PROPOSED
TOTAL MAXIMUM DAILY LOAD (TMDL)

for

E. Coli

in the

Stones River Watershed

(HUC 05130203)

Bedford, Cannon, Coffee, Davidson, Rutherford, Williamson, and Wilson Counties, Tennessee

FINAL

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DEPARTMENT OF ENVIRONMENT & CONSERVATION

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LIST OF ABBREVIATIONS

ADB	Assessment Database
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
DEM	Digital Elevation Model
DWPC	Division of Water Pollution Control
E. coli	Escherichia coli
EPA	Environmental Protection Agency
GIS	Geographic Information System
HSPF	Hydrological Simulation Program - Fortran
HUC	Hydrologic Unit Code
LA	Load Allocation
LDC	Load Duration Curve
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
Rf3	Reach File v.3
RM	River Mile
SSO	Sanitary Sewer Overflow
STP	Sewage Treatment Plant
SWMP	Storm Water Management Program
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
WCS	Watershed Characterization System
WLA	Waste Load Allocation
WWTF	Wastewater Treatment Facility

SUMMARY SHEET

Total Maximum Daily Load for E. coli in Stones River Watershed (HUC 05130203)

Impaired Waterbody Information

State: Tennessee
Counties: Cannon, Davidson, Rutherford, and Wilson
Watershed: Stones River (HUC 05130203)
Constituents of Concern: E. coli
Waterbodies Addressed in This Document:

Waterbody ID	Waterbody	Miles Impaired
TN05130203001 – 0100	MCCRORY CREEK	1.4
TN05130203003T – 0100	FINCH BRANCH	5.7
TN05130203010 – 2000	STEWARTS CREEK	5.5
TN05130203018 – 0100	*SINKING CREEK*	*15.5*
TN05130203018 – 0210	CHRISTMAS CREEK	12.3
TN05130203022 – 0100	TOWN CREEK	0.13
TN05130203022 – 1000	LYTLE CREEK	8.9
TN05130203022 – 2000	LYTLE CREEK	10.1
TN05130203026 – 2000	*EAST FORK STONES RIVER*	*6.5*
TN05130203035 – 1000	STONERS CREEK	1.9
TN05130203036 – 1000	*HURRICANE CREEK*	*8.5*

* Maximum water quality target is 487 CFU/100 mL for lakes, reservoirs, State Scenic Rivers, or Exceptional Tennessee Waters waterbodies and 941 CFU/100 mL for other waterbodies. Waterbodies utilizing the 487 CFU/100 mL target are italicized.

Designated Uses:

The designated use classifications for waterbodies in the Stones River Watershed include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. East Fork Stones River (entire length, except miles 44.5 to 45.2) is also designated for domestic water supply and industrial water supply.

Water Quality Targets:

Derived from *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, 2007 Version* 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, Exceptional Tennessee Water or ONRW (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.

For further information on Tennessee's general water quality standards, see:

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

TMDL Scope:

Waterbodies identified on the Final 2010 303(d) list as impaired due to E. coli. TMDLs were developed for impaired waterbodies on a HUC-12 subwatershed or waterbody drainage area basis.

The E. coli TMDLs developed in this document supersede the fecal TMDLs approved by EPA in 2004 and the E. coli TMDLs approved by EPA in 2006.

Analysis/Methodology:

The TMDLs for impaired waterbodies in the Stones 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 Exceptional Tennessee Waters 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 geometric mean criterion.

Critical Conditions:

Water quality data collected over a period of up to 10 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 and the percent of samples exceeding TMDL target concentrations (percent exceedance), for each hydrologic flow zone, to meet the target (TMDL) loading for E. coli. The percent load reduction goal and/or the percent exceedance of the greatest magnitude corresponds with the critical flow zone(s).

Seasonal Variation:

The 10-year period used for WinHSPF model simulation period for development of 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.

Summary of TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Stones River Watershed (HUC 05130203)

HUC-12 Subwatershed (05130203__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs			LAs [c]
					WWTFs [a]	Collection Systems	MS4s [b,c]	
			[CFU/day]	[CFU/day]	[CFU/day]	[CFU/day]	[CFU/d/ac]	[CFU/d/ac]
East Fork Stones River DA	East Fork Stones River	TN05130203026 – 2000	$1.20 \times 10^{10} \times Q$	$1.20 \times 10^{9} \times Q$	1.106×10^{10}	0	NA	$(3.838 \times 10^{5} \times Q) - (3.930 \times 10^{5})$
0203	Lytle Creek	TN05130203022 – 1000	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	$1.237 \times 10^{6} \times Q$	$1.237 \times 10^{6} \times Q$
	Lytle Creek	TN05130203022 – 2000						
	Town Creek	TN05130203022 – 0100						
Christmas Creek DA	Christmas Creek	TN05130203018 – 0210	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	$4.501 \times 10^{6} \times Q$	$4.501 \times 10^{6} \times Q$
Sinking Creek DA	Sinking Creek	TN05130203018 – 0210	$1.20 \times 10^{10} \times Q$	$1.20 \times 10^{9} \times Q$	NA	0	$3.096 \times 10^{6} \times Q$	$3.096 \times 10^{6} \times Q$
Stewarts Creek DA	Stewarts Creek	TN05130203010 – 2000	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	3.562×10^{9}	0	$(7.566 \times 10^{5} \times Q) - (1.302 \times 10^{5})$	$(7.566 \times 10^{5} \times Q) - (1.302 \times 10^{5})$
0304	Hurricane Creek	TN05130203036 – 1000	$1.20 \times 10^{10} \times Q$	$1.20 \times 10^{9} \times Q$	NA	NA	$9.841 \times 10^{5} \times Q$	$9.841 \times 10^{5} \times Q$
Finch Branch DA	Finch Branch	TN05130203003T – 0100	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	$6.404 \times 10^{6} \times Q$	$6.404 \times 10^{6} \times Q$
0308	Stoners Creek	TN05130203035 – 1000	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	$1.081 \times 10^{6} \times Q$	$1.081 \times 10^{6} \times Q$
McCrory Creek DA	McCrory Creek	TN05130203001 – 0100	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	$3.595 \times 10^{6} \times Q$	$3.595 \times 10^{6} \times Q$

Notes: NA = Not Applicable.
Q = Mean Daily In-stream Flow (cfs).

a. WLAs for WWTFs are expressed as E. coli loads (CFU/day). All current and future WWTFs must meet water quality standards as specified in their NPDES permit.
b. Applies to any MS4 discharge loading in the subwatershed. Future MS4s will be assigned waste load allocations (WLAs) consistent with load allocations (LAs) assigned to precipitation induced nonpoint sources.
c. WLAs and LAs expressed as a "per acre" load are calculated based on the drainage area at the pour point of the HUC-12 or drainage area.

PROPOSED E. COLI TOTAL MAXIMUM DAILY LOAD (TMDL)
STONES RIVER WATERSHED (HUC 05130203)

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 Stones River Watershed, identified on the Final 2010 303(d) list as not supporting designated uses due to E. coli. TMDL analyses were performed primarily on a 12-digit hydrologic unit area (HUC-12) basis. In some cases, where appropriate, TMDLs were developed for an impaired waterbody drainage area only.

The E. coli TMDLs developed in this document supersede the fecal TMDLs approved by EPA in 2004 and the E. coli TMDLs approved by EPA in 2006.

3.0 WATERSHED DESCRIPTION

The Stones River Watershed (HUC 05130203) is located in Middle Tennessee (Figure 1). The watershed includes parts of Bedford, Cannon, Coffee, Davidson, Rutherford, Williamson, and Wilson counties. The Stones River Watershed lies within one Level III ecoregion (Interior Plateau) and contains three Level IV subecoregions as shown in Figure 2 (USEPA, 1997):

- **Eastern Highland Rim (71g)** has level terrain, with landforms characterized as tablelands of moderate relief and irregular plains. Mississippian-age limestone, chert, shale and dolomite predominate, and karst terrain sinkholes and depressions are especially noticeable between Sparta and McMinnville. Numerous springs and spring-associated fish fauna also typify the region. Natural vegetation for the region is transitional between the oak-hickory type to the west and the mixed mesophytic forests of the Appalachian ecoregions to the east. Bottomland hardwoods forests were once abundant in some areas, although much of the original bottomland forest has been inundated by several large impoundments. Barrens and former prairie areas are now mostly oak thickets or pasture and cropland.

- **Outer Nashville Basin (71h)** is a heterogeneous region, with rolling and hilly topography and slightly higher elevations. The region encompasses most all of the outer areas of the generally no-cherty Mississippian-age formations, and some Devonian-age Chattanooga shale, remnants of the Highland Rim. The region's limestone rocks and soils are high in phosphorus, and commercial phosphate is mined. Deciduous forest with pasture and cropland are the dominant land covers. Streams are low to moderate gradient, with productive, nutrient-rich waters, resulting in algae, rooted vegetation and occasionally high densities of fish. The Nashville Basin as a whole has a distinctive fish fauna, notable for fish that avoid the region, as well as those that are present.

- **Inner Nashville Basin (71i)** is less hilly and lower than the Outer Nashville Basin. Outcrops of the Ordovician-age limestone are common, and the generally shallow soils are redder and lower in phosphorus than those of the Outer Basin. Streams are lower gradient than surrounding regions, often flowing over large expanses of limestone bedrock. The most characteristic hardwoods within the Inner Basin are a maple-oak-hickory-ash association. The limestone cedar glades of Tennessee, a unique mixed grassland/forest/cedar glades vegetation type with many endemic species, are located primarily on the limestone of the Inner Nashville Basin. The more xeric, open characteristics and shallow soils of the cedar glades also result in a distinct distribution of amphibian and reptile species.

The Stones River Watershed (HUC 05130203) has approximately 1,022 miles of streams (based on USEPA/TDEC Assessment Database (ADB)) and drains approximately 935 square miles to the Stones River, which drains to the Cumberland River. Watershed land use distribution is based on the Multi-Resolution Land Characteristic (MRLC) databases derived from Landsat Thematic Mapper digital images from around 2001. Although changes in the land use of the Stones River Watershed have occurred since 2001 as a result of rapid development, this is the most current land use data available. Land use for the Stones River Watershed is summarized in Table 1 and shown in Figure 3. Predominant land use in the Stones River Watershed is forest (47.2%) followed by pasture (30.5%). Urban areas represent approximately 15.4% of the total drainage area of the watershed. Details of land use distribution of impaired subwatersheds in the Stones River Watershed are presented in Appendix A.

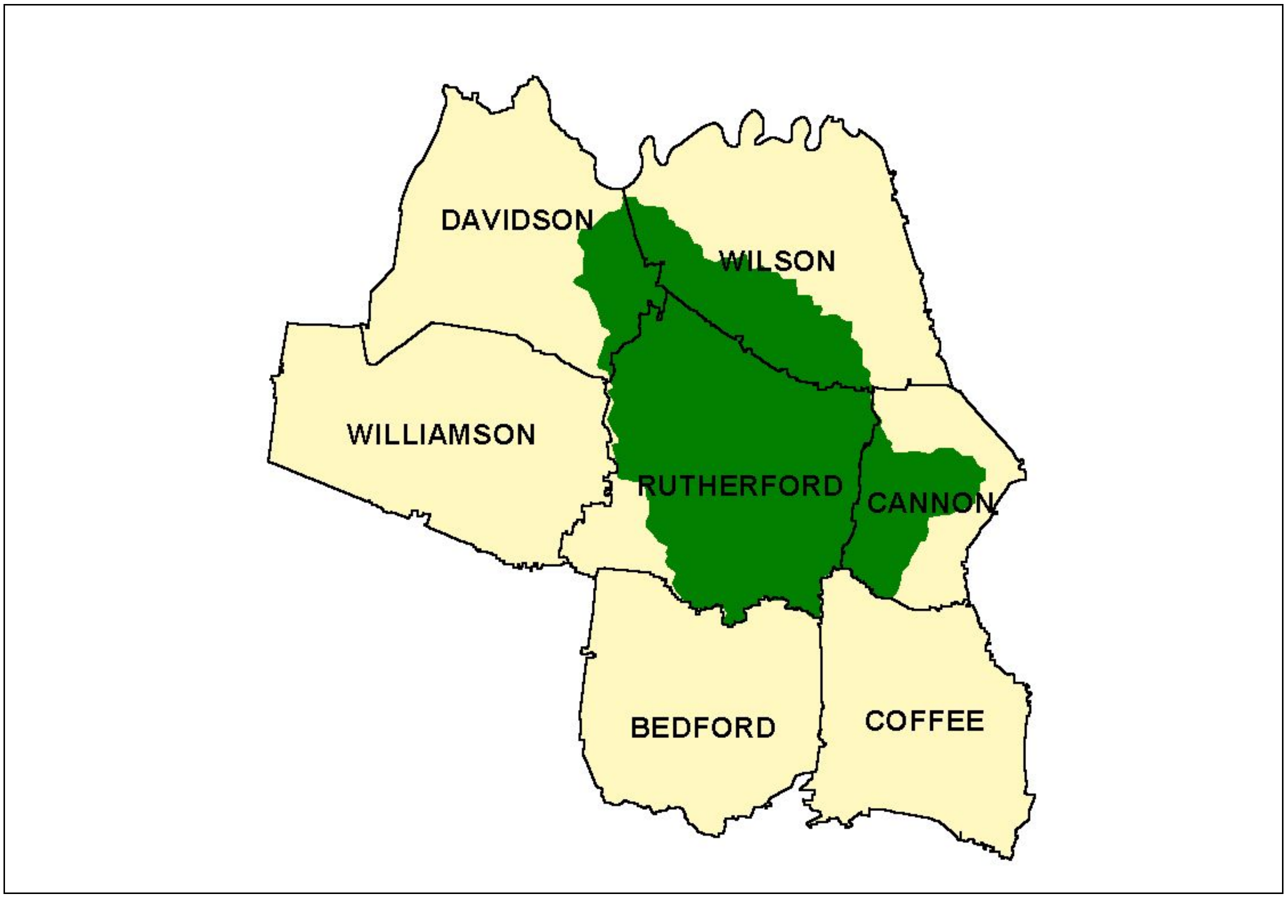

Figure 1. Location of the Stones River Watershed.

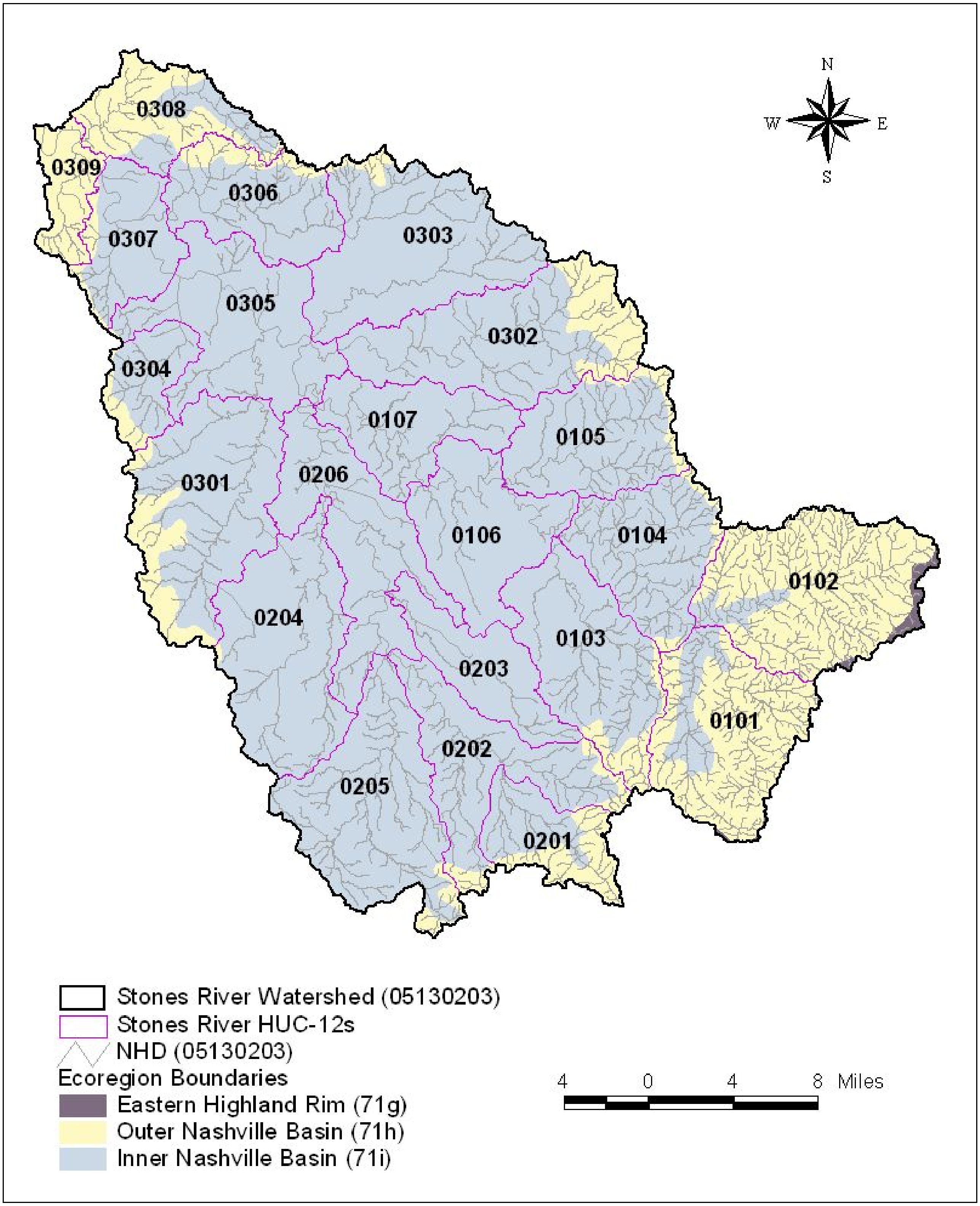

Figure 2. Level IV Ecoregions in the Stones River Watershed.

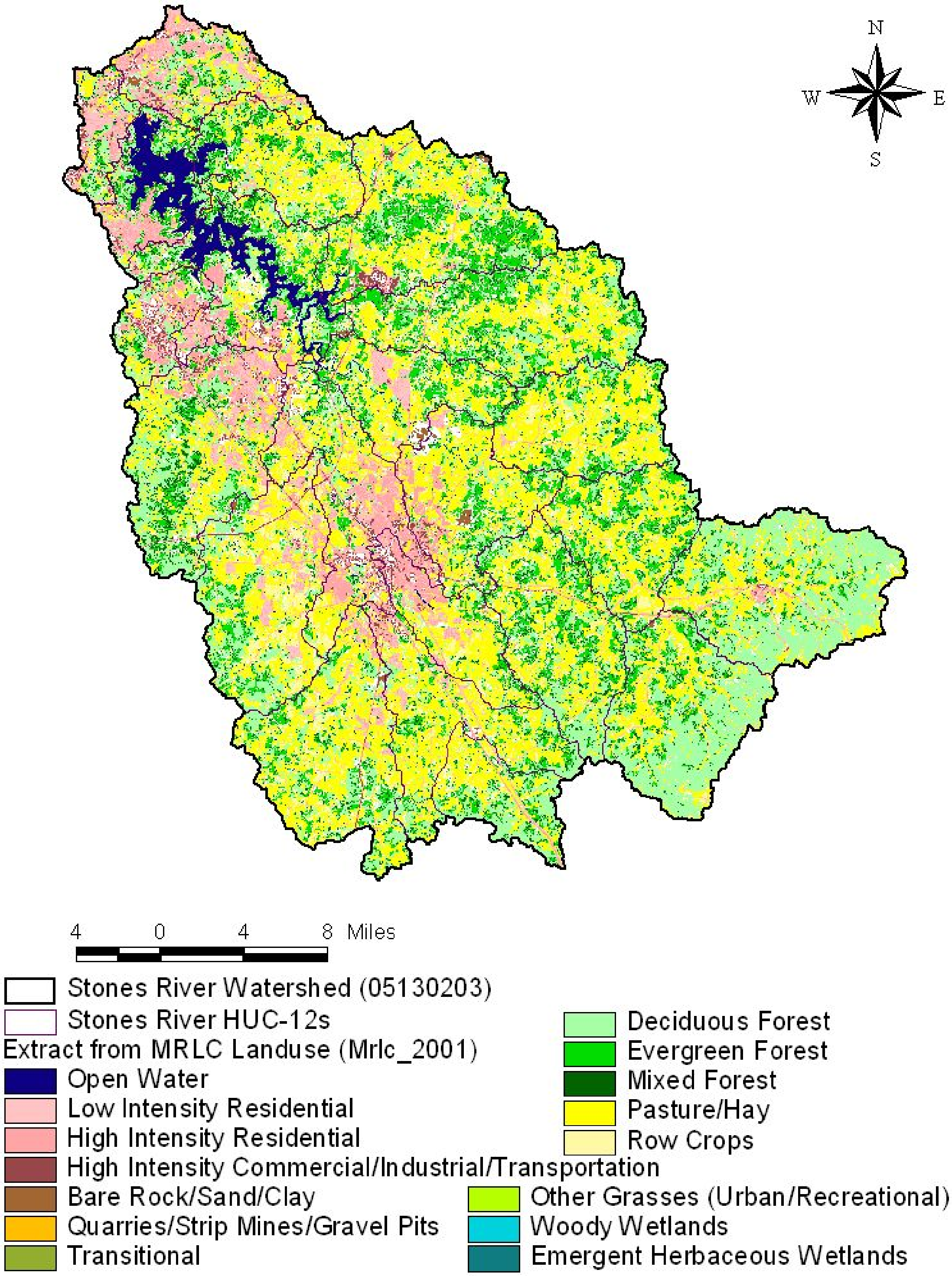

Figure 3. Land Use Characteristics of the Stones River Watershed.

Table 1 2001 MRLC Land Use Distribution – Stones River Watershed

Land Use	Area	
	[acres]	[%]
Unclassified	0	0.0
Open Water	13,594	2.3
Developed Open Spaces	46,470	7.8
Low Intensity Residential	33,296	5.6
Medium Intensity Residential	8,444	1.4
High Intensity Residential	3,713	0.6
Bare Rock/Sand/Clay	2,096	0.4
Deciduous Forest	141,866	23.7
Evergreen Forest	66,172	11.1
Mixed Forest	35,452	5.9
Shrub/Scrub	22,157	3.7
Grasslands/Herbaceous	13,234	2.2
Pasture/Hay	182,467	30.5
Row Crops	27,966	4.7
Woody Wetlands	1,737	0.3
Emergent Herbaceous Wetlands	120	0.0
Total	**598,843**	**100.00**

4.0 PROBLEM DEFINITION

The State of Tennessee's Final 2010 303(d) list (TDEC, 2011), http://tn.gov/environment/wpc/publications/pdf/2010_303d_final.pdf, was approved by the U.S. Environmental Protection Agency (EPA), Region IV in October of 2011. This list identified a number of waterbodies in the Stones River Watershed as not fully supporting designated use classifications due, in part, to E. coli (see Table 2 & Figure 4). The designated use classifications for these waterbodies include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. East Fork Stones River (entire length, except miles 44.5 to 45.2) is also designated for domestic water supply and industrial water supply.

5.0 WATER QUALITY CRITERIA & TMDL TARGET

As previously stated, the designated use classifications for the Stones River waterbodies include fish & aquatic life, recreation, irrigation, livestock watering & wildlife, 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, 2007 Version* (TDEC, 2007).

Portions of East Fork Stones River, Sinking Creek (018-0100), and Hurricane Creek (036-1000) have been classified as Exceptional Tennessee Waters because of the presence of state endangered species. As of March 1, 2012, none of the other impaired waterbodies in the Stones River Watershed have been classified as lakes, reservoirs, State Scenic Rivers, or Exceptional Tennessee Waters.

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

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

The geometric mean standard for the E. coli group of 126 colony forming units per 100 ml (CFU/100 ml) and the sample maximum of 487 CFU/100 ml have been selected as the appropriate numerical targets for TMDL development for Exceptional Tennessee Waters. The geometric mean standard for the E. coli group of 126 colony forming units per 100 ml (CFU/100 ml) and the sample maximum of 941 CFU/100 ml have been selected as the appropriate numerical targets for TMDL development for the other impaired waterbodies.

