 0300	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	2.03×10^{6} * Q	2.03×10^{6} * Q
	Marys Creek Headwaters	TN08010210022 – 0350	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	8.68×10^{6} * Q	8.68×10^{6} * Q
0306	Harrington Creek	TN08010210001 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	2.79×10^{6} * Q	2.79×10^{6} * Q
	Workhouse Bayou	TN08010210001 – 0300	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.34×10^{7} * Q	1.34×10^{7} * Q

Table C-1. TMDLs, WLAs, & LAs for the Wolf River Watershed (Cont.)

HUC-12 Subwatershed (08010210__)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs[a]			LAs
					WWTFs[b]	Leaking Collection Systems	MS4s	
			[CFU/day]	[CFU/day]	[CFU /day]	[CFU /day]	[CFU/day/acre]	[CFU/day/acre]
0306 (cont.)	Wolf River	TN08010210001 – 1000	$1.19 \times 10^{10} * Q$	$1.19 \times 10^{9} * Q$	4.31×10^{11}	0	$2.04 \times 10^{4} * Q - 8.22 \times 10^{5}$	$2.04 \times 10^{4} * Q - 8.22 \times 10^{5}$
	Cypress Creek	TN08010210032 – 1000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$1.72 \times 10^{6} * Q$	$1.72 \times 10^{6} * Q$
0307	Wolf River	TN08010210002 – 1000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	4.31×10^{11}	0	$4.47 \times 10^{4} * Q - 1.16 \times 10^{6}$	$4.47 \times 10^{4} * Q - 1.16 \times 10^{6}$
0308	Unnamed Tributary to Fletcher Creek	TN08010210023 – 0100	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$3.01 \times 10^{6} * Q$	$3.01 \times 10^{6} * Q$
	Unnamed Tributary to Fletcher Creek	TN08010210023 – 0200	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$8.10 \times 10^{6} * Q$	$8.10 \times 10^{6} * Q$
	Fletcher Creek	TN08010210023 – 1000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$1.00 \times 10^{6} * Q$	$1.00 \times 10^{6} * Q$

Note: *NA = Not applicable.*
Q = Mean Daily In-stream Flow (cfs).
a. *There are no CAFOs in impaired subwatersheds of the Wolf River watershed.*
b. *WLAs for WWTFs expressed as E. coli loads (CFU/day). Future WWTFs must meet water quality standards at the point of discharge as specified in their NPDES permits. At no time shall concentration exceed appropriate, site-specific (487 CFU/100 mL or 941 CFU/100 mL) water quality standards.*

APPENDIX D

Hydrodynamic Modeling Methodology

D.1 Model Selection

The Loading Simulation Program C++ (LSPC) was selected for flow simulation of E. coli-impaired waters in the Wolf River watershed. LSPC is a watershed model capable of performing flow routing through stream reaches. LSPC is a dynamic watershed model based on the Hydrologic Simulation Program - Fortran (HSPF).

D.2 Model Set Up

The impaired waterbodies were delineated into subwatersheds in order to facilitate model hydrologic calibration. Boundaries were constructed so that subwatershed “pour points” coincided with HUC-12 delineations, 303(d)-listed waterbodies, USGS monitoring stations (see Section C.1), and water quality monitoring stations. Watershed delineation was based on the National Hydrography Dataset (NHD) stream coverage and Digital Elevation Model (DEM) data. This discretization facilitates simulation of daily flows at water quality monitoring stations.

Several computer-based tools were utilized to generate input data for the LSPC model. 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 selected subwatersheds. This information includes land use categories, point source dischargers, soil types and characteristics, population data (human and livestock), and stream characteristics.

An important factor influencing model results is the precipitation data contained in the meteorological data files used in these simulations. Weather data from the Memphis Airport, Mason, and Bolivar Waterworks meteorological stations were available for the time period from January 1970 through December 2005. Meteorological data for a selected 11-year period was used for all simulations. The first year of this period was used for model stabilization with simulation data from the subsequent 10-year period (1/1/96 – 12/31/05) used for TMDL analyses.

D.3 Model Calibration

Hydrologic calibration of the watershed model involves comparison of simulated streamflow to historic streamflow data from USGS stream gaging stations (http://waterdata.usgs.gov/tn/nwis/sw) for the same period of time. Due to the size variation of impaired waterbody drainage areas and dissimilarities in ecoregion flow characteristics, three USGS continuous record stations located in the Wolf River watershed were selected as the basis of the hydrology calibration. The calibrations at each station involved comparison of simulated and observed hydrographs until discrepancies in statistical stream volumes and flows were minimized, as reported in the literature (Lumb, et al., 1994).

Initial values for hydrologic 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 streamflow. Model parameters adjusted include: evapotranspiration, infiltration, upper and lower zone storage, groundwater storage, recession, losses to the deep groundwater system, and interflow discharge.

The results of the hydrologic calibrations for Wolf River at LaGrange (USGS 07030392), Wolf River at Germantown (USGS 07031650), and Fletcher Creek at Sycamore View Road (USGS 07031692) are shown in Tables D-1 through D-3 and Figures D-1 through D-3, respectively.

Table D-1. Hydrologic Calibration Summary: Wolf River at LaGrange (USGS 07030392)

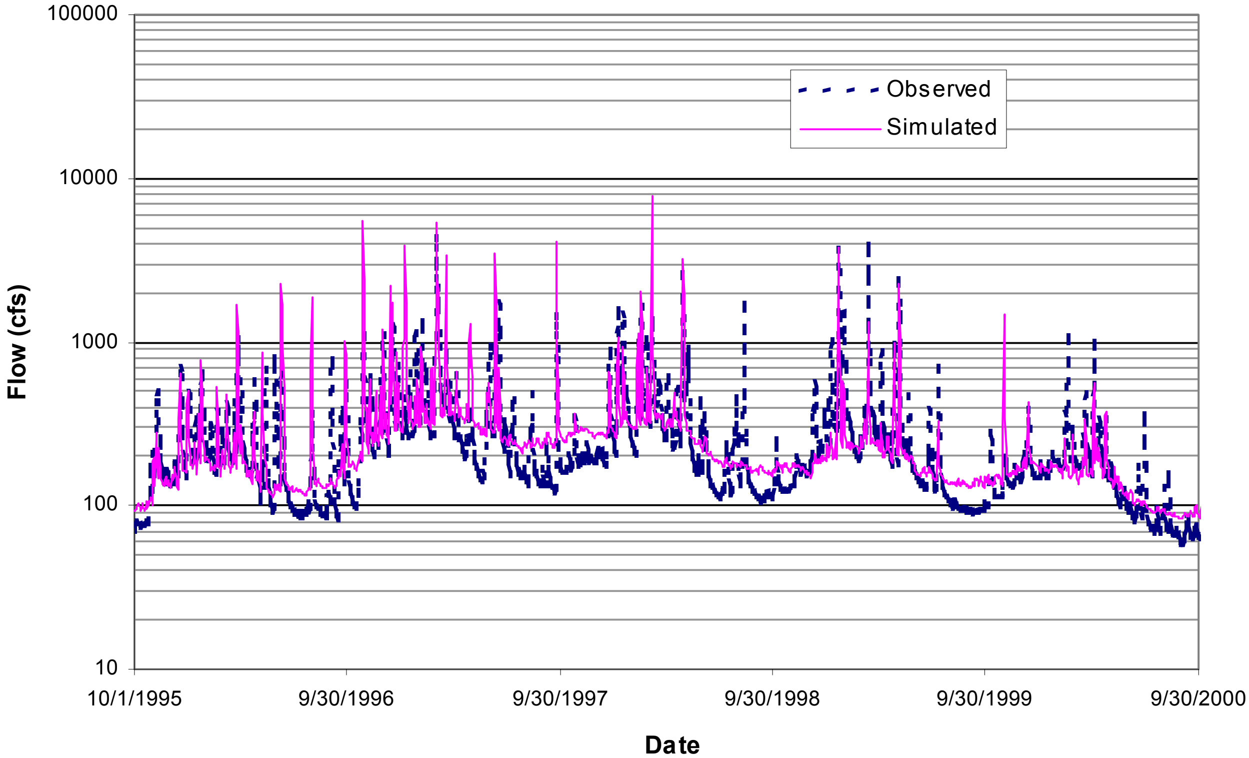
Simulation Name:	**WolfGS20 (calibration)**	**Simulation Period:**	
	Wolf River at LaGrange	**Watershed Area (ac):**	134400.00
Period for Flow Analysis	(USGS 07030392)		
Begin Date:	**10/01/95**	**Baseflow PERCENTILE:**	2.5
End Date:	**09/30/05**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**191.55**	Total Observed In-stream Flow:	**203.68**
Total of highest 10% flows:	**74.85**	Total of Observed highest 10% flows:	**80.68**
Total of lowest 50% flows:	**47.38**	Total of Observed Lowest 50% flows:	**43.41**
Simulated Summer Flow Volume (months 7-9):	**30.89**	Observed Summer Flow Volume (7-9):	**27.10**
Simulated Fall Flow Volume (months 10-12):	**47.83**	Observed Fall Flow Volume (10-12):	**51.44**
Simulated Winter Flow Volume (months 1-3):	**64.54**	Observed Winter Flow Volume (1-3):	**74.36**
Simulated Spring Flow Volume (months 4-6):	**48.29**	Observed Spring Flow Volume (4-6):	**50.78**
Total Simulated Storm Volume:	**132.10**	Total Observed Storm Volume:	**157.17**
Simulated Summer Storm Volume (7-9):	**15.95**	Observed Summer Storm Volume (7-9):	**15.42**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**-5.95**	10	
Error in 50% lowest flows:	**9.15**	10	
Error in 10% highest flows:	**-7.23**	15	
Seasonal volume error - Summer:	**13.99**	30	
Seasonal volume error - Fall:	**-7.02**	30	
Seasonal volume error - Winter:	**-13.20**	30	
Seasonal volume error - Spring:	**-4.90**	30	
Error in storm volumes:	**-15.95**	20	
Error in summer storm volumes:	**3.40**	50	

Table D-2. Hydrologic Calibration Summary: Wolf River at Germantown (USGS 07031650)

Simulation Name:	**WolfGS20 (calibration)**	**Simulation Period:**	
	Wolf River at Germantown	**Watershed Area (ac):**	447360.00
Period for Flow Analysis	(USGS 07031650)		
Begin Date:	**10/01/95**	**Baseflow PERCENTILE:**	2.5
End Date:	**09/30/05**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**202.36**	Total Observed In-stream Flow:	**210.45**
Total of highest 10% flows:	**102.49**	Total of Observed highest 10% flows:	**90.51**
Total of lowest 50% flows:	**34.82**	Total of Observed Lowest 50% flows:	**38.36**
Simulated Summer Flow Volume (months 7-9):	**25.55**	Observed Summer Flow Volume (7-9):	**27.31**
Simulated Fall Flow Volume (months 10-12):	**55.73**	Observed Fall Flow Volume (10-12):	**54.78**
Simulated Winter Flow Volume (months 1-3):	**72.62**	Observed Winter Flow Volume (1-3):	**77.03**
Simulated Spring Flow Volume (months 4-6):	**48.45**	Observed Spring Flow Volume (4-6):	**51.34**
Total Simulated Storm Volume:	**160.74**	Total Observed Storm Volume:	**165.81**
Simulated Summer Storm Volume (7-9):	**15.10**	Observed Summer Storm Volume (7-9):	**16.08**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**-3.85**	10	
Error in 50% lowest flows:	**-9.23**	10	
Error in 10% highest flows:	**13.23**	15	
Seasonal volume error - Summer:	**-6.42**	30	
Seasonal volume error - Fall:	**1.74**	30	
Seasonal volume error - Winter:	**-5.71**	30	
Seasonal volume error - Spring:	**-5.63**	30	
Error in storm volumes:	**-3.06**	20	
Error in summer storm volumes:	**-6.14**	50	

Table D-3. Hydrologic Calibration Summary: Fletcher Creek at Sycamore View Road (USGS 07031692)

Simulation Name:	**WolfGS11 (calibration)**	**Simulation Period:**	
	Fletcher Cr. at Sycamore View Rd.	**Watershed Area (ac):**	19520.00
Period for Flow Analysis	(USGS 07031692)		
Begin Date:	**10/01/96**	**Baseflow PERCENTILE:**	2.5
End Date:	**09/30/05**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**245.07**	Total Observed In-stream Flow:	**245.85**
Total of highest 10% flows:	**201.28**	Total of Observed highest 10% flows:	**208.58**
Total of lowest 50% flows:	**3.83**	Total of Observed Lowest 50% flows:	**3.65**
Simulated Summer Flow Volume (months 7-9):	**23.46**	Observed Summer Flow Volume (7-9):	**35.76**
Simulated Fall Flow Volume (months 10-12):	**77.86**	Observed Fall Flow Volume (10-12):	**82.12**
Simulated Winter Flow Volume (months 1-3):	**87.80**	Observed Winter Flow Volume (1-3):	**76.62**
Simulated Spring Flow Volume (months 4-6):	**55.95**	Observed Spring Flow Volume (4-6):	**51.36**
Total Simulated Storm Volume:	**245.04**	Total Observed Storm Volume:	**245.53**
Simulated Summer Storm Volume (7-9):	**23.45**	Observed Summer Storm Volume (7-9):	**35.67**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**-0.32**	10	
Error in 50% lowest flows:	**4.85**	10	
Error in 10% highest flows:	**-3.50**	15	
Seasonal volume error - Summer:	**-34.39**	30	
Seasonal volume error - Fall:	**-5.18**	30	
Seasonal volume error - Winter:	**14.59**	30	
Seasonal volume error - Spring:	**8.94**	30	
Error in storm volumes:	**-0.20**	20	
Error in summer storm volumes:	**-34.26**	50	



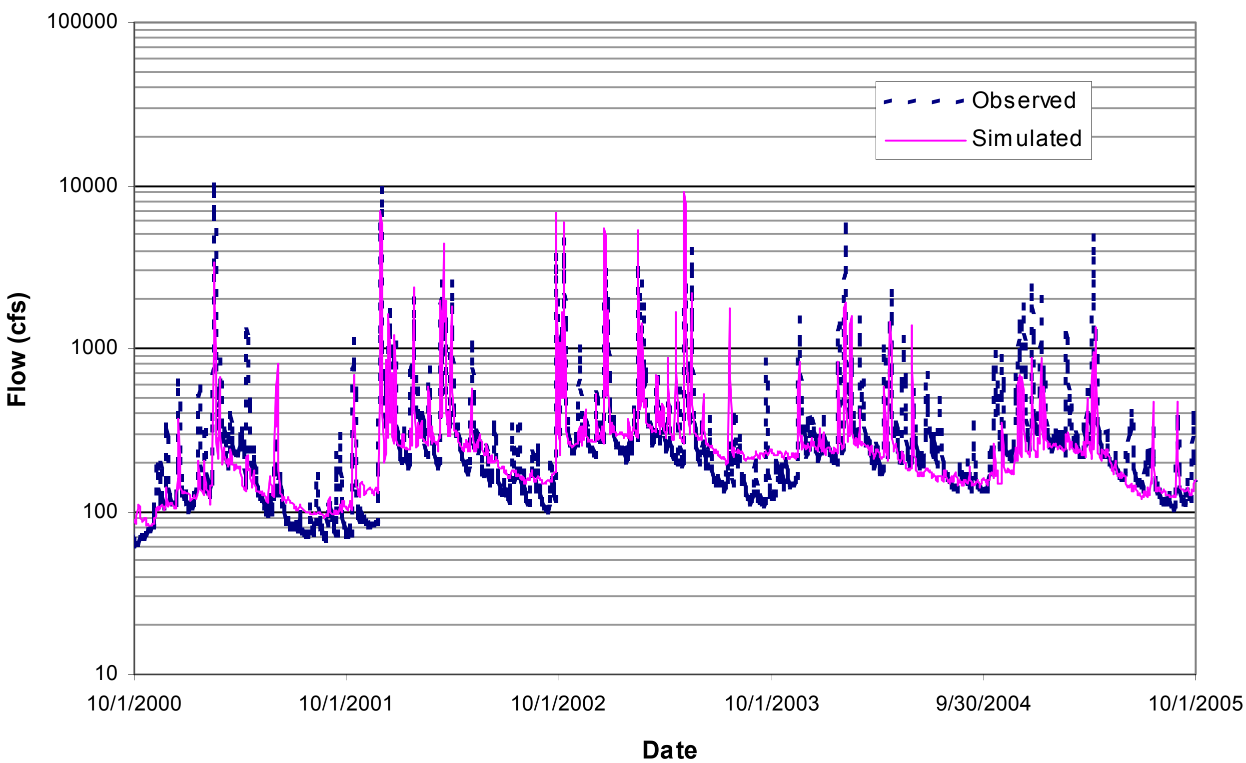
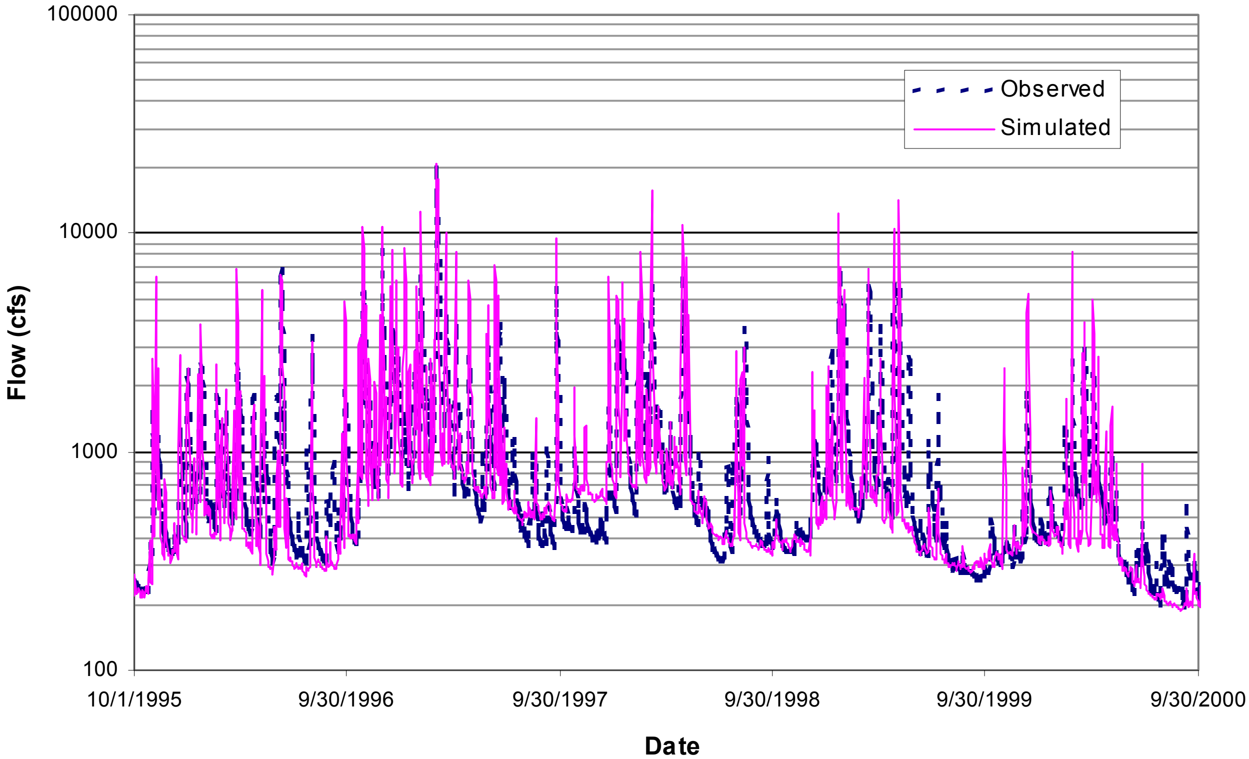


Figure D-1. Hydrologic Calibration: Wolf River at LaGrange (USGS 07030392)



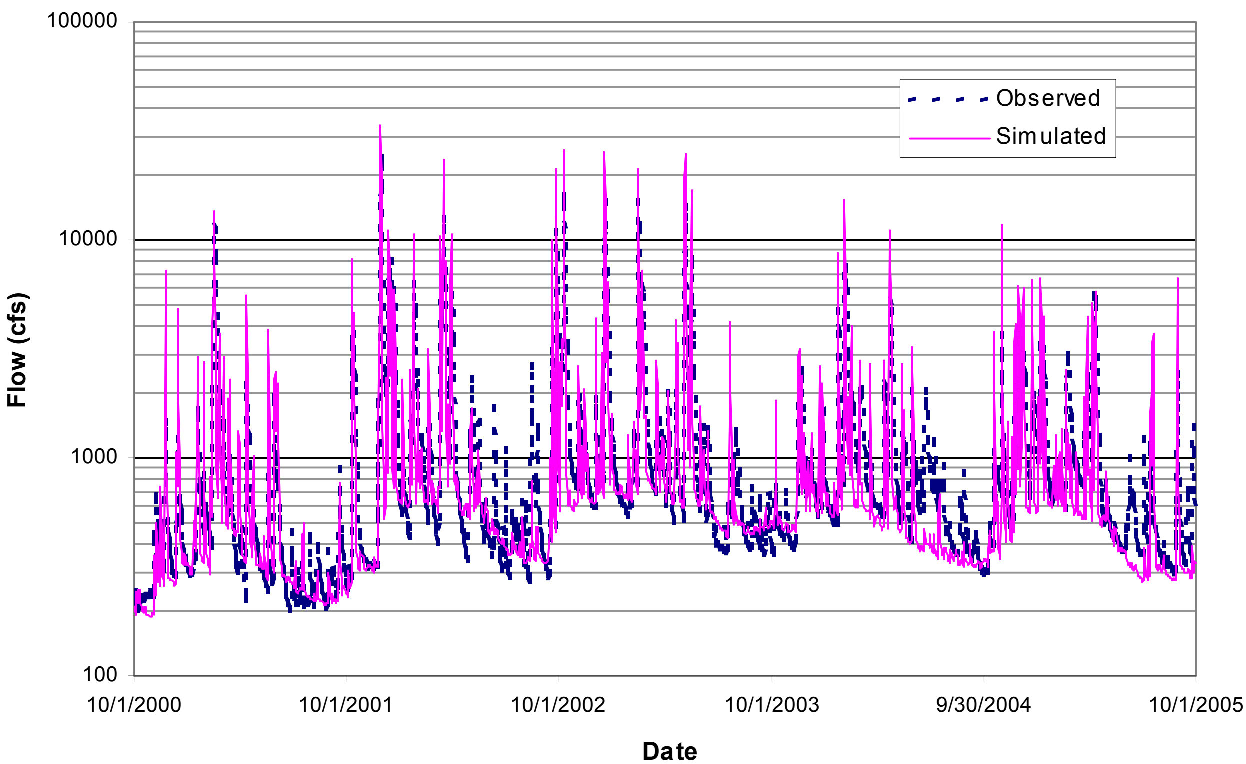
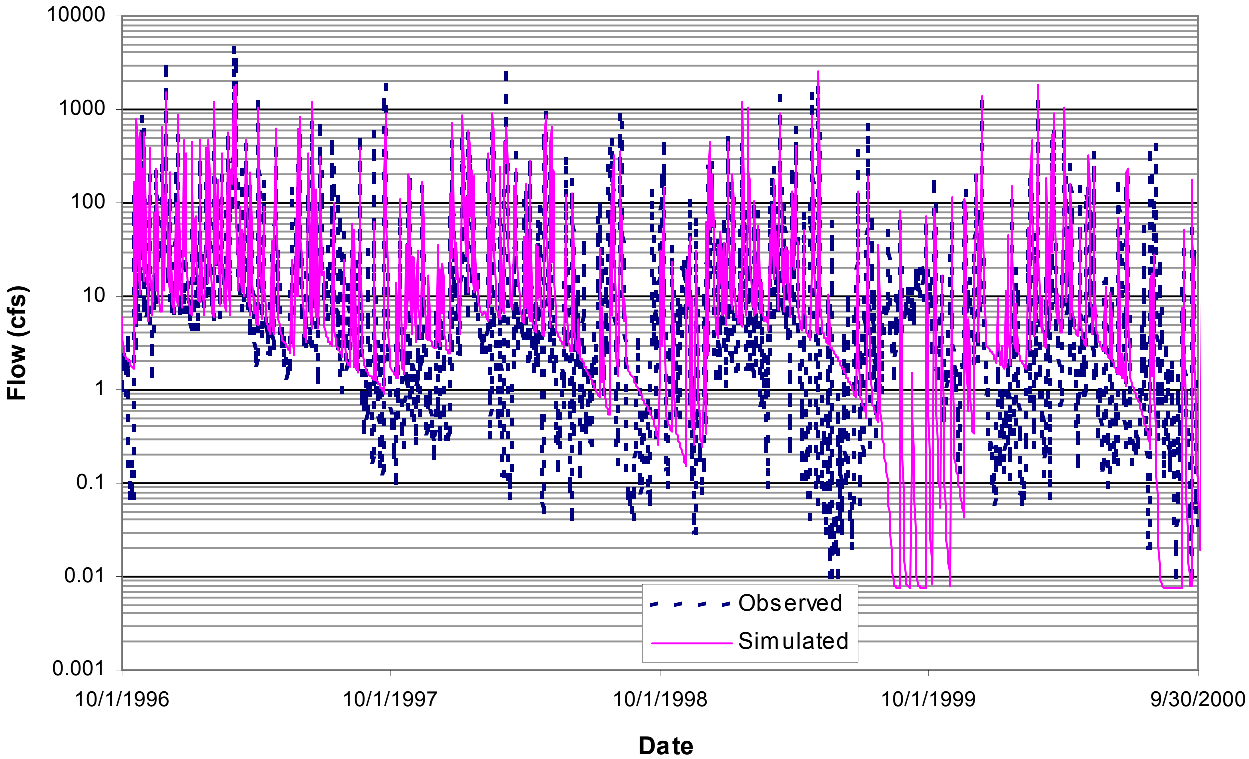


Figure D-2. Hydrologic Calibration: Wolf River at Germantown (USGS 07031650)



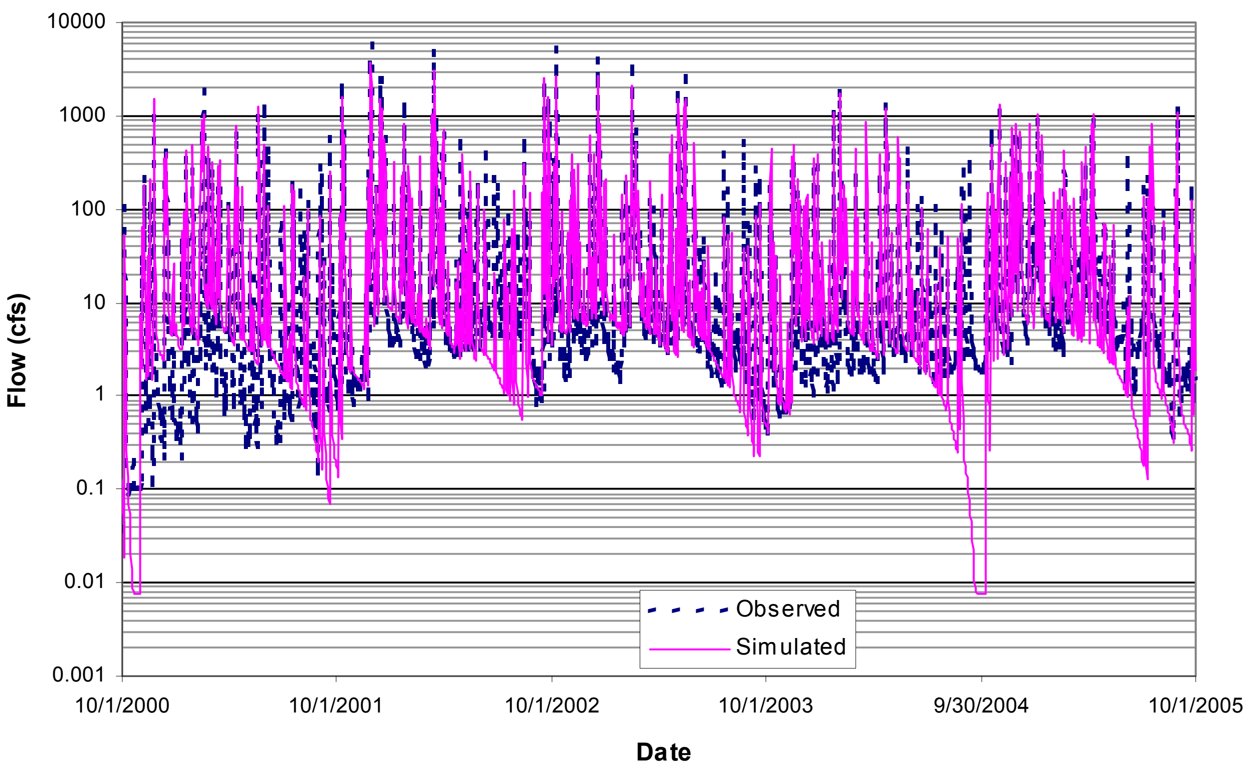


Figure D-3. Hydrologic Calibration: Fletcher Creek at Sycamore View Road (USGS 07031692)

APPENDIX E

Source Area Implementation Strategy

All impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas have been classified according to their respective source area types in Section 9.5, Table 9. The implementation for each area will be prioritized according to the guidance provided in Sections 9.5.1 and 9.5.2, with examples provided in Sections E.1 and E.2, below. For all impaired waterbodies, the determination of source area types serves to identify the predominant sources contributing to impairment (i.e., those that should be targeted initially for implementation). However, it is not intended to imply that sources in other landuse areas are not contributors to impairment and/or to grant an exemption from addressing other source area contributions with implementation strategies and corresponding load reduction. For mixed use areas, implementation will follow the guidance established for both urban and agricultural areas, at a minimum.

E.1 Urban Source Areas

For impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas identified as predominantly urban source area types, the following example for Fletcher Creek provides guidance for implementation analysis:

The Fletcher Creek watershed, HUC-12 080102100308, lies almost entirely within the City of Memphis Urban Area District. The drainage area for Fletcher Creek at mile 1.5 is approximately 20,558 acres (32.1 mi^2) and zero flows occur during a significant percentage of time under baseflow conditions; therefore, four flow zones were used for the duration curve analysis (see Sect. 9.1.1). The landuse for Fletcher Creek is greater than 50% urban, as defined above. Agricultural areas make up less than 20% of total area. Therefore, the predominate landuse type and sources are urban.

Note: The Final 2006 303(d) List includes Pasture Grazing as a Pollutant Source category for Fletcher Creek; therefore, Fletcher Creek is listed in the Mixed use source area type in Section 9.5, Table 9.

The flow duration curve for Fletcher Creek at mile 1.5 was constructed using simulated daily mean flow for the period from 1/1/96 through 12/31/05 (mile 1.5 corresponds to the location of monitoring station 6W, City of Memphis monitoring station). This flow duration curve is shown in Figure E-1 and represents the cumulative distribution of daily discharges arranged to show percentage of time specific flows were exceeded during the period of record. Flow duration curves for other impaired waterbodies were developed using a similar procedure (Appendix C) and are shown in Figures E-3 and E-5 to E-27.

The E. coli LDC for Fletcher Creek at Mile 1.5 (Figure E-2) was analyzed to determine the frequency with which observed daily water quality loads exceed the E. coli target maximum daily loading (941 CFU/100 mL x flow [cfs] x conversion factor) under four flow conditions (low, mid-range, moist, and high). Observation of the plot illustrates that exceedances occur under all flow zones indicating the Fletcher Creek watershed is impacted by point and non-point-type sources. LDCs for other impaired waterbodies were developed using a similar procedure (Appendix C) and are shown in Figures E-4 and E-28 to E-50.

Critical conditions for the Fletcher Creek watershed (HUC-12 080102100308) occur during low flows, typically indicative of point source contributions (see Table E-3, Section E.4). However, the high and mid-range flow conditions have equal or higher percentages of exceedances, while the moist and mid-range flow conditions have comparable percent load reduction goals (PLRGs) to meet WQS. In addition, exceedances of the E. coli water quality standard are well distributed across the full range of flows and all flow zones, though the magnitude of exceedances varies widely.

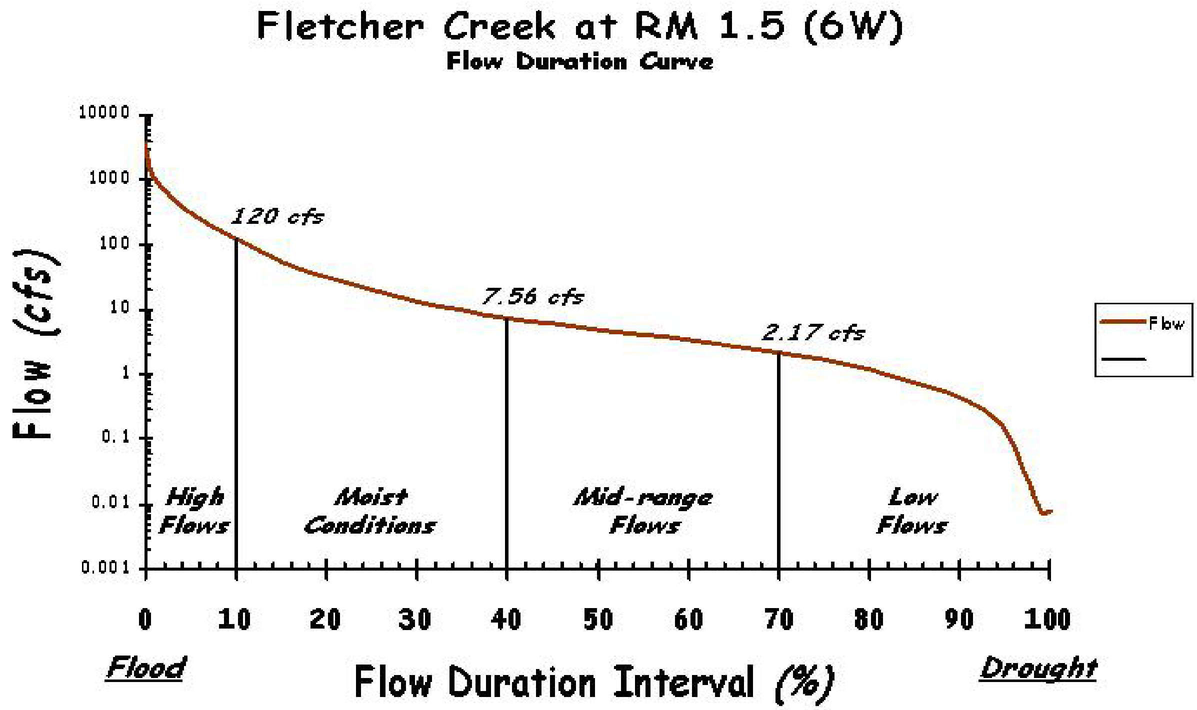


Figure E-1. Flow Duration Curve for Fletcher Creek at Mile 1.5 (6W).

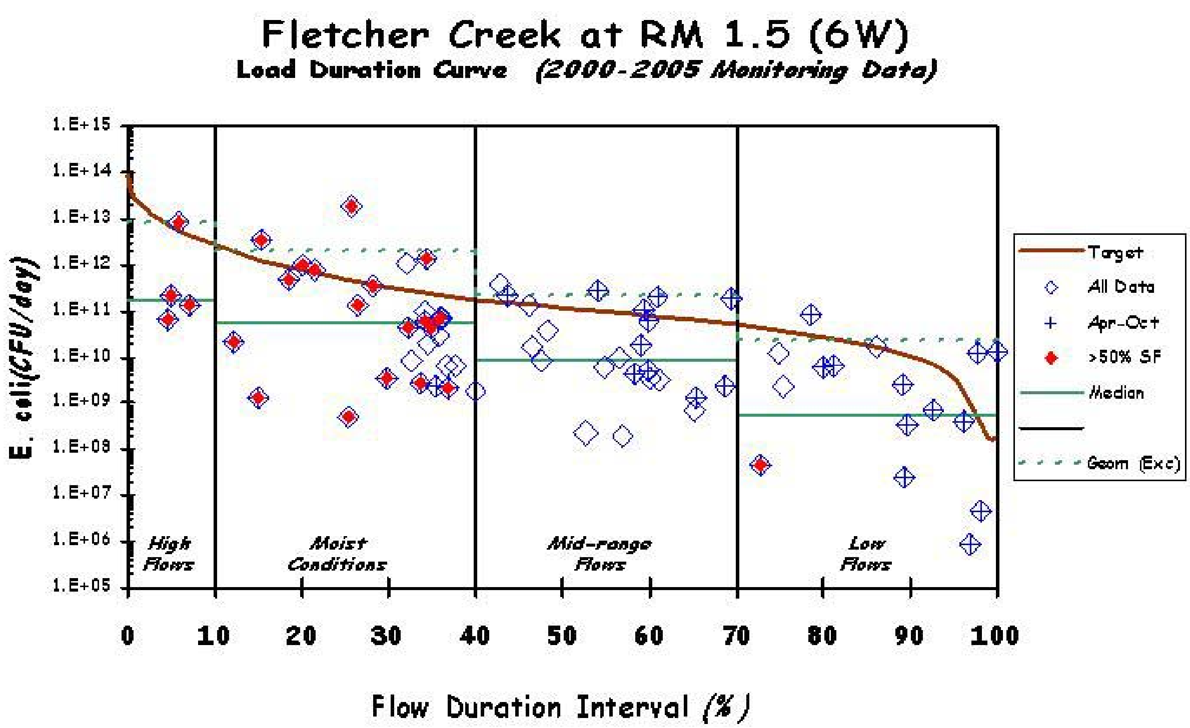


Figure E-2. E. Coli Load Duration Curve for Fletcher Creek at Mile 1.5 (6W).

According to hydrograph separation analysis, most of the exceedances (6 of 7) in the moist and high-flow ranges occur during stormflow events while the majority of the exceedances occurring in the mid-range and low-flow ranges occur during non-storm (baseflow) periods. These factors indicate that non-point sources are also significant contributors to impairment in the Fletcher Creek watershed. Therefore, it is reasonable to say that point and non-point type sources contribute to exceedances of the E. coli standard in Fletcher Creek.

Results indicate the implementation strategy for the Fletcher Creek watershed will require BMPs targeting point sources (dominant under low flow/baseflow conditions) and non-point sources (dominant under high flow/runoff conditions). Table E-1 presents an allocation table of LDC analysis statistics for Fletcher Creek E. coli and implementation strategies for each source category covering the entire range of flow (Stiles, 2003). The implementation strategies listed in Table E-1 are a subset of the categories of BMPs and implementation strategies available for application to the Wolf River watershed for reduction of E. coli loading and mitigation of water quality impairment from urban sources. Targeted implementation strategies and LDC analysis statistics for other impaired waterbodies and corresponding HUC-12 subwatersheds and drainage areas identified as predominantly urban source area types can be derived from the information and results available in Tables 10 and E-4.

Table E-4 presents LDC analyses (TMDLs, WLAs, LAs, and MOS) and PLRGs for all flow zones for all E. coli impaired waterbodies in the Wolf River watershed.

E.2 Agricultural Source Areas

For impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas identified as predominantly agricultural source area types, the following example for Russell Creek provides guidance for implementation analysis:

The Russell Creek drainage area, a subwatershed of HUC-12 080102100301, lies in a non-urbanized area in Fayette County, TN and Marshall County, MS. The drainage area for Russell Creek at mile 1.5 is approximately 4,898 acres (7.7 mi^2) and zero flows occur during a significant percentage of time under baseflow conditions; therefore, four flow zones were used for the duration curve analysis (see Sect. 9.1.1). The landuse for Russell Creek is greater than 75% agricultural, with most of the remainder being forested. Urban areas make up less than 1% of the total area. Therefore, the predominate landuse type and sources are agricultural.

The flow duration curve for Russell Creek at mile 1.5 was constructed using simulated daily mean flow for the period from 1/1/96 through 12/31/05. This flow duration curve is shown in Figure E-3 and represents the cumulative distribution of daily discharges arranged to show percentage of time specific flows were exceeded during the period of record. Flow duration curves for other impaired waterbodies were developed using a similar procedure (see Appendix C) and are shown in Figures E-5 to E-27.

The E. coli LDC for Russell Creek at Mile 1.5 (Figure E-4) was analyzed to determine the frequency with which observed daily water quality loads exceed the E. coli target maximum daily loading (941 CFU/100 mL x flow [cfs] x conversion factor) under four flow conditions (low, mid-range, moist, and high). Observation of the plot illustrates that exceedances occur under all flow zones indicating the Russell Creek watershed is impacted by point and non-point-type sources. LDC s for other impaired waterbodies were developed using a similar procedure (Appendix C) and are shown in Figures E-28 to E-50.

Table E-1. Load Duration Curve Summary for Implementation Strategies (Example: Fletcher Creek subwatershed, HUC-12 080102100308) (4 Flow Zones).

Hydrologic Condition		High	Moist	Mid-range	Low*
% Time Flow Exceeded		0-10	10-40	40-70	70-100
Fletcher Creek (080102100308)	Number of Samples	4	29	23	16
	% > 941 CFU/100 mL[1]	25.0	20.7	26.1	25.0
	Load Reduction[2]	8.2%	12.3%	13.4%	16.6%
TMDL (CFU/day)		6.71E+12	4.72E+11	9.46E+10	1.77E+10
Margin of Safety (CFU/day)		6.71E+11	4.72E+10	9.46E+09	1.77E+09
WLA (WWTFs) (CFU/day)		NA	NA	NA	NA
WLAs (MS4s) (CFU/day/acre)[3]		2.92E+08	2.05E+07	4.12E+06	7.70E+05
LA (CFU/day/acre)[3]		2.92E+08	2.05E+07	4.12E+06	7.70E+05
Implementation Strategies[4]					
Municipal NPDES			L	M	H
Stormwater Management			H	H	
SSO Mitigation		H	H	M	
Collection System Repair			L	M	H
Septic System Repair			L	M	M
Potential for source area contribution under given flow condition (H: High; M: Medium; L: Low)					

* The Low flow zone represents the critical conditions for E. coli loading in the Fletcher Creek subwatershed.
[1] Tennessee Maximum daily water quality criterion for E. coli.
[2] Reductions (percent) based on mean of observed percent load reductions in range.
[3] LAs and MS4s are expressed as daily load per unit area in order to provide for future changes in the distribution of LAs and MS4s (WLAs).
[4] Watershed-specific Best Management Practices for Urban Source reduction. Actual BMPs applied may vary and should not be limited according to this grouping.

Critical conditions for the Russell Creek drainage area (a subwatershed of HUC-12 080102100301) occur during low flows, typically indicative of point source contributions (see Table E-3, Section E.4). Exceedances of the E. coli water quality standard are fairly well distributed across the full range of flows and all flow zones, though the magnitude of exceedances varies widely.

According to hydrograph separation analysis, two exceedances in the moist and high-flow ranges occur during stormflow events while the remaining five (5) exceedances occurring in the mid-range and low-flow ranges occur during non-storm (baseflow) periods. These factors indicate that non-point sources are also significant contributors to impairment in the Russell Creek watershed. Therefore, it is reasonable to say that point and non-point type sources contribute to exceedances of the E. coli standard in Russell Creek.

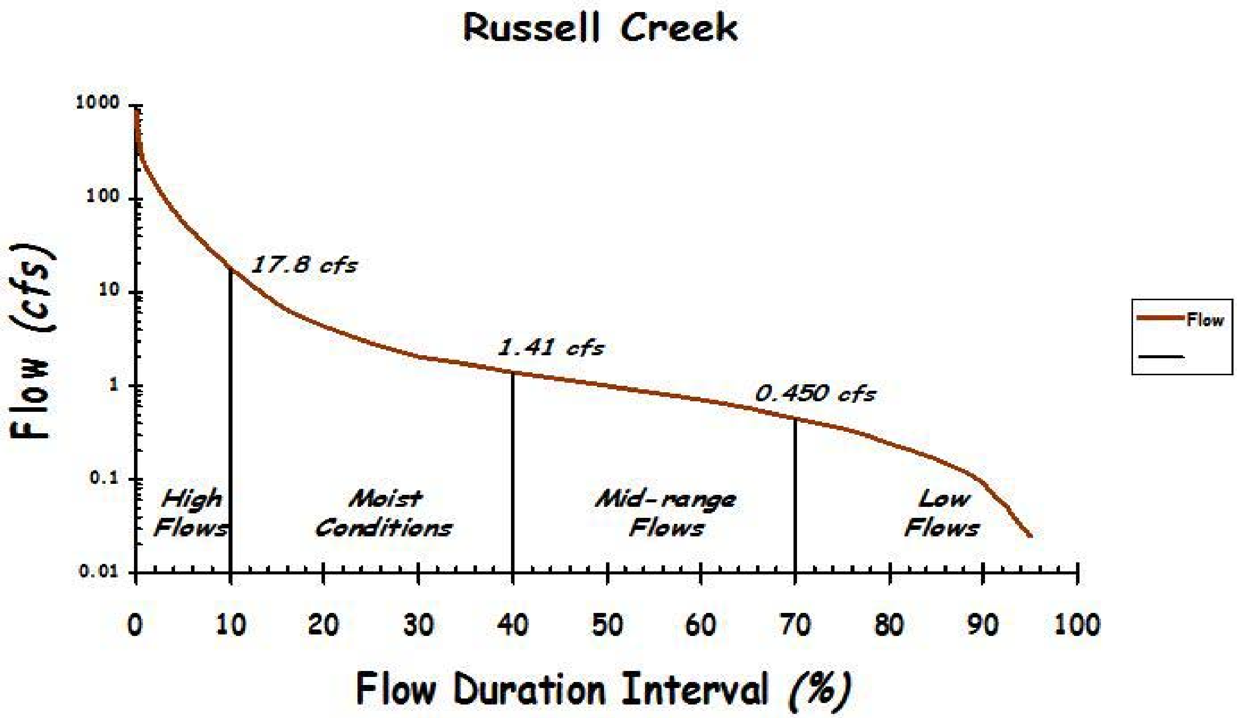


Figure E-3. Flow Duration Curve for Russell Creek.

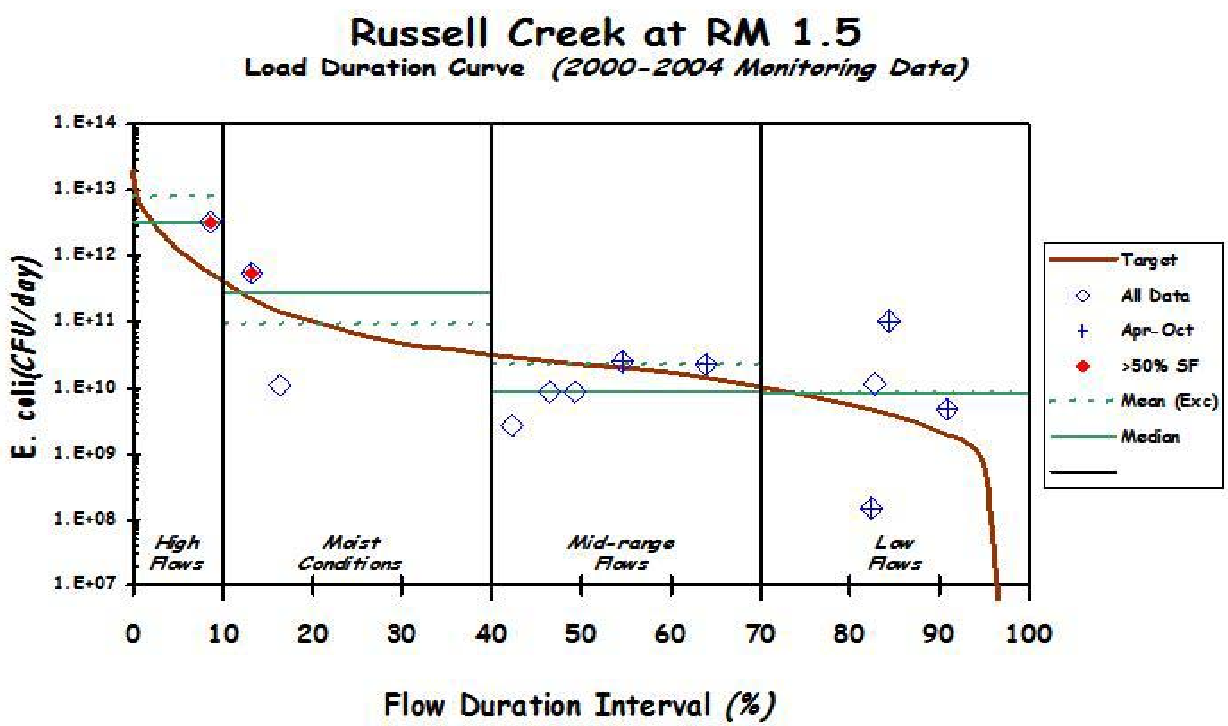


Figure E-4. E. Coli Load Duration Curve for Russell Creek at Mile 1.5.

Results indicate the implementation strategy for the Russell Creek watershed will require BMPs targeting point-type sources (dominant under low flow/baseflow conditions) and non-point sources (dominant under high flow/runoff conditions). Table E-2 presents an allocation table of Load Duration Curve analysis statistics for Russell Creek E. coli and targeted implementation strategies for each source category covering the entire range of flow (Stiles, 2003). The implementation strategies listed in Table E-2 are a subset of the categories of BMPs and implementation strategies available for application to the Wolf River watershed for reduction of E. coli loading and mitigation of water quality impairment from agricultural sources. Targeted implementation strategies and LDC analysis statistics for other impaired waterbodies and corresponding HUC-12 subwatersheds and drainage areas identified as predominantly agricultural source area types can be derived from the information and results available in Tables 11 and E-4.

Table E-7 presents LDC analyses (TMDLs, WLAs, LAs, and MOS) and PLRGs for all flow zones for all E. coli impaired waterbodies in the Wolf River watershed.

Table E-2. Load Duration Curve Summary for Implementation Strategies (Example: Russell Creek drainage area, HUC-12 080102100301) (4 Flow Zones).

Hydrologic Condition		High	Moist	Mid-range	Low*
% Time Flow Exceeded		0-10	10-40	40-70	70-100
Russell Creek (080102100301)	Number of Samples	1	2	5	4
	% > 941 CFU/100 mL[1]	100	50.0	40.0	75.0
	Load Reduction[2]	83.8	30.6	12.2	54.6
TMDL (CFU/day)		1.28E+12	6.47E+10	1.97E+10	3.74E+09
Margin of Safety (CFU/day)		1.28E+11	6.47E+09	1.97E+09	3.74E+08
WLA (WWTFs) (CFU/day)		NA	NA	NA	NA
WLA (MS4s) (CFU/day/acre)[3]		NA	NA	NA	NA
LAs (CFU/day/acre)[3]		2.35E+08	1.19E+07	3.62E+06	6.88E+05
Implementation Strategies[4]					
Pasture and Hayland Management		H	H	M	L
Livestock Exclusion				M	H
Fencing				M	H
Manure Management		H	H	M	L
Riparian Buffers		L	M	H	M
Potential for source area contribution under given flow condition (H: High; M: Medium; L: Low)					

* The Low flow zone represents the critical conditions for E. coli loading in the Russell Creek subwatershed.
1 Tennessee Maximum daily water quality criterion for E. coli.
2 Reductions (percent) based on mean of observed percent load reductions in range.
3 LAs and MS4s are expressed as daily load per unit area in order to provide for future changes in the distribution of LAs and MS4s (WLAs).
4 Example Best Management Practices for Agricultural Source reduction. Actual BMPs applied may vary and should not be limited according to this grouping.

E.3 Forestry Source Areas

There are no impaired waterbodies with corresponding HUC-12 subwatersheds or drainage areas classified as source area type predominantly forested, with the predominate source category being wildlife, in the Wolf River watershed.

E.4 Calculation of Percent Load Reduction Goals and Determination of Critical Flow Zones

In order to facilitate implementation, corresponding percent reductions in loading required to decrease existing, in-stream E. coli loads to TMDL target levels (percent load reduction goals) were calculated. The following example is from Russell Creek at mile 1.5:

1. For each flow zone, the mean of the percent exceedances of individual loads relative to their respective target maximum loads (at their respective PDFEs) was calculated. Each negative percent exceedance was assumed to be equal to zero.

   Example: Under Low Flow Conditions (Low Flow Zone):

Date	Sample Conc. (CFU/100 mL)	Flow (cfs)	Existing Load (CFU/Day)	Target (TMDL) Load (CFU/Day)	Percent Reduction
8/18/03	30.6	0.201	1.51E+08	4.63E+09	0 (-2975)
9/10/03	2419.2	0.198	1.17E+10	4.56E+09	61.1
10/8/03	24192	0.171	1.01E+11	3.94E+09	96.1
11/5/03	2419.2	0.0817	4.84E+09	1.88E+09	61.1
Percent Load Reduction Goal (PLRG) for Low-Flow Zone (Mean)					**54.6**

2. The PLRGs calculated for each of the flow zones, not including the high flow zone, were compared and the PLRG of the greatest magnitude indicates the critical flow zone for prioritizing implementation actions for Russell Creek.

   Example: High Flow Zone Percent Load Reduction Goal = 83.8%
   Moist Flow Zone Percent Load Reduction Goal = 30.6%
   Mid-Range Flow Zone Percent Load Reduction Goal = 12.2%
   Low Flow Zone Percent Load Reduction Goal = 54.6%

   Therefore, the critical flow zone for prioritization of Russell Creek implementation activities is the Low Flow Zone and subsequently actions targeting point source controls.

PLRG s and critical flow zones of the other impaired waterbodies were derived in a similar manner and are shown in Table E-4.

Table E-3. Summary of Critical Conditions for impaired waterbodies in the Wolf River watershed.

Waterbody ID	Moist	Mid-range	Dry	Low
Early Grove Creek[a]		ò		
McKinnie Creek[a]		ò		
May Creek[a]	ò			
North Fork Creek[a]		ò		
North Fork Wolf River[a]		ò		
Hurricane Creek[b]		ò		
UT to Wolf River[b]				ò
Russell Creek[b]				ò
Teague Branch[b]		ò		
Grissum Creek[b]		ò		
Alexander Creek[b]		ò		
Shaws Creek[a]		ò		
Wolf River #1[a]	ò			
Johnson Creek[b]	ò			ò
UT to Grays Creek[b]	ò			
Marys Creek[b]	ò			
Marys Creek Headwaters[b]		ò		
Harrington Creek[b]	ò			
Workhouse Bayou[a]		ò		
Wolf River #2[a]				ò
Cypress Creek[b]		ò		
Wolf River #3[a]	ò			
UT #1 to Fletcher Creek[b]		ò		
UT #2 to Fletcher Creek[b]	ò			
Fletcher Creek[b]				ò

[a] Waterbody(ies) with 5 flow zones.
[b] Waterbody(ies) with 4 flow zones.

Geometric Mean Data

For cases where five or more samples were collected over a period of not more than 30 consecutive days, the geometric mean E. coli concentration was determined and compared to the target geometric mean E. coli concentration of 126 CFU/100mL. If the sample geometric mean exceeded the target geometric mean concentration, the reduction required to reduce the sample geometric mean value to the target geometric mean concentration was calculated.

Example: Insufficient monitoring data were available for Fletcher Creek. In addition, insufficient data were available for all Wolf River watershed impaired waterbody monitoring stations. The following example is from the Obion River watershed:

Sampling Period = 9/7/05 – 10/4/05 (5 samples: 108.6, 228.2, 259.5, 770, 520)
Geometric Mean Concentration = 303 CFU/100 mL
Target Concentration = 126 CFU/100 mL
Reduction to Target = 58.5%

For impaired waterbodies where monitoring data are limited to geometric mean data only, results can be utilized for general indication of relative impairment and, when plotted on a load duration curve, may indicate areas for prioritization of implementation efforts. For impaired waterbodies where both types of data are available, geometric mean data may be utilized to supplement the results of the individual flow zone calculations.

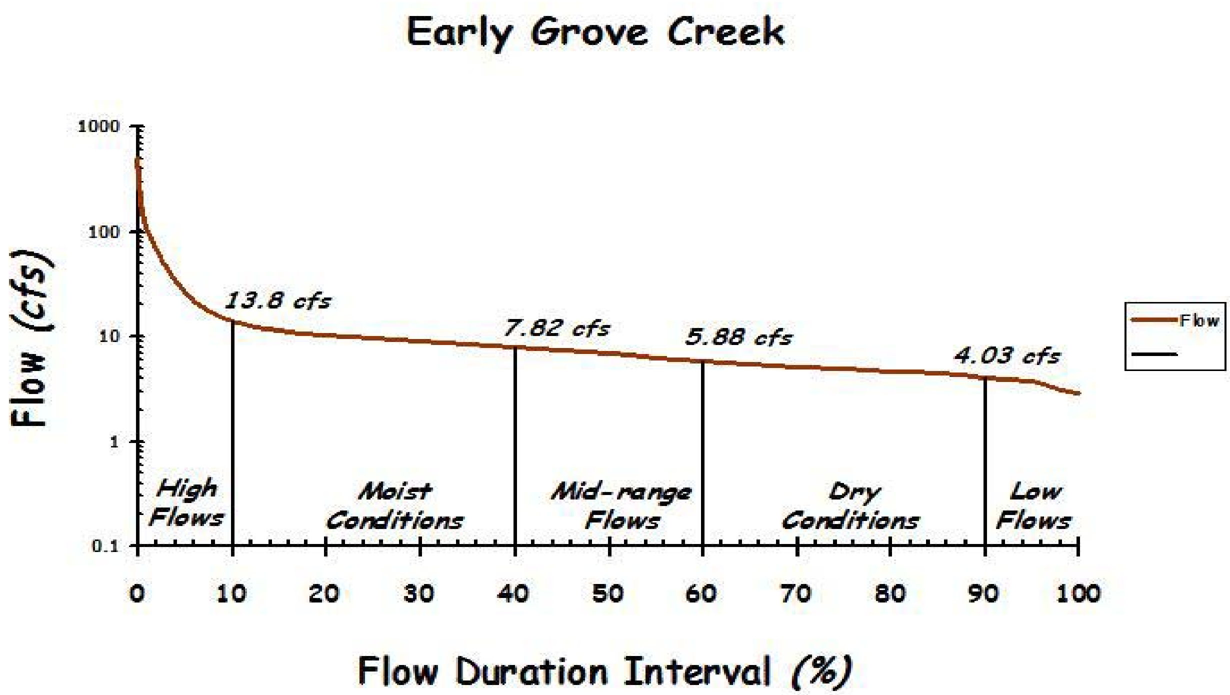


Figure E-5. Flow Duration Curve for Early Grove Creek.

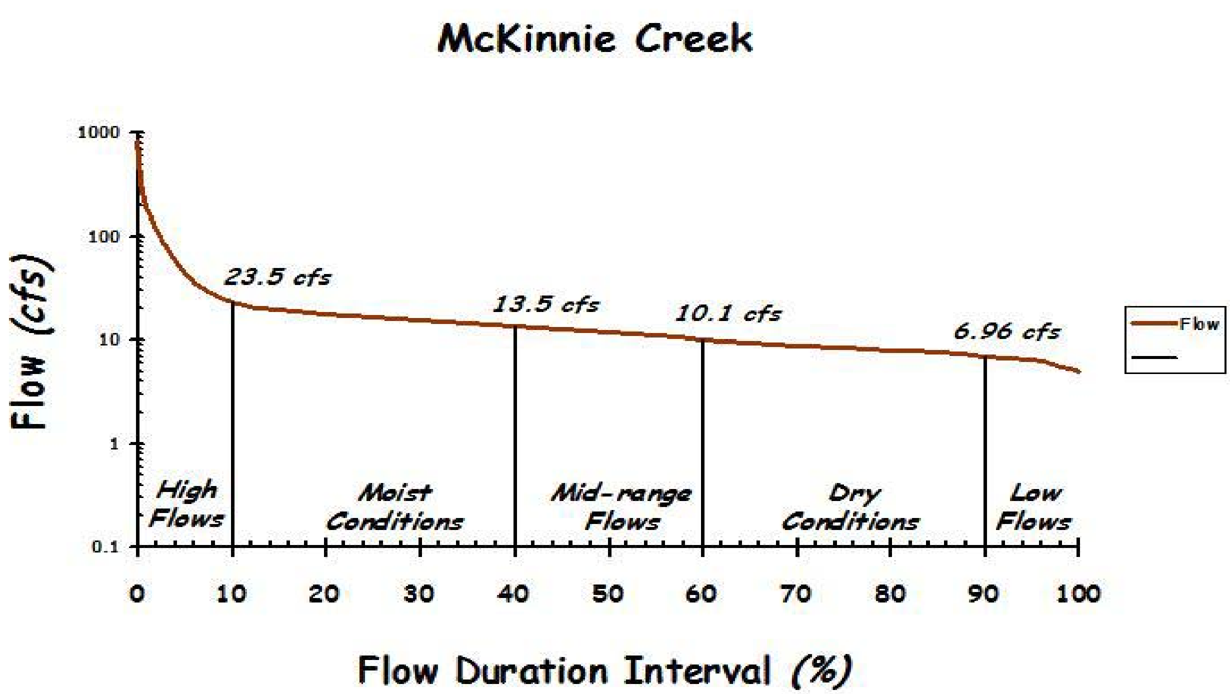


Figure E-6. Flow Duration Curve for McKinnie Creek.

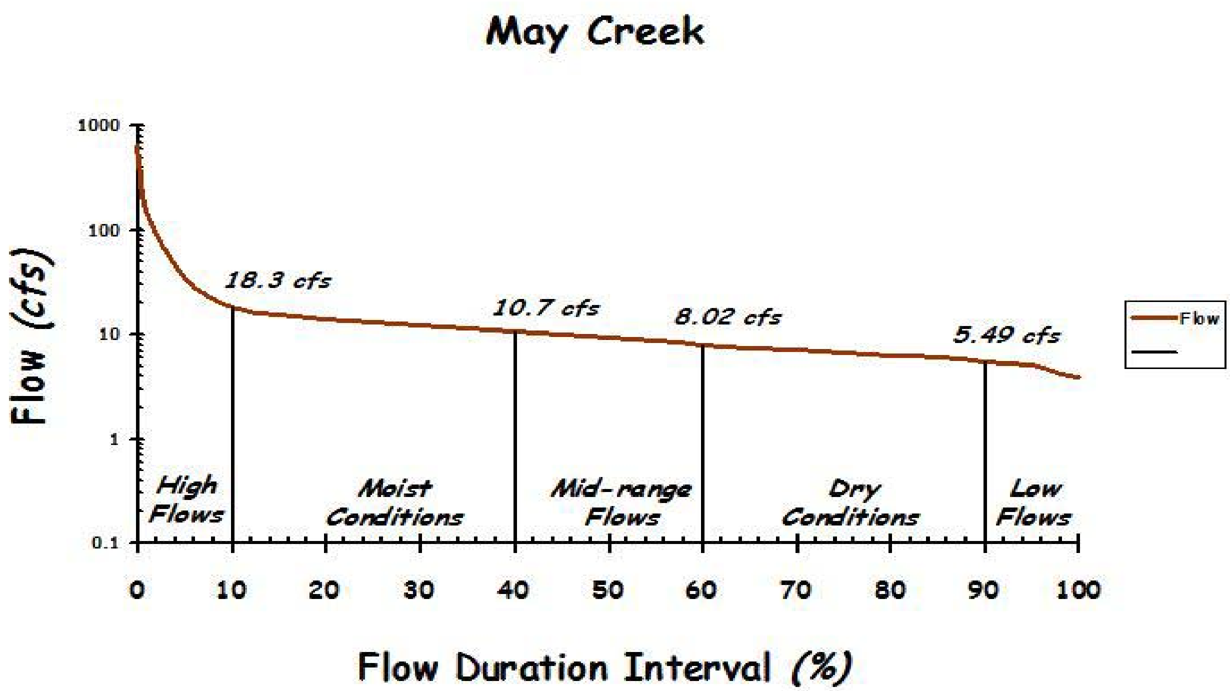


Figure E-7. Flow Duration Curve for May Creek.