Table 2 Final 2010 303(d) List for E. coli Impaired Waterbodies – Stones River Watershed

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	Cause (Pollutant)	Pollutant Source
TN05130203001 – 0100	MCCRORY CREEK (Stones River to Stewarts Ferry Pike)	1.4	Nitrate+Nitrite Loss of biological integrity due to siltation Habitat loss due to alteration in stream-side or littoral vegetative cover Escherichia coli	Highways, Roads, Bridges, Infrastructure Construction Discharges from MS4 Area Collection System Failure
TN05130203003T – 0100	FINCH BRANCH	5.7	Nutrients Habitat loss due to alteration in stream-side or littoral vegetative cover Escherichia coli	Land Development Collection System Failure
TN05130203010 – 2000	STEWARTS CREEK (Old Nashville Hwy to Rocky Fork Creek)	5.5	Escherichia coli	Discharges from MS4 Area
TN05130203018 – 0100	SINKING CREEK	15.5	Alteration in stream-side or littoral vegetative cover Escherichia coli	Land Development Discharges from MS4 Area
TN05130203018 – 0210	CHRISTMAS CREEK	12.3	Escherichia coli	Pasture Grazing
TN05130203022 – 0100	TOWN CREEK (formerly Unnamed Trib to Lytle Creek)	0.13	Low Dissolved Oxygen Escherichia coli	Undetermined Source
TN05130203022 – 1000	LYTLE CREEK (West Fork Stones River to Dilton Rd)	8.9	Habitat loss due to alteration in stream-side or littoral vegetative cover Loss of biological integrity due to siltation Escherichia coli	Discharges from MS4 area
TN05130203022 – 2000	LYTLE CREEK (Dilton Rd to headwaters)	10.1	Habitat loss due to alteration in stream-side or littoral vegetative cover Loss of biological integrity due to siltation Escherichia coli	Pasture Grazing Land Development
TN05130203026 – 2000	EAST FORK STONES RIVER (Rush Creek to Shonborne Creek)	6.5	Escherichia coli	Pasture Grazing

Table 2 (cont'd) Final 2010 303(d) List for E. coli Impaired Waterbodies – Stones River Watershed

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	Cause (Pollutant)	Pollutant Source
TN05130203035 – 1000	STONERS CREEK (Stones River to unnamed trib)	1.9	Loss of biological integrity due to siltation Escherichia coli	Land Development Collection System Failure
TN05130203036 – 1000	HURRICANE CREEK	8.5	Nutrients Loss of biological integrity due to siltation Escherichia coli	Industrial Point Source Land Development Discharges from MS4 area

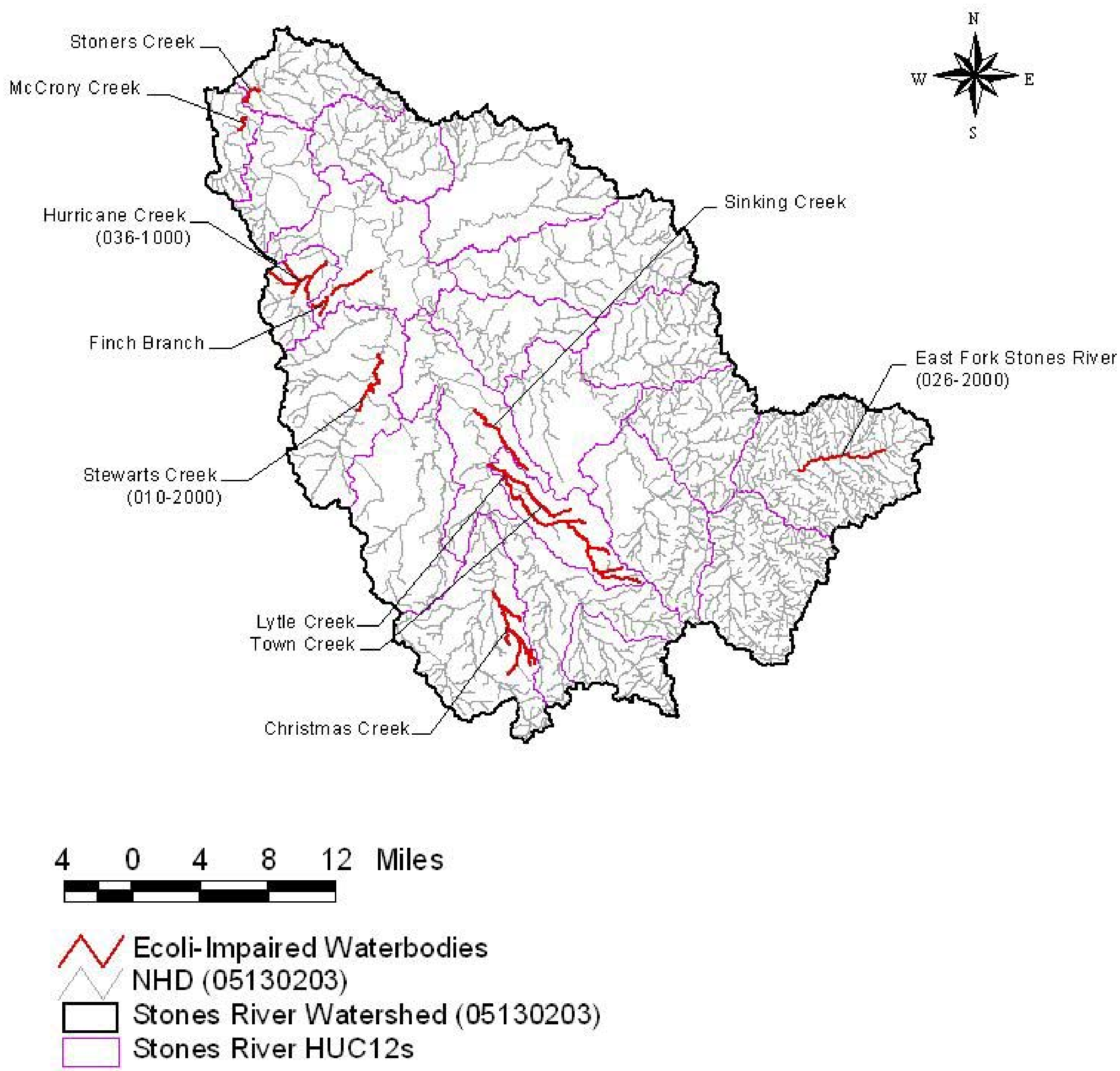

Figure 4. Waterbodies Impaired by E. Coli (as Documented on the Final 2010 303(d) List).

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 Stones River Watershed:

- HUC-12 05130203_0102:
    - *EFSTO044.3CN – East Fork Stones River, off Hwy 70S, d/s Woodbury STP*
- HUC-12 05130203_0203:
    - LYTLE000.6RU – Lytle Creek, near Old Fork Park, @ Overall St.
    - LYTLE001.1RU – Lytle Creek, off W. Main St (@ Greenway)
    - LYTLE008.7RU – Lytle Creek, at Mankin Rd.
    - TOWN000.1RU – Town Creek, Cannonsburg S Front St
- HUC-12 05130203_0205:
    - CHRIS000.7RU – Christmas Creek, 500 yds d/s of Crescent Rd
- HUC-12 05130203_0206:
    - *SINKI000.2RU – Sinking Creek, at Thompson Lane (d/s Murfreesboro)*
- HUC-12 05130203_0301:
    - STEWA009.8RU – Stewarts Creek, at Old Nashville Hwy
- HUC-12 05130203_0304:
    - *HURRI004.2RU – Hurricane Creek, d/s Murfreesboro Rd bridge near first trib*
- HUC-12 05130203_0305:
    - FINCH001.4RU – Finch Branch, at Jones Mill Rd.
- HUC-12 05130203_0308:
    - STONE000.9DA – Stoners Creek, d/s Central Pike
- HUC-12 05130203_0309:
    - MCCRO001.5DA – McCrory Creek, at Stewarts Ferry Pike

The location of these monitoring stations is shown in Figure 5. Water quality monitoring results for these stations are tabulated in Appendix B. Examination of the data shows exceedances of the 941 CFU/100 mL maximum E. coli standard at several monitoring stations. Water quality monitoring results for those stations with 10% or more of samples exceeding water quality maximum criteria are summarized in Table 3. Whenever a minimum of 5 samples was collected at a given monitoring station over a period of not more than 30 consecutive days, the geometric mean was calculated.

Table 3 Summary of TDEC Water Quality Monitoring Data

Monitoring Station	Date Range	E. Coli (Max WQ Target = 941 CFU/100 mL)**				
		Data Pts.	Min. [CFU/100 ml]	Avg. [CFU/100 ml]	Max. [CFU/100 ml]	No. Exceed. WQ Max. Target
CHRIS000.7RU	2006 – 2007	13	11	418	1,600	2
EFSTO044.3CN	*2006 – 2006*	*12*	*36*	*511*	*2,420*	*4*
FINCH001.4RU	2006 – 2007	8	32	696	2,400	2
HURRI004.2RU	*2006 – 2010*	*25*	*20*	*564*	*4,610*	*6*
MCCRO001.5DA	2006 – 2007	12	56	513	1,414	2
SINKI000.2RU	*2006 – 2007*	*14*	*108*	*327*	*1,100*	*3*
STEWA009.8RU	2006 – 2007	21	55	418	2,420	2
STONE000.9DA	2006 – 2010	26	44	418	2,400	3

** Maximum water quality target is 487 CFU/100 mL for lakes, reservoirs, State Scenic Rivers, or Exceptional Tennessee Waters waterbodies and 941 CFU/100 mL for other waterbodies. Waterbodies utilizing the 487 CFU/100 mL target are italicized.

Several of the water quality monitoring stations (Table 3 and Appendix B) have at least one E. coli sample value reported as >2419. 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. 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.)

Water quality monitoring data were available for a number of waterbodies in the Stones River watershed that are not listed on the Final 2010 303(d) List as impaired due to E. coli. Analysis of the pathogen data suggests an existing condition of impairment for several of these waterbody segments. Appendix G documents the analyses of pathogen data for these seven waterbody segments in the Stones River watershed. The analyses of water quality data for these waterbodies parallels the analyses of the waterbodies on Tennessee's Final 2010 303(d) list designated as not fully supporting designated use classifications due to E. coli.

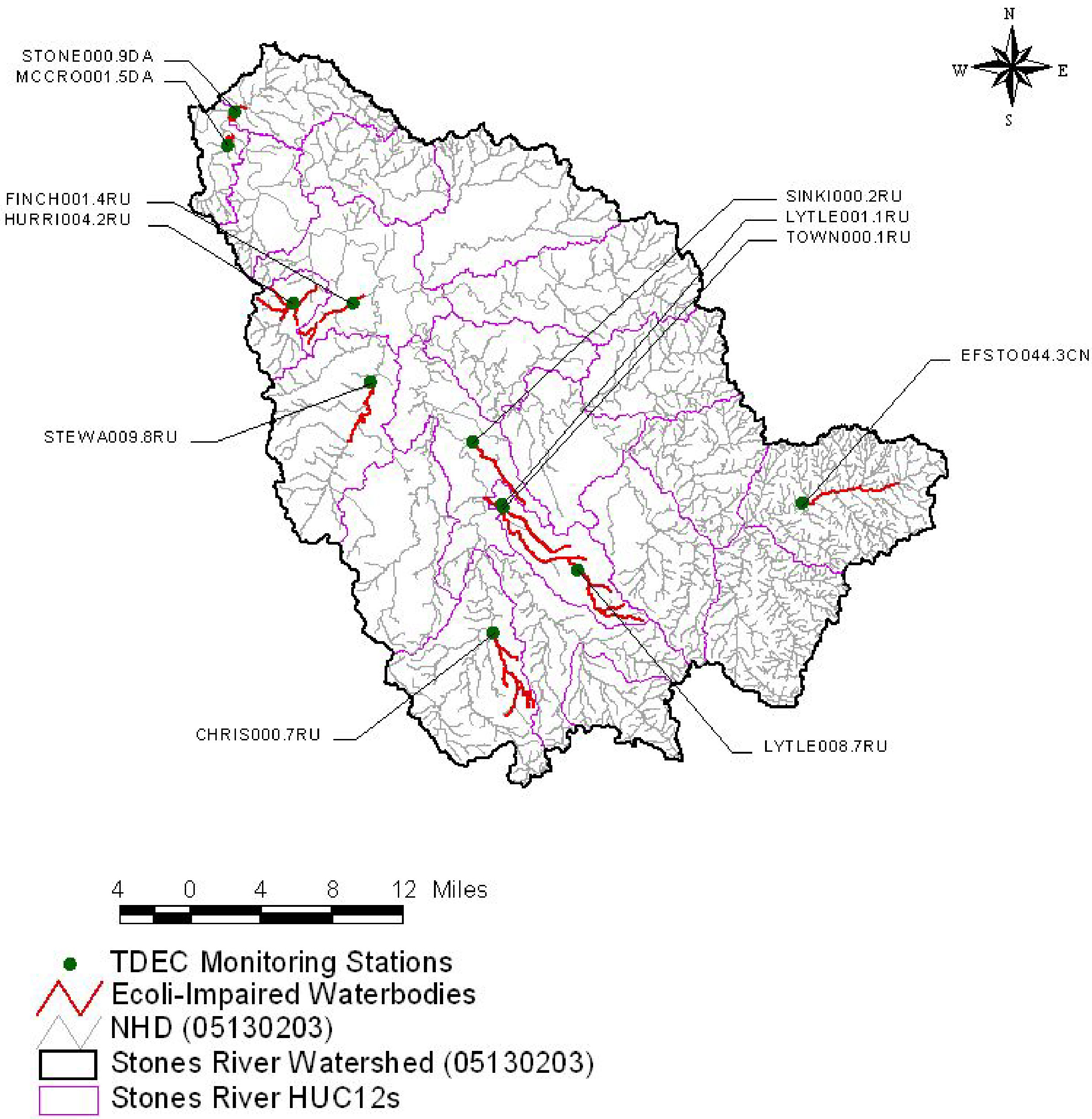

Figure 5. Water Quality Monitoring Stations in the Stones River Watershed

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 pathogen 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.dfm?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 Waste Load Allocations (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 Load Allocation (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 are 14 facilities in the Stones River Watershed that have NPDES permits authorizing the discharge of treated sanitary wastewater. Four of these facilities are located in or near impaired subwatersheds or drainage areas. (see Figure 6 and Table 4). Two of the facilities are sewage treatment plants (STPs) serving municipalities and are major facilities with design capacities equal to or greater than 1.0 million gallons per day (MGD). The permit limits for discharges from these WWTFs are in accordance with the coliform criteria specified in Tennessee Water Quality Standards for the protection of the recreation use classification.

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.*

Table 4 NPDES Permitted WWTFs with Collection Systems Serving Impaired Subwatersheds or Drainage Areas

NPDES Permit No.	Facility	Design Flow [MGD]	Receiving Stream
TN0020541	Smyrna STP	5.85	Stewart Creek @RM5.65
TN0022586	Murfreesboro-Sinking Creek STP	16.0	West Fork Stones River @RM10.5
TN0025089	Woodbury STP	0.6	East Fork Stones River @RM45.2
TN0057975	Bill Rice Ranch	0.1	Unnamed trib @RM3.2 to Stewart Creek @RM18.5

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. A portion of the Metro Nashville/Davidson County MS4 is in the Stones River Watershed.

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). The cities of Murfreesboro, Mount Juliet, LaVergne, and Smyrna, and Rutherford and Wilson Counties are covered under Phase II of the NPDES Storm Water Program.

The Tennessee Department of Transportation (TDOT) has been issued an individual MS4 permit (TNS077585) that authorizes discharges of storm water runoff from State roads 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. . The TDOT MS4 will not be considered a potential source because: (1) The area covered by the permit is less than 0.5% of the total drainage area of the watershed; (2) Sampling of stormwater runoff from state highways indicates negligible contribution of E. coli; and (3) An extensive study conducted by California Dept. of Transportation (Caltrans) concluded that highway facilities, including maintenance stations, do not appear to be a significant source of pathogens in urban drainage. (For more detail, see Appendix I.)

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 pathogen loading and are required to obtain an NPDES permit. Most CAFOs in Tennessee obtain coverage under SOPC00000 or SOPCD0000, *General State Operating Permit for Concentrated Animal Feeding Operations* (http://tn.gov/environment/wpc/pdf/sopc00000pmt.pdf or http://tn.gov/environment/wpc/pdf/sopcd0000pmt.pdf), while larger, Class I CAFOs are required to obtain an individual NPDES permit.

As of December 1, 2011, there are no Class I CAFOs with individual permits located in the Stones River Watershed. There is one Class II CAFO covered under the new general SOP permit.

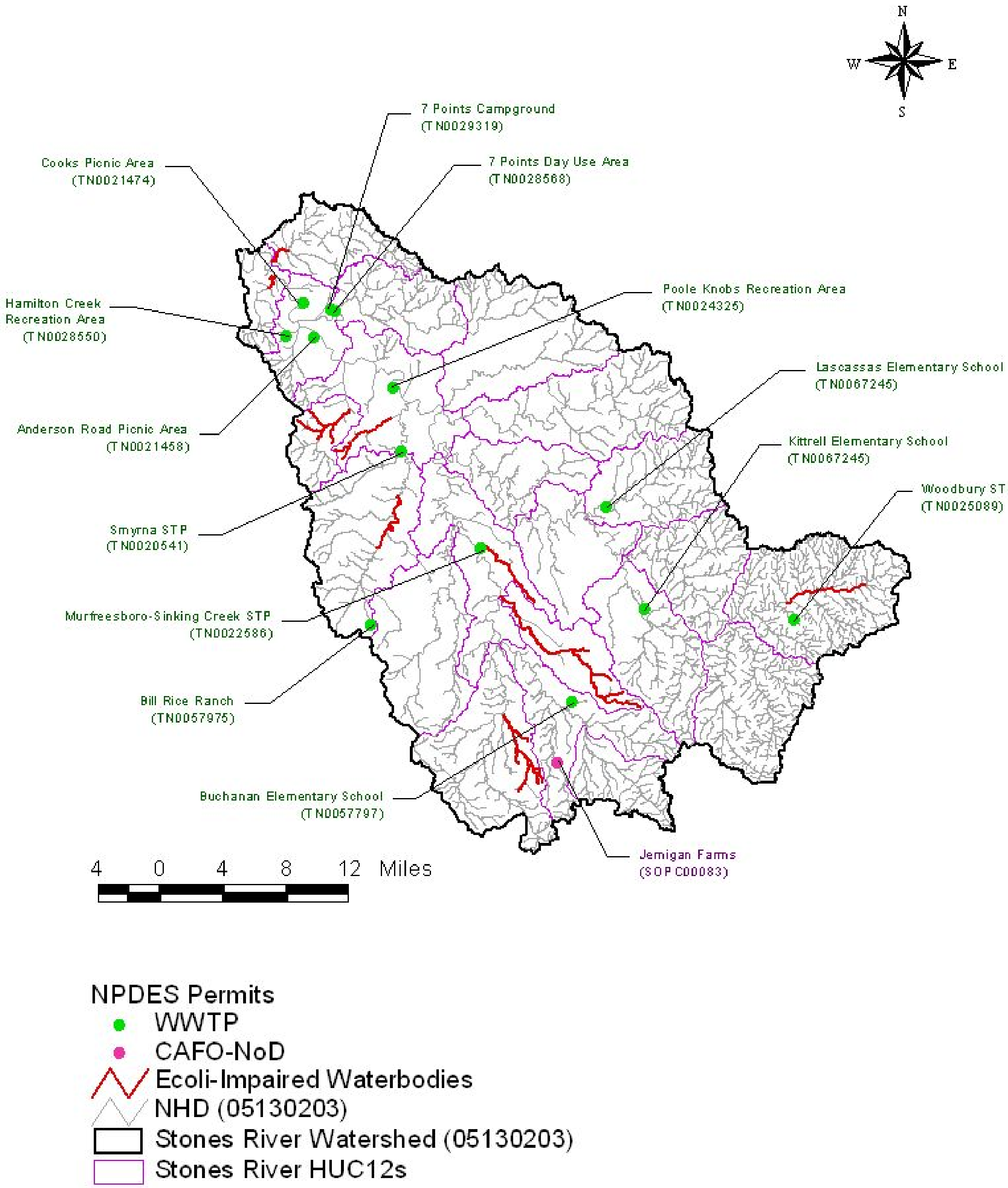

Figure 6. NPDES Regulated Point Sources in and near Impaired Subwatersheds and Drainage Areas of the Stones River Watershed.

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 2010 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 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 2007 Census of Agriculture http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/Tennessee/index.asp. Livestock data for counties located within the Stones River Watershed 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, 2009).

7.2.3 Failing Septic Systems

Some of the coliform loading in the Stones River Watershed can be attributed to failure of septic systems and illicit discharges of raw sewage. Estimates from 1997 county census data of people in the Stones River Watershed utilizing septic systems were compiled using the WCS and are summarized in Table 6. In middle Tennessee, it is estimated that there are approximately 2.47 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 5 Livestock Distribution in the Stones River Watershed

County	Livestock Population (2007 Census of Agriculture)							
	Beef Cow	Milk Cow	Poultry		Hogs	Sheep	Goats	Horse
			Layers	Broilers				
Bedford	32,648	1,117	69,340	7,494,442	(D)	500	3,559	5,611
Cannon	14,729	379	(D)	328	96	173	4,265	2,516
Coffee	14,771	2,081	22,935	505,304	428	134	2,065	1,894
Davidson	3,290	0	563	(D)	21	(D)	1,237	1,230
Rutherford	17,048	791	14,982	804	1,079	760	4,335	3,899
Williamson	19,347	732	2,345	5,273	342	775	2,707	4,762
Wilson	26,857	658	24	191	235	1,137	6,562	4,145

* In keeping with the provisions of Title 7 of the United States Code, no data are published in the 2007 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, 2009).

Table 6 Estimated Population on Septic Systems in the Stones River Watershed

County	Total Population (2000 Census)	Total Population (1990 Census)	% of Population on Septic Systems (1990 Census)
Bedford	37,586	30,411	45.9
Cannon	12,826	10,467	70.9
Coffee	48,014	40,339	43.9
Davidson	569,891	510,784	7.8
Rutherford	182,023	118,570	40.5
Williamson	126,638	81,021	48.1
Wilson	88,809	67,675	61.5

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. Urban land use area in impaired subwatersheds in the Stones River Watershed ranges from 3% to 83%. Land use for the Stones River drainage areas is summarized in Figures 7 thru 10, and tabulated in Appendix A.