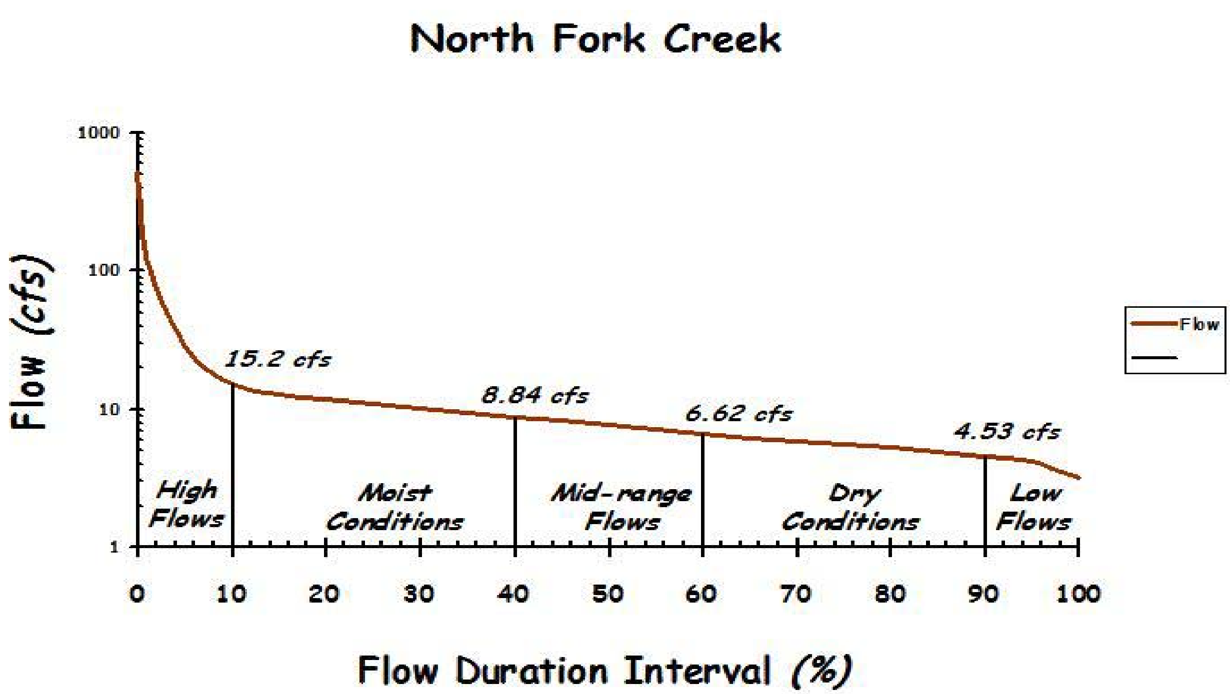


Figure E-8. Flow Duration Curve for North Fork Creek.

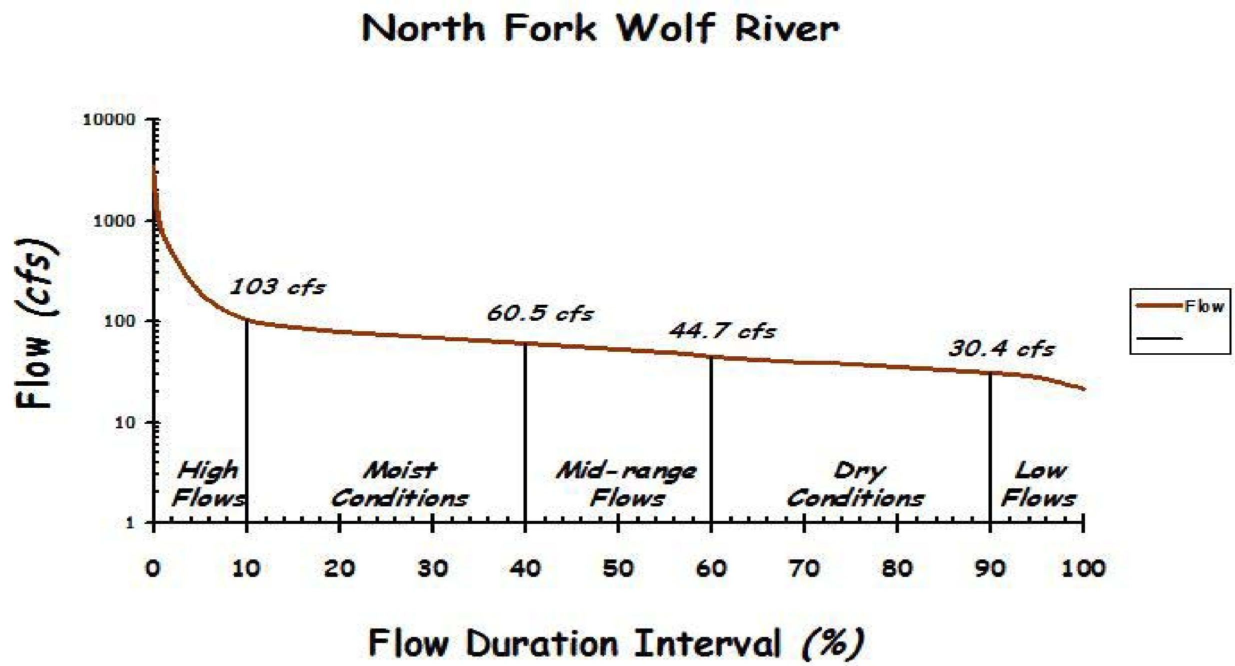


Figure E-9. Flow Duration Curve for North Fork Wolf River.

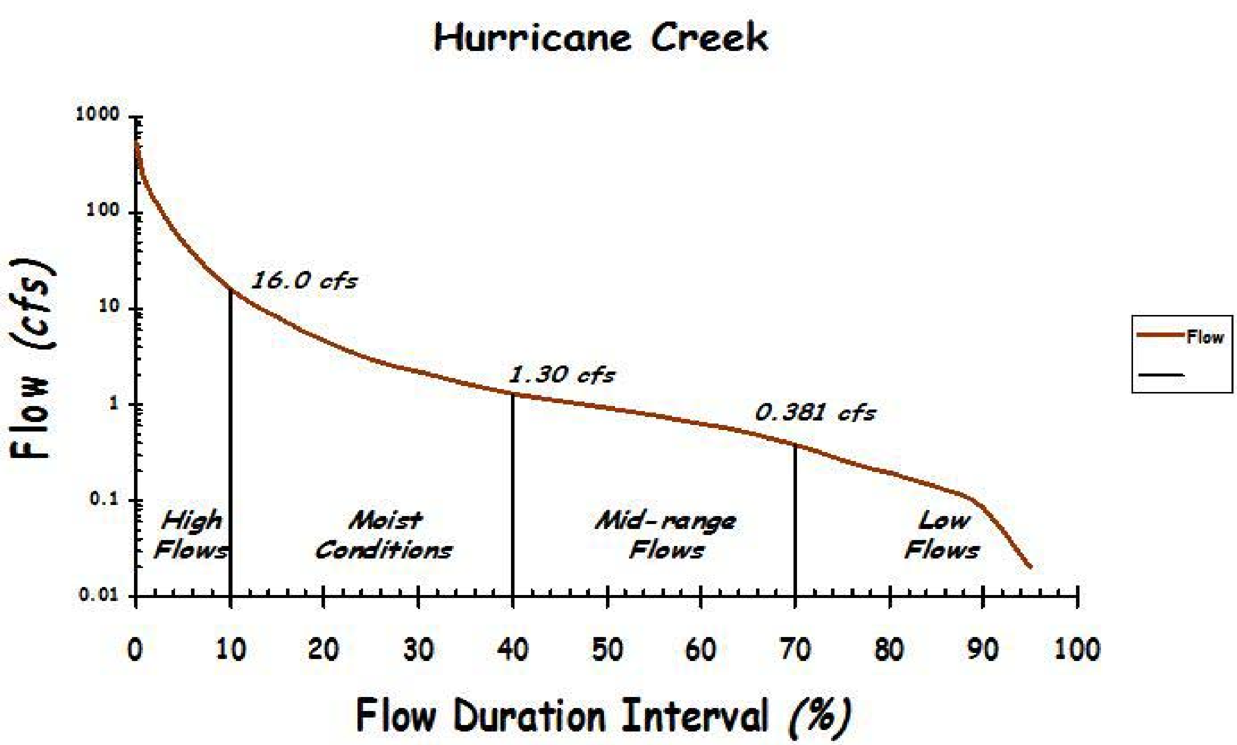


Figure E-10. Flow Duration Curve for Hurricane Creek.

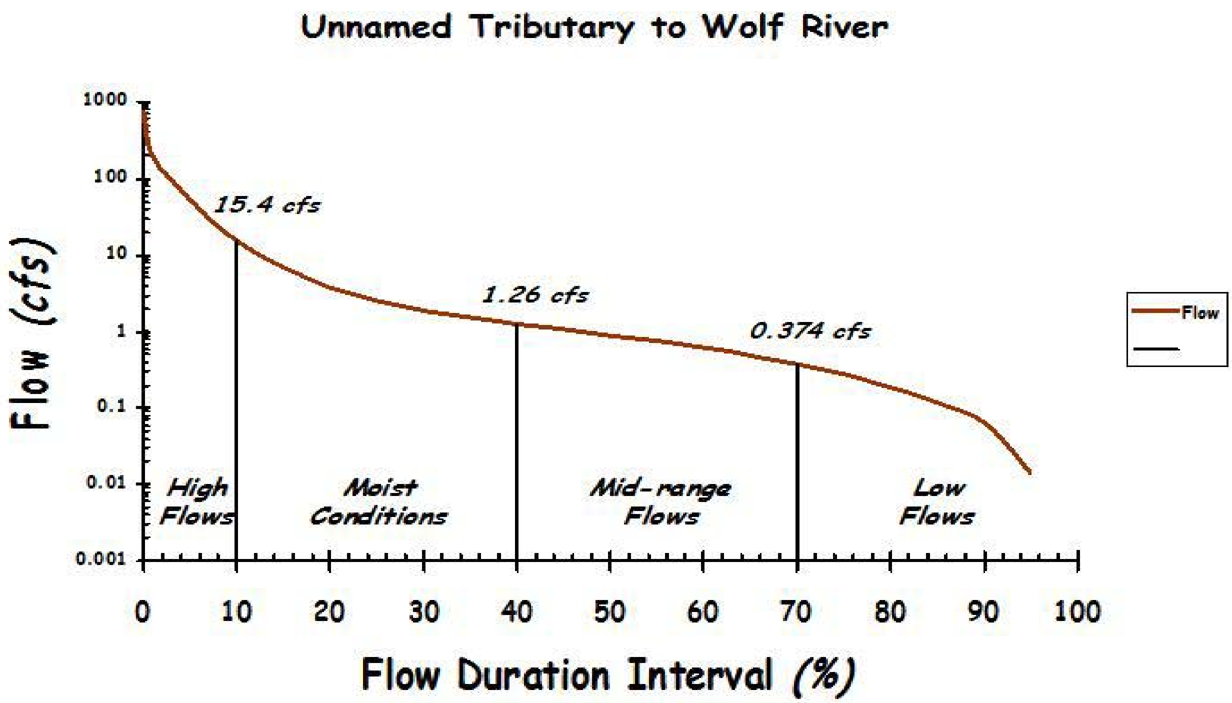


Figure E-11. Flow Duration Curve for Unnamed Tributary to Wolf River.

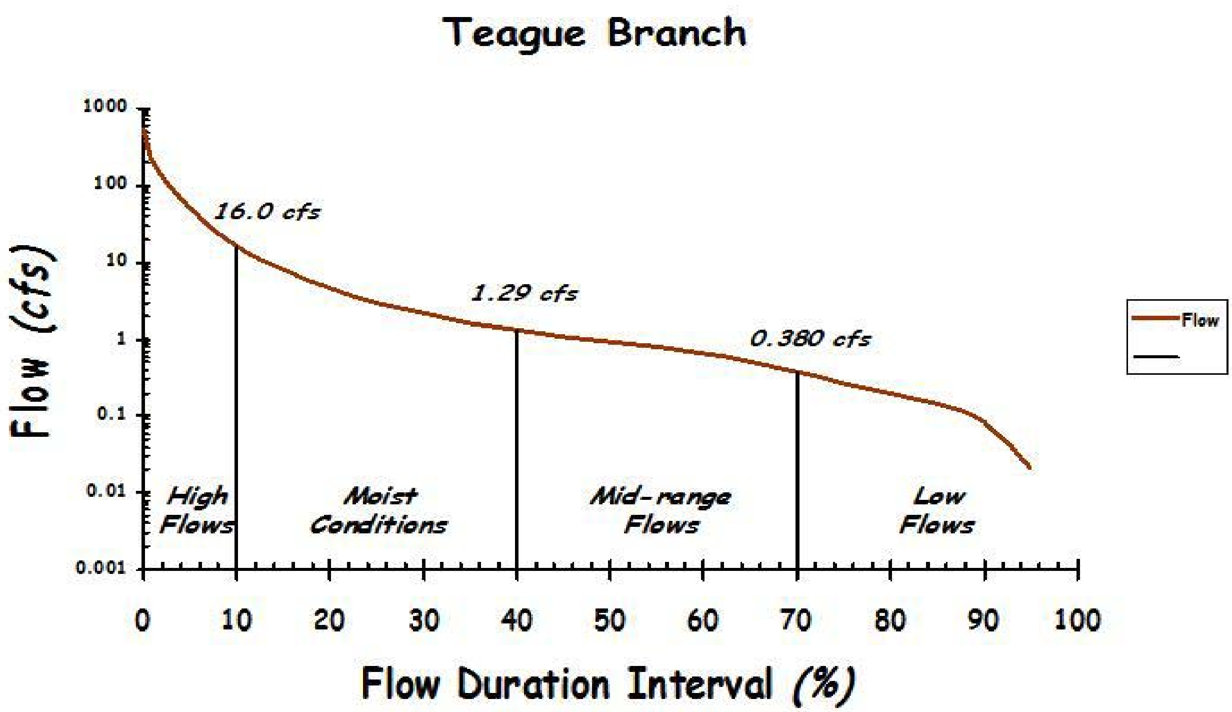


Figure E-12. Flow Duration Curve for Teague Branch.

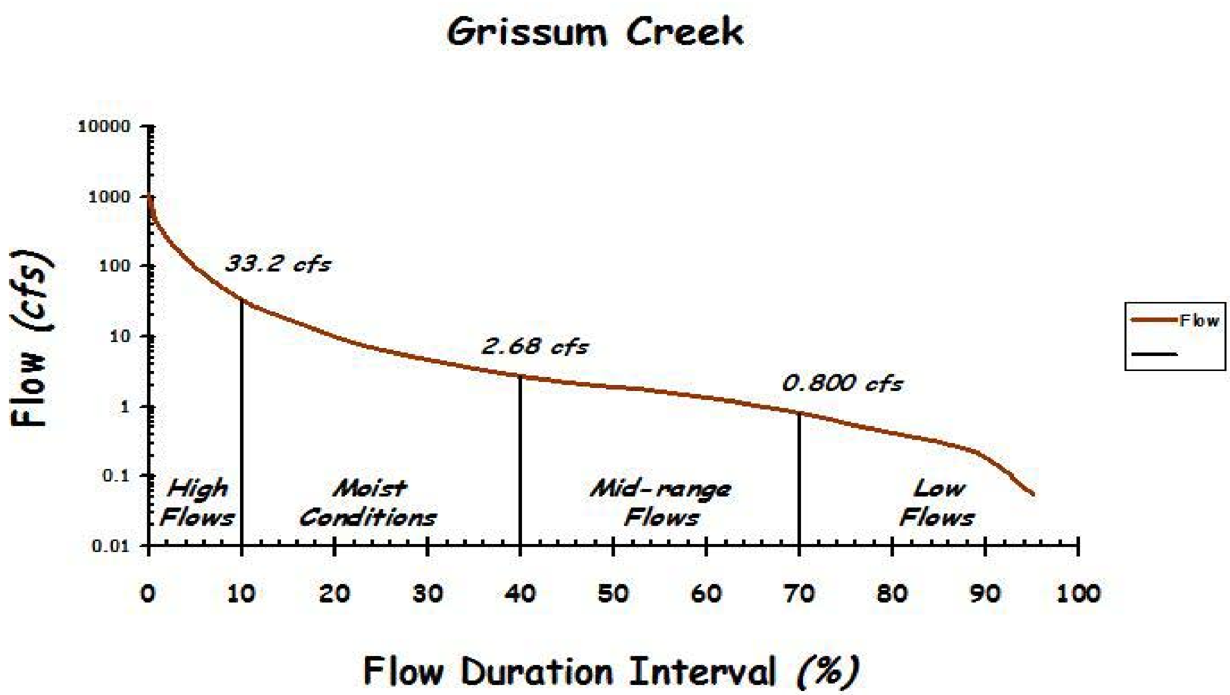


Figure E-13. Flow Duration Curve for Grissum Creek.

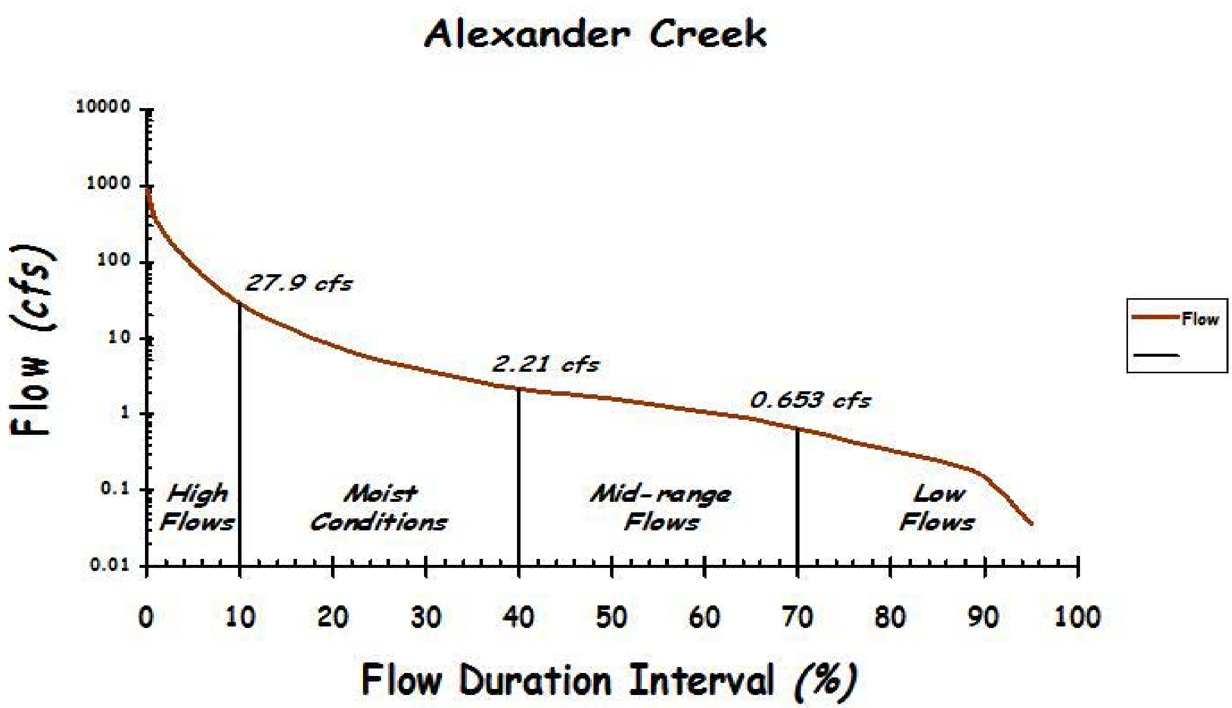


Figure E-14. Flow Duration Curve for Alexander Creek.

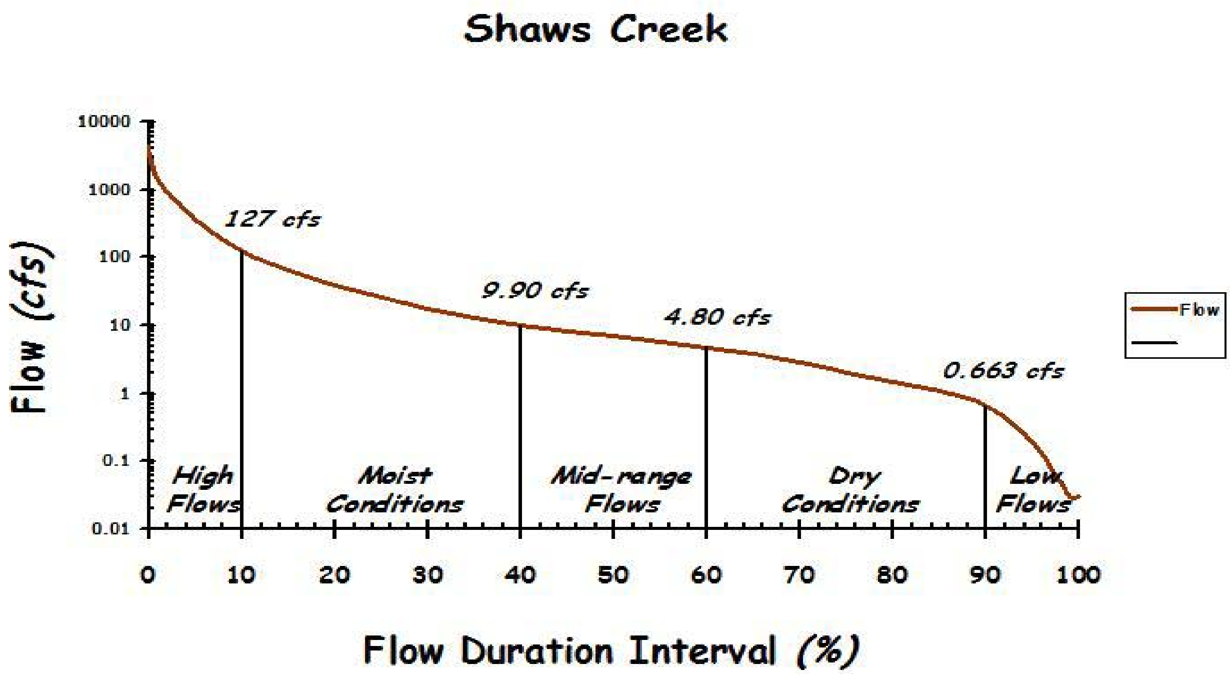


Figure E-15. Flow Duration Curve for Shaws Creek.

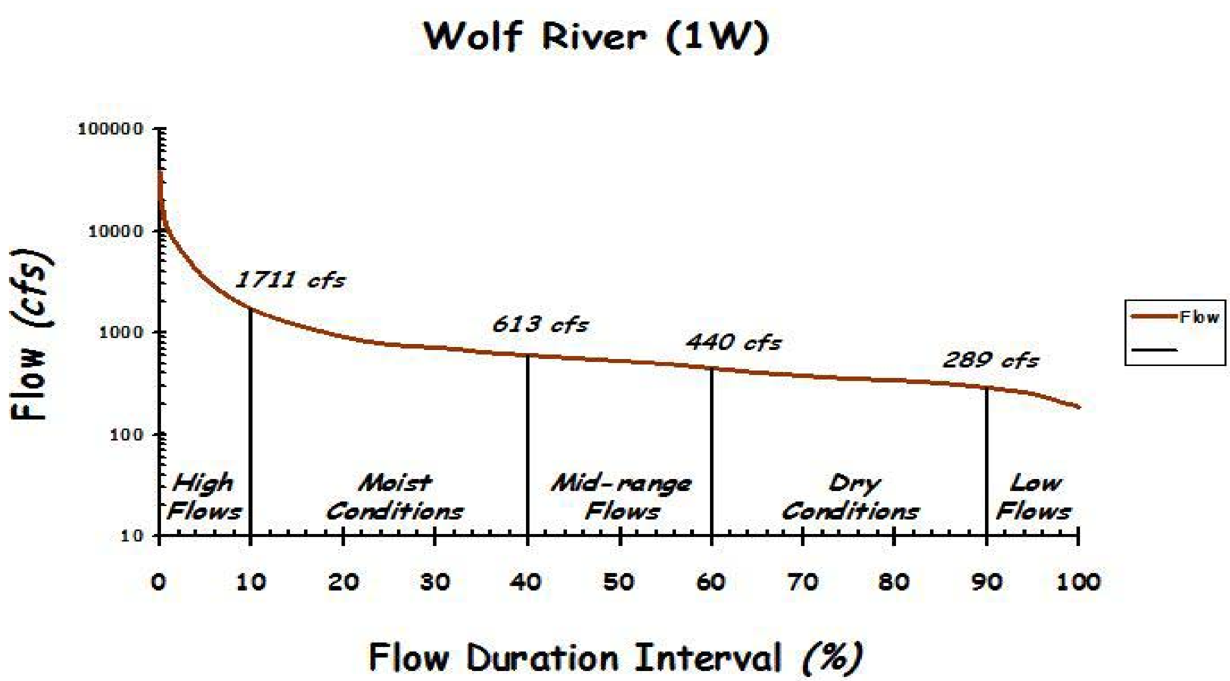


Figure E-16. Flow Duration Curve for Wolf River (1W).

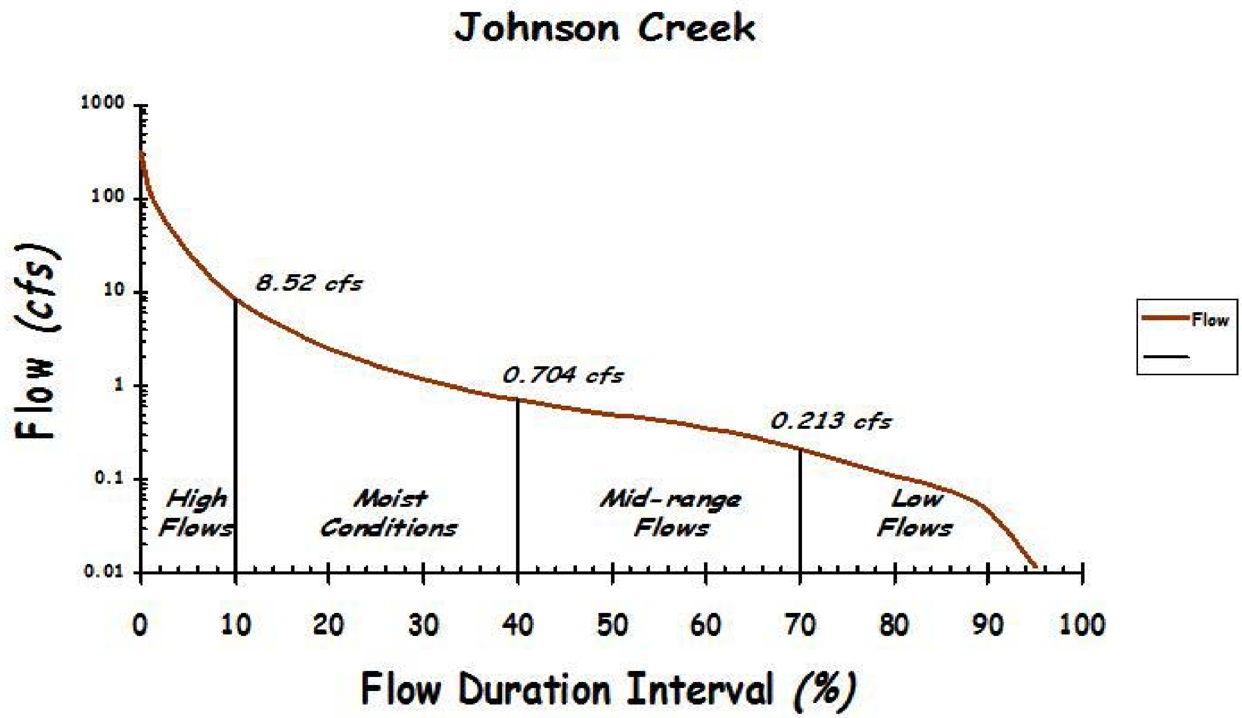


Figure E-17. Flow Duration Curve for Johnson Creek.

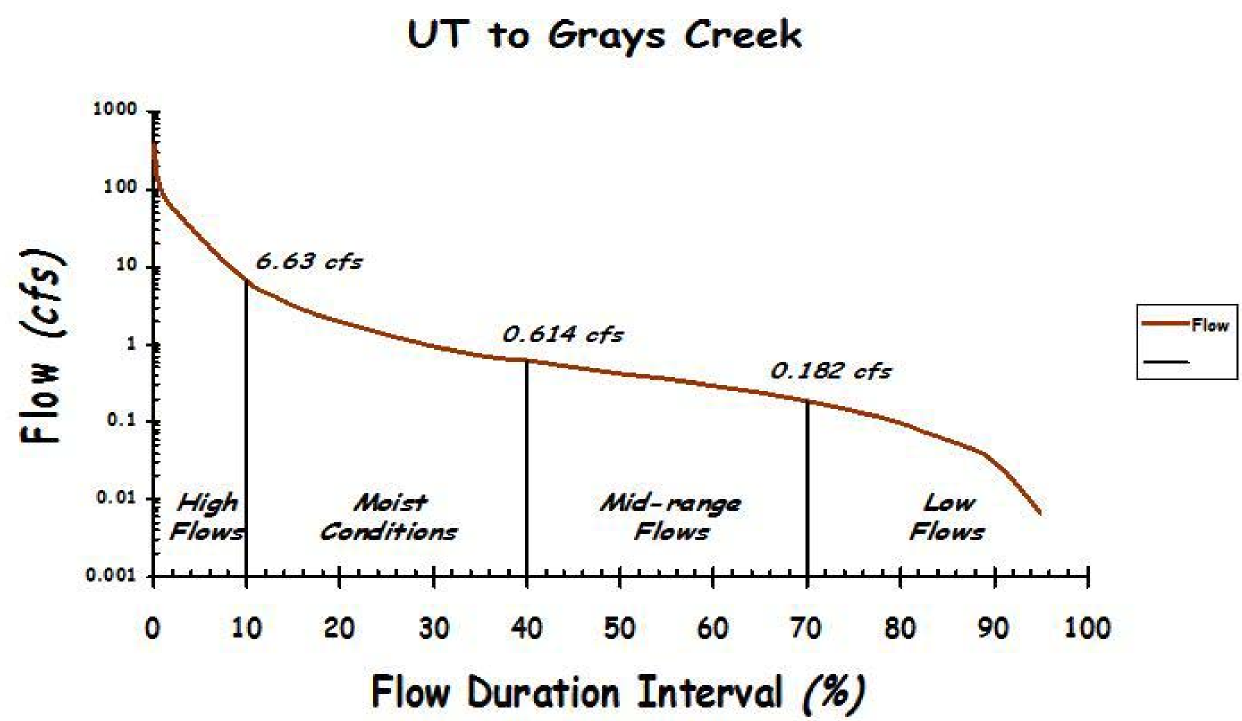


Figure E-18. Flow Duration Curve for Unnamed Tributary to Grays Creek.

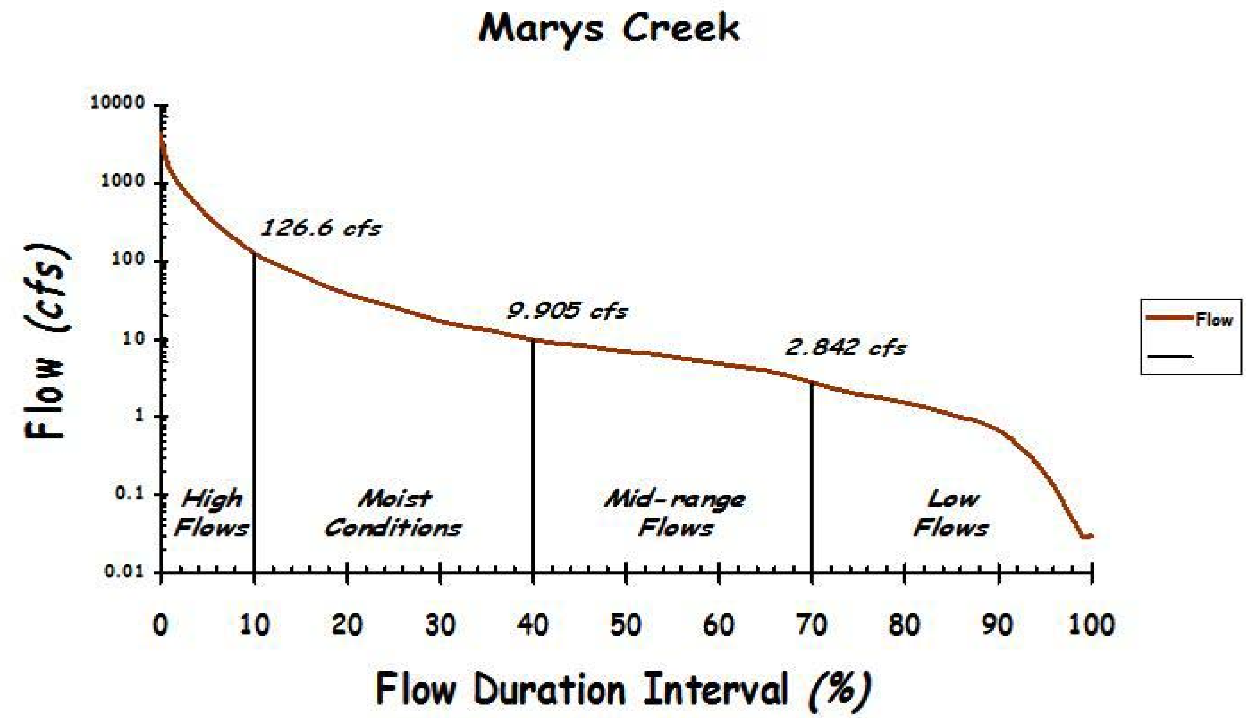


Figure E-19. Flow Duration Curve for Marys Creek.