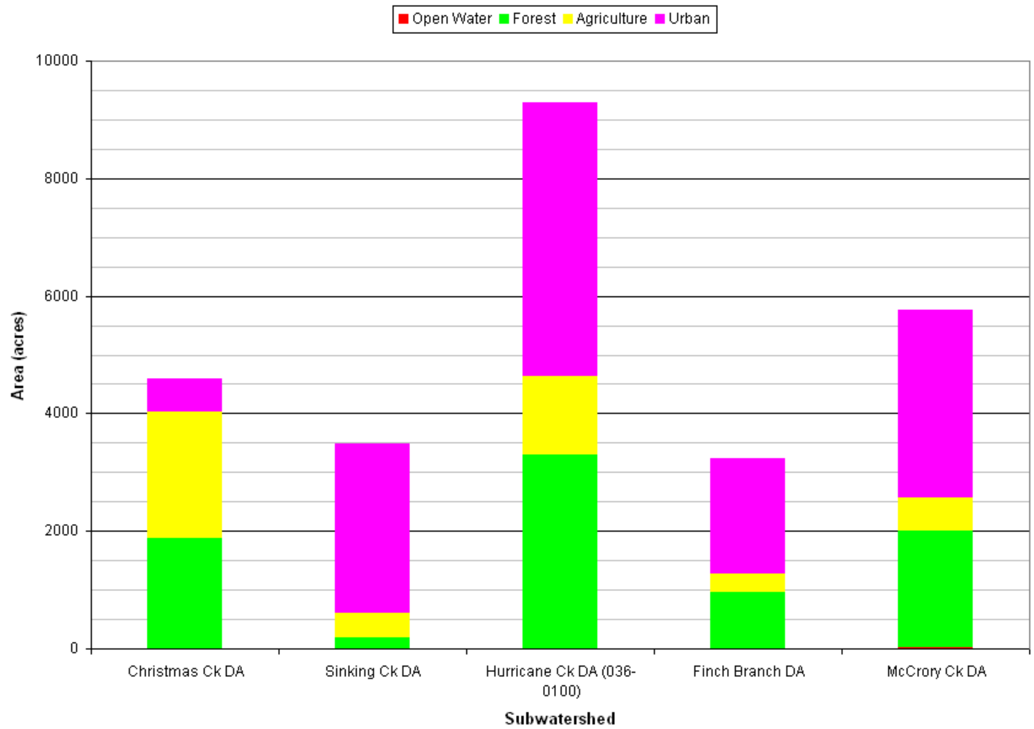

Figure 7. Land Use Area of Stones River E. coli-Impaired Subwatersheds (less than 10,000 acres)

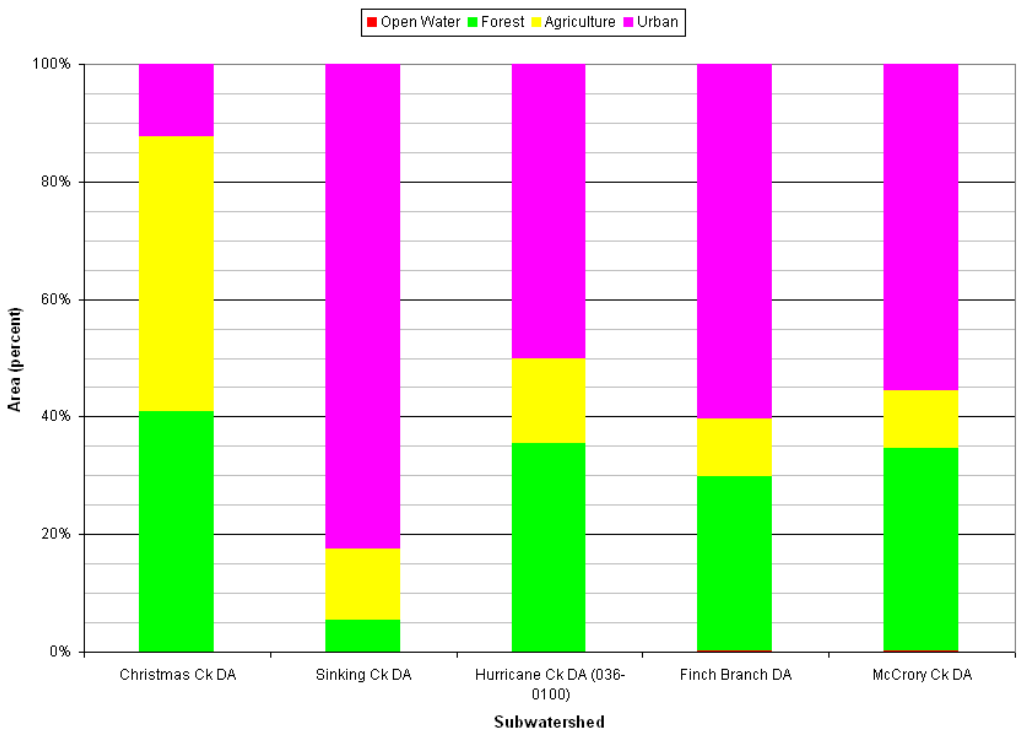

Figure 8. Land Use Percent of Stones River E. coli-Impaired Subwatersheds (less than 10,000 acres)

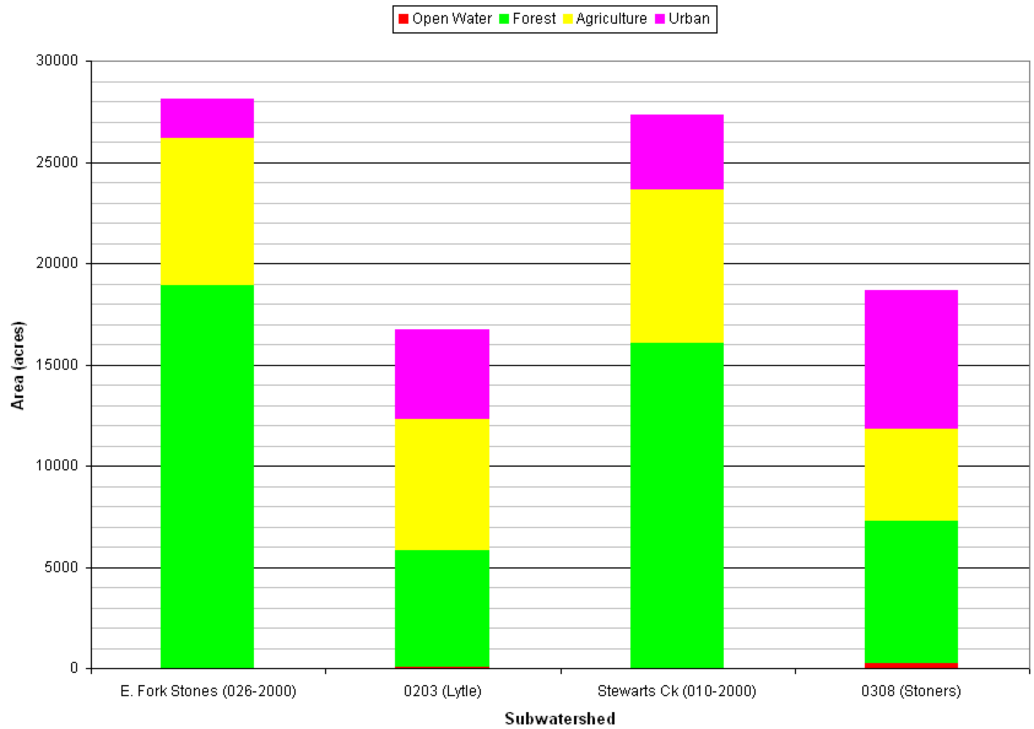

Figure 9. Land Use Area of Stones River E. coli-Impaired Subwatersheds (greater than 10,000 acres)

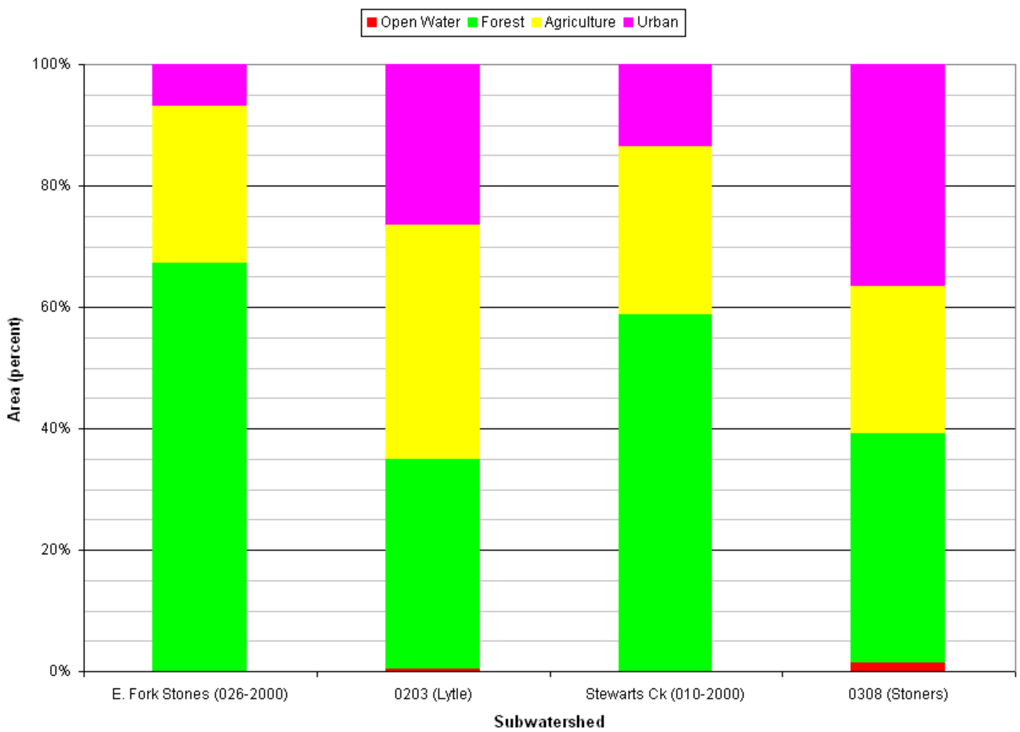

Figure 10. Land Use Percent of the Stones River E. coli-Impaired Subwatershed (greater than 10,000 acres)

8.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOADS

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:

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

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) (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 2010 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 was the HUC-12 subwatershed containing one or more waterbodies assessed as impaired due to E. coli (as documented on the Final 2010 303(d) List). In some cases, however, TMDLs may be 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.

Table 7 Determination of Analysis Areas for TMDL Development

HUC-12 Subwatershed (06020001____)	Impaired Waterbody	Area
0102	E. Fork Stones River (026-2000)	DA
0203	Lytle Creek	HUC-12
	Town Creek	
0205	Christmas Creek	DA
0206	Sinking Creek	DA
0301	Stewarts Creek (010-2000)	DA
0304	Hurricane Creek (036-1000)	DA
0305	Finch Branch	DA
0308	Stoners Creek	HUC-12
0309	McCrory Creek	DA

Note: HUC-12 = HUC-12 Subwatershed
DA = Waterbody Drainage Area

8.3 TMDL Analysis Methodology

TMDLs for the Stones 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 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, 2001 to December 31, 2010 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 all 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 Stones River Watershed (see Section 9.1.2 and 9.1.3).

Seasonal variation was incorporated in the load duration curves by using the entire simulation period and all water quality data collected at the monitoring stations. Some water quality data were collected during all seasons. Most water quality data were collected during periods of mid-range to low flows.

8.5 Margin of Safety

There are two methods for incorporating MOS in TMDL 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 pathogen TMDLs in the Stones 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 (lakes, reservoirs, State Scenic Rivers, or Exceptional Tennessee Waters waterbodies):	MOS = 49 CFU/100 ml
Instantaneous Maximum (all other waterbodies):	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 Stones River Watershed using LDCs to evaluate compliance with the single maximum target concentrations according to the procedure in Appendix C. These TMDL loading functions for impaired segments and 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 <u>after application of the explicit MOS</u>. 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 (with few exceptions in Tennessee) and recognition that loading from these facilities are 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. Summary of TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Stones River Watershed (HUC 05130203)

HUC-12 Subwatershed (05130203__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs			LAs [c]
					WWTFs [a]	Collection Systems	MS4s [b,c]	
			[CFU/day]	[CFU/day]	[CFU/day]	[CFU/day]	[CFU/d/ac]	[CFU/d/ac]
East Fork Stones River DA	East Fork Stones River	TN05130203026 – 2000	$1.20 \times 10^{10} \times Q$	$1.20 \times 10^{9} \times Q$	1.106×10^{10}	0	NA	$(3.838 \times 10^{5} \times Q) - (3.930 \times 10^{5})$
0203	Lytle Creek	TN05130203022 – 1000	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	$1.237 \times 10^{6} \times Q$	$1.237 \times 10^{6} \times Q$
	Lytle Creek	TN05130203022 – 2000						
	Town Creek	TN05130203022 – 0100						
Christmas Creek DA	Christmas Creek	TN05130203018 – 0210	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	$4.501 \times 10^{6} \times Q$	$4.501 \times 10^{6} \times Q$
Sinking Creek DA	Sinking Creek	TN05130203018 – 0210	$1.20 \times 10^{10} \times Q$	$1.20 \times 10^{9} \times Q$	NA	0	$3.096 \times 10^{6} \times Q$	$3.096 \times 10^{6} \times Q$
Stewarts Creek DA	Stewarts Creek	TN05130203010 – 2000	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	3.562×10^{9}	0	$(7.566 \times 10^{5} \times Q) - (1.302 \times 10^{5})$	$(7.566 \times 10^{5} \times Q) - (1.302 \times 10^{5})$
0304	Hurricane Creek	TN05130203036 – 1000	$1.20 \times 10^{10} \times Q$	$1.20 \times 10^{9} \times Q$	NA	NA	$9.841 \times 10^{5} \times Q$	$9.841 \times 10^{5} \times Q$
Finch Branch DA	Finch Branch	TN05130203003T – 0100	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	$6.404 \times 10^{6} \times Q$	$6.404 \times 10^{6} \times Q$
0308	Stoners Creek	TN05130203035 – 1000	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	$1.081 \times 10^{6} \times Q$	$1.081 \times 10^{6} \times Q$
McCrory Creek DA	McCrory Creek	TN05130203001 – 0100	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	$3.595 \times 10^{6} \times Q$	$3.595 \times 10^{6} \times Q$

Notes: NA = Not Applicable.
Q = Mean Daily In-stream Flow (cfs).

a. WLAs for WWTFs are expressed as E. coli loads (CFU/day). All current and future WWTFs must meet water quality standards as specified in their NPDES permit.

b. Applies to any MS4 discharge loading in the subwatershed. Future MS4s will be assigned waste load allocations (WLAs) consistent with load allocations (LAs) assigned to precipitation induced nonpoint sources.

c. WLAs and LAs expressed as a "per acre" load are calculated based on the drainage area at the pour point of the HUC-12 or drainage area (see Table A-1).

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 Stones 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 11): 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 zero flows) throughout their period of record. For these waterbodies, 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.

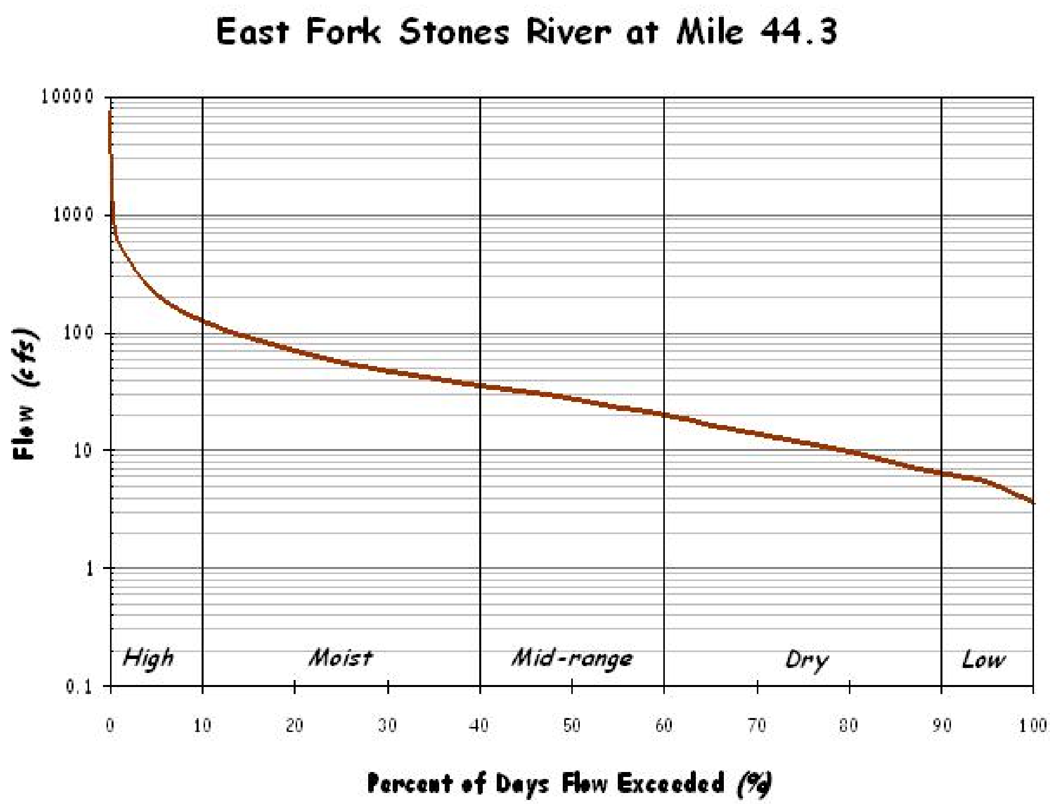

Figure 11. Five-Zone Flow Duration Curve for East Fork Stones River at RM 44.3

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) and/or the highest percent of samples exceeding the TMDL target 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 and/or percent exceedance, 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 and/or percent exceedance in this zone is greater than all the other zones, the zone with the second highest PLRG and/or percent exceedance will be considered 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. With few exceptions, 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 Program (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%General%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 the 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/permits/cafo.shtml.

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. An excellent example of stakeholder involvement is the Friends of the Greenway (FOG). The FOG is a non-profit group that exists to aid the Murfreesboro Parks and Recreation Dept. in achieving the goals and objectives of the Murfreesboro Greenway System. The Murfreesboro Greenway lies along the West Fork Stones River and Lytle Creek in the heart of downtown Murfreesboro. An additional spur trail connects the Stones River National Battlefield Park. Building this Greenway has enhanced the water quality of the West Fork Stones River and Lytle Creek tremendously. FOG has worked with the Stones River National Battlefield to remove invasive/exotic species and to plant native plants along the greenway. FOG has also worked with the Stones River Watershed Association and Murfreesboro Parks and Recreation to conduct a series of classes on watershed awareness along the Greenway at Lytle Creek. Information regarding the accomplishments of the Friends of the Greenway and volunteer opportunities is available at the following website:

http://www.murfreesborotn.gov/default.aspx?ekmenu=316&id=6161

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 Stones River Watershed to reduce the amount of coliform bacteria transported to surface waters from agricultural sources. These BMPs (e.g., animal waste management systems, waste utilization, stream stabilization, fencing, heavy use area treatment, livestock exclusion, etc.) may have contributed to reductions in in-stream concentrations of coliform bacteria in one or more Stones River Watershed E. coli-impaired subwatersheds during the TMDL evaluation period. The Natural Resources Conservation Service (NRCS) keeps a database of BMPs implemented in Tennessee. Those listed in the Stones River Watershed are shown in Figure 12. 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 modeling 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.

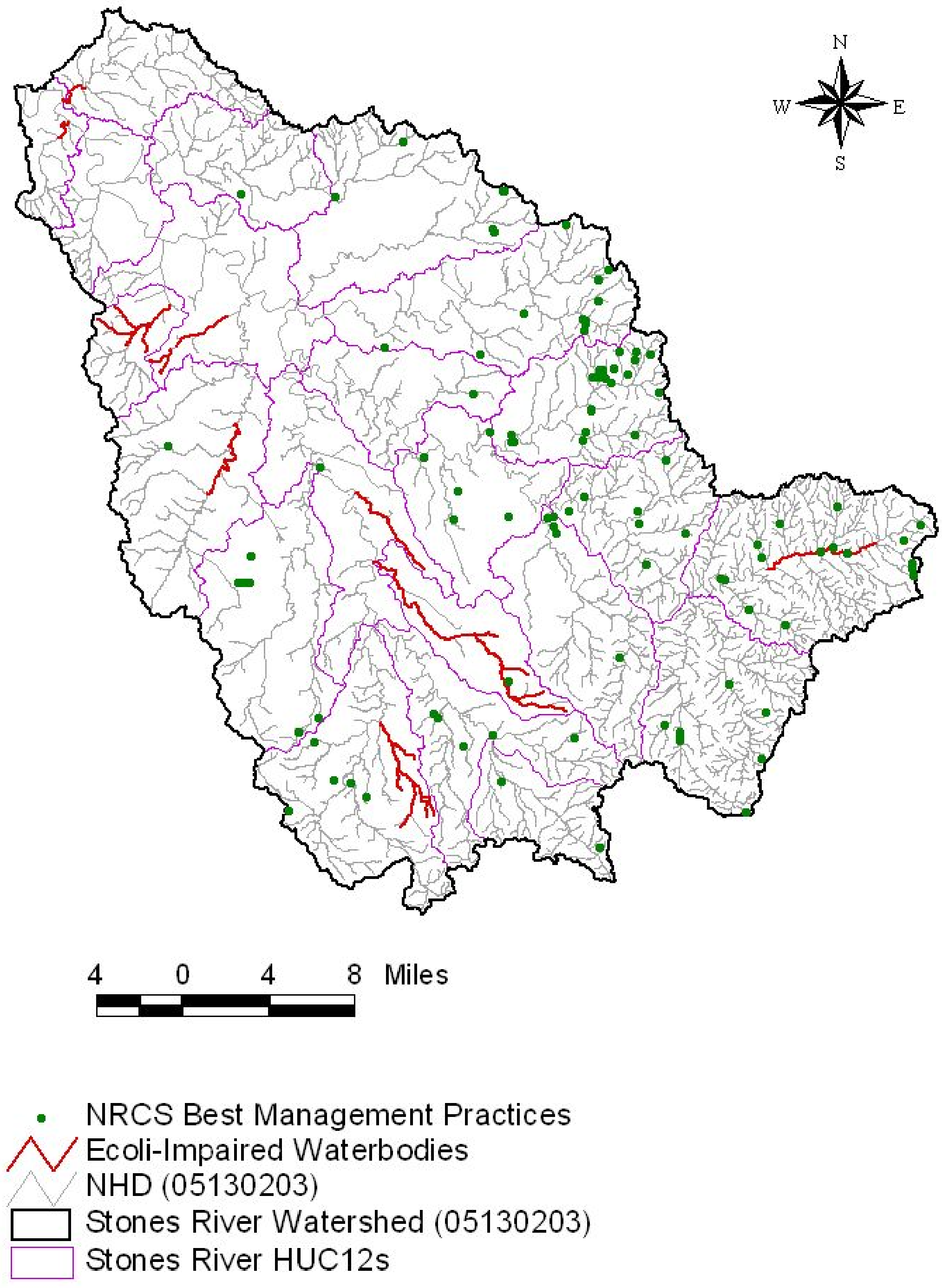

Figure 12. NRCS Best Management Practices located in the Stones River Watershed.

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

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 groundwater 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 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 Stones River Watershed:

> Evaluate the effectiveness of implementation measures (see Sect. 9.6). Includes BMP performance analysis and monitoring by permittees 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 Stones 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, 2004).

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 emerging 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, 2002b). 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 (Layton, 2006). 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/JournalPapers/Layton06AEM.pdf .

BST technology was utilized in a study conducted in Stock Creek (Little River watershed) (Layton, 2004). Microbial source tracking using real-time PCR assays to quantify *Bacteroides* 16S rRNA genes was used to determine the percent of fecal contamination attributable to cattle. E. coli loads attributable to cattle were calculated for each of nine sampling sites in the Stock Creek subwatershed on twelve sampling dates. At the site on High Bluff Branch (tributary to Stock Creek), none of the sample dates had E. coli loads attributable to cattle above the threshold. This suggests that at this site removal of E. coli attributable to cattle would have little impact on the total E. coli loads. The E. coli load attributable to cattle made a large contribution to the total E. coli load at each of the eight remaining sampling sites. At two of the sites (STOCK005.3KN and GHOLL000.6KN), 50–75% of the E. coli attributable to cattle loads alone was above the 126 CFU/100mL threshhold. This suggests that removal of the E. coli attributable to cattle at these sites would reduce the total E. coli load to acceptable limits.

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 distributation of impaired subwatersheds. For the purpose of implementation evaluation, urban is defined as residential, commercial, and industrial landuse areas with predominant 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 predominant 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 predominant source category being wildlife.

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 Stones River Watershed are summarized in Table E-27.

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

HUC-12 / Waterbody Name	Source Area Type*			
	Urban	Agricultural	Mixed	Forested
East Fork Stones River (026-2000)		ò		
0203 (Lytle Creek & Town Creek)	ò			
Christmas Creek			ò	
Sinking Creek	ò			
Stewarts Creek (010-2000)			ò	
Hurricane Creek (036-1000)	ò			
Finch Branch	ò			
0308 (Stoners Creek)	ò			
0309 (McCrory Creek)	ò			

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

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.

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	

Table 10 (cont'd). Example Urban Area Management Practice/Hydrologic Flow Zone Considerations.

Management Practice	Duration Curve Zone (Flow Zone)				
	High	**Moist**	**Mid-Range**	**Dry**	**Low**
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*)					

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 present 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.

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 (cont'd). 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
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.

9.5.3 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 predominant source category being wildlife, in the Stones River Watershed.