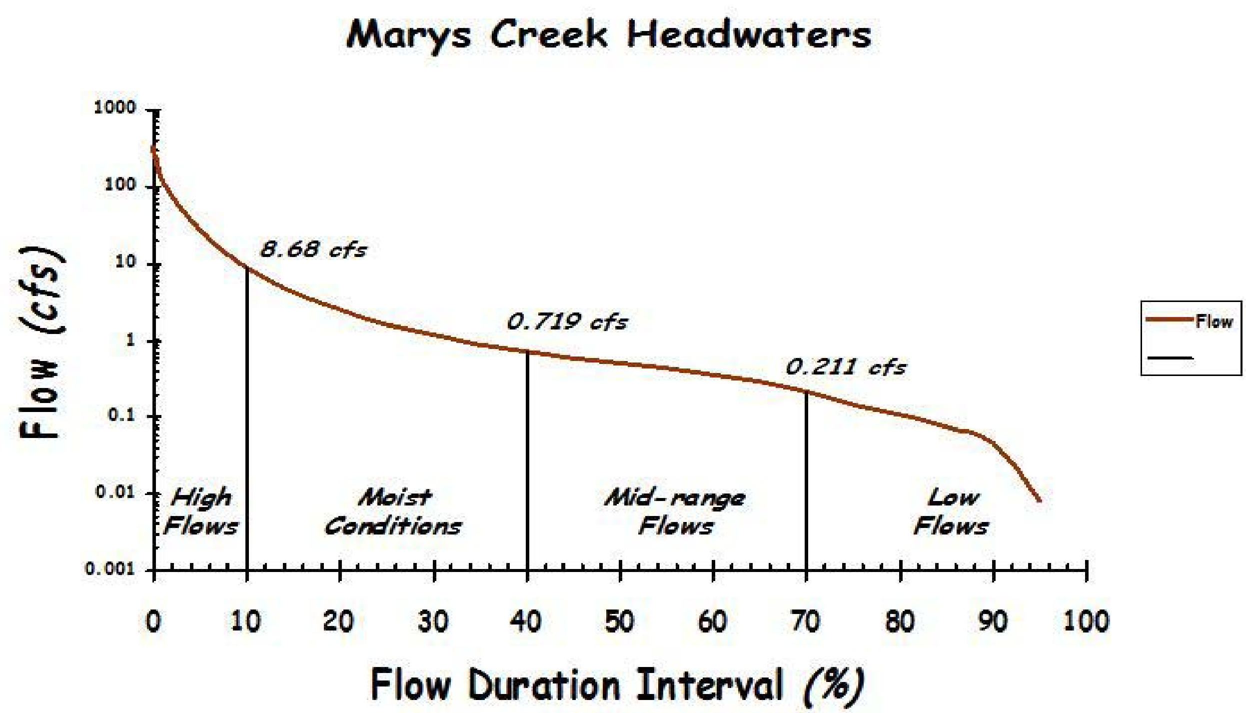


Figure E-20. Flow Duration Curve for Marys Creek Headwaters.

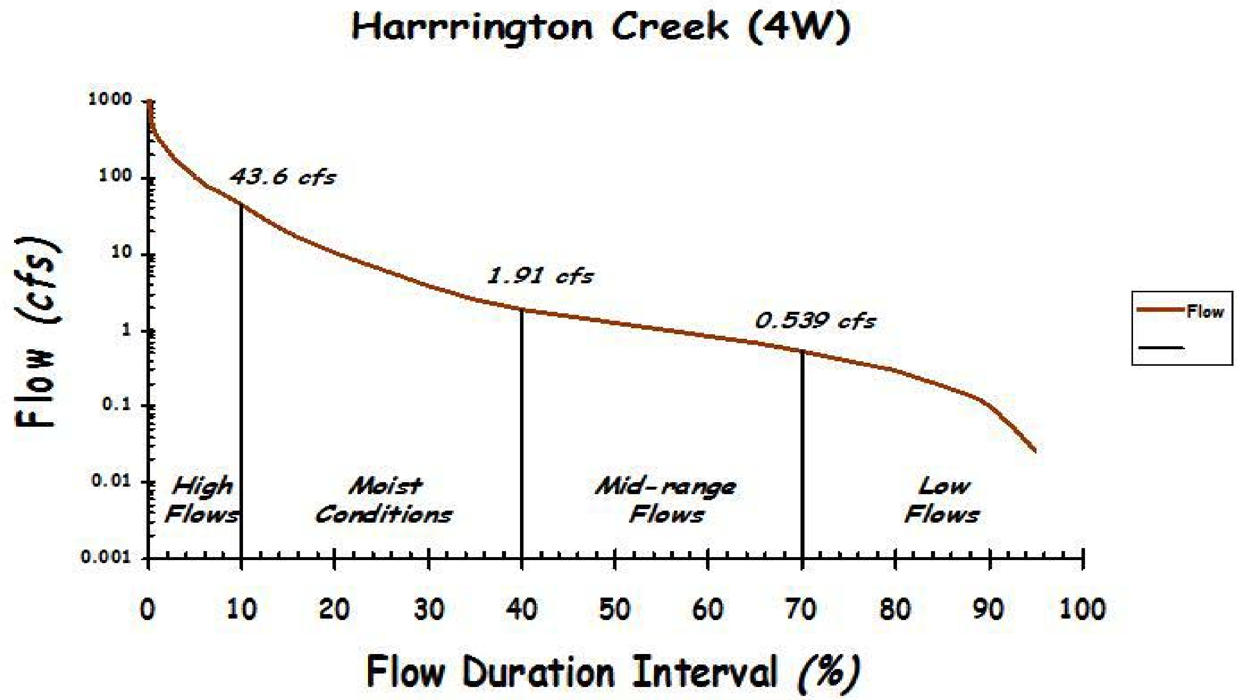


Figure E-21. Flow Duration Curve for Harrington Creek.

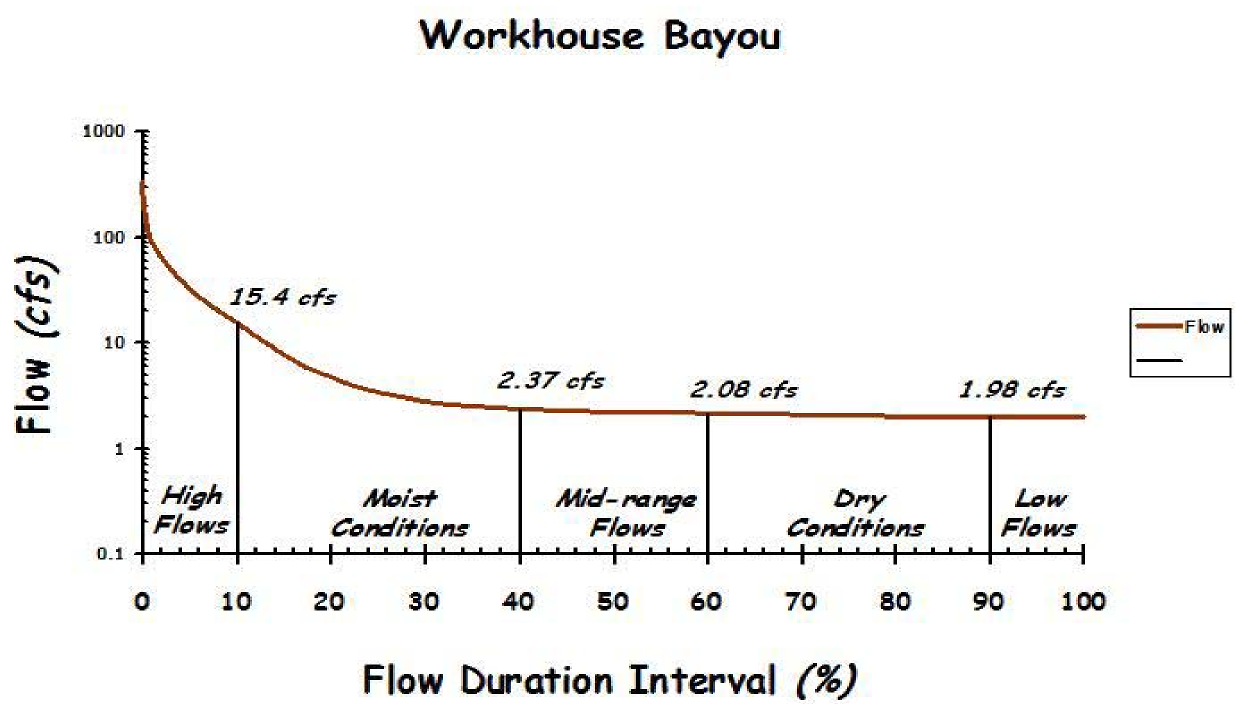


Figure E-22. Flow Duration Curve for Workhouse Bayou.

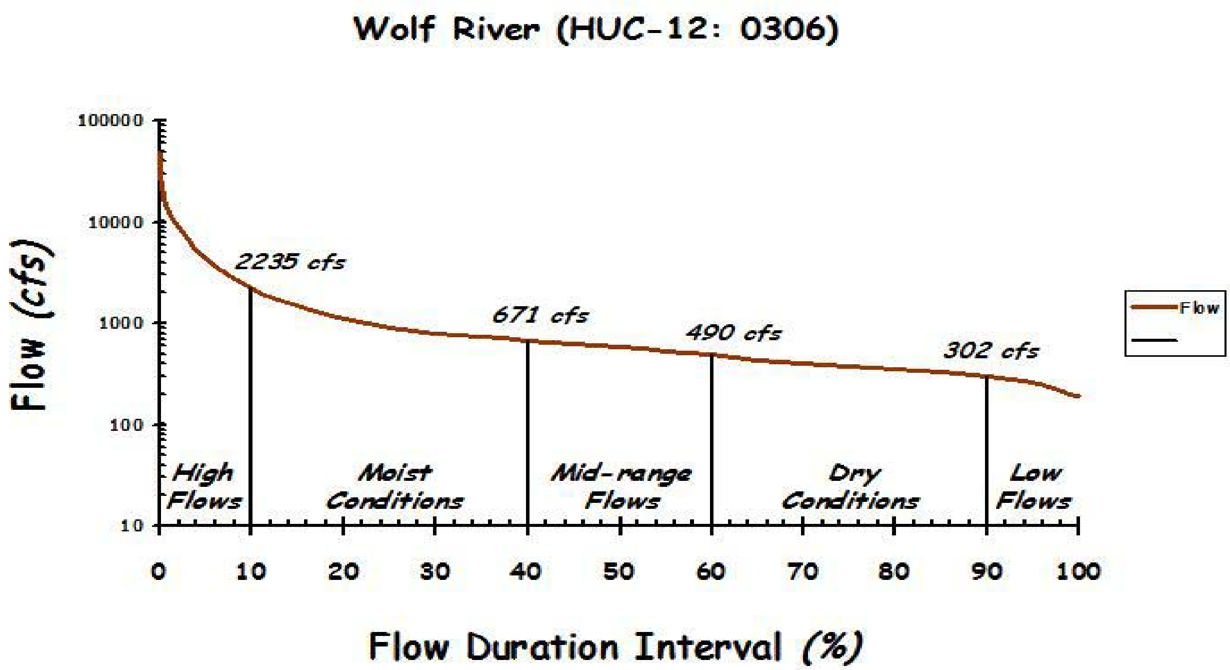


Figure E-23. Flow Duration Curve for Wolf River (HUC-12: 0306).

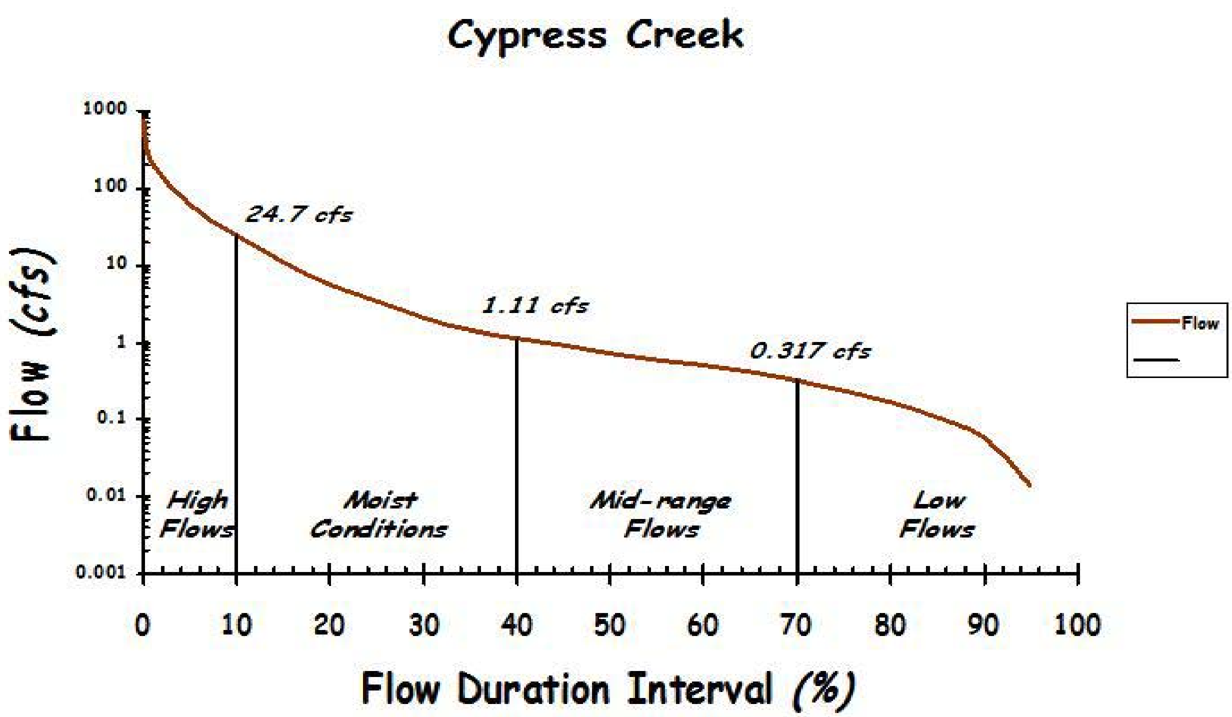


Figure E-24. Flow Duration Curve for Cypress Creek.

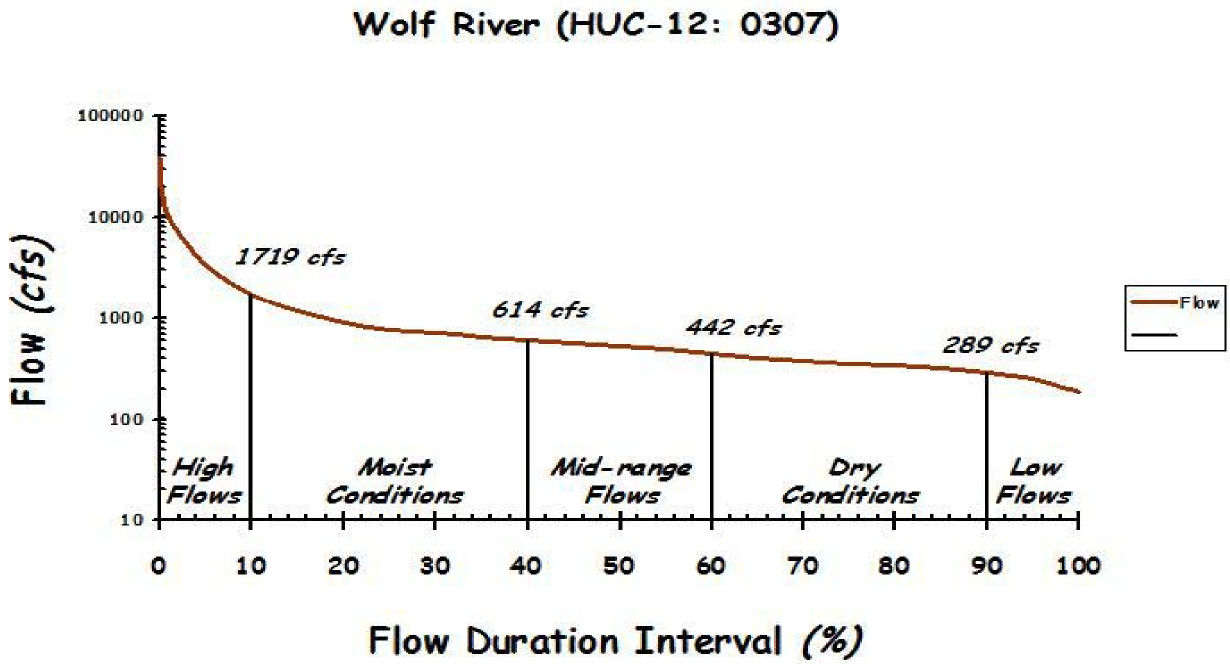


Figure E-25. Flow Duration Curve for Wolf River (HUC-12: 0307).

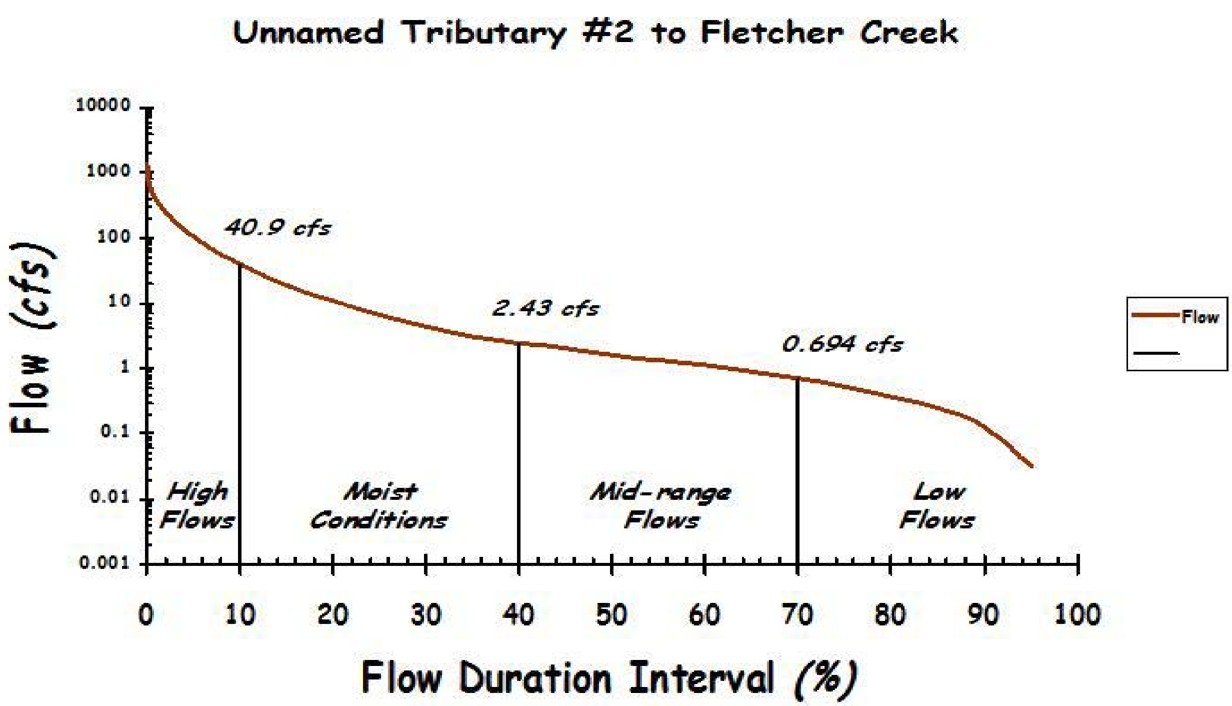


Figure E-26. Flow Duration Curve for Unnamed Tributary #2 to Fletcher Creek.

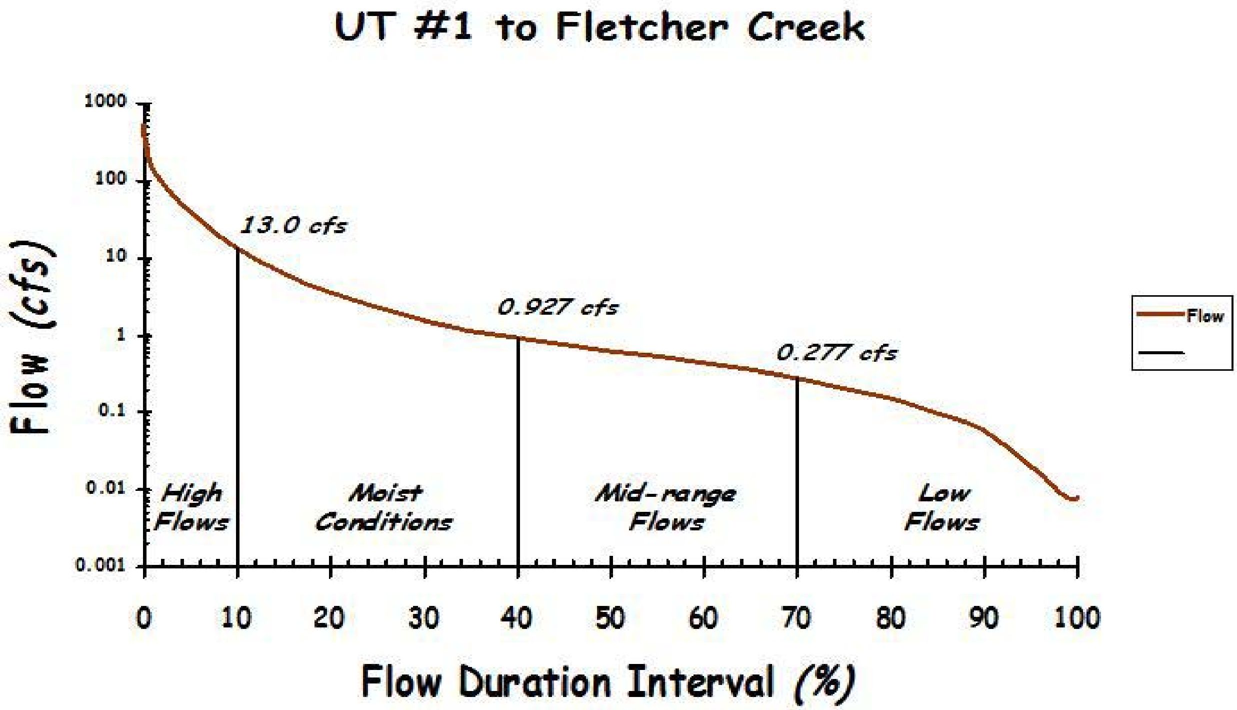


Figure E-27. Flow Duration Curve for Unnamed Tributary #1 to Fletcher Creek.

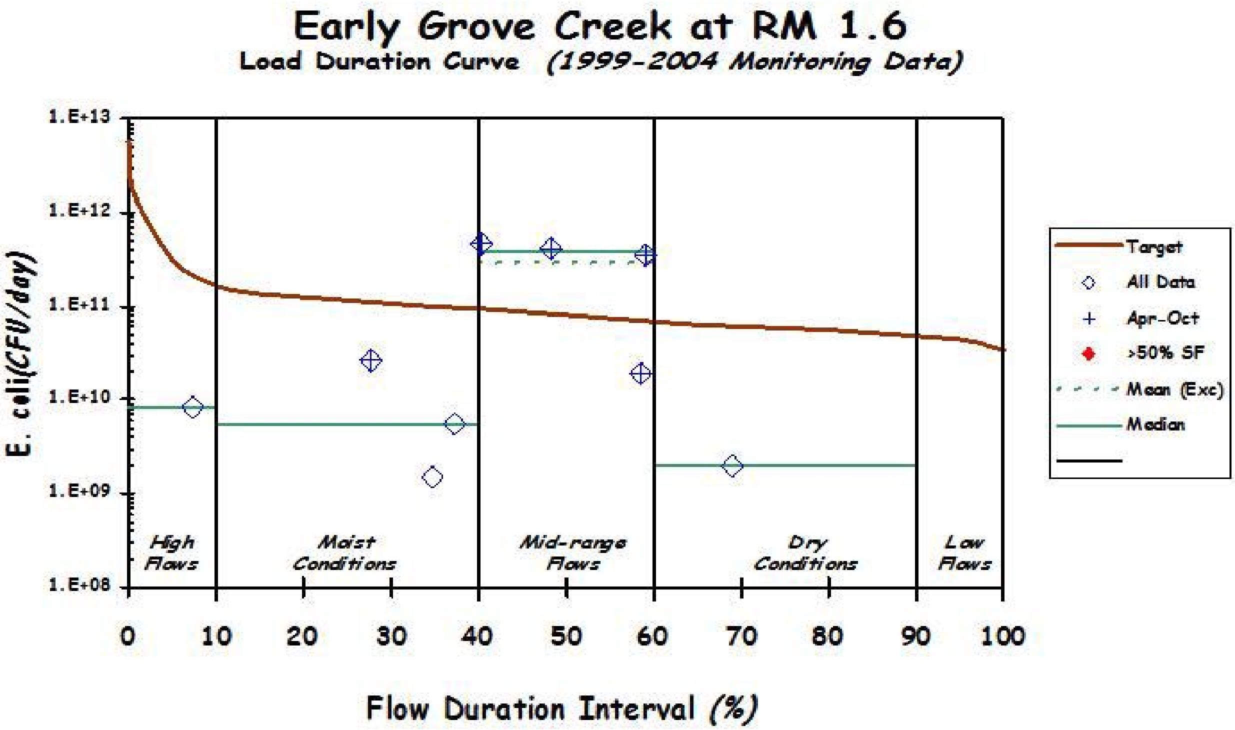


Figure E-28. E. Coli Load Duration Curve for Early Grove Creek at Mile 1.6.

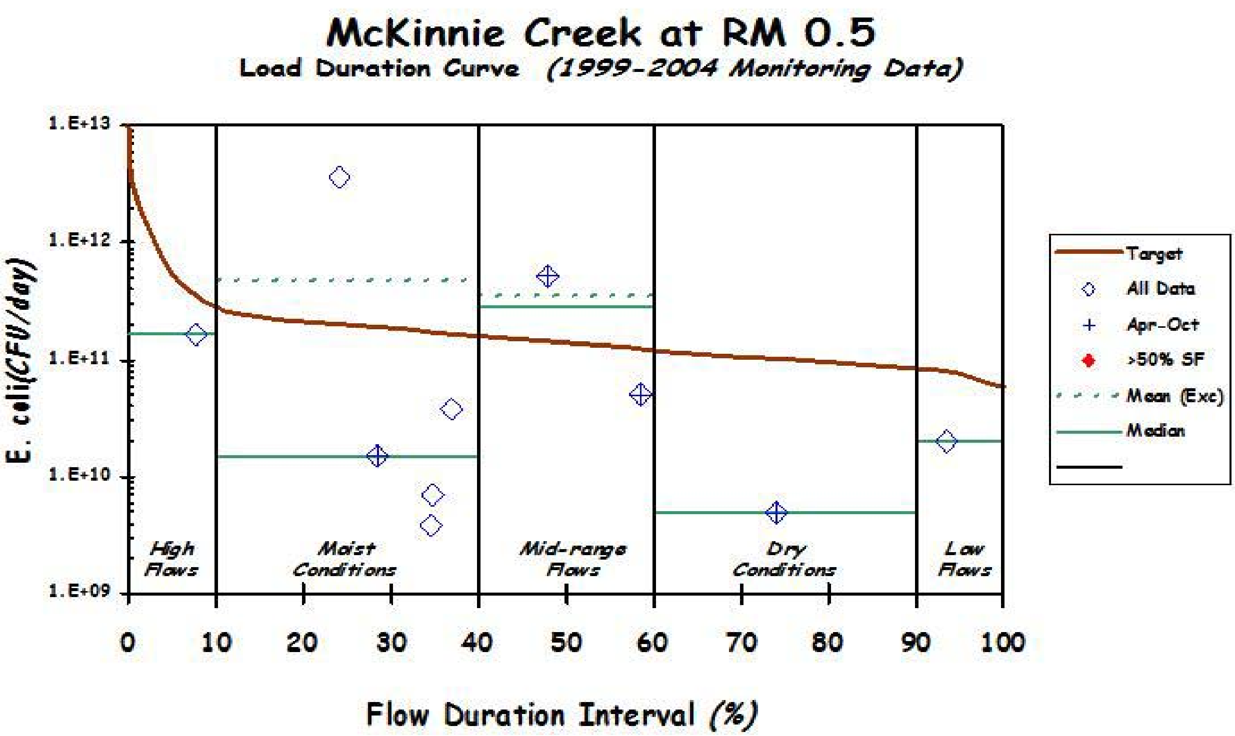


Figure E-29. E. Coli Load Duration Curve for McKinnie Creek at Mile 0.5.

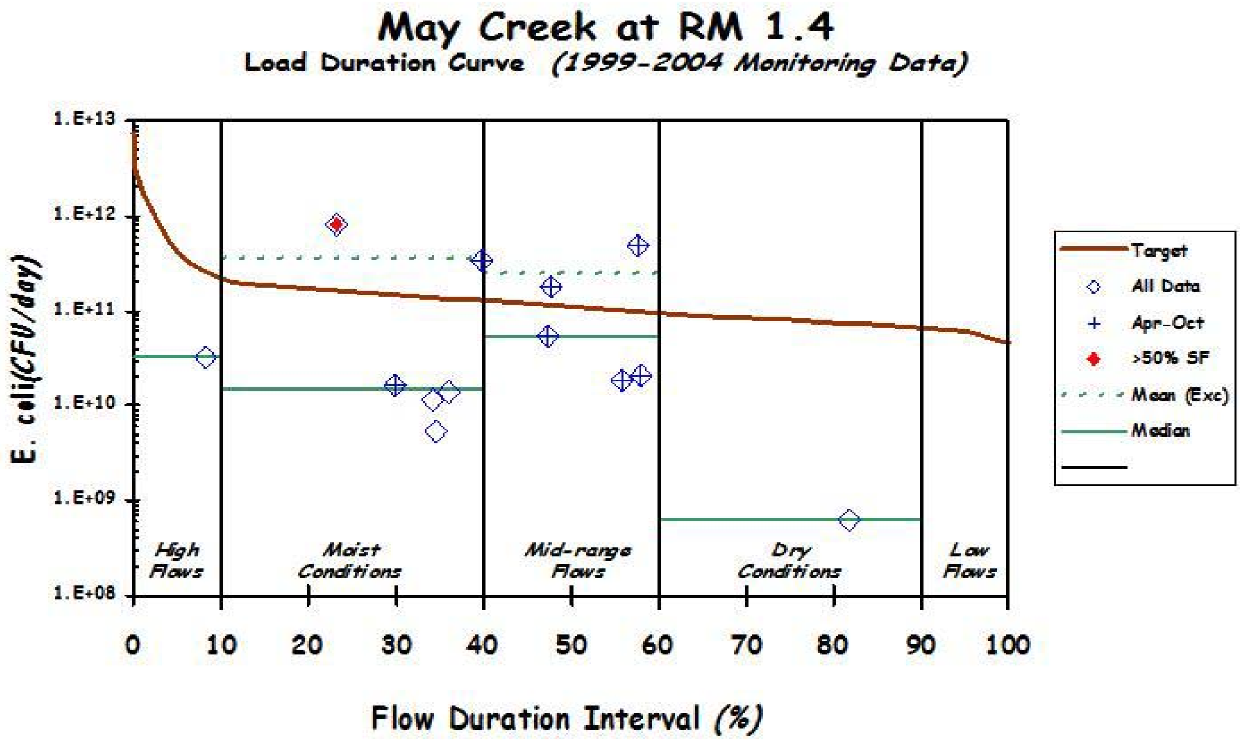


Figure E-30. E. Coli Load Duration Curve for May Creek at Mile 1.4.

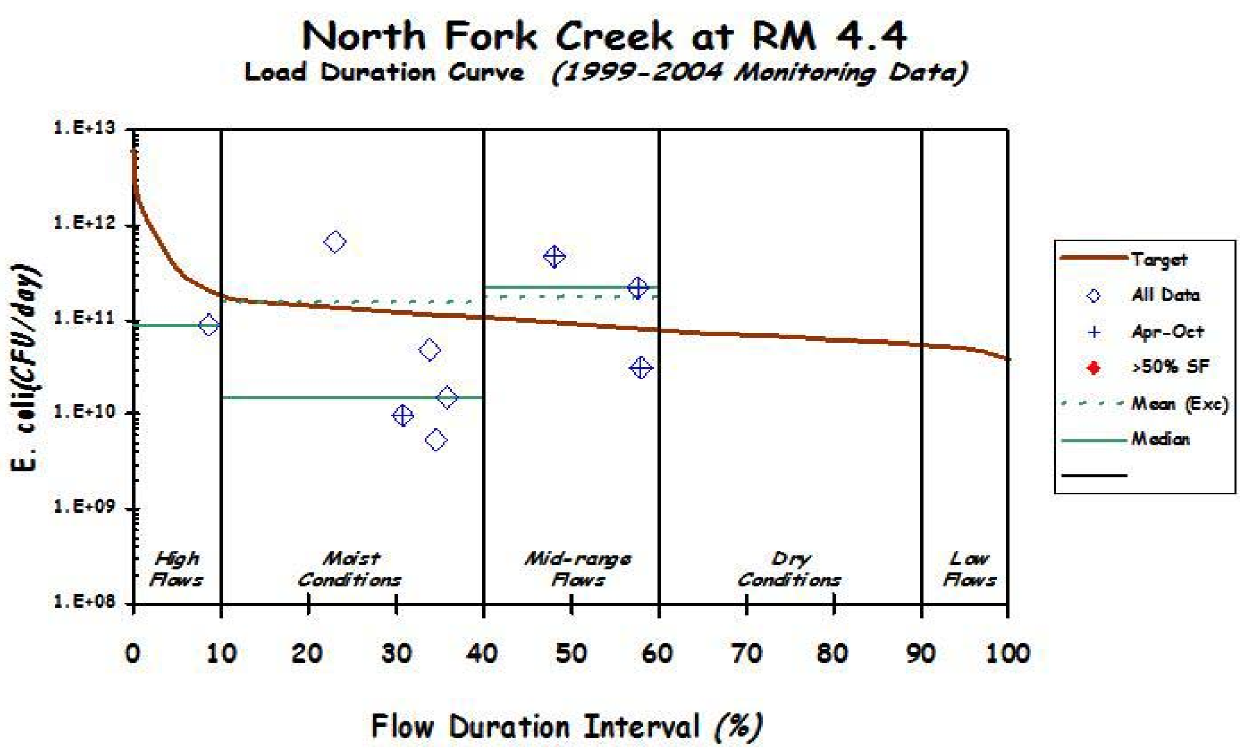


Figure E-31. E. Coli Load Duration Curve for North Fork Creek at Mile 4.4.

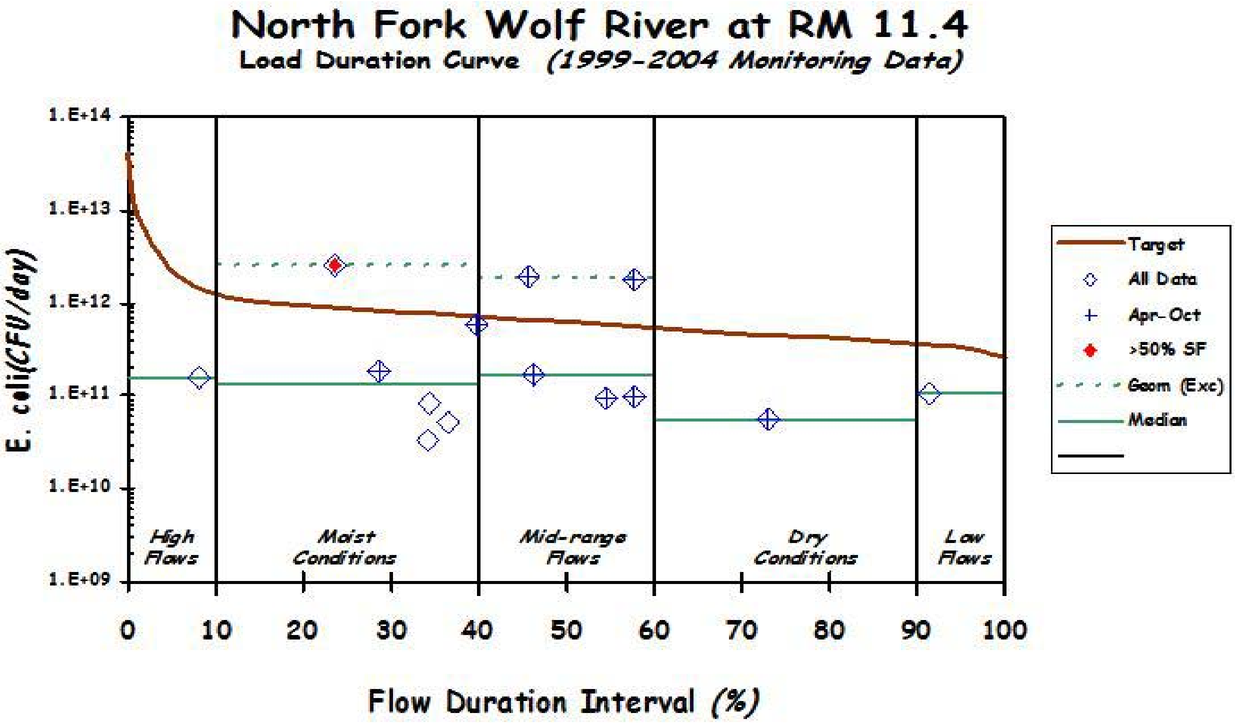


Figure E-32. E. Coli Load Duration Curve for North Fork Wolf River at Mile 11.4.

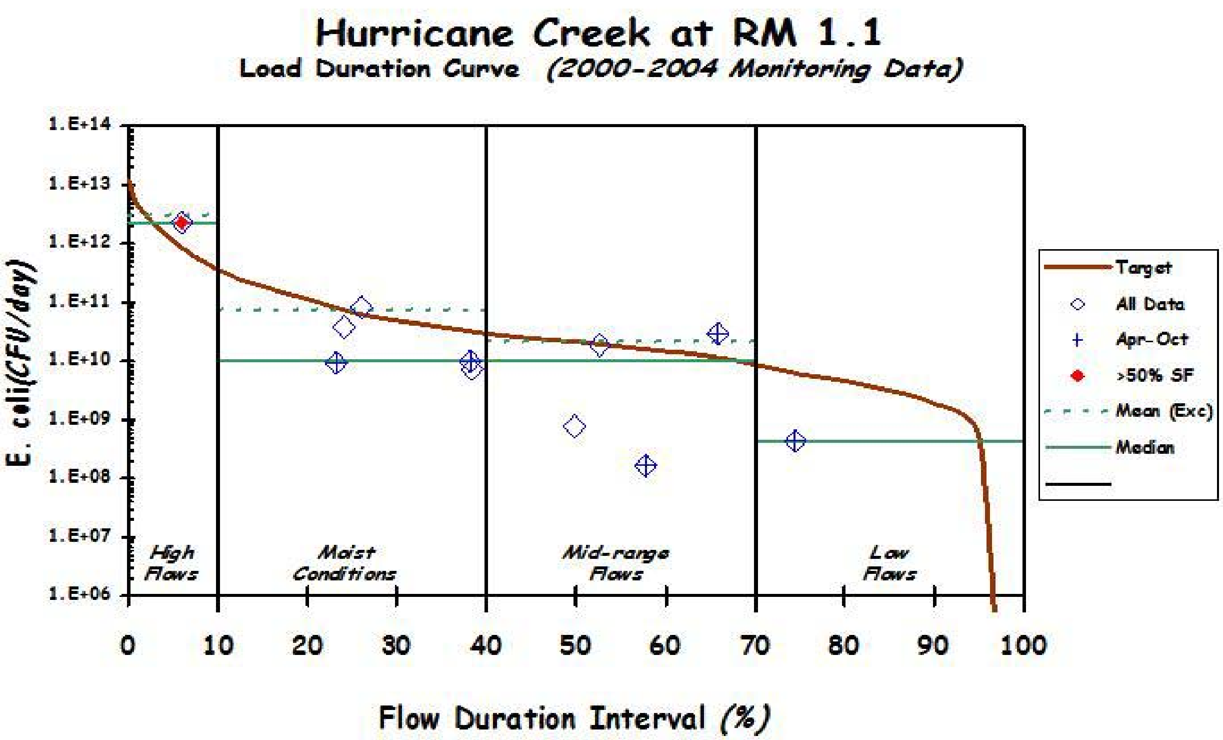


Figure E-33. E. Coli Load Duration Curve for Hurricane Creek at Mile 1.1.

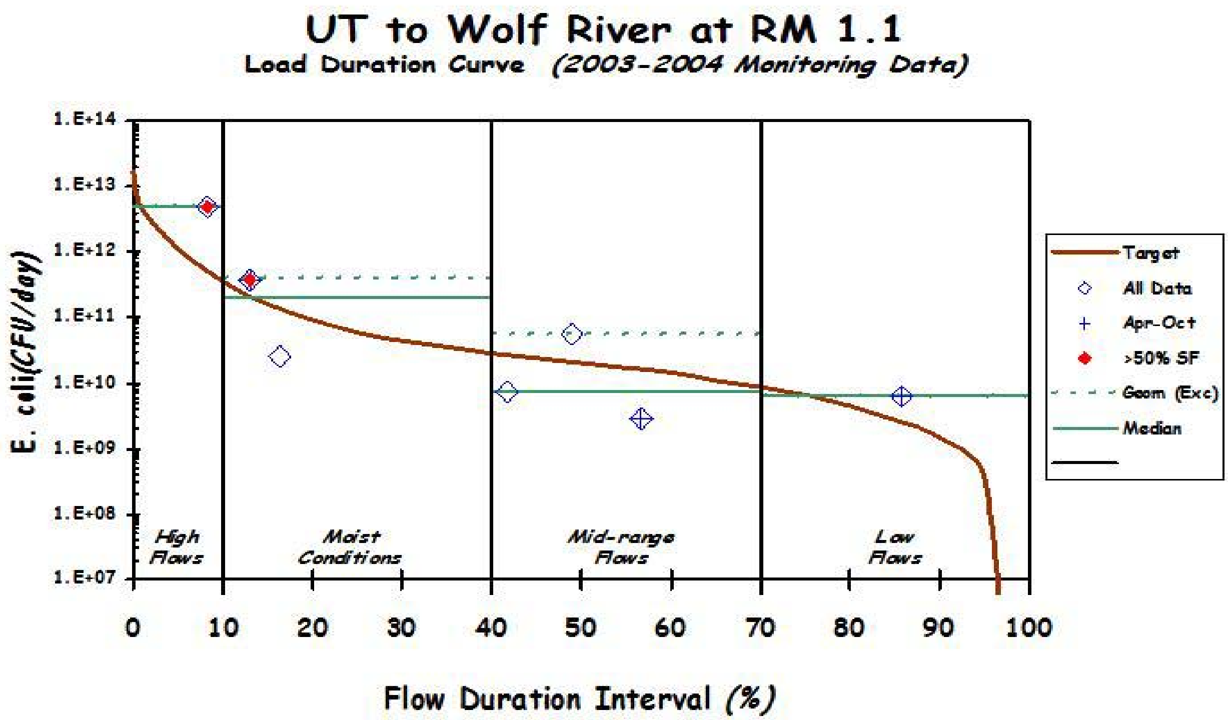


Figure E-34. E. Coli Load Duration Curve for Unnamed Tributary to Wolf River at Mile 1.1.

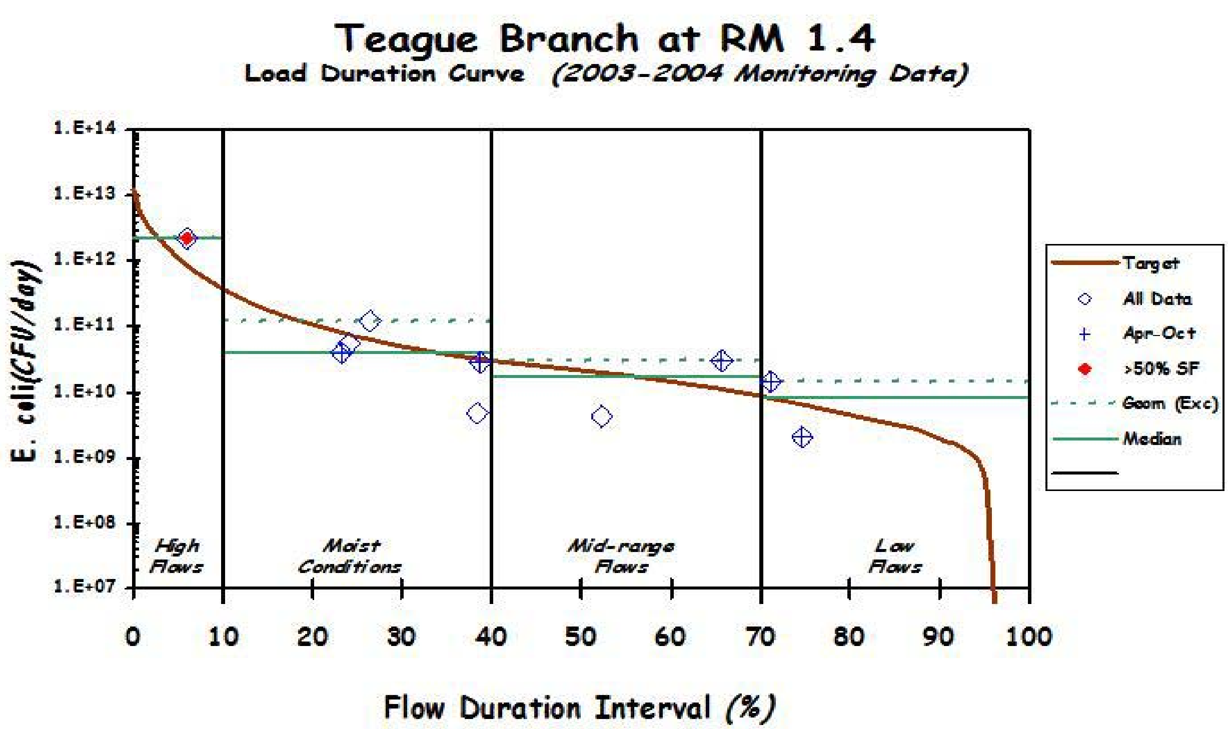


Figure E-35. E. Coli Load Duration Curve for Teague Branch at Mile 1.4.

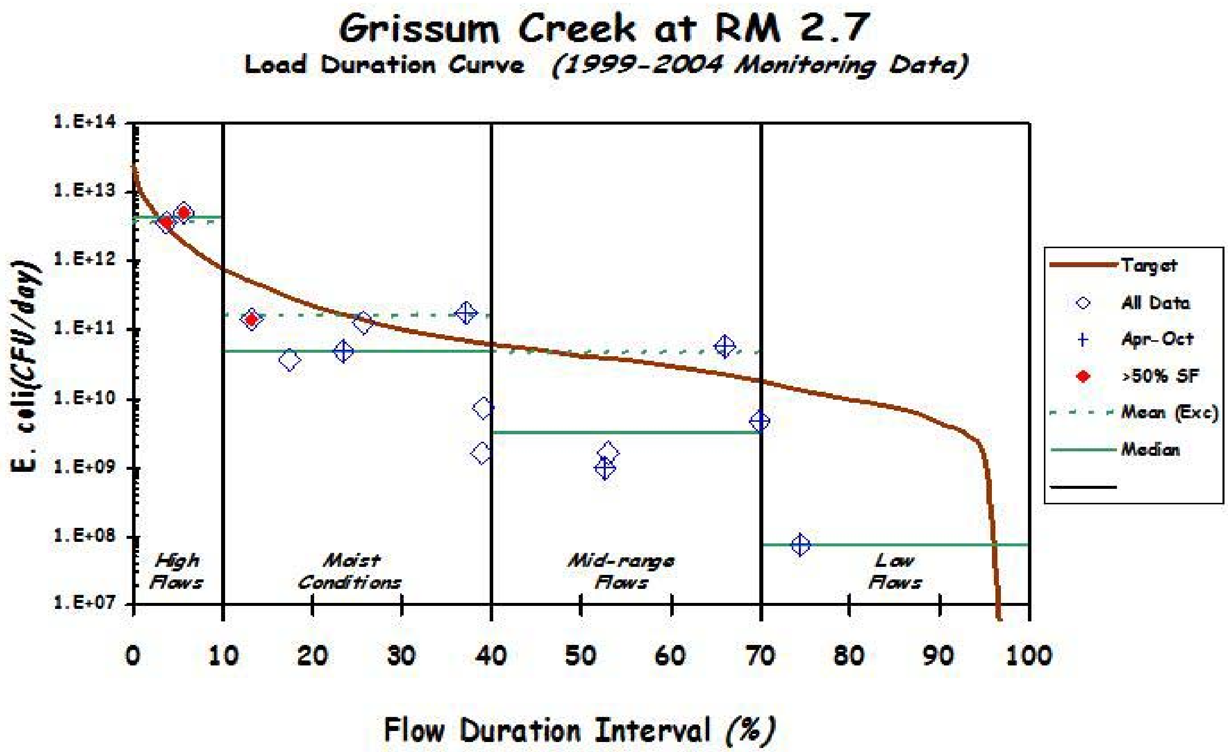


Figure E-36. E. Coli Load Duration Curve for Grissum Creek at Mile 2.7.

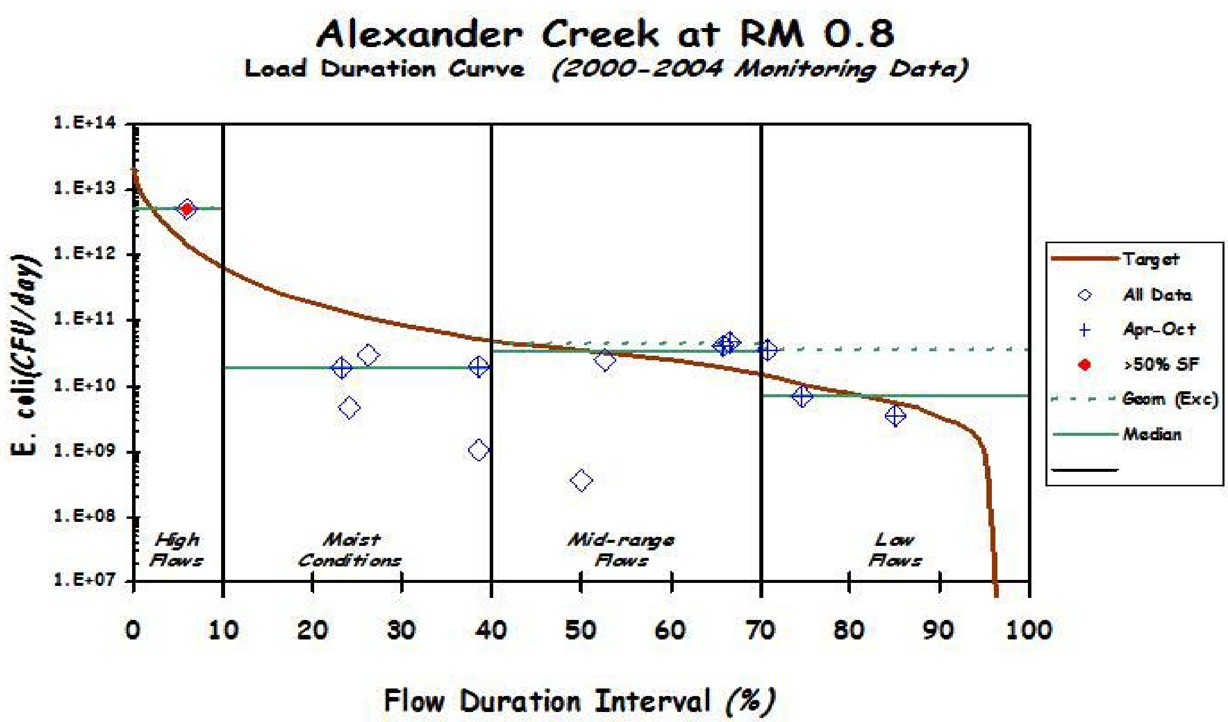


Figure E-37. E. Coli Load Duration Curve for Alexander Creek at Mile 0.8.

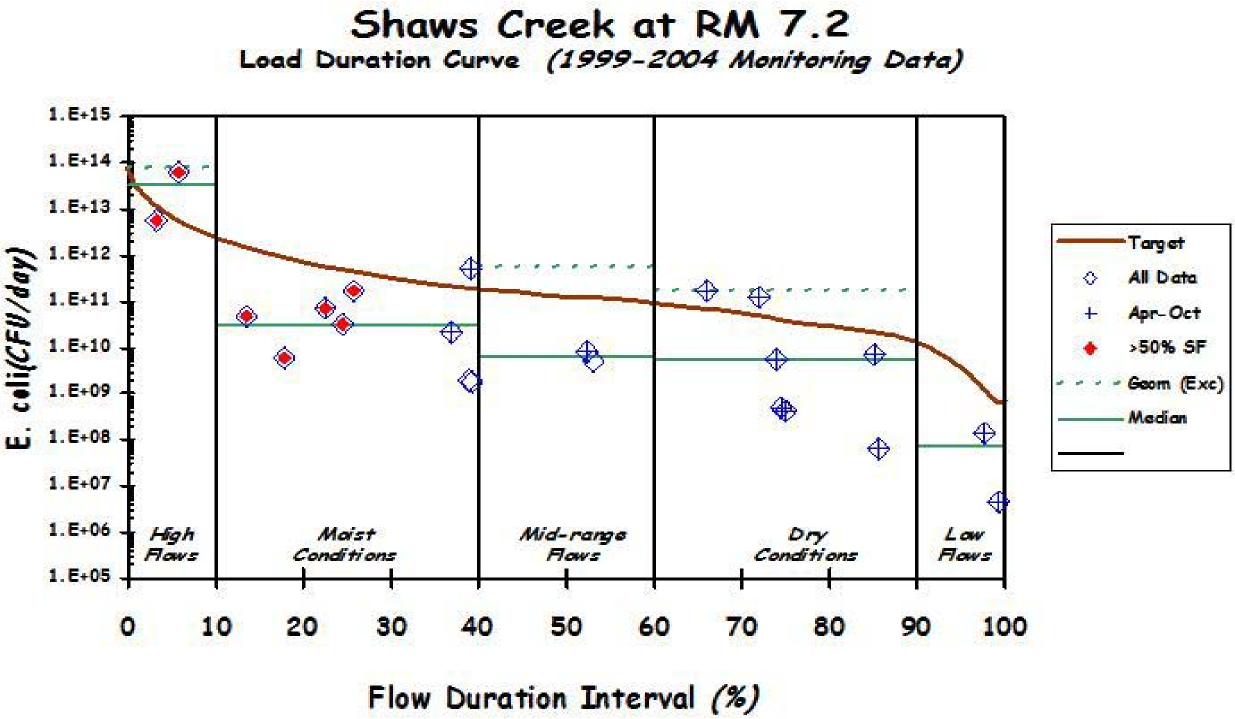


Figure E-38. E. Coli Load Duration Curve for Shaws Creek at Mile 7.2.

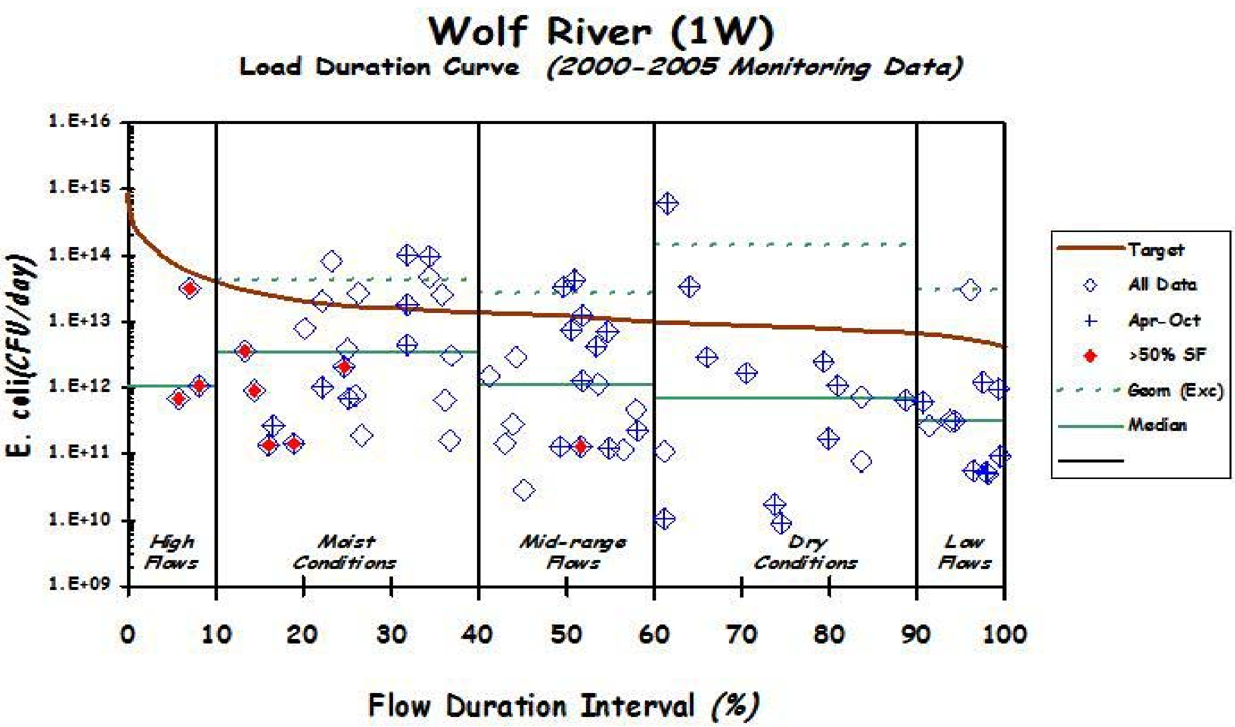


Figure E-39. E. Coli Load Duration Curve for Wolf River (1W).

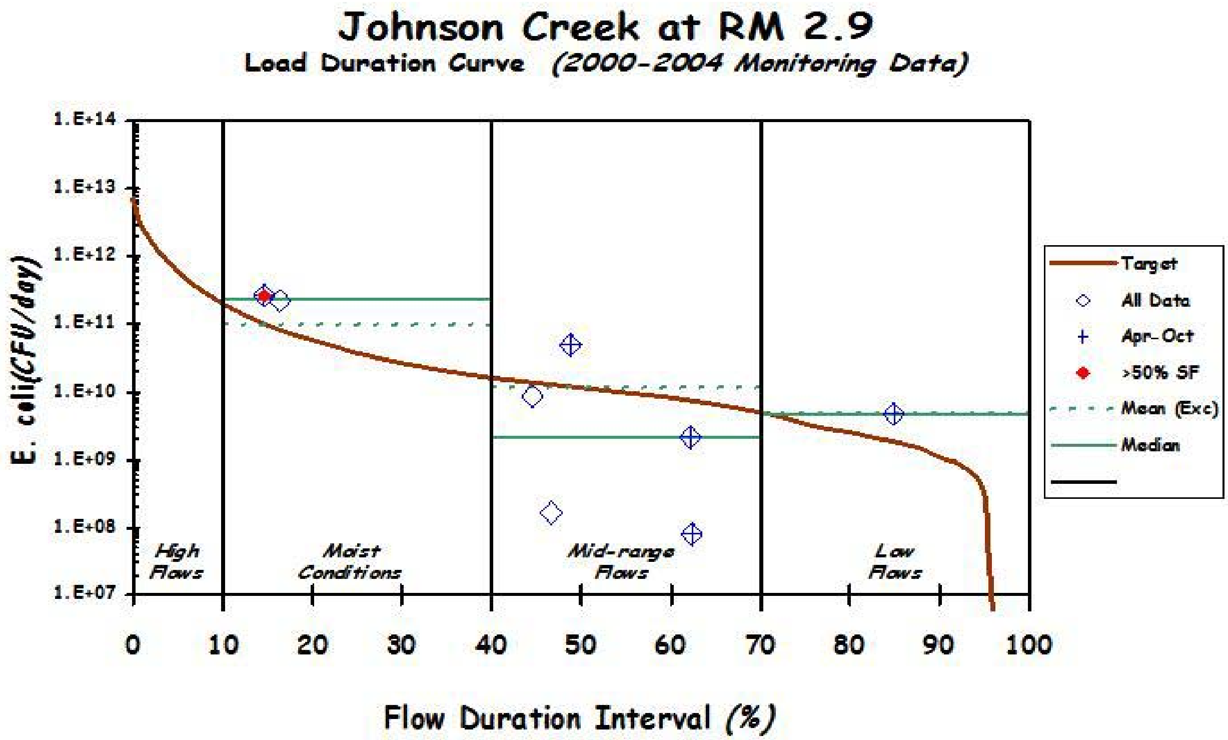


Figure E-40. E. Coli Load Duration Curve for Johnson Creek at Mile 2.9.

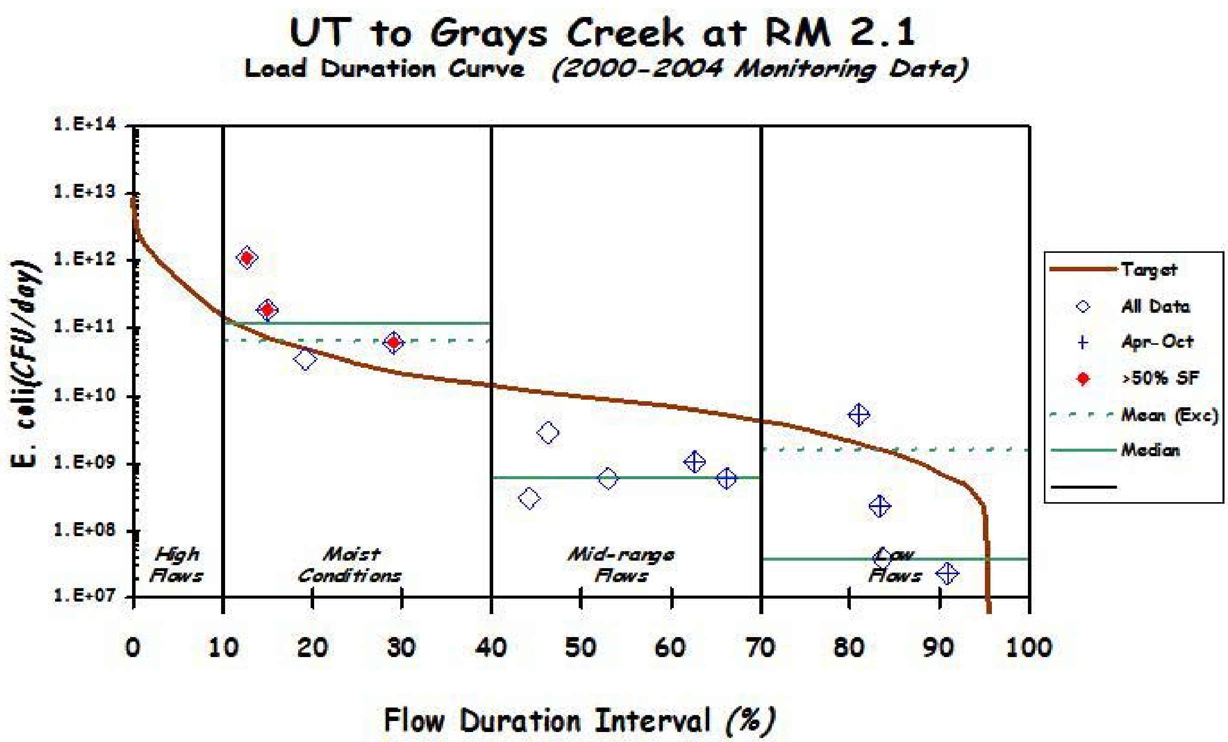


Figure E-41. E. Coli Load Duration Curve for Unnamed Tributary to Grays Creek at Mile 2.1.