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 13 shows best fit curve analyses (regressions) of flow (percent time exceeded) versus fecal coliform loading, for a historical (2002) TMDL analysis period versus a recent post-implementation period of sampling data (revised TMDL), for Oostanaula Creek at mile 28.4 (Hiwassee River watershed). The LDC of the single sample maximum water quality standard is also plotted to illustrate the relative degree of impairment for each period. Figure 14 shows a LDC analysis of fecal coliform loading statistics for Oostanaula Creek for the same two periods. In addition, the 90th percentiles for each flow zone are plotted for comparison. Lastly, Figure 15 shows fecal coliform concentration data statistics for recent versus historical data. The individual flow zone analyses are presented in a box and whisker plot of recent [2] versus historical [1] data. Note that Figures 13-15 present the same data, from approved TMDLs (2 cycles), each clearly illustrating improving conditions between historical and recent periods.

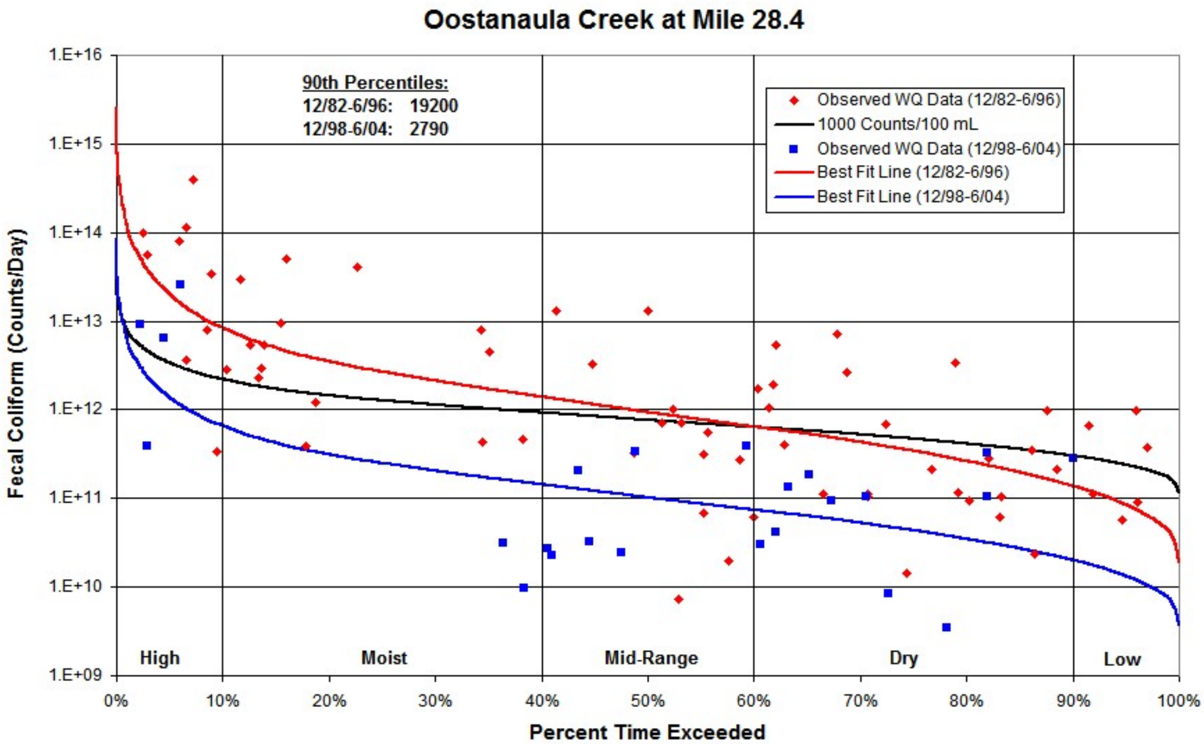

Figure 13. Example Graph of TMDL implementation effectiveness (LDC regression analysis).

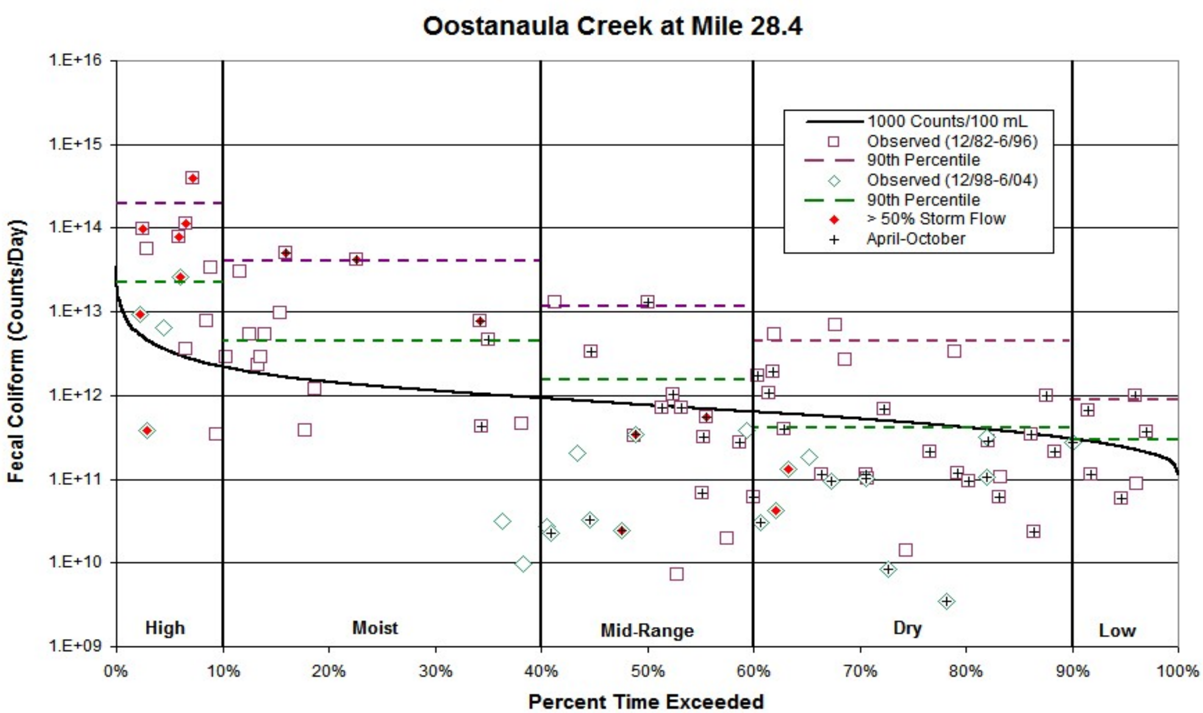

Figure 14. Example Graph of TMDL implementation effectiveness (LDC analysis).

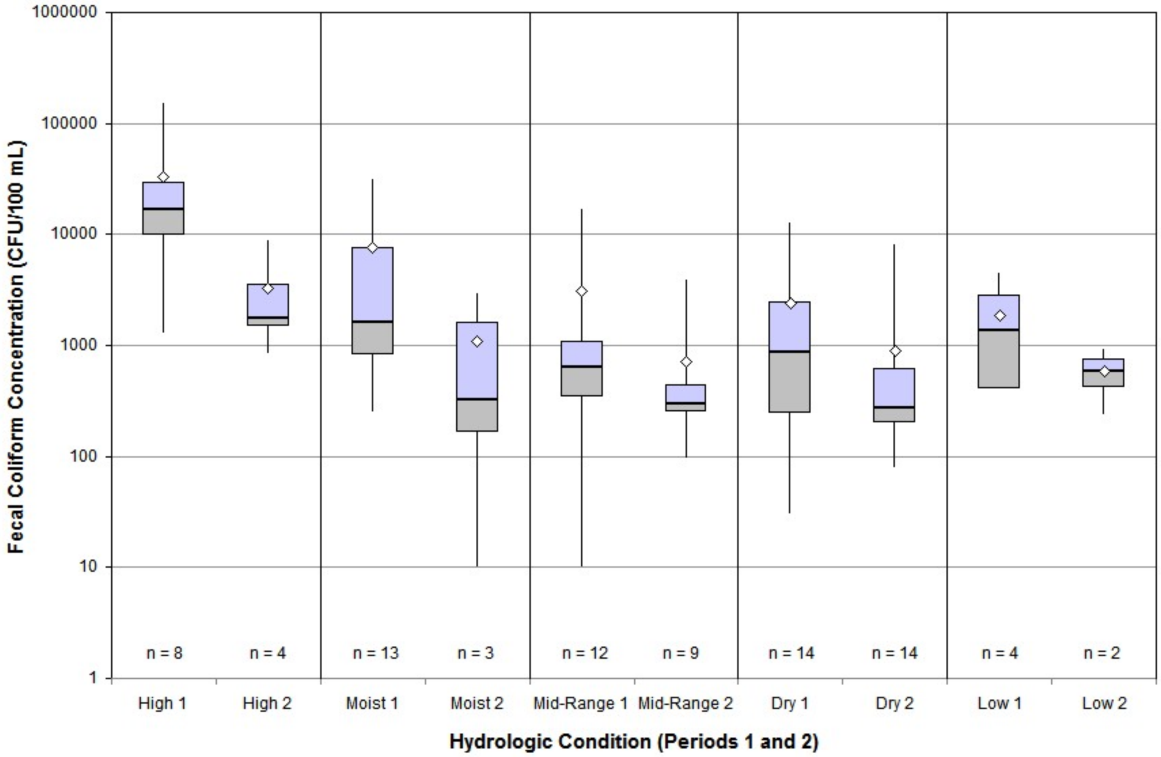

Figure 15. Example Graph of TMDL implementation effectiveness (box and whisker plot).

10.0 PUBLIC PARTICIPATION

In accordance with 40 CFR §130.7, the proposed pathogen TMDLs for the Stones 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 Tennessee Department of Environment and Conservation 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 is sent to approximately 90 interested persons or groups who have requested this information.

3) Letters were sent to WWTFs located in E. coli-impaired subwatersheds or drainage areas in the Stones River Watershed, permitted to discharge treated effluent containing pathogens, 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. A letter was sent to the following facilities:

   Smyrna STP (TN0020541)
   Murfreesboro-Sinking Creek STP (TN0022586)
   Woodbury STP (TN0025089)
   Bill Rice Ranch (TN0057975)

4) A draft copy of the proposed TMDL was sent to those MS4s that are wholly or partially located in E. coli-impaired subwatersheds. A draft copy was sent to the following entities:

   Metro Nashville/Davidson County, Tennessee (TNS068047)
   City of Murfreesboro, Tennessee (TNS075469)
   City of Mount Juliet, Tennessee (TNS075451)
   City of Lavergne, Tennessee (TNS075418)
   Town of Smyrna, Tennessee (TNS075779)
   Rutherford County, Tennessee (TNS075647)
   Wilson County, Tennessee (TNS075809)
   Tennessee Dept. of Transportation (TNS077585)

5) A letter was sent to water quality partners in the Stones River Watershed advising them of the proposed pathogen TMDLs and their availability on the TDEC website. The letter also stated that a written copy of the draft TMDL document would be provided upon request. A letter was sent to the following partners:

Natural Resources Conservation Service
Tennessee Department of Agriculture
Tennessee Wildlife Resources Agency
The Nature Conservancy
Stones River Watershed Association
Friends of Murfreesboro Greenway

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 Stones River Watershed

Table A-1 2001 MRLC Land Use Distribution of Impaired HUC-12s & Drainage Areas

Land Use	Impaired Subwatershed (05130203____)					
	East Fork Stones River (026-2000) (in 0102)		0203 (Lytle Creek)		Christmas Creek (in 0205)	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Unclassified	0.0	0.00	0.0	0.00	0.00	0.00
Open Water	0.0	0.00	58.5	0.35	3.68	0.08
Developed Open Space	1,334.0	4.74	1,629.3	9.74	372.02	8.09
Low Intensity Development	484.1	1.72	2,014.1	12.04	148.53	3.23
Medium Intensity Development	87.2	0.31	560.4	3.35	48.28	1.05
High Intensity Development	31.0	0.11	232.5	1.39	0.00	0.00
Bare Rock	8.4	0.03	38.5	0.23	0.00	0.00
Deciduous Forest	16,210.5	57.60	2,102.7	12.57	920.16	20.01
Evergreen Forest	959.7	3.41	1,574.1	9.41	412.49	8.97
Mixed Forest	785.2	2.79	776.2	4.64	244.18	5.31
Shrub/Scrub	678.3	2.41	823.0	4.92	214.75	4.67
Grassland/Herbaceous	261.7	0.93	374.7	2.24	82.77	1.80
Pasture/Hay	6,881.0	24.45	5,523.6	33.02	1,848.14	40.19
Row Crops	416.5	1.48	928.4	5.55	301.66	6.56
Woody Wetlands	2.8	0.01	92.0	0.55	2.76	0.06
Emergent Herbaceous Wetland	0.0	0.00	3.3	0.02	0.46	0.01
Subtotal – Urban	1,936.3	6.88	4,436.3	26.52	568.8	12.37
Subtotal - Agriculture	7,297.6	25.93	6,452.0	38.57	2,149.8	46.75
Subtotal – Forest	18,906.7	67.18	5,784.5	34.58	1,877.6	40.83
Total	**28,141**	**100.0**	**16,731**	**100.00**	**4,600**	**100.00**

Table A-1 (cont'd) 2001 MRLC Land Use Distribution of Impaired HUC-12s & Drainage Areas

Land Use	Impaired Subwatershed (05130203____)					
	Sinking Creek (in 0206)		Stewarts Creek (010-2000) (in 0301)		0304 (Hurricane Creek) (036-1000)	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Unclassified	0.0	0.00	0.0	0.00	0.0	0.00
Open Water	1.0	0.03	13.7	0.05	4.4	0.04
Developed Open Space	790.5	22.66	2,273.5	8.31	1,246.8	11.36
Low Intensity Development	1,637.1	46.93	1,171.0	4.28	2,326.7	21.20
Medium Intensity Development	367.3	10.53	158.7	0.58	1,161.2	10.58
High Intensity Development	84.1	2.41	98.5	0.36	760.6	6.93
Bare Rock	2.8	0.08	24.6	0.09	1.1	0.01
Deciduous Forest	78.1	2.24	8,837.0	32.30	2,275.1	20.73
Evergreen Forest	13.6	0.39	2,580.0	9.43	406.1	3.70
Mixed Forest	17.1	0.49	3,097.1	11.32	655.2	5.97
Shrub/Scrub	28.6	0.82	697.7	2.55	275.5	2.51
Grassland/Herbaceous	37.3	1.07	801.6	2.93	261.2	2.38
Pasture/Hay	394.9	11.32	7,088.7	25.91	1,523.3	13.88
Row Crops	27.2	0.78	478.8	1.75	63.7	0.58
Woody Wetlands	8.4	0.24	35.6	0.13	14.3	0.13
Emergent Herbaceous Wetland	0.0	0.00	0.0	0.01	0.0	0.00
Subtotal – Urban	2,879.0	82.53	3,701.7	13.53	5,495.2	50.07
Subtotal - Agriculture	422.1	12.10	7,567.5	27.66	1,587.0	14.46
Subtotal – Forest	185.9	5.33	16,073.5	58.76	3,888.4	35.43
Total	**3,488**	**100.0**	**27,356**	**100.00**	**10,975**	**100.00**

Table A-1 (cont'd) 2001 MRLC Land Use Distribution of Impaired HUC-12s & Drainage Areas

Land Use	Impaired Subwatershed (05130203____)					
	Finch Branch (in 0305)		0308 (Stoners Creek)		McCrory Creek (in 0309)	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Unclassified	0.00	0.00	0.0	0.00	0.0	0.00
Open Water	3.88	0.12	258.5	1.35	17.3	0.30
Developed Open Space	851.76	26.35	3,582.4	18.71	1,620.2	28.14
Low Intensity Development	766.43	23.71	2,749.5	14.36	1,030.1	17.89
Medium Intensity Development	168.41	5.21	520.8	2.72	368.5	6.40
High Intensity Development	166.47	5.15	151.3	0.79	178.5	3.10
Bare Rock	2.59	0.08	128.3	0.67	1.2	0.02
Deciduous Forest	405.03	12.53	3,712.6	19.39	1,118.2	19.42
Evergreen Forest	206.88	6.40	1,102.9	5.76	262.6	4.56
Mixed Forest	167.12	5.17	1,451.3	7.58	393.3	6.83
Shrub/Scrub	62.06	1.92	459.5	2.40	135.3	2.35
Grassland/Herbaceous	102.79	3.18	340.8	1.78	60.9	1.06
Pasture/Hay	298.04	9.22	4,378.9	22.87	525.7	9.13
Row Crops	17.13	0.53	277.6	1.45	34.5	0.60
Woody Wetlands	13.90	0.43	34.5	0.18	12.7	0.22
Emergent Herbaceous Wetland	0.00	0.00	0.0	0.00	0.0	0.00
Subtotal – Urban	1,953.1	60.42	7,004.0	36.58	3,197.3	55.53
Subtotal - Agriculture	315.2	9.75	4,656.6	24.32	560.2	9.73
Subtotal – Forest	960.4	29.71	7,229.9	37.76	1,984.0	34.46
Total	**3,233**	**100.00**	**19,147**	**100.0**	**5,759**	**100.00**

APPENDIX B

Water Quality Monitoring Data
For Stones River Watershed

There are a number of water quality monitoring stations that provide data for waterbodies identified as impaired for pathogens in the Stones River Watershed. The location of these monitoring stations is shown in Figure 5. Monitoring data recorded by TDEC at these stations are tabulated in Table B-1. Monitoring data reported by Metro Nashville and Murfreesboro are tabulated in Tables B-2 and B-3 respectively.

Table B-1. TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100 mL]
CHRIS000.7RU	9/11/06	48
	9/13/06	11
	9/21/06	1600
	9/25/06	610
	9/26/06	770
	9/28/06	980
	5/8/07	308
	5/9/07	248
	5/15/07	185
	5/16/07	166
	5/23/07	201
	5/24/07	162
	5/29/07	140
EFSTO044.3CN	7/24/06	160
	8/21/06	110
	9/13/06	87
	10/17/06	1000
	11/28/06	73
	12/12/06	173
	1/10/07	816
	2/26/07	36
	3/8/07	61
	4/11/07	276
	5/22/07	921
	6/12/07	2420
FINCH001.4RU	11/7/06	2400
	1/8/07	1300
	1/10/07	160
	1/17/07	365
	1/18/07	197
	1/23/07	219
	1/25/07	59
	5/7/07	866

Table B-1 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100 mL]
HURRI004.2RU	10/2/06	550
	10/9/06	26
	10/11/06	730
	10/18/06	120
	10/23/06	93
	10/25/06	20
	10/31/06	33
	1/8/07	192
	1/10/07	96
	1/17/07	435
	1/18/07	148
	1/23/07	150
	1/25/07	155
	1/30/07	40
	6/4/07	308
	6/5/07	210
	6/11/07	54
	6/12/07	76
	6/18/07	142
	6/19/07	2420
	6/25/07	308
	5/11/10	4610
	5/13/10	1733
	5/19/10	1120
	5/24/10	326
LYTLE001.1RU	9/6/06	61
	9/11/06	110
	9/13/06	920
	9/21/06	68
	9/25/06	410
	9/26/06	140
	9/28/06	260
	5/8/07	219
	5/9/07	206

Table B-1 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100 mL]
LYTLE001.1RU (cont'd)	5/15/07	132
	5/16/07	435
	5/23/07	101
	5/24/07	64
	5/29/07	102
	5/11/10	127
	5/13/10	238
	5/19/10	137
LYTLE008.7RU	5/8/07	205
	5/9/07	866
	5/15/07	86
	5/16/07	140
	5/23/07	25
	5/24/07	111
MCCRO001.5DA	10/1/06	490
	10/12/06	820
	10/17/06	920
	10/19/06	190
	10/26/06	56
	10/30/06	160
	11/2/06	160
	5/10/07	1120
	5/15/07	1414
	5/22/07	228
	5/29/07	326
	5/31/07	276
SINKI000.2RU	9/6/06	340
	9/11/06	550
	9/13/06	1100
	9/21/06	190
	9/25/06	580
	9/26/06	460
	9/28/06	240
	5/8/07	131
	5/9/07	248

Table B-1 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100 mL]
SINKI000.2RU (cont'd)	5/15/07	112
	5/16/07	225
	5/23/07	108
	5/24/07	153
	5/29/07	140
STEWA009.8RU	10/2/06	240
	10/9/06	55
	10/11/06	81
	10/18/06	270
	10/23/06	120
	10/25/06	130
	10/31/06	300
	1/8/07	1986
	1/10/07	345
	1/17/07	517
	1/18/07	308
	1/23/07	461
	1/25/07	199
	1/30/07	64
	6/4/07	291
	6/5/07	155
	6/11/07	140
	6/12/07	122
	6/18/07	91
	6/19/07	2420
	6/25/07	488
STONE000.9DA	7/18/06	160
	8/3/06	220
	9/19/06	1400
	10/1/06	280
	10/11/06	170
	10/12/06	190
	10/17/06	2400
	10/19/06	130
	10/26/06	75
	10/30/06	140

Table B-1 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100 mL]
STONE000.9DA (cont'd)	11/2/06	150
	11/7/06	1400
	1/23/07	199
	2/12/07	91
	3/13/07	44
	4/25/07	147
	5/7/07	488
	5/8/07	387
	5/10/07	194
	5/15/07	387
	5/22/07	291
	5/29/07	270
	5/31/07	387
	6/26/07	365
	5/19/10	517
	5/24/10	387
TOWN000.1RU	9/6/06	77
	9/11/06	150
	9/13/06	730
	9/21/06	75
	9/25/06	440
	9/26/06	340
	9/28/06	130
	5/8/07	161
	5/9/07	105
	5/15/07	276
	5/16/07	649
	5/23/07	185
	5/24/07	96
	5/29/07	102

Table B-2. Metro Nashville Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100 mL]
MCCRO001.5DA	12/10/07	48.3
	12/11/07	93.2
	12/18/07	79.8
	12/20/07	101.7
	12/26/07	60.2
	2/7/08	80.9
	2/11/08	69.1
	2/14/08	71.7
	2/25/08	218.7
	3/3/08	201.4
	6/5/08	435.2
	6/10/08	344.8
	6/16/08	613.1
	6/17/08	613.1
	6/18/08	980.4
	8/4/08	387.3
	8/5/08	461.1
	8/6/08	2419.6
	8/14/08	108.6
	8/19/08	78.9
	11/4/08	218.7
	11/6/08	129.1
	11/10/08	105.0
	11/11/08	93.2
	11/18/08	90.8
	2/3/09	73.8
	2/4/09	16.0
	2/9/09	49.6
	2/10/09	145.5
	2/17/09	85.5
	5/20/09	178.5
	5/21/09	461.1
	5/27/09	816.4
	5/29/09	387.3
	5/30/09	155.3

Table B-2 (cont'd). Metro Nashville Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100 mL]
MCCRO001.5DA (cont'd)	8/10/09	344.8
	8/13/09	214.0
	8/17/09	224.7
	8/24/09	228.2
	8/25/09	238.2
STONE000.9DA	12/5/07	143.9
	12/18/07	290.9
	12/20/07	185.0
	12/26/07	93.3
	1/2/08	72.7
	2/14/08	46.2
	2/19/08	119.8
	2/25/08	155.3
	3/3/08	145.0
	6/5/08	290.9
	6/10/08	325.5
	6/16/08	686.7
	6/17/08	727.0
	6/18/08	461.1
	8/4/08	184.2
	8/5/08	172.5
	8/6/08	122.4
	8/14/08	325.5
	8/19/08	275.5
	11/4/08	727.0
	11/6/08	285.1
	11/10/08	63.8
	11/11/08	54.6
	11/18/08	56.6
	2/3/09	157.6
	2/4/09	59.8
	2/9/09	36.4
	2/10/09	54.6
	2/17/09	51.2

Table B-2 (cont'd). Metro Nashville Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100 mL]
STONE000.9DA (cont'd)	5/20/09	613.1
	5/21/09	344.8
	5/27/09	150.0
	5/29/09	727.0
	5/30/09	159.7
	8/10/09	579.4
	8/13/09	387.0
	8/17/09	410.6
	8/24/09	260.3
	8/25/09	461.1

Table B-3. Murfreesboro MS4 Water Quality Monitoring Data

Monitoring Station	Date/Time	E. Coli [cts./100 mL]
SC-1 (SINKI000.2RU)	6/12/08 11:45	191.8
	6/19/08 10:43	346
	6/24/08 10:30	242
	6/26/08 11:20	220
	7/1/08 11:01	192
	7/3/08 10:50	532
SC-2 (SINKI003.2RU)	6/12/08 11:30	496.2
	6/24/08 10:15	398
SC-3 (SINKI1T0.1RU)	6/12/08 11:00	55.8
	6/24/08 10:30	216
SC-4 (SINKI2T0.0RU)	6/12/08 11:07	1034.4
TC-1 (TOWN000.1RU)	6/12/08 10:40	476.4
	6/19/08 10:15	220
	6/24/08 9:40	82
	6/26/08 9:45	150
	7/1/08 10:10	244
TC-2 (TOWN000.5RU)	6/26/08 9:55	220
	7/8/08 9:39	736
	7/22/08 9:57	690
TC-3 (TOWN000.9RU)	6/19/08 10:23	196
	6/24/08 9:45	718
	6/26/08 10:05	82
	7/1/08 10:00	1434
	7/3/08 10:00	462
	7/8/08 9:22	322
	7/10/08 10:15	758
	7/17/08 9:24	20
	7/22/08 9:45	192
	7/24/08 9:40	82
	7/29/08 9:35	126
	8/5/08 9:25	500

Table B-3 (cont'd). Murfreesboro MS4 Water Quality Monitoring Data

Monitoring Station	Date/Time	E. Coli [cts./100 mL]
LC-1 (LYTLE000.6RU)	6/26/08 10:19	62
	7/17/08 10:43	< 20
	8/12/08 10:54	1986
	8/14/08 9:58	104
	8/19/08 10:23	< 20
	8/21/08 9:44	82
	8/26/08 9:57	672
LC-2a (LYTLE001.1RU)	7/10/08 10:45	126
LC-2b (LYTLE001.5RU)	7/10/08 10:30	432
LC-3 (LYTLE002.3RU)	7/8/08 9:55	244
LC-4 (LYTLE003.8RU)	7/10/08 10:04	40
	8/12/08 10:17	62
	8/14/08 9:47	< 20
	8/18/08 10:12	20
	8/21/08 0:00	20
	8/26/08 9:41	13734
LC-5 (LYTLE003.2RU)	7/17/08 9:45	104
	7/24/08 10:00	196
	7/31/08 10:00	150
LC-6a (LYTLE003.0RU)	7/17/08 9:55	338
	7/31/08 10:21	1152
LC-6b (LYTLE003.0RU)	7/24/08 10:15	48000
	7/31/08 10:20	1302
	8/5/08 9:44	322
	8/7/08 9:45	882
	8/12/08 10:34	82
LC-6c (LYTLE003.0RU)	7/31/08 10:22	786
LC-6d (LYTLE003.0RU)	8/12/08 10:41	170

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), nonpoint 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.

C.1 Development of TMDLs

E. coli TMDLs, WLAs, and LAs were developed for impaired subwatersheds and drainage areas in the Stones 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 discharges of flow 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 Windows version of Hydrologic Simulation Program - Fortran (WinHSPF).

Flow duration curves for impaired waterbodies in the Stones River Watershed were derived from WinHSPF hydrologic simulations based on parameters derived from calibrations at several USGS gaging stations (see Appendix D for details of calibration). For example, a flow-duration curve for East Fork Stones River was constructed using simulated daily mean flow for the period from 1/1/01 through 12/31/10 (RM 44.3 corresponds to the location of monitoring stations EFSTO044.3CN). 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 Stones 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. Load duration curves and required load reductions were developed using the following procedure (East Fork Stones River at RM44.3 is shown as an example):

1. A target load-duration curve (LDC) was generated for East Fork Stones River by applying the E. coli target concentration of 487 CFU/100 mL to each of the ranked flows used to generate the flow duration curve (ref.: Section D.1) and plotting the results. The E. coli target maximum load corresponding to each ranked daily mean flow is:

   $(\text{Target Load})_{\text{East Fork Stones River}} = (487\ \text{CFU/100 mL}) \times (Q) \times (\text{UCF})$

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

   TMDL = $(1.20\times10^{10}) \times (Q)$ CFU/day

2. Daily loads were calculated for each of the water quality samples collected at monitoring station EFSTO044.3CN (ref.: Table B-1) by multiplying the sample concentration by the daily mean flow for the sampling date and the required unit conversion factor. EFSTO044.3CN was selected for LDC analysis because it has a longer period of record 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 was available for some sampling dates.

   Example – 4/11/07 sampling event:
   Modelled Flow = 84.3 cfs
   Concentration = 276 CFU/100 mL
   Daily Load = 5.69×10^{11} CFU/day

3. Using the flow duration curves developed in 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 load duration curves developed in Step 1 according to the PDFE. The resulting E. coli load duration curve for 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

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:

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

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

- $[\sum WLAs]_{WWTF}$ is the allowable load associated with discharges of NPDES permitted WWTFs located in impaired subwatersheds or drainage areas. 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.
- $[\sum WLAs]_{CAFO}$ is the allowable load for all CAFOs in an impaired subwatershed or drainage area. 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:
  - o All process wastewater resulting from the operation of the CAFO (such as wash water, parlor water, watering system overflow, etc.); plus,
  - o 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.
- $[\sum WLAs]_{MS4}$ 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:

- $[\sum LAs]_{DS}$ 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).

- $[\sum LAs]_{SW}$ represents the allowable E. coli loading 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 $[\sum WLAs]_{CAFO} = 0$ and $[\sum LAs]_{DS} = 0$, the expression relating TMDLs to precipitation-based point and nonpoint sources may be simplified to:

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

As stated in Section 8.4, 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 and WLAs and LAs:

Instantaneous Maximum (lake, reservoir, State Scenic River, Exceptional Tennessee Waters):

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:

$$WLA[MS4] = LA = \{TMDL - MOS - WLA[WWTFs]\} / DA$$

where: DA = waterbody drainage area (acres)

Using East Fork Stones River as an example:

$$TMDL_{East\ Fork\ Stones\ River} = (487\ CFU/100\ mL) \times (Q) \times (UCF)$$
$$= 1.20 \times 10^{10} \times Q$$

$MOS_{East\ Fork\ Stones\ River}$ = TMDL x 0.10 = 1.20×10^{9} x Q

MOS = (1.20×10^{9}) x (Q) CFU/day

$WLA[MS4]_{East\ Fork\ Stones\ River}$ = $LA_{East\ Fork\ Stones\ River}$

= {TMDL – MOS – WLA[WWTFs]} / DA

= $\{(1.20 \times 10^{10} \times Q) - (1.20 \times 10^{9} \times Q) - (1.106 \times 10^{10})\} / (2.814 \times 10^{5})$

WLA[MS4] = LA = $[3.838 \times 10^{5} \times Q] - [3.930 \times 10^{5}]$

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

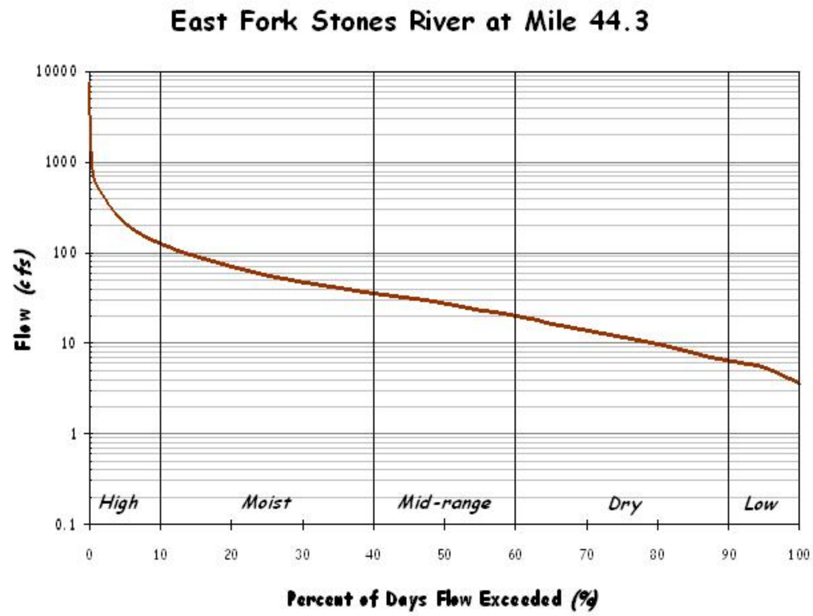

Figure C-1. Flow Duration Curve for East Fork Stones River at Mile 44.3

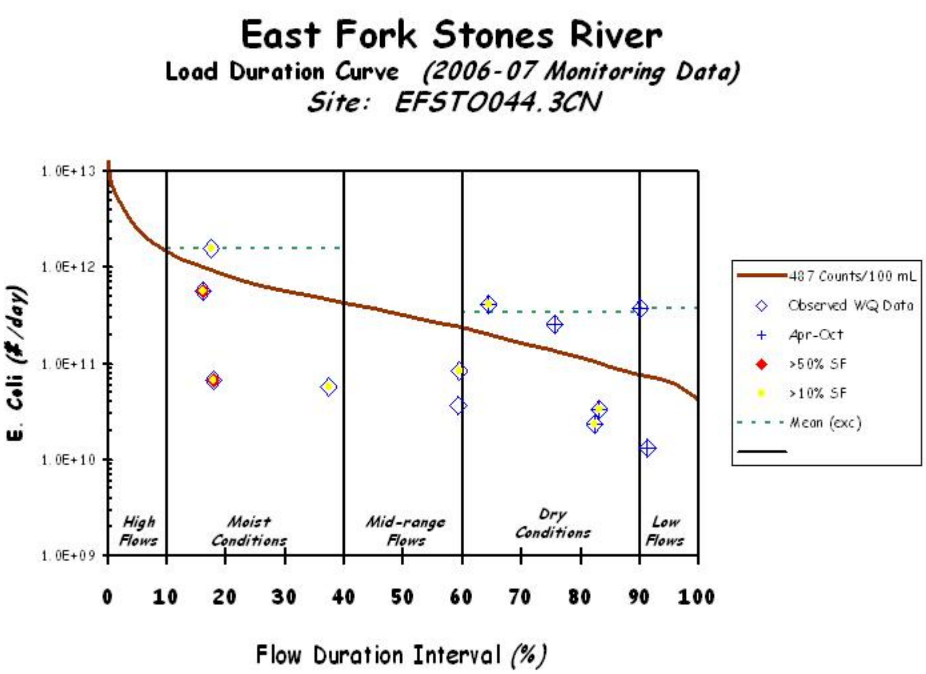

Figure C-2. E. Coli Load Duration Curve for East Fork Stones River at Mile 44.3

Table C-1. TMDLs, WLAs, & LAs for Impaired Waterbodies in the Stones River Watershed (HUC 05130203)

HUC-12 Subwatershed (05130203__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs			LAs [c]
					WWTFs [a]	Collection Systems	MS4s [b,c]	
			[CFU/day]	[CFU/day]	[CFU/day]	[CFU/day]	[CFU/d/ac]	[CFU/d/ac]
East Fork Stones River DA	East Fork Stones River	TN05130203026 – 2000	$1.20 \times 10^{10} \times Q$	$1.20 \times 10^{9} \times Q$	1.106×10^{10}	0	NA	$(3.838 \times 10^{5} \times Q) - (3.930 \times 10^{5})$
0203	Lytle Creek	TN05130203022 – 1000	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	$1.237 \times 10^{6} \times Q$	$1.237 \times 10^{6} \times Q$
	Lytle Creek	TN05130203022 – 2000						
	Town Creek	TN05130203022 – 0100						
Christmas Creek DA	Christmas Creek	TN05130203018 – 0210	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	$4.501 \times 10^{6} \times Q$	$4.501 \times 10^{6} \times Q$
Sinking Creek DA	Sinking Creek	TN05130203018 – 0210	$1.20 \times 10^{10} \times Q$	$1.20 \times 10^{9} \times Q$	NA	0	$3.096 \times 10^{6} \times Q$	$3.096 \times 10^{6} \times Q$
Stewarts Creek DA	Stewarts Creek	TN05130203010 – 2000	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	3.562×10^{9}	0	$(7.566 \times 10^{5} \times Q) - (1.302 \times 10^{5})$	$(7.566 \times 10^{5} \times Q) - (1.302 \times 10^{5})$
0304	Hurricane Creek	TN05130203036 – 1000	$1.20 \times 10^{10} \times Q$	$1.20 \times 10^{9} \times Q$	NA	NA	$9.841 \times 10^{5} \times Q$	$9.841 \times 10^{5} \times Q$
Finch Branch DA	Finch Branch	TN05130203003T – 0100	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	0	$6.404 \times 10^{6} \times Q$	$6.404 \times 10^{6} \times Q$
0308	Stoners Creek	TN05130203035 – 1000	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	$1.081 \times 10^{6} \times Q$	$1.081 \times 10^{6} \times Q$
McCrory Creek DA	McCrory Creek	TN05130203001 – 0100	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	$3.595 \times 10^{6} \times Q$	$3.595 \times 10^{6} \times Q$

Notes: NA = Not Applicable.
Q = Mean Daily In-stream Flow (cfs).

a. WLAs for WWTFs are expressed as E. coli loads (CFU/day). All current and future WWTFs must meet water quality standards as specified in their NPDES permit.
b. Applies to any MS4 discharge loading in the subwatershed. Future MS4s will be assigned waste load allocations (WLAs) consistent with load allocations (LAs) assigned to precipitation induced nonpoint sources.
c. WLAs and LAs expressed as a “per acre” load are calculated based on the drainage area at the pour point of the HUC-12 or drainage area (see Table A-1).

APPENDIX D

Hydrodynamic Modeling Methodology

HYDRODYNAMIC MODELING METHODOLOGY

D.1 Model Selection

The Windows version of Hydrologic Simulation Program - Fortran (HSPF) was selected for flow simulation of pathogen-impaired waters in the subwatersheds of the Stones River Watershed. HSPF is a watershed model capable of performing flow routing through stream reaches.

D.2 Model Set Up

The Stones River Watershed was 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, and water quality monitoring stations. Watershed delineation was based on the 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 WinHSPF model. The Watershed Characterization System (WCS), a geographic information system (GIS) tool, was used to display, analyze, and compile available information to support hydrology 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 used for the simulation. Weather data from multiple meteorological stations were available for the time period from January 1970 through December 2010. Meteorological data for a selected 11-year period were used for all simulations. The first year of this period was used for model stabilization with simulation data from the subsequent 10-year period (10/1/99 – 9/30/10) used for TMDL analysis. Meteorological data from the stations at Nashville and Murfreesboro, Tennessee was used for hydrologic calibration.

D.3 Model Calibration

Hydrologic calibration of the watershed model involves comparison of simulated streamflow to historic streamflow data from U. S. Geological Survey (USGS) stream gaging stations for the same period of time. Two USGS continuous record stations located in the Stones River watershed were selected as the basis of the hydrology calibration. Station 03430147 is located in the Stones River watershed near Hermitage, TN, within Level IV ecoregions 71H and 71I and has a drainage area of 20 square miles. Calibration parameters determined for station 03430147 were used for impaired waterbodies lying in urban areas. Station 03436800 is located in the Stones River watershed at Woodbury, TN, within Level IV ecoregions 71H and 71I and has a drainage area of 38 square miles. Calibration parameters determined for station 03436800 were used for impaired waterbodies lying in less urban areas.

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 calibration for Stoners Creek near Hermitage, USGS Station 03430147, are shown in Table D-1 and Figure D-1 and D-2. The results of the hydrologic calibration for East Fork Stones River at Woodbury, USGS Station 03436800, are shown in Table D-2 and Figure D-3 and D-4.

Table D-1. Hydrologic Calibration Summary: Stoners Creek (USGS 03430147)

			20.0143746
Simulation Name:	USGS03430147	**Simulation Period:**	
		Watershed Area (ac):	12813.30
Period for Flow Analysis			
Begin Date:	**10/01/94**	**Baseflow PERCENTILE:**	2.5
End Date:	**09/30/04**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**202.70**	Total Observed In-stream Flow:	**213.18**
Total of highest 10% flows:	**123.98**	Total of Observed highest 10% flows:	**126.18**
Total of lowest 50% flows:	**14.82**	Total of Observed Lowest 50% flows:	**14.17**
Simulated Summer Flow Volume (months 7-9):	**19.81**	Observed Summer Flow Volume (7-9):	**16.50**
Simulated Fall Flow Volume (months 10-12):	**44.55**	Observed Fall Flow Volume (10-12):	**40.15**
Simulated Winter Flow Volume (months 1-3):	**81.18**	Observed Winter Flow Volume (1-3):	**94.79**
Simulated Spring Flow Volume (months 4-6):	**57.17**	Observed Spring Flow Volume (4-6):	**61.74**
Total Simulated Storm Volume:	**201.67**	Total Observed Storm Volume:	**211.43**
Simulated Summer Storm Volume (7-9):	**19.55**	Observed Summer Storm Volume (7-9):	**16.07**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**-4.91**	10	
Error in 50% lowest flows:	**4.60**	10	
Error in 10% highest flows:	**-1.74**	15	
Seasonal volume error - Summer:	**20.08**	30	
Seasonal volume error - Fall:	**10.96**	30	
Seasonal volume error - Winter:	**-14.36**	30	
Seasonal volume error - Spring:	**-7.40**	30	
Error in storm volumes:	**-4.61**	20	
Error in summer storm volumes:	**21.71**	50	

Criteria for Median Monthly Flow Comparisons	
Lower Bound (Percentile):	25
Upper Bound (Percentile):	75

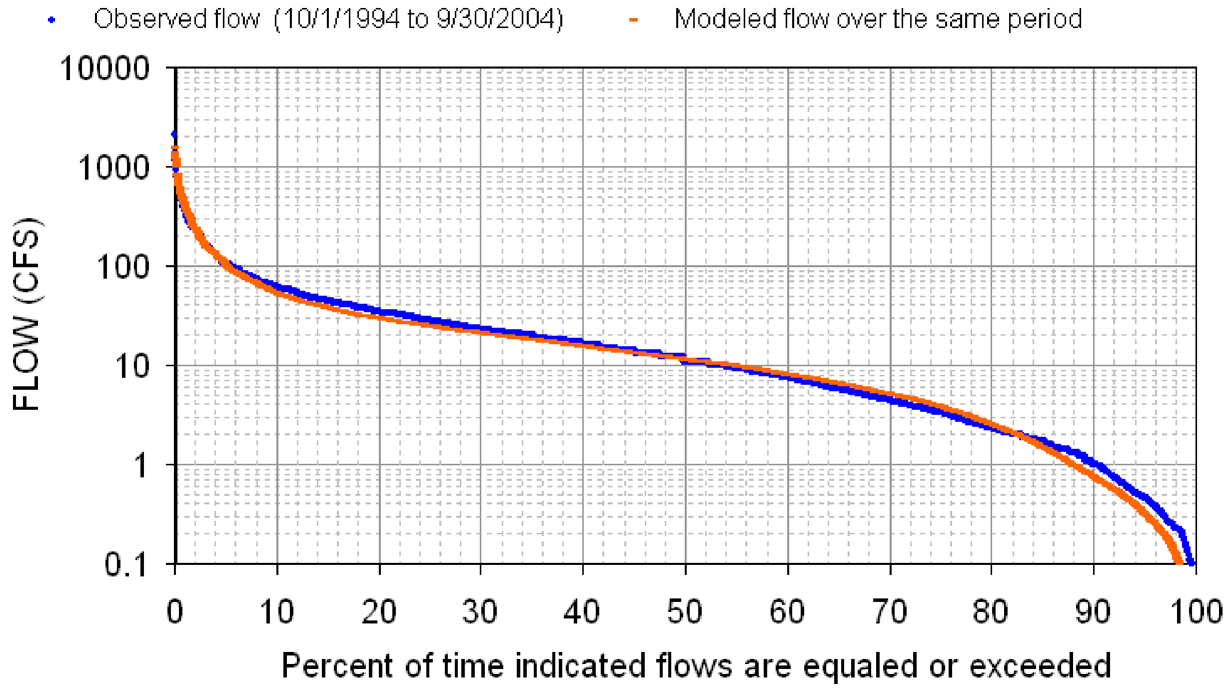

Figure D-1. Hydrologic Calibration: Stoners Creek, USGS 03430147 (WYs 1995-2004)

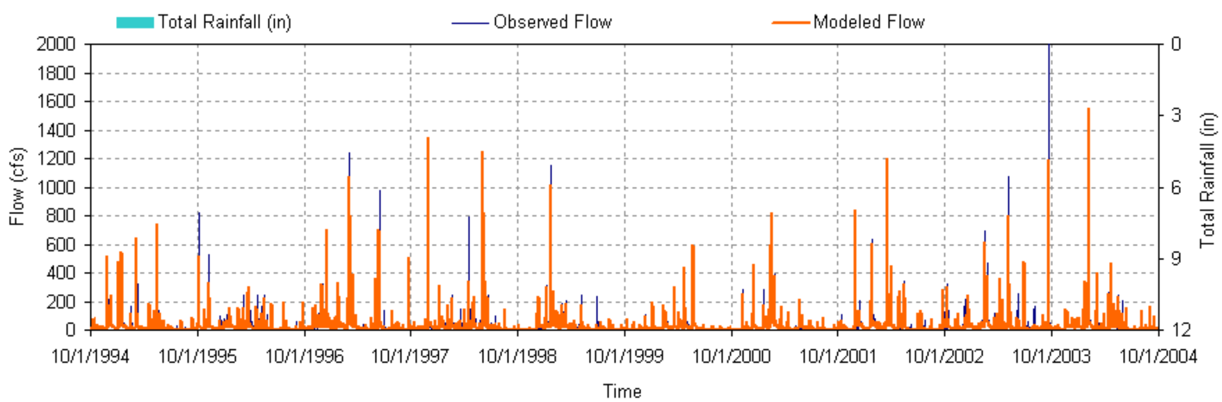

Figure D-2. 10-Year Hydrologic Comparison: Stoners Creek, USGS 03430147

Table D-2. Hydrologic Calibration Summary: East Fork Stones River at Woodbury (USGS 03436800)

		38.3745912	
Simulation Name:	USGS03426800	**Simulation Period:**	
		Watershed Area (ac):	24567.60
Period for Flow Analysis			
Begin Date:	**01/01/75**	**Baseflow PERCENTILE:**	2.5
End Date:	**01/01/85**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**251.80**	Total Observed In-stream Flow:	**245.35**
Total of highest 10% flows:	**138.07**	Total of Observed highest 10% flows:	**131.23**
Total of lowest 50% flows:	**25.38**	Total of Observed Lowest 50% flows:	**26.87**
Simulated Summer Flow Volume (months 7-9):	**24.52**	Observed Summer Flow Volume (7-9):	**21.28**
Simulated Fall Flow Volume (months 10-12):	**61.84**	Observed Fall Flow Volume (10-12):	**53.29**
Simulated Winter Flow Volume (months 1-3):	**93.20**	Observed Winter Flow Volume (1-3):	**106.67**
Simulated Spring Flow Volume (months 4-6):	**72.25**	Observed Spring Flow Volume (4-6):	**64.11**
Total Simulated Storm Volume:	**234.80**	Total Observed Storm Volume:	**220.31**
Simulated Summer Storm Volume (7-9):	**20.29**	Observed Summer Storm Volume (7-9):	**15.00**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**2.63**	10	
Error in 50% lowest flows:	**-5.52**	10	
Error in 10% highest flows:	**5.22**	15	
Seasonal volume error - Summer:	**15.22**	30	
Seasonal volume error - Fall:	**16.03**	30	
Seasonal volume error - Winter:	**-12.63**	30	
Seasonal volume error - Spring:	**12.70**	30	
Error in storm volumes:	**6.58**	20	
Error in summer storm volumes:	**35.26**	50	

Criteria for Median Monthly Flow Comparisons	
Lower Bound (Percentile):	25
Upper Bound (Percentile):	75