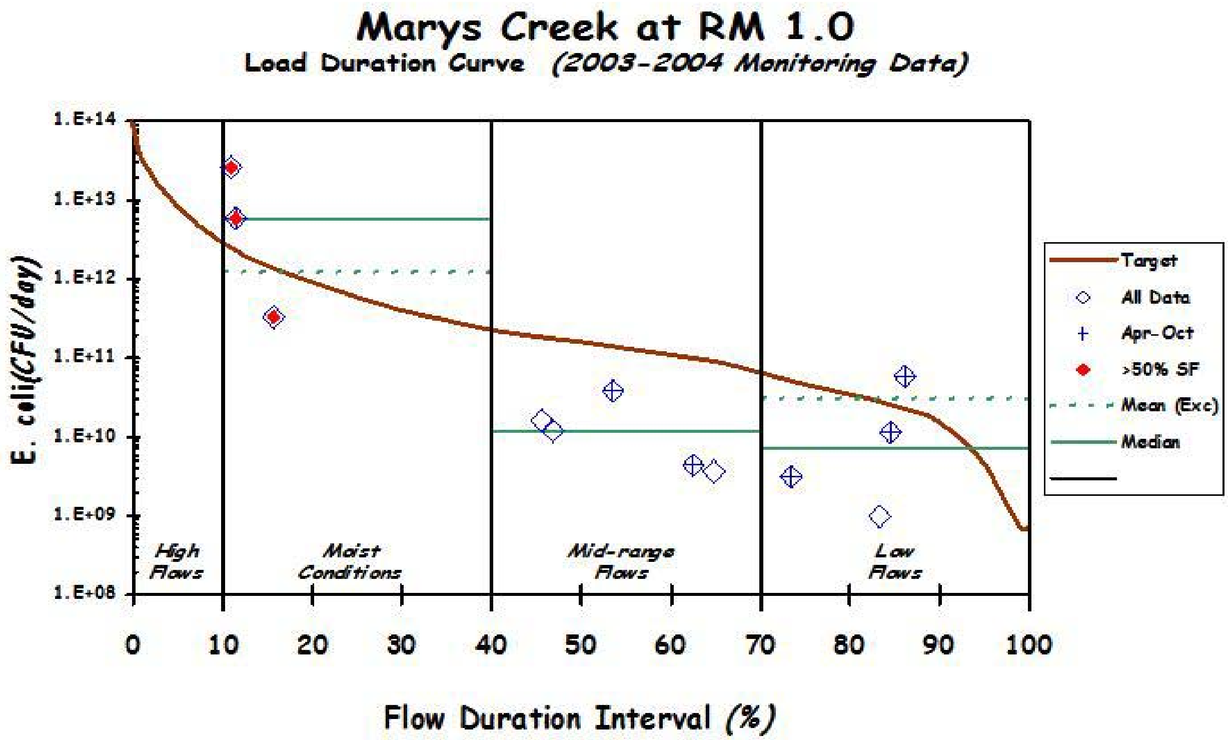


Figure E-42. E. Coli Load Duration Curve for Marys Creek at Mile 1.0.

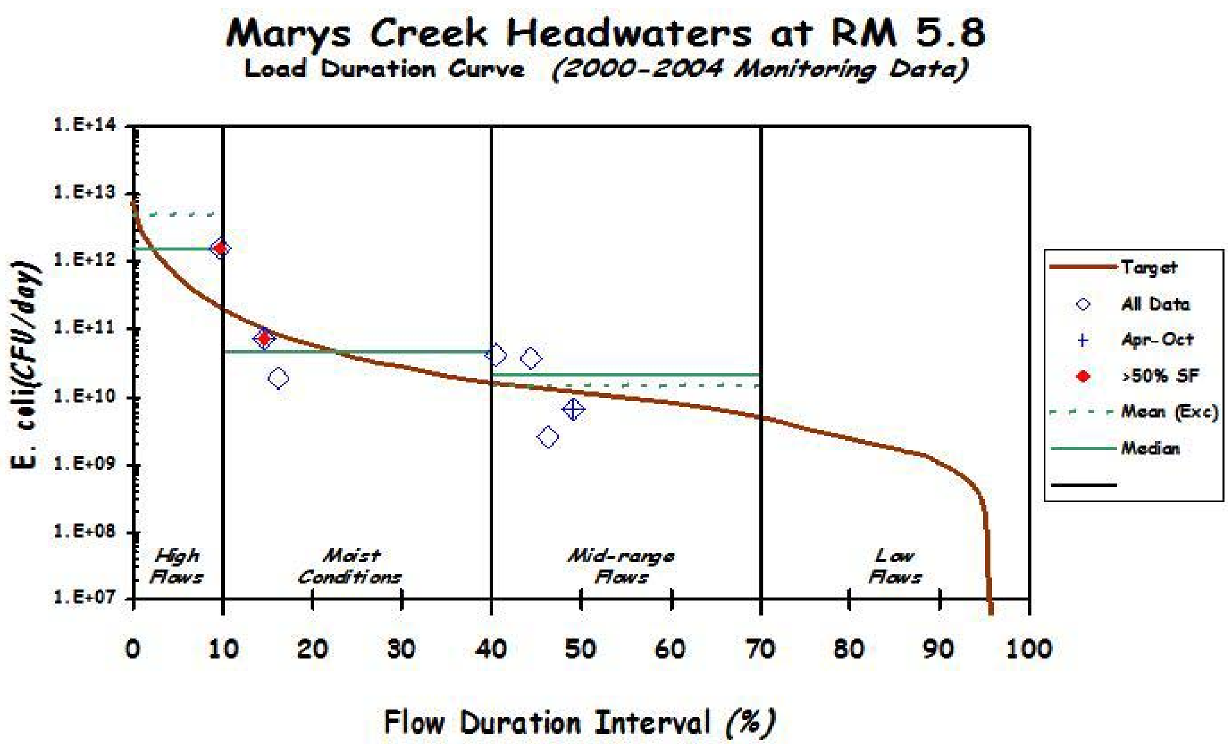


Figure E-43. E. Coli Load Duration Curve for Marys Creek Headwaters at Mile 5.8.

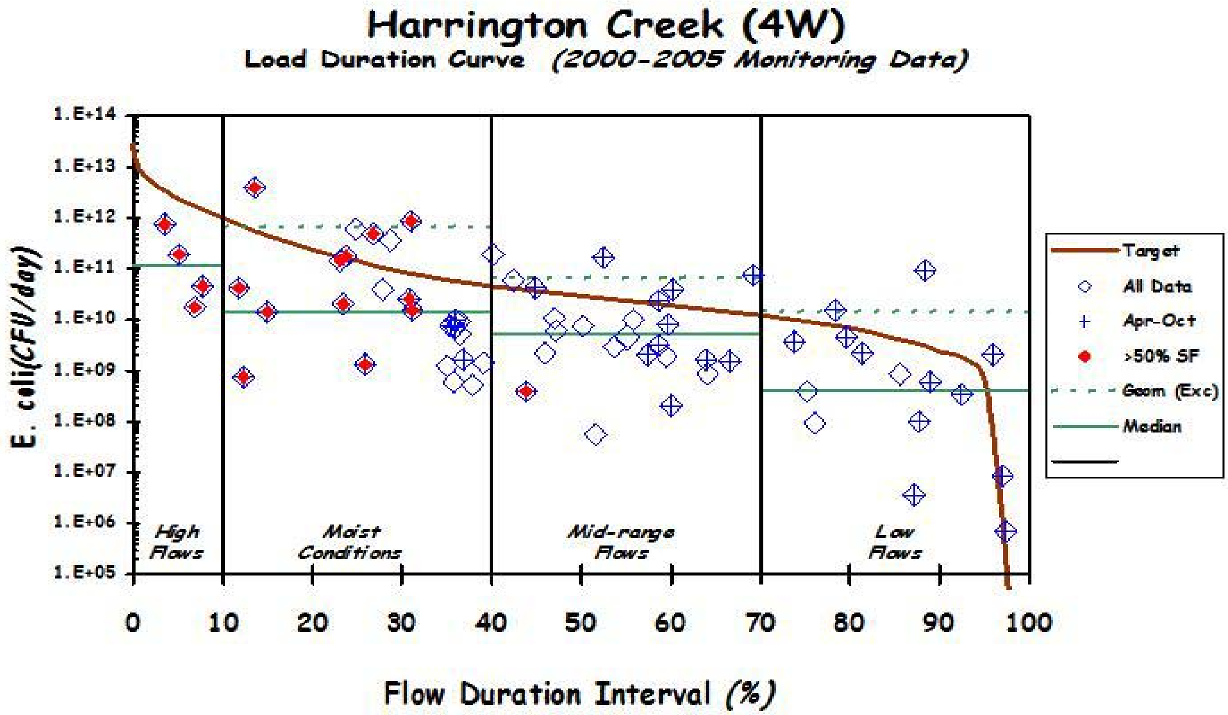


Figure E-44. E. Coli Load Duration Curve for Harrington Creek (4W).

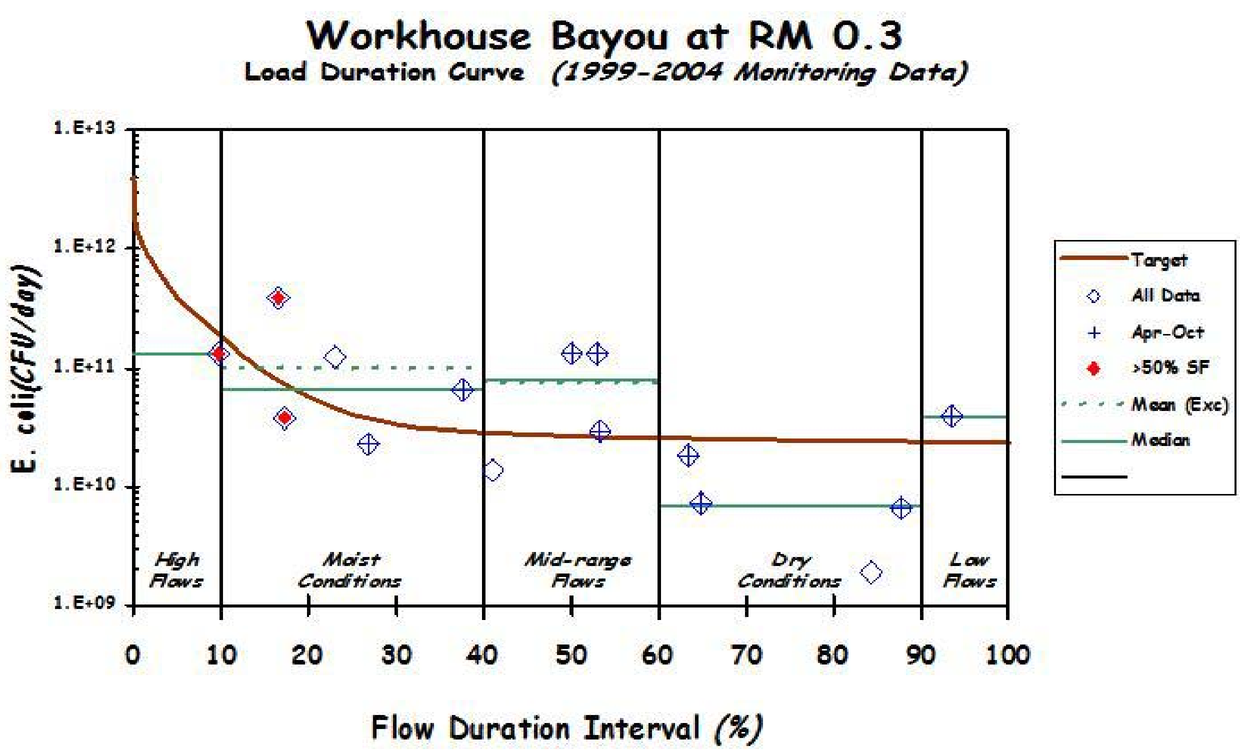


Figure E-45. E. Coli Load Duration Curve for Workhouse Bayou Mile 0.3.

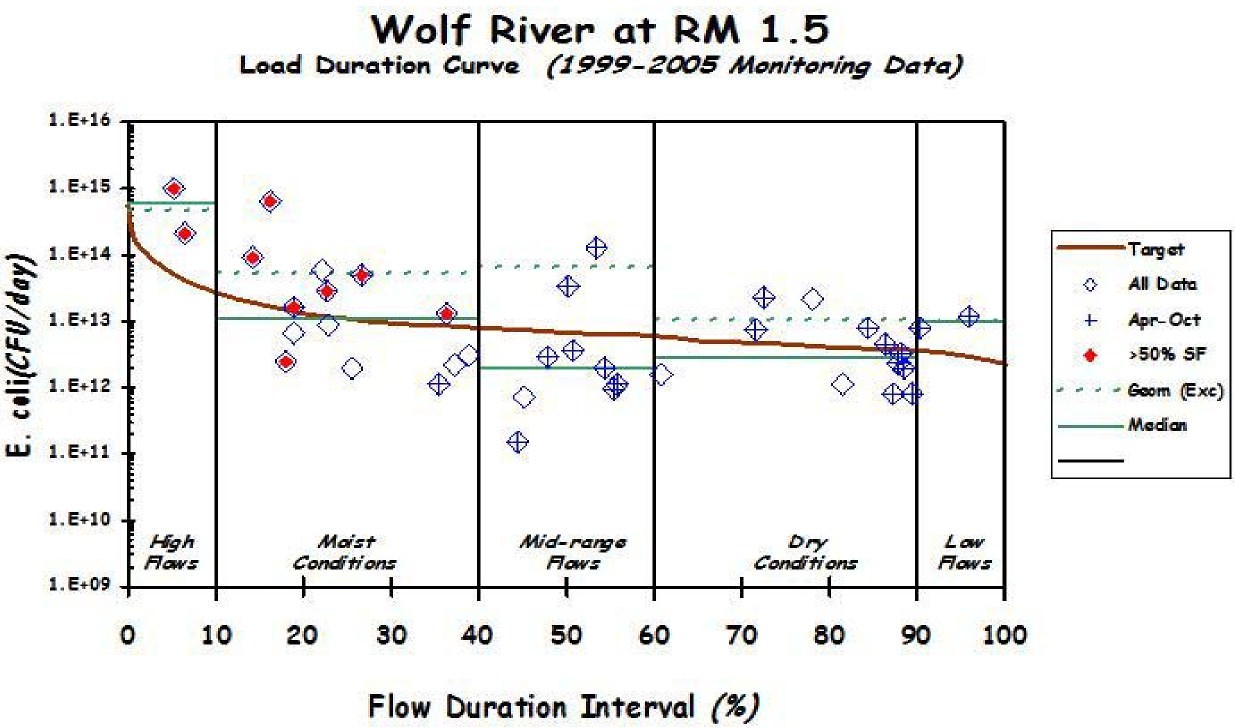


Figure E-46. E. Coli Load Duration Curve for Wolf River at Mile 1.5.

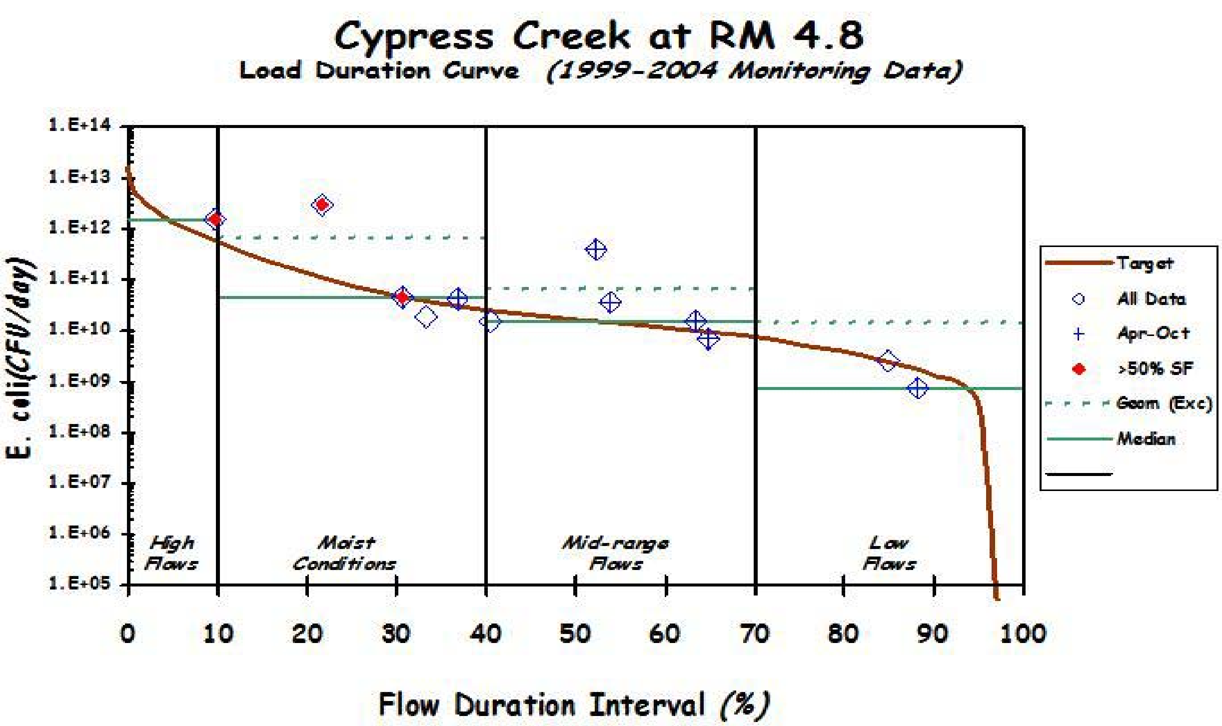


Figure E-47. E. Coli Load Duration Curve for Cypress Creek at Mile 4.8.

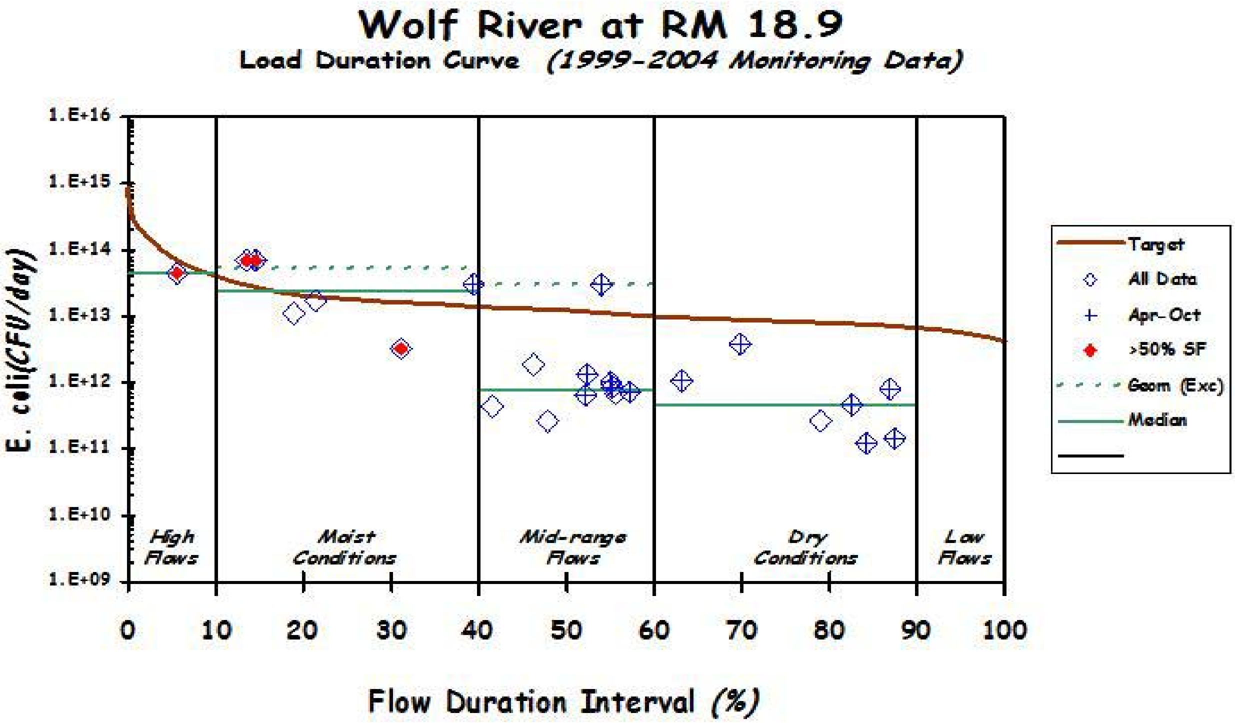


Figure E-48. E. Coli Load Duration Curve for Wolf River at Mile 18.9.

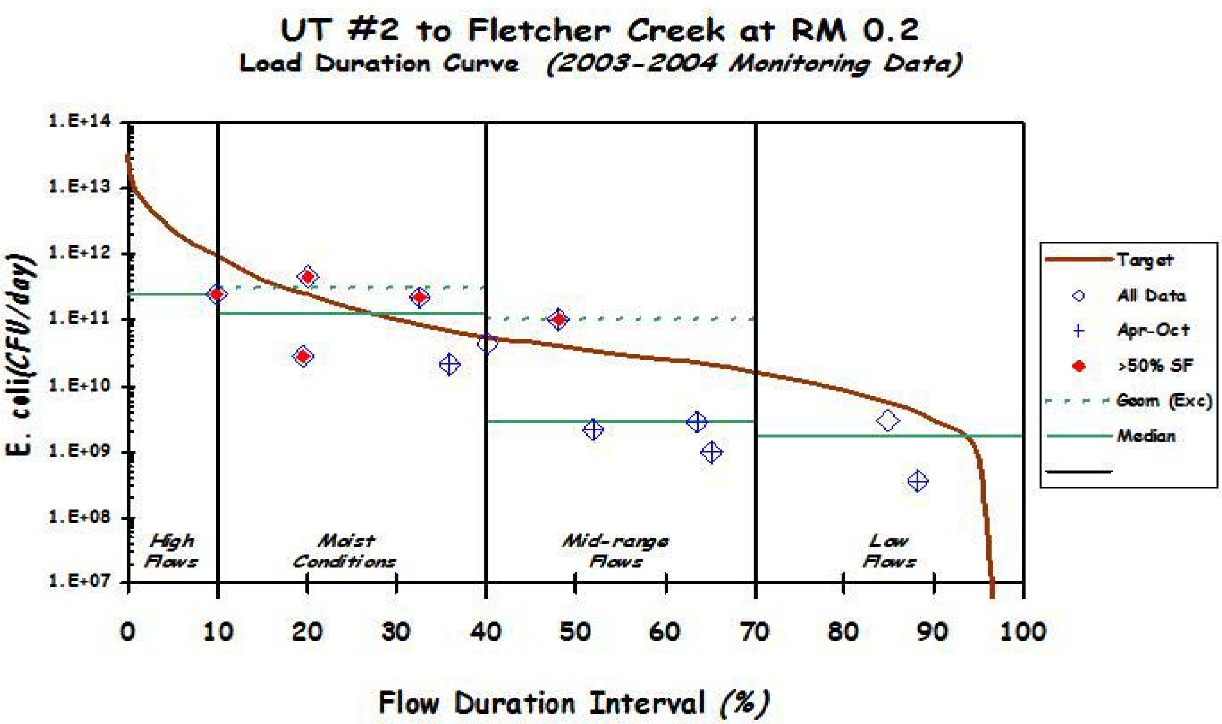


Figure E-49. E. Coli Load Duration Curve for Unnamed Tributary #2 to Fletcher Creek at Mile 0.2.

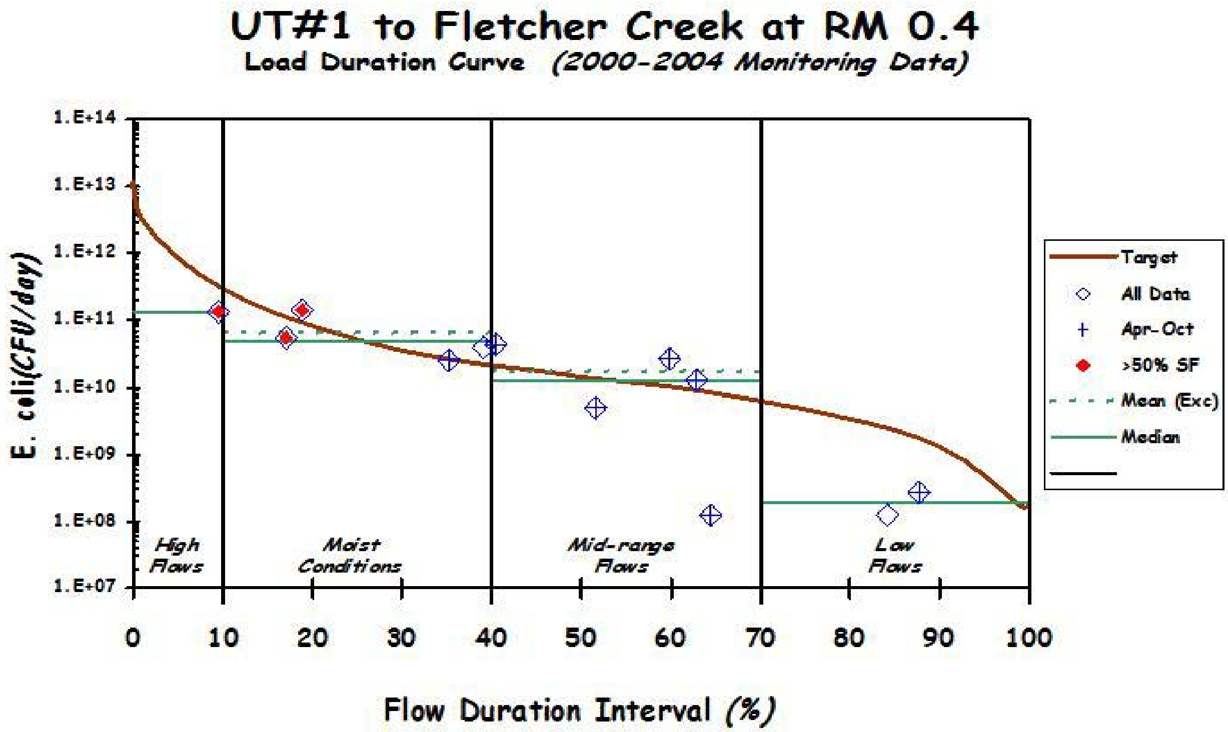


Figure E-50. E. Coli Load Duration Curve for Unnamed Tributary #1 to Fletcher Creek at Mile 0.4.

Table E-4. Summary of TMDLs, MOS, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Wolf River Watershed (HUC 08010210)

Waterbody Description	Hydrologic Condition			Flow[a]	PLRG	TMDL	MOS	WLAs				LAs
	Flow Zone	PDFE Range	Flow Range					WWTFs[b]	LCS	CAFOs	MS4s	
		(%)	(cfs)	(cfs)	(%)	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d/ac]	[CFU/d/ac]
Early Grove Creek Waterbody ID: **TN08010210009 – 0300** HUC-12: 0105	High Flows	0–10	13.8 - 488	26.41	0	6.07×10^{11}	6.07×10^{10}	NA	NA	NA	NA	8.55×10^{7}
	Moist	10-40	7.82 - 13.8	9.664	0	2.22×10^{11}	2.22×10^{10}	NA	NA	NA	NA	3.13×10^{7}
	Mid-Range	40–60	5.88 - 7.82	6.801	45.8	1.56×10^{11}	1.56×10^{10}	NA	NA	NA	NA	2.20×10^{7}
	Dry	60-90	4.04 - 5.88	4.896	0	1.13×10^{11}	1.13×10^{10}	NA	NA	NA	NA	1.59×10^{7}
	Low Flows	90–100	2.86 - 4.04	3.761	0	8.65×10^{10}	8.65×10^{9}	NA	NA	NA	NA	1.22×10^{7}
McKinnie Creek Waterbody ID: **TN08010210020 – 0300** HUC-12: 0201	High Flows	0–10	23.5 - 829	44.38	0	1.02×10^{12}	1.02×10^{11}	NA	NA	NA	NA	9.08×10^{7}
	Moist	10–40	13.5 - 23.5	16.68	17.8	3.84×10^{11}	3.84×10^{10}	NA	NA	NA	NA	3.41×10^{7}
	Mid-Range	40–60	10.1 - 13.5	11.75	22.8	2.70×10^{11}	2.70×10^{10}	NA	NA	NA	NA	2.40×10^{7}
	Dry	60-90	6.96 - 10.1	8.438	0	1.94×10^{11}	1.94×10^{10}	NA	NA	NA	NA	1.73×10^{7}
	Low Flows	90–100	4.90 - 6.96	6.438	0	1.48×10^{11}	1.48×10^{10}	NA	NA	NA	NA	1.32×10^{7}
May Creek Waterbody ID: **TN08010210020 – 0310** HUC-12: 0201	High Flows	0–10	18.3 - 638	34.16	0	7.86×10^{11}	7.86×10^{10}	NA	NA	NA	NA	7.81×10^{7}
	Moist	10–40	10.7 - 18.3	13.24	14.8	3.05×10^{11}	3.05×10^{10}	NA	NA	NA	NA	3.03×10^{7}
	Mid-Range	40–60	8.02 - 10.7	9.326	12.2	2.15×10^{11}	2.15×10^{10}	NA	NA	NA	NA	2.13×10^{7}
	Dry	60-90	5.49 - 8.02	6.669	0	1.54×10^{11}	1.54×10^{10}	NA	NA	NA	NA	1.52×10^{7}
	Low Flows	90–100	3.87 - 5.49	5.079	0	1.17×10^{11}	1.17×10^{10}	NA	NA	NA	NA	1.12×10^{7}
North Fork Creek Waterbody ID: **TN08010210020 – 0400** HUC-12: 0201	High Flows	0–10	15.2 - 520	28.41	0	3.38×10^{11}	3.38×10^{10}	NA	NA	NA	NA	2.35×10^{7}
	Moist	10–40	8.84 - 15.2	10.93	16.0	1.30×10^{11}	1.30×10^{10}	NA	NA	NA	NA	9.05×10^{6}
	Mid-Range	40–60	6.62 - 8.84	7.718	47.5	9.18×10^{10}	9.18×10^{9}	NA	NA	NA	NA	6.39×10^{6}
	Dry	60-90	4.53 - 6.62	5.499	0	6.54×10^{10}	6.54×10^{9}	NA	NA	NA	NA	4.55×10^{6}
	Low Flows	90–100	3.20 - 4.53	4.192	0	4.99×10^{10}	4.99×10^{9}	NA	NA	NA	NA	3.47×10^{6}

Table E-4. Summary of TMDLs, MOS, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Wolf River Watershed (HUC 08010210) (Cont.)