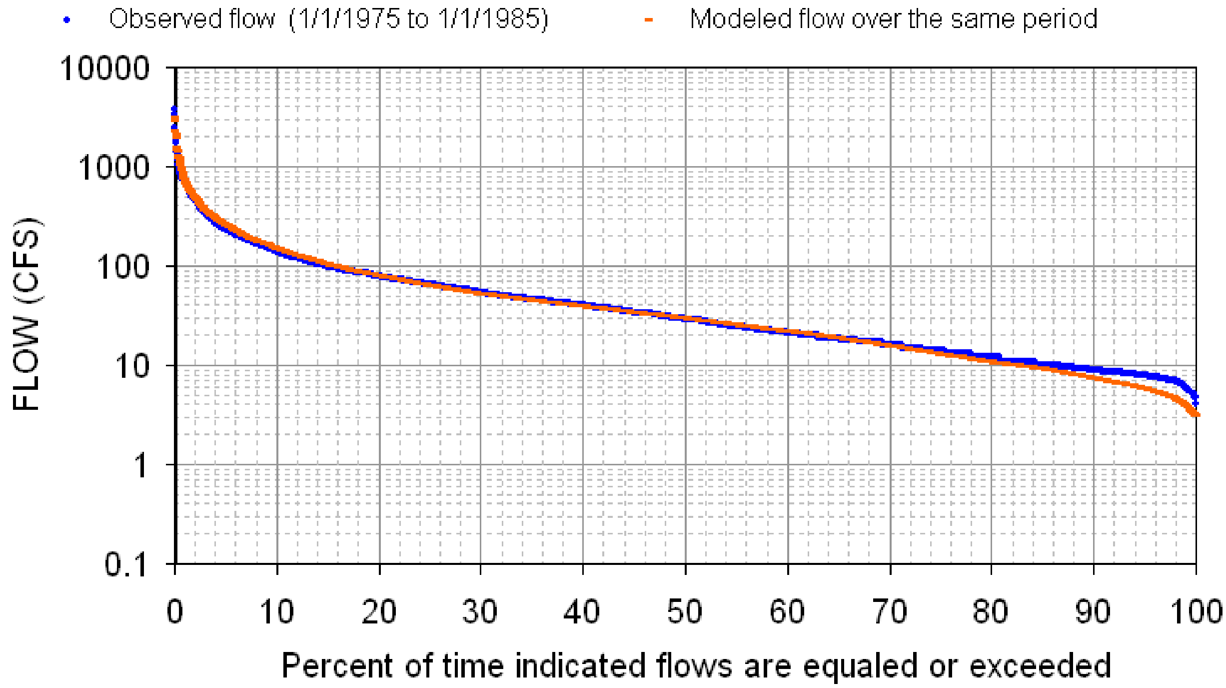

Figure D-3. Hydrologic Calibration: East Fork Stones River, USGS 03436800 (1975-1984)

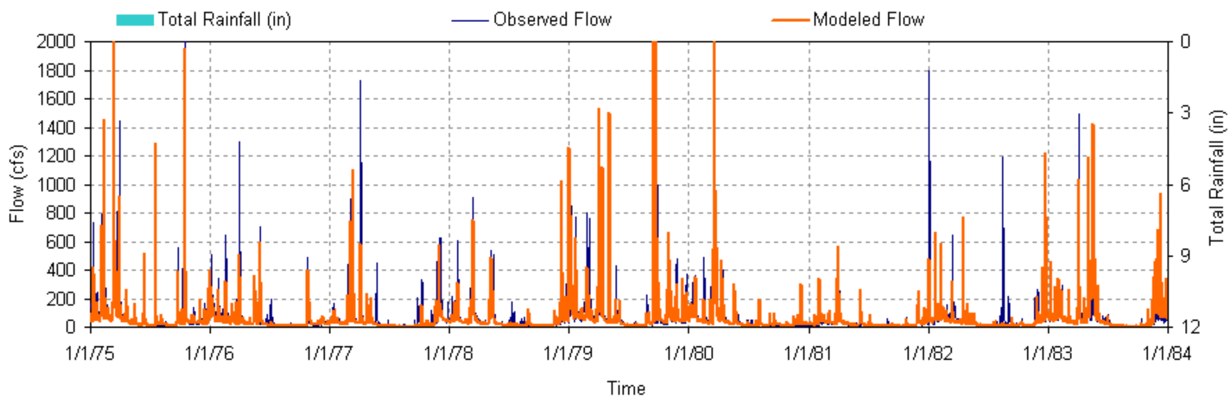

Figure D-4. 10-Year Hydrologic Comparison: East Fork Stones River, USGS 03436800

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 Section 9.5.1 and 9.5.2, with examples provided in Section 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 Sinking Creek provides guidance for implementation analysis:

The Sinking Creek watershed, part of HUC-12 051302030206, lies in Murfreesboro. The drainage area for Sinking Creek is approximately 3,488 acres (5.5 mi^2); therefore, four flow zones were used for the duration curve analysis (see Sect. 9.1.1).

The flow duration curve for Sinking Creek at mile 0.2 was constructed using simulated daily mean flow for the period from 1/1/01 through 12/31/10 (mile 0.2 corresponds to the location of monitoring station SINKI000.2RU). 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).

The E. coli LDC for Sinking Creek (Figure E-2) was analyzed to determine the frequency with which observed daily water quality loads exceed the E. coli target maximum daily loading (487 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 the exceedances occured across several flow regimes indicating the Sinking Creek watershed may be impacted by multiple sources.

Critical conditions for the Sinking Creek watershed occur during low flow conditions, typically indicative of point source contributions (see Table E-3, Section E.4). According to hydrograph separation analysis, only some of the exceedances occured during stormflow events.

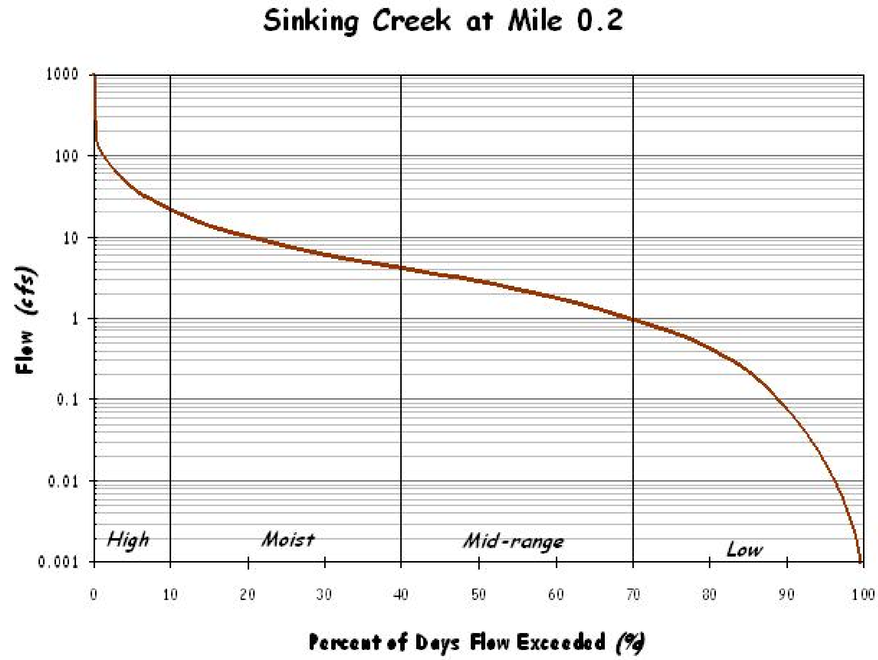

Figure E-1. Flow Duration Curve for Sinking Creek at Mile 0.2

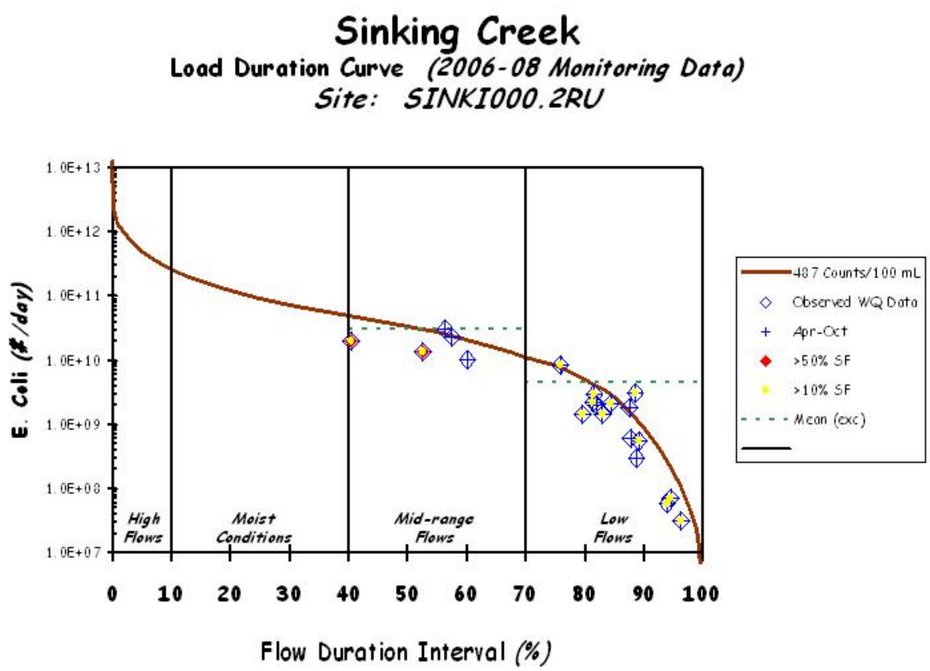

Figure E-2. E. Coli Load Duration Curve for Sinking Creek

Table E-1. Load Duration Curve Summary for Implementation Strategies (Example: Sinking Creek subwatershed, part of HUC-12 051302030206) (4 Flow Zones).

Hydrologic Condition		High	Moist	Mid-range	Low*
% Time Flow Exceeded		0-10	10-40	40-70	70-100
Sinking Creek (051302030206)	Number of Samples	0	0	5	15
	% > 487 CFU/100 mL[1]	NA	NA	20.0	20.0
	Load Reduction[2]	NA	NA	3.2	5.0
TMDL (CFU/day)		5.065E+11	9.204E+10	2.748E+10	2.640E+09
Margin of Safety (CFU/day)		5.065E+10	9.204E+09	2.748E+09	2.640E+08
WLA (WWTFs) (CFU/day)		NA	NA	NA	NA
WLAs (MS4s) (CFU/day/acre)[3]		1.307E+08	2.375E+07	7.090E+06	6.811E+05
LA (CFU/day/acre)[3]		1.307E+08	2.375E+07	7.090E+06	6.811E+05
Implementation Strategies[4]					
Municipal NPDES			L	M	H
Stormwater Management			H	H	
SSO Mitigation		H	M	L	
Collection System Repair			H	M	
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 condition for E. coli loading in the Sinking 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.

Results indicate the implementation strategy for the Sinking Creek watershed will require BMPs targeting point sources (dominant under low flow/baseflow conditions). Table E-1 presents an allocation table of LDC analysis statistics for Sinking 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 Stones 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 9 and E-27.

Table E-27 presents LDC analyses (TMDLs, WLAs, LAs, and MOS) and PLRGs for all flow zones for all E. coli impaired waterbodies in the Stones 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 East Fork Stones River provides guidance for implementation analysis.

The East Fork Stones River subwatershed, HUC-12 051302030102, lies in a non-urbanized area of Cannon county. The drainage area for segment 026-2000 of East Fork Stones River is approximately 28,143 acres (44.0 mi^2); therefore, five flow zones were used for the duration curve analysis (see Sect. 9.1.1). The landuse for this portion of East Fork Stones River is approximately 25.9% agricultural, with most of the remainder being forested. Urban areas make up approximately 6.9% of the total area. Therefore, the predominant landuse type and sources are agricultural, although urban sources may be a contributing factor.

The flow duration curve for East Fork Stones River was constructed using simulated daily mean flow for the period from 1/1/01 through 12/31/10. 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).

The E. coli LDC for East Fork Stones River Creek (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 five flow conditions (low, dry, mid-range, moist, and high). Observation of the plot illustrates that exceedances occured in the moist conditions, dry conditions, and low flow zones indicating that the East Fork Stones River watershed may be impacted by point-type sources. LDCs for other impaired waterbodies were developed using a similar procedure (Appendix C) and are shown in Figures E-5 through E-16.

Critical conditions for the East Fork Stones River watershed occur during low flow conditions, typically indicative of point source contributions (see Table E-3, Section E.4). Exceedances of the E. coli water quality standard can occur under a variety of flow conditions. According to hydrograph separation analysis, exceedances occur during both storm (runoff) and non-storm (baseflow) periods. These factors indicate that point sources are significant contributors to impairment in the East Fork Stones River watershed. However, it is possible that both point and non-point type sources contribute to exceedances of the E. coli standard in East Fork Stones River.

Results indicate the implementation strategy for the East Fork Stones River watershed will require BMPs targeting point sources (dominant under low flow/baseflow conditions). Table E-2 presents an allocation table of Load Duration Curve analysis statistics for East Fork Stones River 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 Stones 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 10 and E-27.

Table E-27 presents LDC analyses (TMDLs, WLAs, LAs, and MOS) and PLRGs for all flow zones for all E. coli impaired waterbodies in the Stones River watershed.

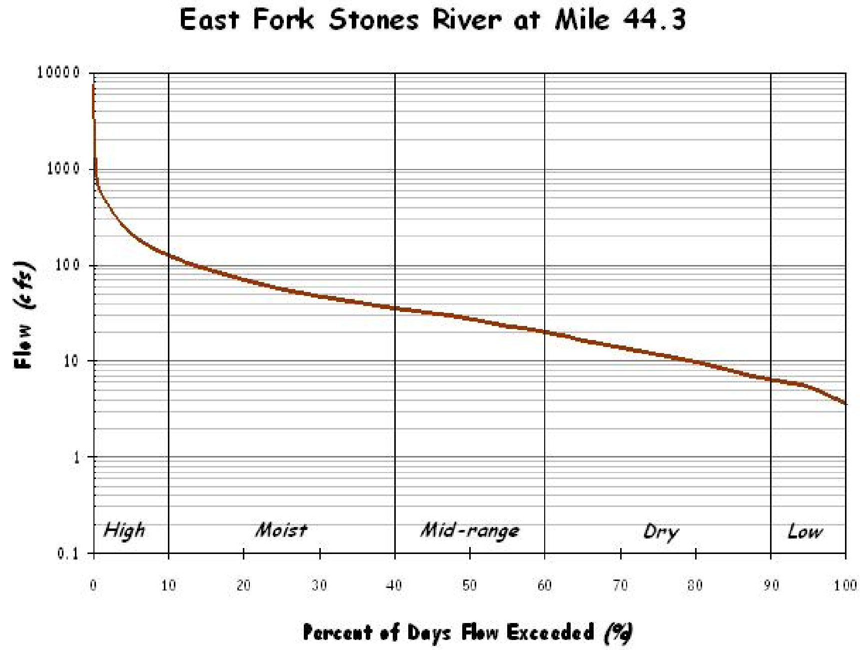

Figure E-3. Flow Duration Curve for East Fork Stones River at Mile 44.3

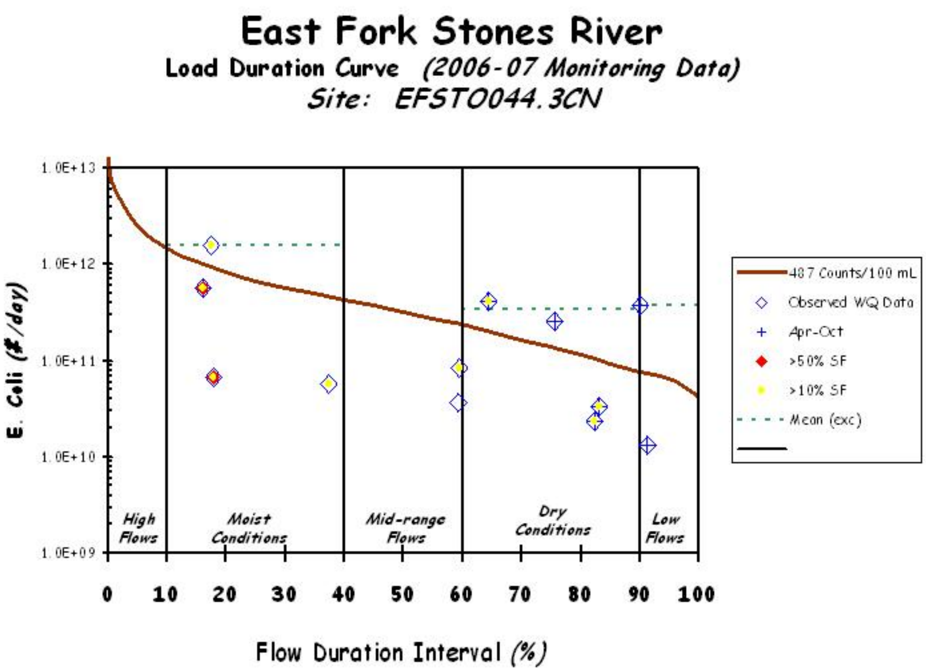

Figure E-4. E. Coli Load Duration Curve for East Fork Stones River

Table E-2. Load Duration Curve Summary for Implementation Strategies (Example: East Fork Stones River subwatershed, HUC-12 051302030102) (5 Flow Zones).

Hydrologic Condition		High	Moist*	Mid-range	Dry	Low
% Time Flow Exceeded		0-10	10-40	40-60	60-90	90-100
East Fork Stones River (051302030102)	Number of Samples	0	4	2	4	2
	% > 941 CFU/100 mL[1]	NA	25.0	0.0	50.0	50.0
	Load Reduction[2]	NA	10.1%	NR	24.6%	39.9
TMDL (CFU/day)		2.539E+12	6.755E+11	3.265E+11	1.394E+11	6.576E+10
Margin of Safety (CFU/day)		2.539E+11	6.755E+10	3.265E+10	1.394E+10	6.576E+09
WLA (WWTFs) (CFU/day)		1.106E+10	1.106E+10	1.106E+10	1.106E+10	1.106E+10
WLAs (MS4s) (CFU/day/acre)[3]		NA	NA	NA	NA	NA
LA (CFU/day/acre)[3]		8.082E+07	2.121E+07	1.005E+07	4.066E+06	1.710E+06
Implementation Strategies[4]						
Municipal NPDES			L	M	H	H
Stormwater Management			H	H		
SSO Mitigation		H	M	L		
Collection System Repair			H	M	L	
Septic System Repair			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 East Fork Stones River 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 predominant source category being wildlife, in the Stones 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. As a result, critical flow zones were determined and subsequently verified by secondary analyses. The following example is from East Fork Stones River.

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.

Date	Sample Conc. (CFU/100 mL)	Flow (cfs)	Existing Load (CFU/Day)	Target (TMDL) Load (CFU/Day)	Percent Reduction
6/12/07	2,420	6.43	3.81E+11	7.66E+10	79.7
9/13/06	87	6.17	1.31E+10	7.35E+10	0 (-460)
Percent Load Reduction Goal (PLRG) for Low Flow (Mean)					**39.9**

2. The PLRGs calculated for each of the flow zones, not including the high flow zone (see Section. 9.1.1), were compared and the PLRG of the greatest magnitude indicates the critical flow zone for prioritizing implementation actions for Overall Creek.

   Example – *High Flow Zone Percent Load Reduction Goal = NA*
   Moist Conditions Flow Zone Percent Load Reduction Goal = 10.1
   Mid-Range Flow Zone Percent Load Reduction Goal = NR
   Dry Conditions Flow Zone Percent Load Reduction Goal = 24.6
   Low Flow Zone Percent Load Reduction Goal = 39.9

Therefore, the critical flow zone for prioritization of East Fork Stones River implementation activities is the Low Flow Zone and subsequently actions targeting point source controls.

3. Due to the frequently limited availability of sampling data and subsequent randomness of distribution of samples by flow zone, the determination of the critical flow zone by PLRG calculation often has a high degree of uncertainty. Therefore, secondary analyses were conducted to verify or supplement the determination of the critical flow zones. For each flow zone, the percent of samples that exceed the E. coli TMDL target levels was calculated. For East Fork Stones River:

Flow Zone	Number of Samples	Samples > 941 CFU/100 mL	% > 941 CFU/100 mL
High	0	NA	NA
Moist	4	1	25.0
Mid-Range	2	0	0.0
Dry	***4***	***2***	***50.0***
Low	***2***	***1***	***50.0***

The critical flow zone for prioritization of East Fork Stones River implementation activities is confirmed as the low flow zone; however, the dry conditions flow zone has the same percent of sample exceedance. In this case, both zones would receive equal emphasis for implementation prioritization.

4. Lastly, emphasis (priority) should be placed on recent data versus historical data. If data from multiple watershed cycles is available, analysis of recent data (current cycle) versus the entire period of record, or previous cycles, may identify different critical areas for implementation.

Zone	Period of Record (2001-2010)			Most Recent (2006-2010)		
	# of samples	% Red.	% Exc.	# of samples	% Red.	% Exc.
High	0	NA	0	0	NA	0
Moist	7	5.8	14.3	4	10.1	25
Mid-Range	6	5.5	11.1	2	NR	0
Dry	6	16.4	33.3	4	24.6	50
Low	**2**	**39.9**	**50.0**	**2**	**39.9**	**50**

The critical flow zone for prioritization of implementation activities for East Fork Stones River is confirmed as the same zone (low flow zone) as initial analyses indicated. However, if a different flow zone, or zones, were identified, the flow zone(s) from analysis of recent data would have emphasis for implementation prioritization.

PLRGs and critical flow zones of the other impaired waterbodies were derived in a similar manner and are shown in Table E-27.

Table E-3. Summary of Critical Conditions for Impaired Waterbodies in the Stones River Watershed.

Waterbody ID	Moist	Mid-range	Dry	Low	Monitoring Station	Drainage Area (ac)
East Fork Stones River (026-2000) [a]				ò	EFSTO044.3CN	28,143.3
Lytle Creek (022-1000) [b]				ò	LYTLE01.1RU	11,322.2
Lytle Creek (022-2000) [b]					LYTLE08.7RU	4,124.5
Town Branch [b]					TOWN000.1RU	3,893.6
Christmas Creek [b]				ò	CHRIS000.7RU	4,598.5
Sinking Creek [b]				ò	SINK000.2RU	3,488.4
Stewarts Creek (010-2000) [a]	ò				STEWA009.8RU	27,359.2
Hurricane Creek (036-1000) [b]	ò				HURRI004.2RU	6,909.7
Finch Branch [b]	ò				FINCH001.4RU	2,898.9
Stoners Creek [b]	ò				STONE000.9DA	18,267.9
McCrory Creek [b]	ò			ò	MCCRO001.5DA	4,939.1

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

<u>Geometric Mean Data</u>

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/100 mL. 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: *Monitoring Location = Sinking Creek*
Sampling Period = 9/6/06 – 9/28/06
Geometric Mean Concentration = 498.1 CFU/100 mL
Target Concentration = 126 CFU/100 mL
Reduction to Target = 74.7%

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.

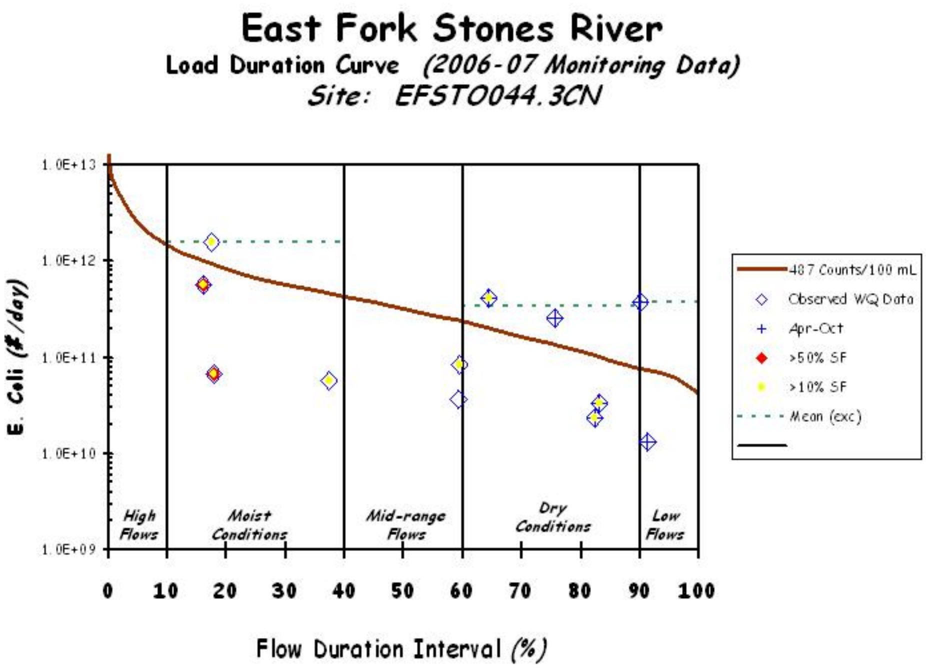

Figure E-5. E. Coli Load Duration Curve for East Fork Stones River – RM44.3

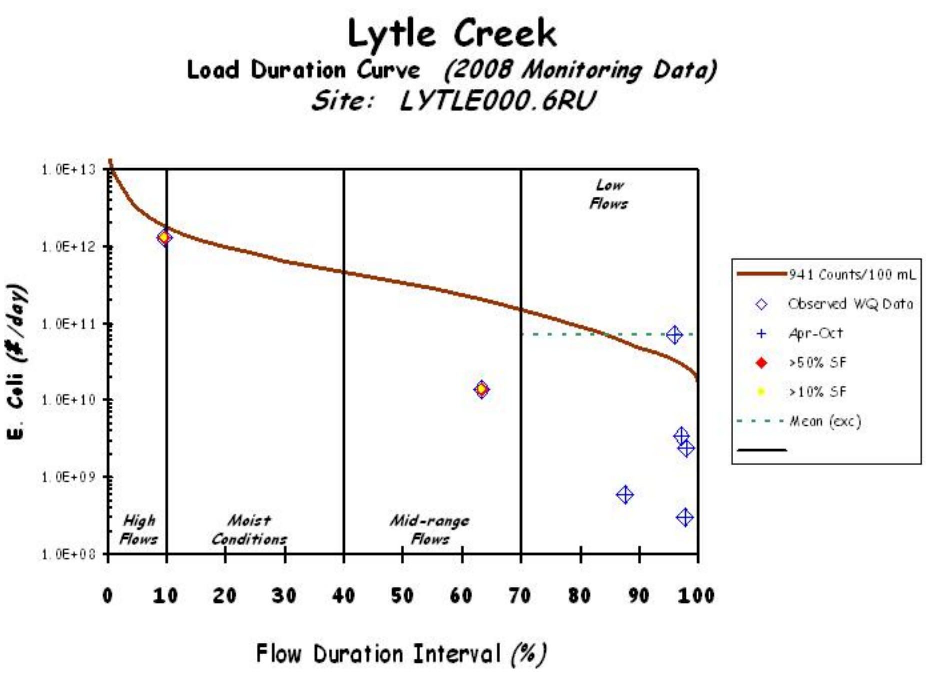

Figure E-6. E. Coli Load Duration Curve for Lytle Creek – RM0.6

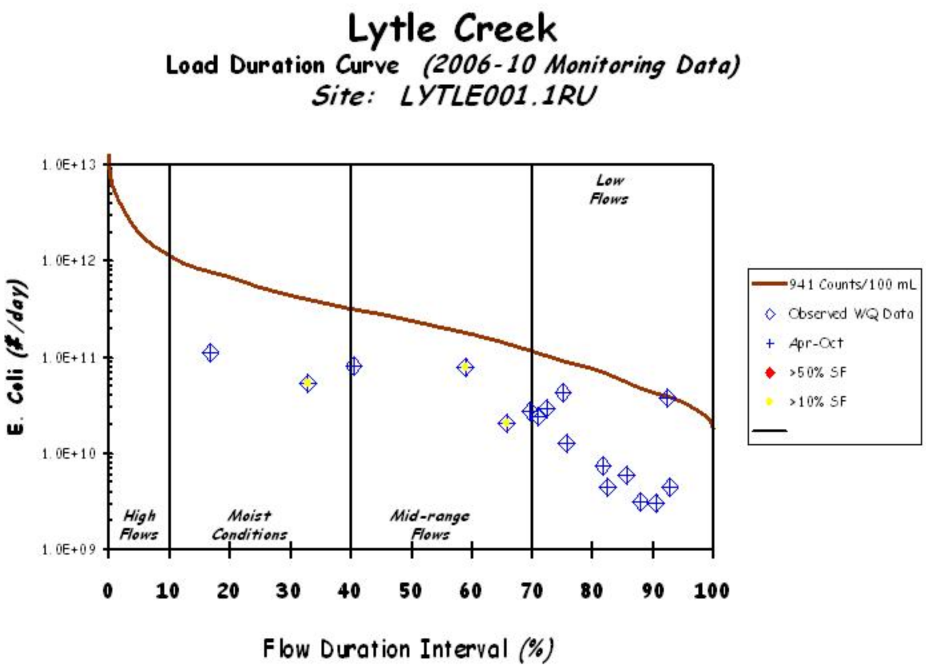

Figure E-7. E. Coli Load Duration Curve for Lytle Creek – RM1.1

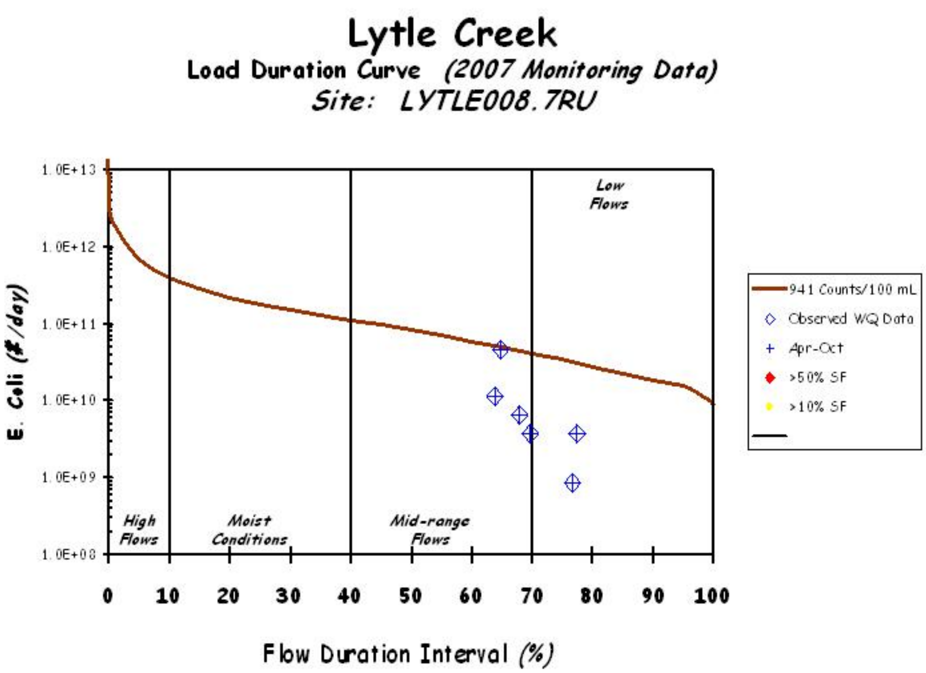

Figure E-8. E. Coli Load Duration Curve for Lytle Creek – RM8.7

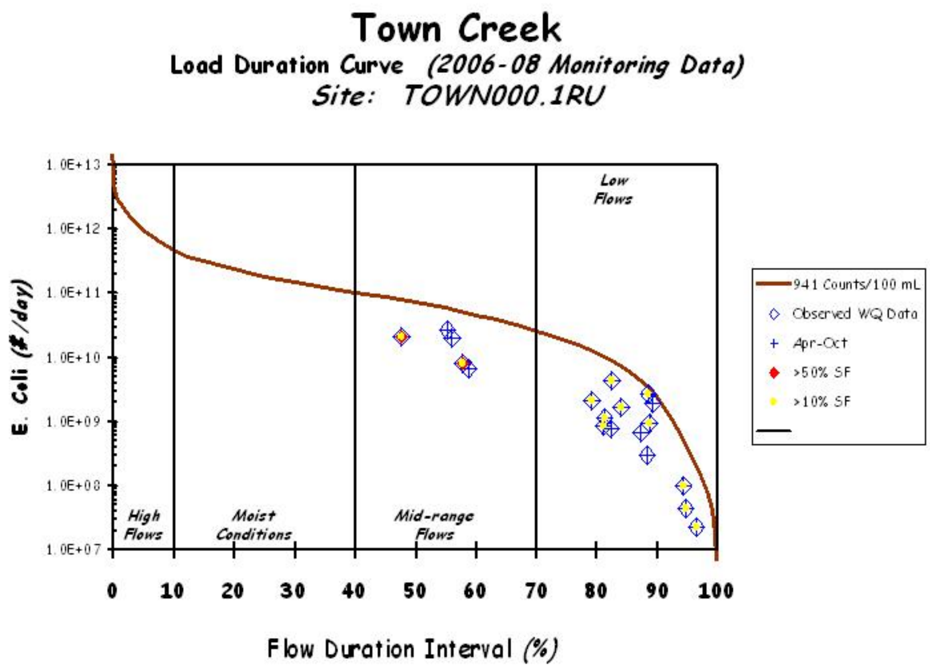

Figure E-9. E. Coli Load Duration Curve for Town Creek – RM0.1

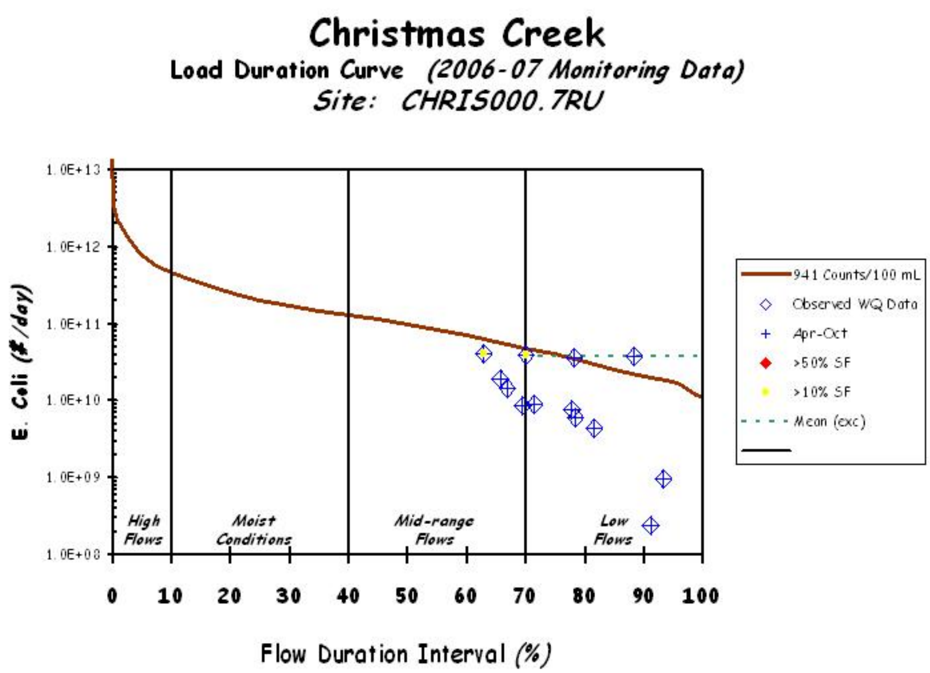

Figure E-10. E. Coli Load Duration Curve for Christmas Creek – RM0.7

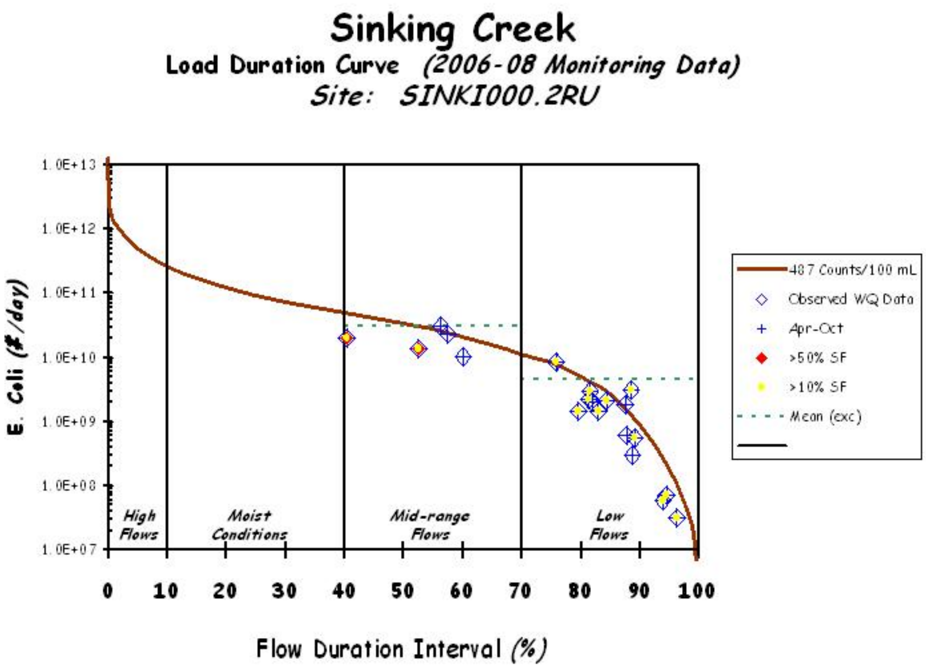

Figure E-11. E. Coli Load Duration Curve for Sinking Creek – RM0.2

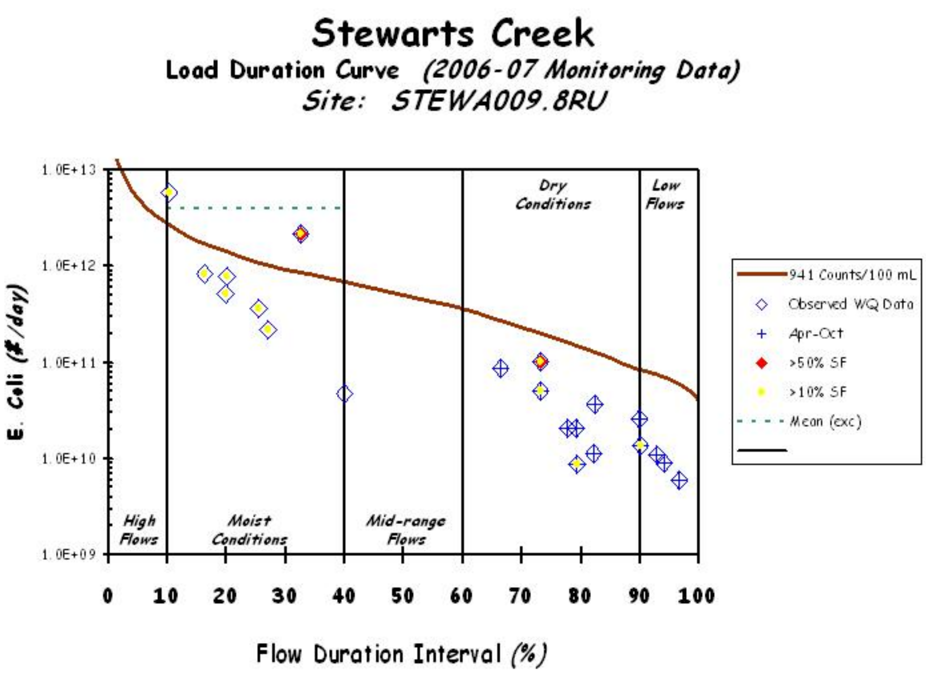

Figure E-12. E. Coli Load Duration Curve for Stewarts Creek – RM9.8

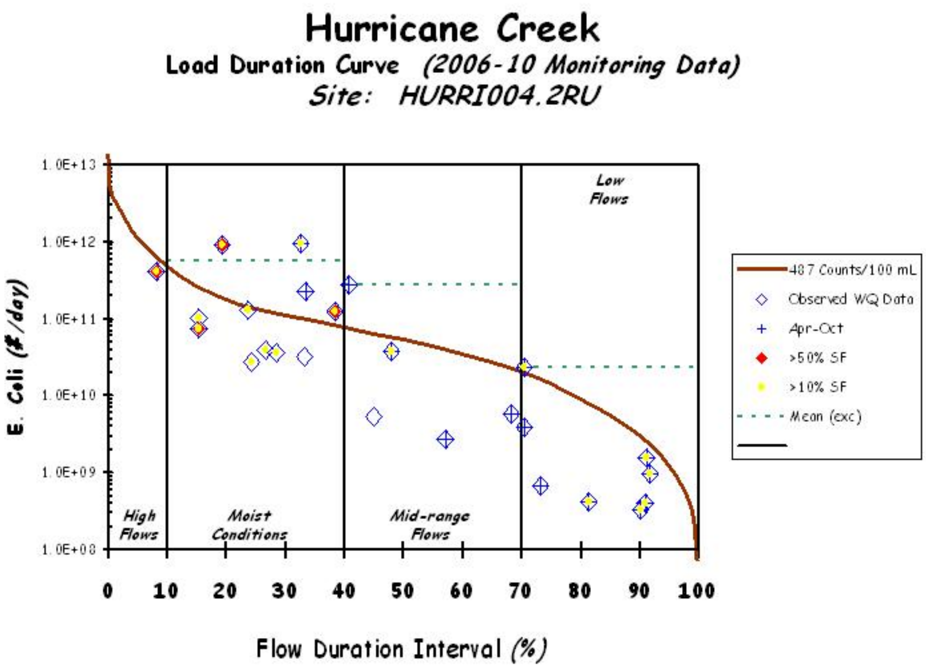

Figure E-13. E. Coli Load Duration Curve for Hurricane Creek – RM4.2 (segment 036-1000)

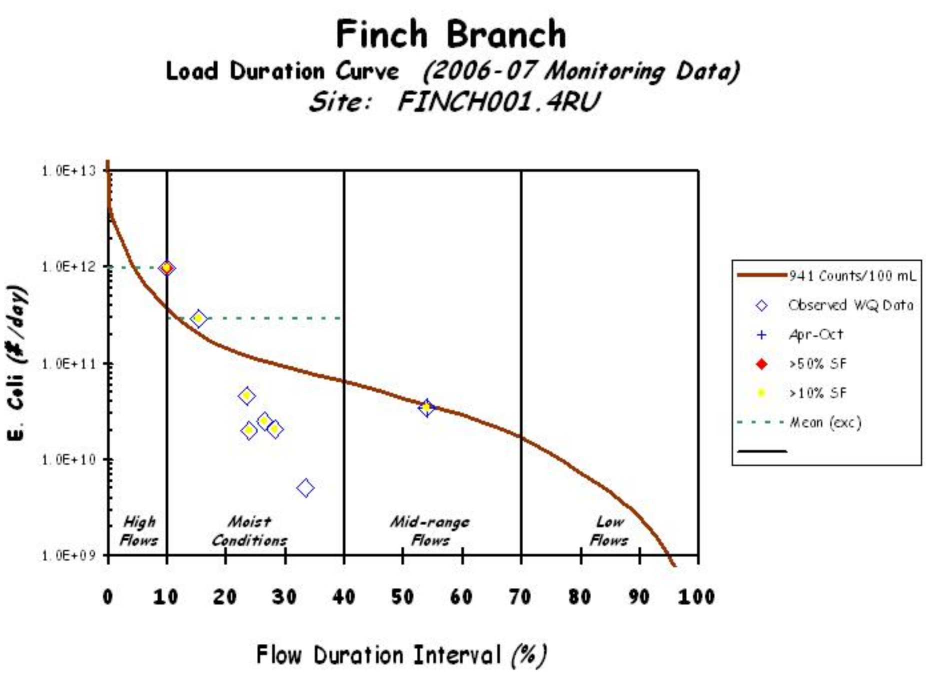

Figure E-14. E. Coli Load Duration Curve for Finch Branch – RM1.4

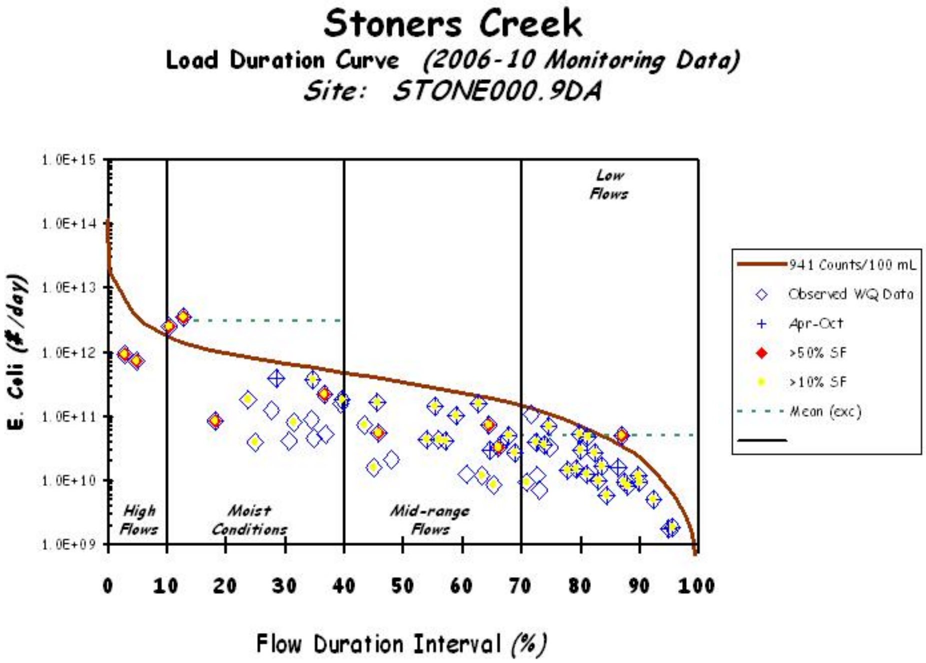

Figure E-15. E. Coli Load Duration Curve for Stoners Creek – RM0.9

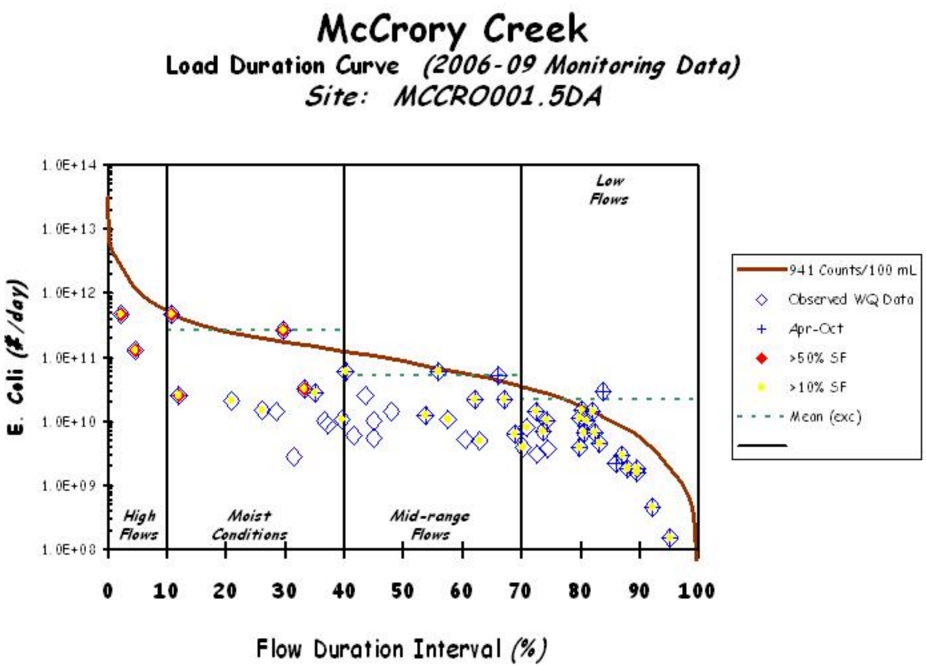

Figure E-16. E. Coli Load Duration Curve for McCrory Creek – RM1.5

Table E-4. Calculated Load Reduction Based on Daily Loading – East Fork Stones River – EFSTO044.3CN