Waterbody Description	Hydrologic Condition			Flow[a]	PLRG	TMDL	MOS	WLAs				LAs
	Flow Zone	PDFE Range	Flow Range					WWTFs[b]	LCS	CAFOs	MS4s	
		(%)	(cfs)	(cfs)	(%)	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d/ac]	[CFU/d/ac]
North Fork Wolf River Waterbody ID: **TN08010210020 – 2000** HUC-12: 0202	High Flows	0–10	103 - 3,440	186.5	0	2.22×10^{12}	2.22×10^{11}	NA	NA	NA	NA	5.89×10^{8}
	Moist	10–40	60.6 - 103	73.89	10.9	8.79×10^{11}	8.79×10^{10}	NA	NA	NA	NA	2.33×10^{8}
	Mid-Range	40–60	44.8 - 60.6	52.70	26.8	6.27×10^{11}	6.27×10^{10}	NA	NA	NA	NA	1.66×10^{8}
	Dry	60-90	30.4 - 44.8	37.48	0	4.46×10^{11}	4.46×10^{10}	NA	NA	NA	NA	1.18×10^{8}
	Low Flows	90–100	21.4 - 30.4	28.11	0	3.35×10^{11}	3.35×10^{10}	NA	NA	NA	NA	8.87×10^{7}
Hurricane Creek Waterbody ID: **TN08010210004 – 0100** HUC-12: 0301	High Flows	0–10	16.0 - 529	49.13	61.1	1.13×10^{12}	1.13×10^{11}	NA	NA	NA	NA	2.31×10^{8}
	Moist	10-40	1.30 – 16.0	3.026	4.3	6.96×10^{10}	6.96×10^{9}	NA	NA	NA	NA	1.42×10^{7}
	Mid-Range	40–70	0.381 - 1.30	0.7807	15.3	1.80×10^{10}	1.80×10^{9}	NA	NA	NA	NA	3.66×10^{6}
	Low Flows	70–100	0.0 - 0.381	0.1413	0	3.25×10^{8}	3.25×10^{7}	NA	NA	NA	NA	6.63×10^{5}
UT to Wolf River Waterbody ID: **TN08010210004 – 0400** HUC-12: 0301	High Flows	0–10	15.4 - 724	50.35	88.5	1.16×10^{12}	1.16×10^{11}	NA	0	NA	NA	1.48×10^{8}
	Moist	10–40	1.26 - 15.4	2.553	22.8	5.87×10^{10}	5.87×10^{9}	NA	0	NA	NA	7.49×10^{6}
	Mid-Range	40–70	0.374 - 1.26	0.7508	20.4	1.73×10^{10}	1.73×10^{9}	NA	0	NA	NA	2.20×10^{6}
	Low Flows	70–100	0.0 - 0.374	0.1194	61.1	2.75×10^{9}	2.75×10^{8}	NA	0	NA	NA	3.50×10^{5}
Russell Creek Waterbody ID: **TN08010210004 – 0500** HUC-12: 0301	High Flows	0–10	17.8 - 842	55.63	83.8	1.28×10^{12}	1.28×10^{11}	NA	NA	NA	NA	2.35×10^{8}
	Moist	10-40	1.41 - 17.8	2.813	30.6	6.47×10^{10}	6.47×10^{9}	NA	NA	NA	NA	1.19×10^{7}
	Mid-Range	40–70	0.450 - 1.41	0.8573	12.2	1.97×10^{10}	1.97×10^{9}	NA	NA	NA	NA	3.62×10^{6}
	Low Flows	70–100	0.0 - 0.450	0.1627	54.6	3.74×10^{9}	3.74×10^{8}	NA	NA	NA	NA	6.88×10^{5}

Table E-4. Summary of TMDLs, MOS, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Wolf River Watershed (HUC 08010210) (Cont.)

Waterbody Description	Hydrologic Condition			Flow[a]	PLRG	TMDL	MOS	WLAs				LAs
	Flow Zone	PDFE Range	Flow Range					WWTFs[b]	LCS	CAFOs	MS4s	
		(%)	(cfs)	(cfs)	(%)	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d/ac]	[CFU/d/ac]
Teague Branch Waterbody ID: **TN08010210005 – 0100** HUC-12: 0302	High Flows	0–10	16.0 - 545	49.60	61.1	1.14×10^{12}	1.14×10^{11}	NA	NA	NA	NA	1.57×10^{8}
	Moist	10–40	1.29 - 16.0	2.964	9.5	6.82×10^{10}	6.82×10^{9}	NA	NA	NA	NA	9.40×10^{6}
	Mid-Range	40–70	0.381 - 1.29	0.7791	30.6	1.79×10^{10}	1.79×10^{9}	NA	NA	NA	NA	2.47×10^{6}
	Low Flows	70–100	0.0 - 0.381	0.1417	22.8	3.26×10^{9}	3.26×10^{8}	NA	NA	NA	NA	4.49×10^{5}
Grissum Creek Waterbody ID: **TN08010210005 – 1000** HUC-12: 0302	High Flows	0–10	33.2 - 1,094	98.00	38.5	2.25×10^{12}	2.25×10^{11}	NA	NA	NA	NA	1.24×10^{8}
	Moist	10-40	2.68 - 33.2	6.443	8.7	1.48×10^{11}	1.48×10^{10}	NA	NA	NA	NA	8.14×10^{6}
	Mid-Range	40–70	0.800 - 2.68	1.605	20.4	3.69×10^{10}	3.69×10^{9}	NA	NA	NA	NA	2.03×10^{6}
	Low Flows	70–100	0.0 - 0.800	0.0565	0	1.30×10^{9}	1.30×10^{8}	NA	NA	NA	NA	7.14×10^{4}
Alexander Creek Waterbody ID: **TN08010210021 – 0100** HUC-12: 0303	High Flows	0–10	27.9 - 911	84.15	71.1	1.94×10^{12}	1.94×10^{11}	NA	NA	NA	NA	2.31×10^{8}
	Moist	10–40	2.21 - 27.9	5.160	0	1.19×10^{11}	1.19×10^{10}	NA	NA	NA	NA	1.41×10^{7}
	Mid-Range	40–70	0.654 - 2.21	1.334	28.4	3.07×10^{10}	3.07×10^{9}	NA	NA	NA	NA	3.66×10^{6}
	Low Flows	70–100	0.0 - 0.654	0.2469	20.4	5.68×10^{9}	5.68×10^{8}	NA	NA	NA	NA	6.77×10^{5}
Shaws Creek Waterbody ID: **TN08010210021 – 1000** HUC-12: 0303	High Flows	0–10	102 - 3,330	297.4	45.2	6.84×10^{12}	6.84×10^{11}	7.13×10^{8}	NA	NA	NA	2.69×10^{8}
	Moist	10–40	7.95 - 102	19.95	0	4.59×10^{11}	4.59×10^{10}	7.13×10^{8}	NA	NA	NA	1.80×10^{7}
	Mid-Range	40–60	3.89 - 7.95	5.538	20.4	1.27×10^{11}	1.27×10^{10}	7.13×10^{8}	NA	NA	NA	4.97×10^{6}
	Dry	60-90	0.554 - 3.89	1.620	17.5	3.73×10^{10}	3.73×10^{9}	7.13×10^{8}	NA	NA	NA	1.43×10^{6}
	Low Flows	90–100	0.0309 - 0.554	0.1606	0	3.69×10^{9}	3.69×10^{8}	7.13×10^{8}	NA	NA	NA	1.32×10^{5}

Table E-4. Summary of TMDLs, MOS, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Wolf River Watershed (HUC 08010210) (Cont.)

Waterbody Description	Hydrologic Condition			Flow[a]	PLRG	TMDL	MOS	WLAs				LAs
	Flow Zone	PDFE Range	Flow Range					WWTFs[b]	LCS	CAFOs	MS4s	
		(%)	(cfs)	(cfs)	(%)	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d/ac]	[CFU/d/ac]
Wolf River Waterbody ID: **TN08010210002 – 2000** HUC-12: 0304	High Flows	0–10	1,711 - 37,231	3318	0	7.63×10^{13}	7.63×10^{12}	4.31×10^{11}	0	NA	1.52×10^{8}	1.52×10^{8}
	Moist	10–40	613 - 1,711	773.7	17.2	1.78×10^{13}	1.78×10^{12}	4.31×10^{11}	0	NA	3.47×10^{7}	3.47×10^{7}
	Mid-Range	40–60	440 - 613	526.0	7.5	1.21×10^{13}	1.21×10^{12}	4.31×10^{11}	0	NA	2.33×10^{7}	2.33×10^{7}
	Dry	60–90	289 - 440	354.7	12.2	8.16×10^{12}	8.16×10^{11}	4.31×10^{11}	0	NA	1.54×10^{7}	1.54×10^{7}
	Low Flows	90–100	187 - 289	248.0	7.5	5.70×10^{12}	5.70×10^{11}	4.31×10^{11}	0	NA	1.05×10^{7}	1.05×10^{7}
Johnson Creek Waterbody ID: **TN08010210003 – 0100** HUC-12: 0304	High Flows	0–10	8.52 - 312	26.58	0	6.11×10^{11}	6.11×10^{10}	NA	NA	NA	1.36×10^{7}	1.36×10^{7}
	Moist	10–40	0.704 – 8.52	1.621	61.1	3.73×10^{10}	3.73×10^{9}	NA	NA	NA	8.27×10^{6}	8.27×10^{6}
	Mid-Range	40–70	0.213 - 0.704	0.4288	15.1	9.86×10^{9}	9.86×10^{8}	NA	NA	NA	2.19×10^{6}	2.19×10^{6}
	Low Flows	70–100	0.0 - 0.213	0.0802	61.1	1.85×10^{9}	1.85×10^{8}	NA	NA	NA	4.09×10^{5}	4.09×10^{5}
UT to Grays Creek Waterbody ID: **TN08010210022 – 0100** HUC-12: 0305	High Flows	0–10	6.64 - 363	23.62	0	5.43×10^{11}	5.43×10^{10}	NA	0	NA	2.10×10^{8}	2.10×10^{8}
	Moist	10-40	0.614 - 6.64	1.316	53.7	3.03×10^{10}	3.03×10^{9}	NA	0	NA	1.17×10^{7}	1.17×10^{7}
	Mid-Range	40–70	0.182 - 0.614	0.3546	0	8.16×10^{9}	8.16×10^{8}	NA	0	NA	3.15×10^{6}	3.15×10^{6}
	Low Flows	70–100	0.0 - 0.182	0.0582	12.2	1.34×10^{9}	1.34×10^{8}	NA	0	NA	5.17×10^{5}	5.17×10^{5}
Marys Creek Waterbody ID: **TN08010210022 – 0300** HUC-12: 0305	High Flows	0–10	127 - 4317	362.8	0	8.34×10^{12}	8.34×10^{11}	NA	NA	NA	7.38×10^{8}	7.38×10^{8}
	Moist	10–40	9.91 - 127	25.57	50.5	5.88×10^{11}	5.88×10^{10}	NA	NA	NA	5.20×10^{7}	5.20×10^{7}
	Mid-Range	40–70	2.84 - 9.91	5.855	0	1.35×10^{11}	1.35×10^{10}	NA	NA	NA	1.19×10^{7}	1.19×10^{7}
	Low Flows	70–100	0.0 - 2.84	1.091	15.3	2.51×10^{10}	2.51×10^{9}	NA	NA	NA	2.22×10^{4}	2.22×10^{4}

Table E-4. Summary of TMDLs, MOS, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Wolf River Watershed (HUC 08010210) (Cont.)

Waterbody Description	Hydrologic Condition			Flow[a]	PLRG	TMDL	MOS	WLAs				LAs
	Flow Zone	PDFE Range	Flow Range					WWTFs[b]	LCS	CAFOs	MS4s	
		(%)	(cfs)	(cfs)	(%)	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d/ac]	[CFU/d/ac]
Marys Creek Headwaters Waterbody ID: **TN08010210022 – 0350** HUC-12: 0305	High Flows	0–10	8.68 - 325	27.34	87.1	6.29×10^{11}	6.29×10^{10}	NA	NA	NA	2.37×10^{8}	2.37×10^{8}
	Moist	10-40	0.719 – 8.68	1.622	0	3.73×10^{10}	3.73×10^{9}	NA	NA	NA	1.41×10^{7}	1.41×10^{7}
	Mid-Range	40–70	0.211 - 0.719	0.4346	30.6	1.00×10^{10}	1.00×10^{9}	NA	NA	NA	3.77×10^{6}	3.77×10^{6}
	Low Flows	70–100	0.0 - 0.211	0.0766	0	1.76×10^{9}	1.76×10^{8}	NA	NA	NA	6.65×10^{5}	6.65×10^{5}
Harrington Creek Waterbody ID: **TN08010210001 – 0100** HUC-12: 0306	High Flows	0–10	43.6 - 1,189	99.71	0	2.29×10^{12}	2.29×10^{11}	NA	0	NA	2.78×10^{8}	2.78×10^{8}
	Moist	10-40	1.91 - 43.6	6.133	16.7	1.41×10^{11}	1.41×10^{10}	NA	0	NA	1.71×10^{7}	1.71×10^{7}
	Mid-Range	40–70	0.541 - 1.91	1.018	14.9	2.34×10^{10}	2.34×10^{9}	NA	0	NA	2.84×10^{6}	2.84×10^{6}
	Low Flows	70–100	0.0 - 0.541	0.1860	13.9	4.28×10^{9}	4.28×10^{8}	NA	0	NA	5.18×10^{4}	5.18×10^{4}
Workhouse Bayou Waterbody ID: **TN08010210001 – 0300** HUC-12: 0306	High Flows	0–10	15.4 - 329	32.89	0	7.57×10^{11}	7.57×10^{10}	NA	0	NA	4.41×10^{8}	4.41×10^{8}
	Moist	10-40	2.37 – 15.4	3.409	20.5	7.84×10^{10}	7.84×10^{9}	NA	0	NA	2.99×10^{7}	2.99×10^{7}
	Mid-Range	40–60	2.15 - 2.37	2.231	30.6	5.13×10^{10}	5.13×10^{9}	NA	0	NA	2.75×10^{7}	2.75×10^{7}
	Dry	60-90	1.99 – 2.15	2.050	0	4.72×10^{10}	4.72×10^{9}	NA	0	NA	2.64×10^{7}	2.64×10^{7}
	Low Flows	90–100	1.97 - 1.99	1.969	0	4.52×10^{10}	4.52×10^{9}	NA	0	NA	2.64×10^{7}	2.64×10^{7}
Wolf River Waterbody ID: **TN08010210001 – 1000** HUC-12: 0306	High Flows	0–10	2,236 - 48,112	4448	87.5	5.29×10^{13}	5.29×10^{12}	4.31×10^{11}	0	NA	2.04×10^{8}	2.04×10^{8}
	Moist	10–40	672 - 2,236	907.8	32.1	1.08×10^{13}	1.08×10^{12}	4.31×10^{11}	0	NA	4.11×10^{7}	4.11×10^{7}
	Mid-Range	40–60	491 - 672	578.0	19.4	6.88×10^{12}	6.88×10^{11}	4.31×10^{11}	0	NA	2.58×10^{7}	2.58×10^{7}
	Dry	60-90	302 – 491	373.7	22.1	4.45×10^{12}	4.45×10^{11}	4.31×10^{11}	0	NA	1.64×10^{7}	1.64×10^{7}
	Low Flows	90–100	190 - 302	260.0	65.2	3.09×10^{12}	3.09×10^{11}	4.31×10^{11}	0	NA	1.12×10^{7}	1.12×10^{7}

Table E-4. Summary of TMDLs, MOS, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Wolf River Watershed (HUC 08010210) (Cont.)

Waterbody Description	Hydrologic Condition: Flow Zone	PDFE Range (%)	Flow Range (cfs)	Flow[a] (cfs)	PLRG (%)	TMDL [CFU/d]	MOS [CFU/d]	WLAs: WWTFs[b] [CFU/d]	WLAs: LCS [CFU/d]	WLAs: CAFOs [CFU/d]	WLAs: MS4s [CFU/d/ac]	LAs [CFU/d/ac]
Cypress Creek Waterbody ID: **TN08010210032 – 1000** HUC-12: 0306	High Flows	0–10	24.7 - 737	59.85	61.1	1.38×10^{12}	1.38×10^{11}	NA	0	NA	1.03×10^{8}	1.03×10^{8}
	Moist	10–40	1.11 - 24.7	3.340	31.2	7.68×10^{10}	7.68×10^{9}	NA	0	NA	5.74×10^{6}	5.74×10^{6}
	Mid-Range	40–70	0.317 - 1.11	0.6047	38.1	1.39×10^{10}	1.39×10^{9}	NA	0	NA	1.04×10^{6}	1.04×10^{6}
	Low Flows	70–100	0.0 - 0.317	0.1064	12.5	2.45×10^{9}	2.45×10^{8}	NA	0	NA	1.83×10^{5}	1.83×10^{5}
Wolf River Waterbody ID: **TN08010210004 – 0100** HUC-12: 0301	High Flows	0–10	1,719 - 37,453	3343	0	7.69×10^{13}	7.69×10^{12}	4.31E+11	0	NA	1.53×10^{8}	1.53×10^{8}
	Moist	10–40	614 - 1,719	776.0	28.3	1.79×10^{13}	1.79×10^{12}	4.31E+11	0	NA	3.49×10^{7}	3.49×10^{7}
	Mid-Range	40–60	443 - 614	526.2	6.1	1.21×10^{13}	1.21×10^{12}	4.31E+11	0	NA	2.33×10^{7}	2.33×10^{7}
	Dry	60–90	289 - 443	355.4	0	8.17×10^{12}	8.17×10^{11}	4.31E+11	0	NA	1.55×10^{7}	1.55×10^{7}
	Low Flows	90–100	187 - 289	248.4	0	5.71×10^{12}	5.71×10^{11}	4.31E+11	0	NA	1.05×10^{7}	1.05×10^{7}
UT to Fletcher Creek Waterbody ID: **TN08010210023 – 0100** HUC-12: 0308	High Flows	0–10	41.0 - 1,384	104.6	0	2.41×10^{12}	2.41×10^{11}	NA	0	NA	3.15×10^{8}	3.15×10^{8}
	Moist	10–40	2.43 - 41.0	6.739	27.0	1.55×10^{11}	1.55×10^{10}	NA	0	NA	2.03×10^{7}	2.03×10^{7}
	Mid-Range	40–70	0.695 - 2.43	1.333	12.2	3.07×10^{10}	3.07×10^{9}	NA	0	NA	4.01×10^{6}	4.01×10^{6}
	Low Flows	70–100	0.0 - 0.695	0.2402	0	5.53×10^{9}	5.53×10^{8}	NA	0	NA	7.23×10^{5}	7.23×10^{5}
UT to Fletcher Creek Waterbody ID: **TN08010210023 – 0200** HUC-12: 0308	High Flows	0–10	13.0 - 520	37.36	0	8.59×10^{11}	8.59×10^{10}	NA	0	NA	3.02×10^{8}	3.02×10^{8}
	Moist	10–40	0.927 - 13.0	2.307	19.8	5.31×10^{10}	5.31×10^{9}	NA	0	NA	1.87×10^{7}	1.87×10^{7}
	Mid-Range	40–70	0.277 - 0.927	0.5254	28.0	1.21×10^{10}	1.21×10^{9}	NA	0	NA	4.25×10^{6}	4.25×10^{6}
	Low Flows	70–100	0.008 - 0.277	0.0077	0	2.24×10^{9}	2.24×10^{8}	NA	0	NA	7.89×10^{5}	7.89×10^{5}

Table E-4. Summary of TMDLs, MOS, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Wolf River Watershed (HUC 08010210) (Cont.)

Waterbody Description	Hydrologic Condition			Flow[a]	PLRG	TMDL	MOS	WLAs				LAs
	Flow Zone	PDFE Range	Flow Range					WWTFs[b]	LCS	CAFOs	MS4s	
		(%)	(cfs)	(cfs)	(%)	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d/ac]	[CFU/d/ac]
Fletcher Creek Waterbody ID: **TN08010210023 – 1000** HUC-12: 0308	High Flows	0–10	120 - 3,669	291.7	8.2	6.71×10^{12}	6.71×10^{11}	NA	0	NA	2.92×10^{8}	2.92×10^{8}
	Moist	10–40	7.56 - 120	20.50	12.3	4.72×10^{11}	4.72×10^{10}	NA	0	NA	2.05×10^{7}	2.05×10^{7}
	Mid-Range	40–70	2.17 - 7.56	4.111	13.4	9.46×10^{10}	9.46×10^{9}	NA	0	NA	4.12×10^{6}	4.12×10^{6}
	Low Flows	70–100	0.008 - 2.17	0.7687	16.6	1.77×10^{10}	1.77×10^{9}	NA	0	NA	7.70×10^{5}	7.70×10^{5}

Note: *NA = Not applicable.*
PDFE = Percent Days Flow Exceeded.
PLRG = Percent Load Reduction Goal.
LCS = Leaking Collection Systems.
Shaded Flow Zone for each waterbody represents the critical flow zone.
a. Flow applied to TMDL, MOS, and allocation (WLA [MS4] and LA) calculations. Flows represent the median value in the respective hydrologic flow zone.
b. WLAs for WWTFs expressed as E. coli loads (CFU/day). Current and future WWTFs must meet water quality standards at the point of discharge as specified in their NPDES permits. At no time shall concentration exceed appropriate, site-specific (487 CFU/100 mL or 941 CFU/100 mL) water quality criteria.

APPENDIX F

Public Notice of Proposed Total Maximum Daily Loads (TMDLs) for E. Coli in the Wolf River Watershed (HUC 08010210)

DIVISION OF WATER POLLUTION CONTROL

PUBLIC NOTICE OF AVAILABILITY OF PROPOSED TOTAL MAXIMUM DAILY LOAD (TMDL) FOR E. COLI IN THE WOLF RIVER WATERSHED (HUC 08010210), TENNESSEE

Announcement is hereby given of the availability of Tennessee's proposed total maximum daily load (TMDL) for E. coli in the Wolf 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.

A number of waterbodies are listed on Tennessee's Final 2006 303(d) List as not supporting designated use classifications due, in part, to discharge of E. coli from MS4 areas, pasture grazing, livestock feeding operations, and sources outside of the state. The TMDL utilizes Tennessee's general water quality criteria, recently collected site specific water quality data, continuous flow data from three USGS discharge monitoring stations located in the watershed, a calibrated hydrologic model, and load duration curves to establish allowable loadings of E. coli which will result in reduced in-stream concentrations and attainment of water quality standards. The TMDL requires reductions of E. coli loading on the order of 15-65% for the listed waterbodies.

The proposed Wolf River E. coli TMDL document can be downloaded from the following website:

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

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

Dennis M. Borders, P.E., Watershed Management Section
Telephone: 615-532-0706

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

Persons wishing to comment on the proposed TMDL are invited to submit their comments in writing no later than July 16, 2007 to:

Division of Water Pollution Control
Watershed Management Section
7th 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, 7th 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 G

Public Comments Received

G.1 Shelby County

From: "Masin, Chris" <Chris.Masin@shelbycountytn.gov>
To: <dennis.borders@state.tn.us>
Date: 7/5/2007 8:37 AM
Subject: Written public comments

Mr. Borders,

I am with the Shelby County SW program and have some questions concerning the TMDL proposed for the Wolf River Watershed.

1.) With regards to the monitoring requirements, if an MS4 has only one listed impaired stream segment within its boundaries, then it needs to complete one round of 5 samples once every five years. Is that correct? And if a municipality is within the watershed, but has no impaired stream segments then there is no requirement to sample.

What is involved and what recordable data is required from Visual Stream Surveys.

2.) Whom should public comments be addressed to and what the best address. Do you except email comments? If so, to whom can those comments be addressed to and what is the address?

Thank you for your help in this matter.

Chris Masin, Senior Engineer

Office (901) 545-4086
Fax (901) 545-3963
Shelby County Engineering Dept.
160 N. Main, Suite 350
Memphis, TN 38103

<u>Comments from Shelby County MS4</u>

From: Chris Masin, P.E. 'Chris.Masin@shelbycountytn.gov'
To: Dennis Borders, P.E. 'Dennis.Borders@state.tn.us'
Date: July 13, 2007
Subject: Proposed TMDL for E. Coli
Wolf River Watershed (HUC 08010210)
Public Comments

Below are comments received from engineering staff and other local stakeholder groups:

3.) Introduction XI, in the Critical Conditions, it states that water quality data for a period of up to nearly seven years is used for the load duration curve analysis, however, a 10-year period is used for the model simulation. What amount of deviation does this cause in the results and why is that not accounted for in the Las?

4.) Section 3.0, Land Use data used in the analysis is from the period 1990-1993. The land use characteristics of unincorporated Shelby County have change drastically during the last 14 years. The Memphis/Shelby County Planning Organization has up-to-date data. Could the updated classification percentages be reentered into the appropriate local models and LAs be updated prior to a five year period?

5.) Section 6.0, We believe that the model only incorporates data from three City of Memphis sites. Data should exist for collected samples at:

a. Wolf River at McLean Ext.
b. Wolf River at Austin Peay
c. Grays Creek at Walnut Grove
d. Cypress Creek at Evergreen

If the data exists and in the watershed, why is it not considered?

6.) Regarding the sampling point located at Fletcher Creek at Sycamore view, on occasion, the Wolf River would crest and it would result in stagnant water and the sampling point was moved upstream to North Shelby Oaks Dr. Would that cause any significant change in LAs?

7.) Section 6.0, The paragraph starting:
"Most of the water quality monitoring stations have at least one E. Coli sample value reported as > 2419.2. In addition, at many of these sites, the maximum E. Coli sample value is > 2419.2" is confusing and in Table 3 and the corresponding data in the appendix on page B-12 show a value of 24192 for CYPRE004.8SH. Is this a data entry error, or is the value correct?

8.) Not enough data was collected to calculate geometric means at any of the monitoring stations. What amount of deviation does this cause in the results and why is that not accounted for in the LAs?

9.) Section 7.1.1, WWTFs considered in the 2003 Wolf River Watershed TMDL included:

- Alpha Corporation (TN0000442)
- Troxel Manufacturing Moscow (TN0000451)
  Number of quarter years in non-compliance (out of 13 possible): 6
- Grand Junction Oxidation Pond (TN0022560)
- Moscow STP (TN0021164)
  Number of quarter years in non-compliance (out of 13 possible): 6
- Northwest TN Headstart Center (TN0065293)
- Rocky Woods Estates (TN0056391)
- Dogwood Village (TN0055069)

Have these sites quit operating and are no longer discharging any wastes?

- In addition, the Springhill School Moscow (TN 0023752) is a listed WWTP that is not considered.

10.) It is noted that a WWTF listed within this proposed TMDL is the Maynard Stiles STP in Memphis. This plant discharges does not discharge into the Wolf River Watershed, but rather, directly into the Mississippi River. Loading from this source should not be included in the model.

11.) Section 7.1.3, there is suspected to be a large pig CAFO north of Moscow that is operational, however a permit could not be found and, unfortunately, an address or location could not be found in time before the closing of the public comment period. If they are found to be a contributor can the model be adjusted?

General Comments

12.) As cited, 30% of the Wolf River Watershed is within Mississippi. Unless the jurisdictions within Mississippi are being held to the same standard that the communities in Tennessee are, it would appear that Shelby County must remediate for other communities.

13.) As cited, 80% of all E. Coli contamination is non-human related. Should the MS4s be tasked with eliminating a pathogen that it has low control over? A number of stream segments list “discharge from the MS4” as the only source of pollution. Since humans contribute only a small amount of the pathogen, it appears that Shelby County must remediate the stream for contamination that is caused upstream.

14.) The model seems to be very precise in terms of significant digits used and required, however, with so many factors affecting the data it may not be very accurate. How can the County be held to such a precise LA when number may not be accurate?

G.2 City of Memphis

12 July 2007

Mr. Dennis Borders
Tennessee Department of Environment and Conservation
Division of Water Pollution Control
401 Church Street
L&C Annex, Seventh Floor
Nashville, Tennessee 37243-1534

**Re: Comments for Proposed Total Maximum Daily Load for E. Coli
Wolf River Watershed, Tennessee**

Dear Mr. Borders:

On 14 June 2007, the City of Memphis received a draft copy of the proposed Total Maximum Daily Load (TMDL) for Escherichia coli (E. coli) for the Wolf River Watershed (HUC 08010210) in Tennessee. We have reviewed the above referenced document and have several questions and concerns.

1.) As stated, a monitoring plan for a Pathogen TMDL must include visual stream surveys and impairment inventories. The accessibility to and safety concerns for traversing miles of watershed boundaries is impractical. We are funding the Storm Water Program locally and have a small staff. If we are compelled to conduct visual stream assessments, we will be forced to redirect our efforts from tasks such as monitoring construction activities or spend valuable funds hiring consultants to complete this work. The City believes it would be more productive to periodically repeat work such as our Infrared Flyover Project which looks for anomalies in the streams. The City of Memphis completed an infrared flyover of approximately 250 miles of waterways in January 2005. The City determined that utilization of infrared thermography technology to conduct an aerial seep survey of waterways, which are co-located with sewer lines, followed by field reconnaissance to inspect discovered thermal anomalies would be an efficient and effective method to detect and eliminate illicit discharges. This study helped us find and resolve several widely scattered problem areas that would have taken much longer to find using visual techniques and might not have been readily visible at ground level. This method could be used in place of the visual stream surveys to save time, personnel costs, and equipment costs.

2.) The City of Memphis Storm Water Program currently samples four more locations that those shown in this document. Since we are more familiar with those locations, we suggest substitution of our sites for the Tennessee Department of Environment and Conservation (TDEC) locations if a more rigorous sampling program is to be implemented. Also, the other four stations seem like they would provide relevant data for the proposed TMDL.

3.) The document states that the Wolf River watershed has approximately 30% of its area lying in Mississippi. The City believes that this large area contained in Mississippi could leave substantial room for error if E. coli were originating within Mississippi before crossing the State line. Are there similar strictures being placed upon the agencies in

Mississippi? If not, are we being expected to "clean up" after Mississippi?

4.) In a similar aspect, is it realistic to label all of the Wolf River as a recreation use water body, one of the most stringent categories? Shelby County is highly urbanized and the Wolf's stream characteristics, especially in large parts of Shelby County, differ markedly from more rural areas upstream due to the land use and the fact that the Wolf River has been straightened and essentially used as a drainage channel for approximately 50 years?

5.) Loading Simulation Program in C++ is a model that is based on a 10-year period for seasonal variation. The period used for the model only contained six years worth of data. Also, the land use distribution period from 1990 - 1993 that was used for the study is not reflective of the current uses within the City and Shelby County. The land use has drastically changed in the past fourteen years within the entire County, primarily as a result of development. What effect does this have on the output of the model?

6.) As stated in the document, the City of Memphis completed a Microbial Source Tracking (MST) Study on South Cypress Creek. The City has done a total of three MST studies. The results indicated that nonhuman sources of E. coli accounted for more than 80% of the total occurrences. How has this been taken into account in the model? Are we expected to "remove" this source from the stream? The City feels that a similar test on the Wolf River Watershed would yield similar results. Since forest and open grass areas are abundant around the water bodies, reducing the impact of wildlife pathogen concentrations would be very difficult. Two areas stated in the document would be, reducing the wildlife concentration in an area or reducing their proximity to the water body. These two options are physically and socially unacceptable.

7.) The document also states that the calculated results are estimates. The geometric mean was not calculated at any of the monitoring stations due to the fact that there was not enough data collected. Also, there is a NPDES Regulated Wastewater Treatment Facility that is not listed in Table 4. The facility not listed is the Moscow Treatment Facility. An abandoned hog Concentrated Animal Feeding Operation along the Wolf River on the north side of Moscow should also be considered as a point source of E. coli. In Table 2, one of the only sources of pollution for locations in Shelby County considered is "discharge from the MS4." Is the "natural" component considered within this descriptor? What about other sources that may already be in the water when it enters our area?

If you have any questions concerning this correspondence, please contact Scott Morgan at (901) 576-4345 or Ron Kirby at (901) 576-7125.

Sincerely,

Paul Patterson
Administrator Environmental Engineering

C: Scott Morgan
Ron Kirby

G.3 Tennessee Water Sentinels

Tennessee Chapter

Chickasaw Group, Sierra Club – Water Sentinels Program

P.O. Box 111094, Memphis, TN 38111

July 14, 2007

Attn.: Division of Water Pollution Control
Watershed Management Section
7th Floor L & C Annex
401 Church Street
Nashville, TN 37243-1534

RE: Comments on Proposed TMDL for *E.coli* in Wolf River Watershed – HUC 08010210

WRITTEN RESPONSE REQUESTED

Dear Sir or Madam,

On behalf of the Tennessee Water Sentinels, I am pleased to be able to participate in the process of making comments of the above referenced documents. I offer the following comments on behalf of the Tennessee Water Sentinels program of the Tennessee Chapter and the Chickasaw Group – Sierra Club.

Comment 1:
3.0 Watershed Description, in the second and third sentences
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. Although changes in the land use of the Wolf River watershed have occurred since 1993 as a result of development, this is the most current land use data readily available for GIS-interfaced hydrologic model input.

It is our contention that using data on land use that is from 14 to 17 years old presents challenges with accurately calculating an accurate TMDL based on land use. Since 1990, the change in land use due to development within the Wolf River watershed in eastern Shelby County has been nothing short of phenomenal. One good example of this is the Gray's Creek watershed in the area surrounding the intersection of Houston Levee Rd. and Macon Rd., Memphis handy map page 160-G [1], **(35º 09' 36" N by 89º 43' 40" W)**. Many hundreds of homes have been built in this area since the early 1990's, with more being built each day. Gray's Creek is not the only area in the watershed experiencing explosive growth. Water Pollution Control needs to utilize its resources and acquire more recent satellite images and land use data and use it to refine this TMDL. After briefing her on the situation and receiving her okay, may I suggest that WPC contact Dr. Esra Ozdenerol-Garner at the University of Memphis, who may be able to assist WPC in these efforts. Her contact information is:

Department of Earth Sciences
236 Johnson Hall, 488 Patterson Street
University of Memphis
Memphis, TN 38152
Ph: 901-678-2787 Fax: 901-678-2178
Email: eozdenrl@memphis.edu
Website: http://des.memphis.edu/esra/

Comment 2:
Based on Table 3 on page 12 of the TMDL document and Appendix B, pages B-6, 7, 8, 9, 10, 14 & 15, I see that Water Pollution Control apparently did not consider all the monthly ambient monitoring samples that were collected by the City of Memphis' storm water program.
Question 1: Will WPC be considering the results from those samples in addition to the ones listed on the above pages of the TMDL document?
Point to notice: See the comments about sample point 6W below.

1W: Wolf River at Germantown Parkway: Memphis handy map page 49-B [1], **(35º 07' 01" N by 89º 48' 06" W)**. 1W was the storm water program's "upstream" sample on the main stem of the Wolf River as it flowed into Memphis' city limits.
4W: Harrington Creek at Raleigh-Lagrange Road: Memphis handy map page 24-D [1], **(35º 11' 14" N by 89º 53' 13" W)**.
6W: Fletcher Creek at North Shelby Oaks:
Unless this sample point was changed after August 2002, the sampling location that was approved by TDEC/WPC and used by the City of Memphis storm water personnel was Fletcher Creek at Sycamore View, Memphis handy map page 25-P [1], **(35º 10' 11" N by 89º 51' 56" W)**. Regarding Fletcher Creek at Sycamore View, on occasion, the Wolf River would have a high river stage and it would result in stagnant water conditions at Sycamore View. When that occurred, the next sample point upstream was used, located at North Shelby Oaks Dr., Memphis handy map page 25-R [1], **(35º 10' 20" N by 89º 51' 17" W)**. At any time the sampling location was changed due to high water and/or stagnant water conditions, those deviations were noted on the chain-of-custody and/or a sample log as well as the data spreadsheets.

The City of Memphis' storm water program also collected monthly ambient samples at:

Wolf River at Old Austin Peay: Memphis handy map page 16-H [1], **(35º 12' 07" N by 89º 55' 21" W)**. This was the City's "mid-point" sample on the main stem of the Wolf River.

Wolf River at McLean Ext.: Memphis handy map page 14-R [1], **(35º 11' 27" N by 89º 59' 35" W)**. The only time this sample was omitted is if the Mississippi River was at a high river stage and that resulted in stagnant water conditions at McLean). This was the City's "downstream sample" on the main stem of the Wolf River. At any time the sampling location was changed due to high water and/or stagnant water conditions, those deviations were noted on the chain-of-custody and/or a sample log as well as the data spreadsheets.

Grays Creek at Walnut Grove Rd.: Memphis handy map page 328-F [1], **(35º 07' 46" N by 89º 44' 18" W)**.

Cypress Creek at Evergreen (the end of the concrete channeled section): Memphis handy-map 21-P [1], **(35º 10' 08" N by 90º 00' 01" W)**. The only time this sample was omitted is if the Wolf River/Mississippi River was at a high river stage and that resulted in stagnant water conditions at this sample location. If stagnant water existed, sampling was attempted where Cypress Creek was bridged at McLean, Memphis handy map page 21-P [1], **(35º 10' 06" N by 89º 59' 45" W)**. If stagnant water existed there, that particular sample was omitted. At any time the sampling location was changed due to high water and/or stagnant water conditions, those deviations were noted on the chain-of-custody and/or a sample log as well as the data spreadsheets.

Comment 3:
Section 7.1.1: NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities
The Maynard C. Stiles Wastewater Treatment Plant (NPDES Permit # TN0020711) discharges directly into the Mississippi River as shown in table 4, NOT into the Wolf River.
Question 1: Is that plant's discharge part of any TMDL calculation for the Wolf River?
Question 2: Is the Stiles Plant now disinfecting its effluent?

Comment 4:
Section 7.1.3: NPDES Concentrated Animal Feeding Operations (CAFOs)
Animal feeding operations (AFOs) are agricultural enterprises where animals are kept and raised in confined situations…. There were two Class II CAFOs (TNA000022 and TNA000100) in the Wolf River watershed with coverage under the general NPDES permit during the TMDL analysis period. Both of these CAFO permits have been terminated. One of the two (TNA000022) was located in the drainage area of the (E. coli) 303(d)-listed waterbody Cypress Creek, TN08010210032-1000.

Tennessee Water Sentinels respectfully submits that the above information is incorrect with regards to location of CAFO # TNA000022. WPC's map on page 13 of the TMDL document shows TNA000022 as being within the Memphis City Limits, somewhere in residential mid-town Memphis. A bit of searching with a November 2004 download of the "List of General and Individual Sites with Coverage under the General NPDES Permit for Concentrated Animal Feeding Operations (CAFOs) November 2004" lists TNA000022 as "Thomas Dairy, at 15920 Highway 196 in Eads, TN, in Fayette County". A quick search on *Google Earth* revealed a high resolution aerial photo of the CAFO at **(35º 12' 37" N by 89º 35' 07" W)**. The CAFO is listed as discharging to "Cypress Creek", but that is another Cypress Creek, which according to the FINAL 2006 303d list, displays a HUC number of 08010209003-1000, which is in the Loosahatchie River watershed.

Comment 5:
Table 8, WLAs & Las for Wolf River, Tennessee
Question: Where is Gray's Creek listed with the Rocky Woods Estates WWTF (NPDES Permit # TN0056391) in this table?

Comment 6:
Table 8, WLAs & Las for Wolf River, Tennessee, see note "b" on page 28 of the TMDL document and Table E-4 of the Appendices
WLAs for WWTFs expressed as E. coli loads (CFU/day). Future WWTFs must meet water quality standards at the point of discharge as specified in their NPDES permits. At no time shall concentration exceed appropriate, site-specific (487 CFU/100 mL or 941 CFU/100 mL) water quality criteria.

The wording for the second sentence should be changed to read, *"**<u>Current</u>** and future WWTFs must meet water quality standards at the point of discharge as specified in their NPDES permits."*

Comment 7:
Section 9.3: Non-point Sources
The Tennessee Department of Environment & Conservation has no direct regulatory authority over most non-point source (NPS) discharges.
Question: Please explain where in the Tennessee Water Quality Control Act of 1977 at § 69-3-101 *et seq*. that TDEC/WPC does not have "direct regulatory authority over most non-point source (NPS) discharges."?

Comment 8:
***more* Section 9.3: Non-point sources**
Voluntary, incentive-based mechanisms will be used to implement NPS management measures in order to assure that measurable reductions in pollutant loadings can be achieved for the targeted impaired waters. Cooperation and active participation by the general public and various industry, business, and environmental groups is critical to successful implementation of TMDLs.
Question: Based on the experience TDEC/WPC has gained from the TMDL for *<u>E.coli</u>* on the Nonconnah Creek watershed, what voluntary, incentive-based mechanisms will work in the Wolf River watershed and that you will plan to pass along to government leaders of Memphis, Collierville, Germantown, City of Lakeland, Shelby County and Bartlett, industry, business leaders, and the general public?

Comment 9:
Section 9.3.1: Urban Non-point Sources
Illicit discharges: Removal of illicit discharges to storm sewer systems, particularly of sanitary wastes, is an effective means of reducing pathogen loading to receiving waters (ENSR, 2005). These include intentional illegal connections from commercial or residential buildings, failing septic systems, and improper disposal of sewage from campers and boats.

Tennessee Water Sentinels requests that the City of Memphis storm water program inspect, on a routine basis, the segment of Cypress Creek between Sam Cooper Blvd. on the south to Tutwiler Ave. on the north, Memphis handy map page 30-P & L [1], **(35º 08' 50" N by 89º 57' 33" W <u>to</u> 35º 09' 12" N by 89º 57' 40" W)**. In the late 1990's, Memphis' storm water program personnel discovered a broken private sanitary sewer line that was discharging raw sewage into Cypress Creek. They required the owners of the private line, Leahy's Weekly Rentals, 3070 Summer Ave., Memphis 38112, to repair their line. Copies of letters on this issue should be in the files at Memphis' storm water management. However, continued vigilance is needed in this particular segment of Cypress Creek.

Tennessee Water Sentinels requests that the City of Memphis storm water program inspect, on a routine basis, the segment of Lick Creek between Madison Ave. on the south to Jefferson Ave. on the north, Memphis handy map page 36-G & C [1], **(35º 08' 13" N by 89º 59' 32" W <u>to</u> 35º 08' 20" N by 89º 59' 31" W)**. There is a large diameter public sewer line that has an inverted siphon crossing of Lick Creek, and the upstream siphon manhole is located just off the western edge of the parking lot of the Malco Studio on the Square movie theater at 2105 Court Ave., Memphis 38104. That manhole is located at **(35º 08' 16.21" N by 89º 59' 30.76" W)**. That manhole has been known to overflow into that segment of Lick Creek when the siphon gets blocked.

Tennessee Water Sentinels would like to see incorporated into Table 10 that Memphis, Collierville, Germantown, City of Lakeland, Shelby County and Bartlett pledge to review the "as-built" plans, and as needed, conduct smoke testing, dye testing, and camera analysis of their inverted sewer siphon crossings of the various creeks in the Wolf River watershed, with an eye to looking for what I call, for lack of a better name, an "engineered relief", which is a bypass pipe that is in the barrel of the upstream sewer siphon manhole that can discharge raw sewage into the creek or river when the sewer is in a surcharged condition. If any of these reliefs are located, then it is paramount to seal those reliefs off so they cannot operate as the discharge point of the relief may be under water and sewage can discharge undetected.

The tasks of searching for potential reliefs should occur within verifiable timelines and the results of those tasks documented within the Annual Storm Reports of the storm water programs of these entities.

Do these reliefs exist? I know of one "engineered relief" that the City of Memphis' storm water program observed discharging in the late 1990's. Its location was immediately reported to the City of Memphis' Sewer Maintenance Department and the relief was sealed off, I believe in the upstream siphon manhole itself. That relief was located at Ten Mile Creek at Knight Arnold Memphis handy map page 66-K [1], **(35º 03' 54" N by 89º 56' 15" W)**. In addition, there was a possible engineered relief or a damaged sewer line that discharged into Fletcher Creek at North Shelby Oaks Dr. Memphis handy map page 25-R [1]. That one was discovered in the early fall of 2000. That one was also sealed off by Sewer Maintenance. The reason I include their exact locations here is that if the relief seal(s) fail, then everyone is back to "square one", trying to locate the source of <u>*E.coli*</u>.

Comment 10:
***more* Section 9.3.1: Urban Non-point Sources**
Pet waste: If the waste is not properly disposed of, these bacteria can wash into storm drains or directly into water bodies and contribute to pathogen impairment. Encouraging pet owners to properly collect and dispose of pet waste is the primary means for reducing the impact of pet waste (USEPA 2002b).

Comment 10, cont.:
Tennessee Water Sentinels would like to see incorporated into Table 10 that Memphis, Collierville, Germantown, City of Lakeland, Shelby County and Bartlett pledge to have periodic stories in the local print media and on TV about pet waste and its proper disposal. These could be local news interest stories rather than paid ads if money is an object.

Informational stories on the proper disposal of pet waste should be done quarterly and documented within the Annual Storm Reports of the storm water programs of these entities.

Comment 11:
Section 9.4.2 Source Identification
An important aspect of E. coli load reduction activities is the accurate identification of the actual sources of pollution. In cases where the sources of E. coli impairment are not readily apparent, Microbial Source Tracking (MST) is one approach to determining the sources of fecal pollution and E. coli affecting a waterbody.

Tennessee Water Sentinels strongly encourages Memphis, Collierville, Germantown, City of Lakeland, Shelby County and Bartlett to pool resources and conduct microbial source tracking to determine source(s) of fecal pollution in the Wolf River watershed.

Sincerely,

James H. Baker
Project Director – Tennessee Water Sentinels
Phone: 901-826-2448
Website: http://sierraclub.org/watersentinels/tennessee/

c. Ms. Katherine Pendleton – Chair, Tennessee Chapter – Sierra Club
Ms. Gloria Griffith – vice-Chair, Tennessee Chapter – Sierra Club
Mr. Gary Bowers – Conservation Chair, Tennessee Chapter – Sierra Club
Mr. Axel Ringe – Water Quality Chair, Tennessee Chapter – Sierra Club
Mr. Tom Lawrence – Chair, Chickasaw Group – Sierra Club
Ms. Juliet Jones – vice Chair, Chickasaw Group – Sierra Club
Ms. Naomi Van Tol – Conservation Chair, Chickasaw Group – Sierra Club
Ms. Renée Hoyos – Executive Director, Tennessee Clean Water Network
Mr. Keith Kirkland – Executive Director, Wolf River Conservancy
Mr. Scott Dye – Director, Sierra Club Water Sentinels Program

[1] Memphis Handy Map - 2007 Ed. by Stacey Map Corporation, 50 South Prescott St., Memphis, TN 38111-0061

All latitudes and longitudes gathered from *Google Earth*.

G.4 City of Bartlett

July 16, 2007

Dennis Borders
Tennessee Department of Environment & Conservation
Division of Water Pollution Control
401 Church Street
L & C Annex, Seventh Floor
Nashville, Tennessee 37243-1534

RE: Comments on Proposed TMDL for *E.coli* in Wolf River Watershed – HUC 08010210

Dear Mr. Borders,

The following are our comments on the proposed TMDL for *E. coli* in the Wolf River Watershed.

Comment 1:
1.0 The TMDL may then be used to develop controls for reducing pollution from both point and nonpoint sources in order to restore and maintain the quality of water resources (USEPA,1991).

What is being done to address non-point source pollution in areas who are not a Phase I or Phase II community? (See percentages in Comment 2)

Comment 2:
2.0 *The majority of the Wolf River Watershed lies in the state of Tennessee with approximately 30% lying in Mississippi.*

According to the "Wolf River Watershed (08010210) of the Tennessee River Basin Watershed Water Quality Management Plan", found at http://state.tn.us/environment/wpc/watershed/wsmplans/wolf/, of the 70% of the watershed inside of the State of Tennessee 38.6% lies within Shelby County. This means that of the total watershed, only 26.74% lies within Shelby County. However, all of the actions to be taken are located within Shelby County.

It seems that the actions proposed are aimed at Shelby County with no other action being proposed throughout the rest of the Watershed. This means that 73.26% of the watershed has no actions directed towards it.

Comment 3:
2.0 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.

The data on land use is 14 – 17 years old. There have been many changes to the landscape in that time. Any assumptions made about the contribution due to landscape usages will be miscalculated.

Comment 4:
5.0 *As previously stated, the designated use classifications for the Wolf River waterbodies include industrial water supply, fish & aquatic life, irrigation, livestock watering & wildlife, recreation, and navigation. Of the use classifications with numeric criteria for E. coli, the recreation use classification is the most stringent and will be used to establish target levels for TMDL development.*

The classification of "recreation use" of waterbodies within our municipality limits seems unwarranted. Most of the water ways are creeks that are not large or deep enough for recreational usages. Additionally the stream side vegetation does not lend to use for recreation. Having a target TMDL using the classification of "recreational use" will set a standard that is more stringent that what our waterbodies are used for; fish & aquatic life and wildlife are the two main usages of the water in our portion of the watershed.

Comment 5:
9.2.2 *In order to evaluate SWMP effectiveness and demonstrate compliance with specified WLAs, MS4s must develop and implement appropriate monitoring programs. An effective monitoring program could include:*

- *Effluent monitoring at selected outfalls that are representative of particular land uses or geographical areas that contribute to pollutant loading before and after implementation of pollutant control measures.*

- *Analytical monitoring of pollutants of concern (e.g., monthly) in receiving waterbodies, both upstream and downstream of MS4 discharges, over an extended period of time. In addition, intensive collection of pollutant monitoring data during the recreation season (June – September) at sufficient frequency to support calculation of the geometric mean.*

Question 1. What is the frequency of sampling to be required? Will it be monthly or so many times a year or so many times a permit cycle?
Question 2. Will this be based on a watershed wide plan or per municipality or area?
Question 3. What about water ways that enter, leave, and re-enter our MS4? Will we be required to test when they enter, when they leave, and when they reenter?

Comment 6:
9.2.2 "*When applicable, the appropriate Division of Water Pollution Control Environmental Field Office should be consulted for assistance in the determination of monitoring strategies, locations, frequency, and methods within 12 months after the approval date of TMDLs or designation as a regulated MS4."*

What will the local field office use to determine the monitoring strategies, locations, frequency, and methods to be used?

Comment 7
9.0 *The TMDLs, WLAs, and LAs developed in Section 8 are intended to be the first phase of a long term effort to restore the water quality of impaired waterbodies in the Wolf River watershed through reduction of excessive E. coli loading.*
9.3 *The Tennessee Department of Environment & Conservation has no direct regulatory*

authority over most nonpoint source (NPS) discharges. . . . Voluntary, incentive-based mechanisms will be used to implement NPS management measures in order to assure that measurable reductions in pollutant loadings can be achieved for the targeted impaired waters. Cooperation and active participation by the general public and various industry, business, and environmental groups is critical to successful implementation of TMDLs.

Most of the watershed, 73.26%, lies in an area where nonpoint source pollution is the main source. If this is the part that is, as is stated, “critical to successful implementation of TMDLs” why is it not the first phase being implemented?

Comment 8:
Visual assessments of streams would be a very laborious job, both in the field and in the office. Our streams run through private properties, all of whose owners would have to be notified of an inspection to be done. The stream banks are not walkable in all areas and the stream beds themselves may be dangerous due to high water or snakes. Most of our waterways are too shallow to be navigational, so the whole length would have to be walked. With our limited manpower, we want to make sure this is the most efficient use of our time and manpower. What is the goal of this recommended requirement? Would sample spot visual inspections provide the same results?

Thank you for taking the time to look over our comments on the proposed TMDL. We hope that you will take into consideration our concerns and questions.

Sincerely,
Stephanie Kruger
City of Bartlett, Storm Water Coordinator
3585 Altruria Road
Bartlett, TN 38135
901-385-6499

APPENDIX H

Response to Public Comments

H.1 Responses to Shelby County

Note: responses correspond to numbered comments (see Appendix G, Section G.1)

1.) The Division of Water Pollution Control has developed guidance for interpretation of TMDL monitoring minimum requirements for Municipal Separate Storm Sewer Systems (MS4s). According to Sect. 9.2.2, "the appropriate Division of Water Pollution Control Environmental Field Office (EFO) should be consulted for assistance in the determination of monitoring strategies, locations, frequency, and methods within 12 months after the approval date of TMDLs or designation as a regulated MS4." In addition, the Statewide Storm Water Coordinator can be contacted for assistance with TMDL monitoring requirements.

2.) See the Public Notice, Appendix F, for contact information, including the Division address for TMDL comments, and a website address for downloading the document. In addition, Section 11.0 provides contact information, including e-mail addresses. TMDL comments are also accepted via these e-mail addresses.

3.) The LSPC model was utilized to simulate flow (only) for the Wolf River watershed. Typically, a minimum of 10 years of flow data is desirable in order to have confidence that the full range of flows are reasonably represented. We had up to nearly 7 years (variable by site) of water quality data for load duration curve development. No significant deviation in results is expected because the TMDLs, WLAs, and LAs are flow based.

4.) According to the Multi-Resolution Land Characteristics (MRLC) Consortium (http://www.mrlc.gov/mrlc2k_faq.asp), regarding comparison of NLCD 92 with land cover from NLCD 2001, "Direct comparison is not recommended. Each dataset was mapped with different methods and slightly different classes. While the two NLCD products are designed to be similar, the slight differences in classification, combined with the final accuracy of the mapping (from 70-80%), result in two distinct products." Efforts will be made in the near future to adapt the new data products to TMDL methodologies and models.

5.) All available data, including samples collected at the four City of Memphis monitoring stations listed, were considered during development of the TMDLs. Many of the impaired waterbodies have multiple water quality monitoring stations. For each individual impaired segment, the station providing the most conservative (most protective) results was utilized for analysis and subsequent development of the TMDL.

6.) The TMDLs, WLAs, and LAs are expressed at the pour point (outlet of the drainage area or HUC-12 subwatershed) as a function of daily mean flow for a particular segment. Therefore, the location of the water quality monitoring station on an impaired segment will have no bearing on the LA for that segment.

Implementation results (percent reductions, critical zones) are evaluated at the monitoring stations. The two stations on Fletcher Creek are very close in proximity, resulting in an insignificant difference in drainage area. Combining sample data from both locations for implementation evaluation should result in insignificant differences in percent reductions and expression of the critical zone.

The data provided by the City of Memphis were provided as hardcopy with station 6W identified as "Fletcher Creek at North Shelby Oaks". No notes were provided indicating that any of the (6W) samples were collected at any other location. In addition, no entries were labeled “Not Sampled”, “Flooded”, or “No Flow” as were occasional entries at stations 4W, 5W, and 7W.

7.) The data value of “24192” for CYPRE004.8SH on 3/2/04 is correct as is the value of “>24192” on 5/5/04.

8.) The current E. coli TMDL methodology is a Load Duration Curve approach based on daily values (maximum water quality criterion). The TMDLs, WLAs, and LAs are expressed as daily values (load as a function of daily mean flow). More or less data (geometric mean, monthly, etc.) would not change the expression of the LAs. The value of geometric mean data is in evaluating compliance with (or exceedance of) the 30-day geometric mean criterion. In addition, more frequent data, or more data in general, provide for more effective and accurate implementation analyses (determination of percent reduction in loading required, identification of the critical zone, source identification, etc.).

9.) All seven (7) facilities were included in the analyses. The only facility on this list that is/was located in an impaired subwatershed (waterbody drainage area or HUC-12) was Rocky Woods Estates (TN0056391). It, like Ridgeway Country Club (TN0023094), was listed in Table 4 but was not assigned a WLA or notified of the proposed TMDL because each has been terminated. Each of the seven facilities was included in the LSPC (hydrologic) model for the purposes of calibrating flow. The facilities with E. coli permits were included in the WLAs of the mainstem (Wolf River) waterbodies because they discharge to the full-scale drainage areas of these segments.

The Division’s records indicate the Springhill School (TN0023752) facility is inactive with a permit expiration date of 4/29/90.

10.) The Maynard C. Stiles STP (TN0020711) is located in a Wolf River impaired subwatershed. Hence, it is listed in Table 4. Section 7.1.1, describing the facilities listed in Table 4, states, “two of the facilities (**TN0020711** and TN0064092) are located in impaired watersheds but discharge to unimpaired waterbodies.” There is no WLA provided for this facility in the Wolf River watershed. Please note that there is no loading model utilized in the development of these TMDLs.

11.) The permit for MCOSA Farms (TNA000100), a hog CAFO located north of Moscow, expired 4/30/04. Permit notes indicate the site is no longer a CAFO and removal of biosolids is (was) scheduled for the spring of 2007.

12.) For waterbodies that originate in Mississippi, the state of Mississippi is required to meet Tennessee’s water quality standards at the state line.

13.) The NPDES General Permit for Small Municipal Separate Storm Sewer Systems, Permit No. TNS000000, Section 1.5, Limitations on Coverage, states, “This permit does not authorize:

1.5.6 Discharges that would cause or contribute to in-stream exceedances of water quality standards. Your storm water management program must include a description of the BMPs that you will be using to ensure that this will not occur. The division may require corrective action or an application for an individual permit or alternative general permit if an MS4 is determined to cause an in-stream exceedance of water quality standards.

1.5.7 Discharges of any pollutant into any water for which a Total Maximum Daily Load (TMDL) has been approved by EPA, where the TMDL applies to storm water discharges from the MS4 a specific wasteload allocation and recommends it be incorporated into an individual NPDES permit."

An MS4 is only responsible for sources within the area covered by their respective jurisdiction. Monitoring at the jurisdictional boundaries can be an effective method for delineating responsibility.

14.) For consistency, the TMDLs, WLAs, and LAs are all expressed in 3 significant digits (WLAs and LAs reduced from 4). This level of precision allows the terms to balance (add up). Ultimately, the water quality standards are either in-stream or effluent (for facilities) requirements.

H.2 Responses to City of Memphis

Note: responses correspond to numbered comments (see Appendix G, Section G.2)

1.) Please refer to Section H.1, response #1.

2.) Please refer to Section H.1, responses #1 and #5.

3.) Please refer to Section H.1, response #12.

4.) The TMDL analyses were conducted according to the currently promulgated designated use of the waterbodies and the subsequent most stringent water quality criteria. To change or remove (declassify) a designated use of a waterbody, a Use Attainability Analysis must be conducted and submitted to EPA for approval. See 40 CFR, Parts 131.3(g) and 131.10(j). States are strongly discouraged from removing designated uses of waterbodies due to impairment according to the water quality standards imposed by those uses.

5.) Please refer to Section H.1, responses #3 and #4.

The LSPC model is calibrated against observed streamflow data from three USGS monitoring stations located in the Wolf River watershed. Two of three station calibrations meet all recommended calibration criteria while the third meets 8 of 9 criteria. Utilizing more recent land use data may result in marginal improvement in model calibration; however, TMDL results are not likely to differ significantly.

6.) The Load Duration Curve methodology does not differentiate between human and non-human sources. Please refer to City of Memphis NPDES Permit No. TNS068276:

PART I, A. PERMIT AREA, states, "This permit covers all areas located within the corporate boundary of The City of Memphis, located in Shelby County, Tennessee."

PART III, D. RECEIVING WATER LIMITATIONS, states (in part), "This SWMP shall reduce the discharge of pollutants to the Maximum Extent Practicable (MEP) and shall not cause or contribute to violations of State water quality standards of the receiving streams. If exceedance(s) of water quality objectives or water quality standards (collectively, WQS) persist notwithstanding implementation of the SWMP and other requirements of this permit, the permittees shall complying with the following procedure:

a. Upon a determination by either the permittees or the Division of Water Pollution Control that discharges are causing or contributing to an exceedance of an applicable WQS, the permittees shall promptly notify and thereafter submit a report to the division that describes BMPs that are currently being implemented and additional BMPs that will be implemented to prevent or reduce any pollutants that are causing or contributing to the exceedance of WQSs."

7.) The calculated summary data statistics referred to in Section 6.0, Water Quality Assessment and Deviation from Target, and percent load reduction goals based, in part, on values of >2419, were considered to be estimates because the absolute value of these samples is not known.

Please refer to Section H.1, responses #9, #11, and #13.

Please refer to City of Memphis NPDES Permit No. TNS068276:

PART I, B. AUTHORIZED DISCHARGES, states, "Except for discharges prohibited under Part I(E), this permit authorizes existing or new storm water point source discharges to Waters of the State of Tennessee from those portions of the Municipal Separate Storm Sewer System (MS4) owned or operated by The City of Memphis."

PART I, E. LIMITATIONS ON COVERAGE, states, "The following discharges are not authorized by this permit:

1. Discharges of non-storm water, except where such discharges are as follows:

   a. in compliance with a separate NPDES permit (or the discharger has applied for such a permit); or,

   b. identified by and in compliance with 40 CFR 122.26(d)(2)(iv)(B)(1); and,

2. Discharges of materials resulting from a spill, except emergency discharges required to prevent imminent threat to human health or to prevent severe property damage, provided reasonable and prudent measures have been taken to minimize the impact of the discharges.

H.3 Responses to Tennessee Water Sentinels

Note: responses correspond to numbered comments (see Appendix G, Section G.3)

1.) Please refer to Section H.1, response #4. As urban areas expand within local jurisdictions, or local municipalities annex expanding urban areas, the local municipalities (MS4s) are responsible for these areas within their jurisdictions.

2.) Please refer to Section H.1, responses #5 and #6.

3.) Please refer to Section H.1, response #10. It is unknown if the Maynard C. Stiles STP (TN0020711) is disinfecting its effluent. This is a permit issue and not within the scope of the TMDL.

4.) TDEC's permit database indicates the Thomas Dairy (TNA000022) was located in the Wolf River watershed. The receiving waterbody is listed as Cypress Creek and the permit was terminated; therefore, no further verification was conducted. This has been corrected in the TMDL and the Division's Permit Section has been notified of the error. Since CAFOs are not permitted to discharge, this has no impact on the TMDL.

5.) This permit has also been terminated; therefore, no WLA is assigned to Grays Creek. This has been clarified in Sections 7.1.1 and 10.0.

6.) The footnote has been changed, as suggested, on page 28 as well as on pages xiii and E-41.

7.) See The Tennessee Water Quality Control Act of 1977, including the 1998 amendments, § 69-3-120:

(g) Nothing whatsoever in this part shall be construed as applying to any agricultural or forestry activity or the activities necessary to the conduct and operations thereof or to any lands devoted to the production of any agricultural or forestry products, unless there is a point source discharge from a discernible, confined, and discrete water conveyance.

(h) The passage of the "Water Quality Control Act of 1977" shall grant no new authority over non-point sources to the department which was not previously established by the "Water Quality Control Act of 1971."

8.) Memphis, Collierville, Germantown, the City of Lakeland, the City of Bartlett, and Shelby County have NPDES (MS4) permits. As stated in Section 7.0, the NPDES program regulates point source discharges. In addition, as stated in Section 7.1.2, "(MS4s) are considered to be point sources of E. coli."

9.) The issues listed are permit and/or compliance issues. Specific requests may be conveyed to the Memphis Environmental Field Office or via a formal complaint to the Division of Water Pollution Control.

Table 10 lists example urban area management practices and is not intended to convey specific requirements for individual permitees.

10.) This would be a voluntary and discretionary effort to satisfy general goals and requirements of MS4 permits.

11.) See #10 above.

H.4 Responses to City of Bartlett

Note: responses correspond to numbered comments (see Appendix G, Section G.4)

1.) Efforts are largely voluntary. These are the areas where local, citizen-lead efforts can be particularly effective where problems exist. A number of resources are provided in Section 9.3; however, this is not an exhaustive list. In addition, the Clean Water Act, Section 319, established the Nonpoint Source Management Program (http://www.epa.gov/OWOW/NPS/cwact.html). Under Section 319, States, Territories, and Indian Tribes receive grant money which supports a wide variety of activities including technical assistance, financial assistance, education, training, technology transfer, demonstration projects, and monitoring to assess the success of specific nonpoint source implementation projects. Historically, 319 grants have focused on the implementation of projects that are designed to improve waters that have been listed as impaired under Section 303(d) of the CWA.

2.) Impaired waterbodies outside of and not influenced by sources in Shelby County are not the responsibility of Shelby County or entities located therein. All impaired waterbodies outside of Shelby County, primarily impaired by agricultural non-point sources, are required to meet water quality standards. Therefore, corrective actions must be taken in order to achieve reductions in loading.

3.) Please refer to Section H.1, response #4.

4.) Please refer to Section H.2, response #4.

5.) Please refer to Section H.1, response #1.

6.) Please refer to Section H.1, response #1.

7.) Development of the TMDLs, including WLAs and LAs represents the first phase. Because many, if not most, NPS measures require voluntary, incentive-based mechanisms to achieve reductions in pollutant loading, they tend to take longer to implement than mandatory, regulatory-driven (e.g., NPDES) measures. Also, see #1, above.

8.) Please refer to Section H.1, response #1.