Sample Date	Flow Regime	Flow [cfs]	PDFE [%]	Concentration [CFU/100 ml]	Load [CFU/day]	% Reduction to Achieve TMDL [%]	Average of Load Reductions [%]	% Reduction to TMDL – MOS [%]
4/11/07	Moist Conditions	84.30	16.2%	276	5.69E+11	NR		
1/10/07		78.64	17.5%	816	1.57E+12	**40.3**		
2/26/07		76.98	18.0%	36	6.78E+10	NR		
3/8/07		38.57	37.5%	61	5.76E+10	NR	**10.1**	**11.6**
11/28/06	Mid-Range Flows	20.29	59.4%	73	3.62E+10	NR		
12/12/06		20.09	59.6%	173	8.50E+10	NR	**NR**	**NR**
10/17/06	Dry Conditions	17.02	64.5%	1,000	4.16E+11	51.3		
5/22/07		11.42	75.7%	921	2.57E+11	47.1		
8/21/06		8.86	82.4%	110	2.38E+10	NR		
7/24/06		8.58	83.3%	160	3.36E+10	NR	**24.6**	**27.2**
6/12/07	Low Flows	6.43	90.3%	2,420	3.81E+11	**79.7**		
9/13/06		6.17	91.5%	87	1.31E+10	NR	**39.9**	**41.0**

Note: NR = No reduction required
NA = Not applicable

Table E-5. Calculated Load Reduction Based on Daily Loading – Lytle Creek – RM0.6

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
8/26/08	High Flows	80.73	9.5%	672	1.33E+12	NR	**NR**	**NR**
6/26/08	Mid-Range Flows	9.13	63.3%	62	1.38E+10	NR	**NR**	**NR**
7/17/08	Low Flows	2.50	87.6%	10	6.11E+08	NR	**10.5**	**11.5**
8/12/08		1.48	96.1%	1,986	7.17E+10	**52.6**		
8/14/08		1.36	97.3%	104	3.47E+09	NR		
8/19/08		1.26	97.8%	10	3.08E+08	NR		
8/21/08		1.21	98.0%	82	2.42E+09	NR		

Note: NR = No reduction required
NA = Not applicable

Table E-6. Calculated Load Reduction Based on Geomean Data – Lytle Creek – RM0.6

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 ml)	Calculated Reduction to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
8/12/08	1.48	96.1%	1986			
8/14/08	1.36	97.3%	104			
8/19/08	1.26	97.8%	10			
8/21/08	1.21	98.0%	82			
8/26/08	80.73	9.5%	672	**162.6**	**22.5**	**30.5**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-7. Calculated Load Reduction Based on Daily Loading – Lytle Creek – RM1.1

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
5/19/10	Moist Conditions	33.80	16.9%	137	1.13E+11	NR		
5/11/10		17.22	33.1%	127	5.35E+10	NR	**NR**	**NR**
5/13/10	Mid-Range Flows	13.88	40.6%	238	8.08E+10	NR		
9/25/06		7.78	59.1%	410	7.80E+10	NR		
9/26/06		6.04	65.9%	140	2.07E+10	NR		
5/8/07		5.13	69.8%	219	2.75E+10	NR	**NR**	**NR**
5/9/07	Low Flows	4.85	71.1%	206	2.45E+10	NR		
9/28/06		4.55	72.5%	260	2.90E+10	NR		
5/16/07		4.04	75.2%	435	4.29E+10	NR		
5/15/07		3.94	75.8%	132	1.27E+10	NR		
5/23/07		3.02	81.8%	101	7.47E+09	NR		
5/24/07		2.88	82.6%	64	4.51E+09	NR		
5/29/07		2.41	85.6%	102	6.00E+09	NR		
9/6/06		2.11	88.0%	61	3.15E+09	NR		
9/21/06		1.85	90.4%	68	3.08E+09	NR		
9/13/06		1.69	92.4%	920	3.79E+10	NR		
9/11/06		1.66	92.8%	110	4.47E+09	NR	**NR**	**NR**

Note: NR = No reduction required
NA = Not applicable

Table E-8. Calculated Load Reduction Based on Geomean Data – Lytle Creek – RM1.1

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 ml)	Calculated Reduction to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/6/06	2.11	88.0%	61			
9/11/06	1.66	92.8%	110			
9/13/06	1.69	92.4%	920			
9/21/06	1.85	90.4%	68			
9/25/06	7.78	59.1%	410	**176.7**	**28.7**	**36.0**
9/26/06	6.04	65.9%	140	**208.6**	**39.6**	**45.8**
9/28/06	4.55	72.5%	260	**247.8**	**49.1**	**54.4**
5/8/07	5.13	69.8%	219			
5/9/07	4.85	71.1%	206			
5/15/07	3.94	75.8%	132			
5/16/07	4.04	75.2%	435			
5/23/07	3.02	81.8%	101	**192.1**	**34.4**	**41.2**
5/24/07	2.88	82.6%	64	**150.2**	**16.1**	**24.8**
5/29/07	2.41	85.6%	102	**130.5**	**3.5**	**13.4**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-9. Calculated Load Reduction Based on Daily Loading – Lytle Creek – RM8.7

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
5/8/07	Mid-Range Flows	2.25	63.8%	205	1.13E+10	NR		
5/9/07		2.16	64.8%	866	4.58E+10	NR		
5/16/07		1.93	67.9%	140	6.62E+09	NR		
5/15/07		1.79	69.7%	86	3.77E+09	NR	**NR**	**NR**
5/23/07	Low Flows	1.40	76.7%	25	8.54E+08	NR		
5/24/07		1.36	77.4%	111	3.70E+09	NR	**NR**	**NR**

Note: NR = No reduction required
NA = Not applicable

Table E-10. Calculated Load Reduction Based on Geomean Data – Lytle Creek – RM8.7

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 ml)	Calculated Reduction to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
5/8/07	2.25	63.8%	205			
5/9/07	2.16	64.8%	866			
5/15/07	1.79	69.7%	86			
5/16/07	1.93	67.9%	140			
5/23/07	1.40	76.7%	25	**139.8**	**9.9**	**19.2**
5/24/07	1.36	77.4%	111	**123.7**	**NR**	**8.6**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-11. Calculated Load Reduction Based on Daily Loading – Town Creek – RM0.1

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
7/1/08	Mid-Range Flows	3.44	47.7%	244	2.06E+10	NR		
9/25/06		2.52	55.4%	440	2.71E+10	NR		
9/26/06		2.39	56.2%	340	1.99E+10	NR		
6/26/08		2.23	57.8%	150	8.18E+09	NR		
9/28/06		2.12	58.9%	130	6.74E+09	NR	**NR**	**NR**
5/8/07	Low Flows	0.546	79.3%	161	2.15E+09	NR		
9/6/06		0.454	81.1%	77	8.55E+08	NR		
5/9/07		0.444	81.3%	105	1.14E+09	NR		
6/24/08		0.393	82.3%	82	7.88E+08	NR		
6/12/08		0.375	82.6%	476.4	4.37E+09	NR		
6/19/08		0.316	84.1%	220	1.70E+09	NR		
9/11/06		0.184	87.4%	150	6.75E+08	NR		
9/21/06		0.160	88.3%	75	2.94E+08	NR		
9/13/06		0.148	88.5%	730	2.64E+09	NR		
5/15/07		0.138	88.8%	276	9.32E+08	NR		
5/16/07		0.122	89.3%	649	1.94E+09	NR		
5/23/07		0.022	94.3%	185	9.96E+07	NR		
5/24/07		0.019	94.8%	96	4.46E+07	NR		
5/29/07		0.009	96.6%	102	2.25E+07	NR	**NR**	**NR**

Note: NR = No reduction required
NA = Not applicable

Table E-12. Calculated Load Reduction Based on Geomean Data – Town Creek – RM0.1

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction	
					to Target GM (126 CFU/100 ml)	to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/6/06	0.454	81.1%	77			
9/11/06	0.184	87.4%	150			
9/13/06	0.148	88.5%	730			
9/21/06	0.160	88.3%	75			
9/25/06	2.52	55.4%	440	**194.5**	**35.2**	**41.9**
9/26/06	2.39	56.2%	340	**261.7**	**51.9**	**56.8**
9/28/06	2.12	58.9%	130	**254.4**	**50.5**	**55.6**
5/8/07	0.546	79.3%	161			
5/9/07	0.444	81.3%	105			
5/15/07	0.138	88.8%	276			
5/16/07	0.122	89.3%	649			
5/23/07	0.022	94.3%	185	**223.7**	**43.7**	**49.5**
5/24/07	0.019	94.8%	96	**201.7**	**37.5**	**44.0**
5/29/07	0.009	96.6%	102	**200.6**	**37.2**	**43.7**
6/12/08	0.375	82.6%	476.4	**223.7**	**43.7**	**49.5**
6/19/08	0.316	84.1%	220	**180.2**	**30.1**	**37.3**
6/24/08	0.393	82.3%	82			
6/26/08	2.23	57.8%	150	**167.4**	**24.7**	**32.5**
7/1/08	3.44	47.7%	244	**199.3**	**36.8**	**43.3**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-13. Calculated Load Reduction Based on Daily Loading – Christmas Creek – RM0.7

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
9/25/06	Mid-Range Flows	2.79	62.9%	610	4.17E+10	NR	**NR**	**NR**
5/8/07		2.53	65.8%	308	1.90E+10	NR		
5/9/07		2.42	66.9%	248	1.47E+10	NR		
5/16/07		2.16	69.6%	166	8.78E+09	NR		
9/26/06	Low Flows	2.11	70.2%	770	3.98E+10	NR	**5.0**	**6.7**
5/15/07		2.01	71.5%	185	9.11E+09	NR		
5/23/07		1.57	77.8%	201	7.74E+09	NR		
9/28/06		1.54	78.3%	980	3.69E+10	**4.0**		
5/24/07		1.54	78.4%	162	6.10E+09	NR		
5/29/07		1.31	81.7%	140	4.47E+09	NR		
9/21/06		0.970	88.5%	1,600	3.80E+10	**41.2**		
9/13/06		0.882	91.2%	11	2.37E+08	NR		
9/11/06		0.816	93.5%	48	9.58E+08	NR		

Note: NR = No reduction required
NA = Not applicable

Table E-14. Calculated Load Reduction Based on Geomean Data – Christmas Creek – RM0.7

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 ml)	Calculated Reduction to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/11/06	0.816	93.5%	48			
9/13/06	0.882	91.2%	11			
9/21/06	0.970	88.5%	1600			
9/25/06	2.79	62.9%	610			
9/26/06	2.11	70.2%	770	**208.8**	**39.7**	**45.9**
9/28/06	1.54	78.3%	980	**381.7**	**67.0**	**70.4**
5/8/07	2.53	65.8%	308			
5/9/07	2.42	66.9%	248			
5/15/07	2.01	71.5%	185			
5/16/07	2.16	69.6%	166			
5/23/07	1.57	77.8%	201	**216.1**	**41.7**	**47.7**
5/24/07	1.54	78.4%	162	**190.1**	**33.7**	**40.5**
5/29/07	1.31	81.7%	140	**169.5**	**25.7**	**33.3**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-15. Calculated Load Reduction Based on Daily Loading – Sinking Creek – RM0.2

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
7/1/08	Mid-Range Flows	4.16	40.4%	192	1.96E+10	NR		
6/26/08		2.57	52.6%	220	1.38E+10	NR		
9/25/06		2.18	56.3%	580	3.09E+10	**16.0**		
9/26/06		2.04	57.5%	460	2.29E+10	NR		
9/28/06		1.77	60.1%	240	1.04E+10	NR	**3.2**	**5.9**
7/3/08	Low Flows	0.659	75.9%	532	8.58E+09	NR		
5/8/07		0.455	79.6%	131	1.46E+09	NR		
5/9/07		0.364	81.5%	248	2.21E+09	NR		
9/6/06		0.355	81.7%	340	2.95E+09	NR		
6/24/08		0.340	82.0%	242	2.01E+09	NR		
6/12/08		0.307	83.0%	191.8	1.44E+09	NR		
6/19/08		0.246	84.5%	346	2.08E+09	NR		
9/11/06		0.139	87.6%	550	1.87E+09	**11.5**		
9/21/06		0.132	87.9%	190	6.14E+08	NR		
9/13/06		0.114	88.7%	1,100	3.07E+09	**55.7**		
5/15/07		0.109	88.9%	112	2.99E+08	NR		
5/16/07		0.099	89.3%	225	5.45E+08	NR		
5/23/07		0.022	94.0%	108	5.81E+07	NR		
5/24/07		0.019	94.6%	153	7.11E+07	NR		
5/29/07		0.009	96.5%	140	3.08E+07	NR	**5.0**	**6.5**

Note: NR = No reduction required
NA = Not applicable

Table E-16. Calculated Load Reduction Based on Geomean Data – Sinking Creek – RM0.2

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 ml)	Calculated Reduction to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/6/06	0.355	81.7%	340			
9/11/06	0.139	87.6%	550			
9/13/06	0.114	88.7%	1100			
9/21/06	0.132	87.9%	190			
9/25/06	2.18	56.3%	580	**468.9**	**73.1**	**75.9**
9/26/06	2.04	57.5%	460	**498.1**	**74.7**	**77.3**
9/28/06	1.77	60.1%	240	**422.0**	**70.1**	**73.2**
5/8/07	0.455	79.6%	131			
5/9/07	0.364	81.5%	248			
5/15/07	0.109	88.9%	112			
5/16/07	0.099	89.3%	225			
5/23/07	0.022	94.0%	108	**154.6**	**18.5**	**26.9**
5/24/07	0.019	94.6%	153	**159.5**	**21.0**	**29.2**
5/29/07	0.009	96.5%	140	**142.3**	**11.4**	**20.6**
6/12/08	0.307	83.0%	191.8	**158.4**	**20.5**	**28.7**
6/19/08	0.246	84.5%	346	**172.7**	**27.0**	**34.6**
6/24/08	0.340	82.0%	242			
6/26/08	2.57	52.6%	220	**218.2**	**42.3**	**48.2**
7/1/08	4.16	40.4%	192	**232.4**	**45.8**	**51.4**
7/3/08	0.659	75.9%	532	**285.0**	**55.8**	**60.4**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-17. Calculated Load Reduction Based on Daily Loading – Stewarts Creek – RM9.8

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
1/8/07	Moist Conditions	118.90	10.4%	1986	5.78E+12	**52.6**		
1/23/07		74.21	16.4%	461	8.37E+11	NR		
1/10/07		61.58	20.0%	345	5.20E+11	NR		
1/17/07		61.45	20.1%	517	7.77E+11	NR		
1/18/07		47.99	25.5%	308	3.62E+11	NR		
1/25/07		45.25	27.0%	199	2.20E+11	NR		
6/19/07		36.83	32.7%	2420	2.18E+12	**61.1**	**16.2**	**17.5**
1/30/07	Mid-Range Flows	29.87	40.0%	64	4.68E+10	NR	**NR**	**NR**
10/31/06	Dry Conditions	11.70	66.6%	300	8.59E+10	NR		
10/2/06		8.67	73.3%	240	5.09E+10	NR		
6/25/07		8.63	73.4%	488	1.03E+11	NR		
10/23/06		7.01	77.8%	120	2.06E+10	NR		
10/25/06		6.58	79.3%	130	2.09E+10	NR		
10/9/06		6.51	79.5%	55	8.77E+09	NR		
10/11/06		5.63	82.2%	81	1.12E+10	NR		
10/18/06		5.58	82.5%	270	3.68E+10	NR	**NR**	**NR**
6/4/07	Low Flows	3.65	90.1%	291	2.60E+10	NR		
6/5/07		3.64	90.2%	155	1.38E+10	NR		
6/11/07		3.18	93.0%	140	1.09E+10	NR		
6/12/07		3.04	94.2%	122	9.08E+09	NR		
6/18/07		2.67	96.8%	91	5.94E+09	NR	**NR**	**NR**

Note: NR = No reduction required
NA = Not applicable

Table E-18. Calculated Load Reduction Based on Geomean Data – Stewarts Creek – RM9.8

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 ml)	Calculated Reduction to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
10/2/06	8.67	73.3%	240			
10/9/06	6.51	79.5%	55			
10/11/06	5.63	82.2%	81			
10/18/06	5.58	82.5%	270			
10/23/06	7.01	77.8%	120	**128.2**	**1.7**	**11.9**
10/25/06	6.58	79.3%	130	**113.4**		**0.4**
10/31/06	11.70	66.6%	300	**159.2**	**20.9**	**29.0**
1/8/07	118.90	10.4%	1986			
1/10/07	61.58	20.0%	345			
1/17/07	61.45	20.1%	517			
1/18/07	47.99	25.5%	308			
1/23/07	74.21	16.4%	461	**549.9**	**77.1**	**79.5**
1/25/07	45.25	27.0%	199	**347.1**	**63.7**	**67.4**
1/30/07	29.87	40.0%	64	**247.8**	**49.2**	**54.4**
6/4/07	3.65	90.1%	291			
6/5/07	3.64	90.2%	155			
6/11/07	3.18	93.0%	140			
6/12/07	3.04	94.2%	122			
6/18/07	2.67	96.8%	91	**147.6**	**14.6**	**23.5**
6/19/07	36.83	32.7%	2420	**225.5**	**44.1**	**49.9**
6/25/07	8.63	73.4%	488	**283.6**	**55.6**	**60.2**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-19. Calculated Load Reduction Based on Daily Loading – Hurricane Creek – RM4.2 (segment 036-1000)

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
6/25/07	High Flows	54.41	8.1%	308	4.10E+11	NR	**NR**	**NR**
1/8/07	Moist Conditions	21.46	15.4%	192	1.01E+11	NR	**23.6**	**24.8**
6/18/07		21.26	15.4%	142	7.39E+10	NR		
6/19/07		15.67	19.4%	2,420	9.28E+11	**79.9**		
1/17/07		12.09	23.8%	435	1.29E+11	NR		
1/10/07		11.90	24.3%	96	2.79E+10	NR		
1/23/07		10.88	26.7%	150	3.99E+10	NR		
1/18/07		10.10	28.4%	148	3.66E+10	NR		
5/11/10		8.54	32.7%	4,610	9.64E+11	**89.4**		
1/25/07		8.37	33.3%	155	3.17E+10	NR		
5/19/10		8.31	33.4%	1,120	2.28E+11	**56.5**		
10/11/06		7.01	38.4%	730	1.25E+11	**33.3**		
5/13/10	Mid-Range Flows	6.41	40.9%	1,733	2.72E+11	**71.9**	**14.4**	**14.9**
1/30/07		5.43	45.0%	40	5.31E+09	NR		
5/24/10		4.82	48.0%	326	3.85E+10	NR		
10/31/06		3.32	57.2%	33	2.68E+09	NR		
10/18/06		1.97	68.3%	120	5.77E+09	NR		
10/2/06	Low Flows	1.71	70.5%	550	2.30E+10	**11.5**	**1.4**	**2.5**
10/23/06		1.71	70.5%	93	3.89E+09	NR		
10/25/06		1.39	73.3%	20	6.78E+08	NR		
10/9/06		0.653	81.4%	26	4.15E+08	NR		
6/11/07		0.251	90.3%	54	3.32E+08	NR		
6/12/07		0.218	91.1%	76	4.05E+08	NR		
6/4/07		0.210	91.3%	308	1.58E+09	NR		
6/5/07		0.186	91.9%	210	9.56E+08	NR		

Note: NR = No reduction required
NA = Not applicable

Table E-20. Calculated Load Reduction Based on Geomean Data – Hurricane Creek – RM4.2 (segment 036-1000)

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 ml)	Calculated Reduction to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
10/2/06	1.71	70.5%	550			
10/9/06	0.653	81.4%	26			
10/11/06	7.01	38.4%	730			
10/18/06	1.97	68.3%	120			
10/23/06	1.71	70.5%	93	**163.4**	**22.9**	**30.8**
10/25/06	1.39	73.3%	20	**84.2**		
10/31/06	3.32	57.2%	33	**88.3**		
1/8/07	21.46	15.4%	192			
1/10/07	11.90	24.3%	96			
1/17/07	12.09	23.8%	435			
1/18/07	10.10	28.4%	148			
1/23/07	10.88	26.7%	150	**177.9**	**29.2**	**36.5**
1/25/07	8.37	33.3%	155	**170.4**	**26.1**	**33.7**
1/30/07	5.43	45.0%	40	**143.0**	**11.9**	**21.0**
6/4/07	0.210	91.3%	308			
6/5/07	0.186	91.9%	210			
6/11/07	0.251	90.3%	54			
6/12/07	0.218	91.1%	76			
6/18/07	21.26	15.4%	142	**130.4**	**3.4**	**13.3**
6/19/07	15.67	19.4%	2420	**196.9**	**36.0**	**42.6**
6/25/07	54.41	8.1%	308	**212.6**	**40.7**	**46.8**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-21. Calculated Load Reduction Based on Daily Loading – Finch Branch – RM1.4

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
11/7/06	High Flows	16.59	10.0%	2,400	9.74E+11	**60.8**	**60.8**	**64.7**
1/8/07	Moist Conditions	9.11	15.3%	1,300	2.90E+11	**27.6**	**4.6**	**5.8**
1/17/07		5.14	23.6%	365	4.59E+10	NR		
1/10/07		5.06	23.9%	160	1.98E+10	NR		
1/23/07		4.62	26.5%	219	2.47E+10	NR		
1/18/07		4.29	28.2%	197	2.07E+10	NR		
1/25/07		3.55	33.4%	59	5.13E+09	NR		
5/7/07	Mid-Range Flows	1.64	53.9%	866	3.47E+10	NR	**NR**	**NR**

Note: NR = No reduction required
NA = Not applicable

Table E-22. Calculated Load Reduction Based on Geomean Data – Finch Branch – RM1.4

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 ml)	Calculated Reduction to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
1/8/07	9.11	15.3%	1300			
1/10/07	5.06	23.9%	160			
1/17/07	5.14	23.6%	365			
1/18/07	4.29	28.2%	197			
1/23/07	4.62	26.5%	219	**318.5**	**60.4**	**64.5**
1/25/07	3.55	33.4%	59	**171.6**	**26.6**	**34.1**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-23. Calculated Load Reduction Based on Daily Loading – Stoners Creek – RM0.9

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
3/3/08	High Flows	264.30	2.7%	145.0	9.38E+11	NR		
12/20/07		166.90	4.7%	185.0	7.55E+11	NR	**NR**	**NR**
11/7/06	Moist Conditions	75.21	10.4%	1,400	2.58E+12	**32.8**		
10/17/06		60.51	12.8%	2,400	3.55E+12	**60.8**		
10/26/06		46.00	18.1%	75	8.44E+10	NR		
1/23/07		37.00	23.7%	199	1.80E+11	NR		
2/14/08		35.97	24.9%	46.2	4.07E+10	NR		
2/3/09		32.54	27.5%	157.6	1.25E+11	NR		
5/19/10		31.06	28.4%	517	3.93E+11	NR		
2/4/09		29.56	30.6%	59.8	4.32E+10	NR		
2/19/08		28.84	31.2%	119.8	8.45E+10	NR		
12/5/07		26.45	34.2%	143.9	9.31E+10	NR		
5/20/09		26.13	34.6%	613.1	3.92E+11	NR		
1/2/08		25.85	34.9%	72.7	4.60E+10	NR		
5/15/07		23.88	36.6%	387	2.26E+11	NR		
12/26/07		24.23	36.6%	93.3	5.53E+10	NR		
12/18/07		22.26	39.4%	290.9	1.58E+11	NR		
5/21/09		21.96	39.7%	344.8	1.85E+11	NR	**5.8**	**6.5**
2/25/08	Mid-Range Flows	19.57	43.4%	155.3	7.44E+10	NR		
2/9/09		18.58	44.9%	36.4	1.65E+10	NR		
5/24/10		17.66	45.7%	387	1.67E+11	NR		
10/19/06		17.62	45.8%	130	5.60E+10	NR		
2/10/09		16.58	47.9%	54.6	2.21E+10	NR		
10/30/06		12.72	54.0%	140	4.36E+10	NR		
5/7/07		12.11	55.3%	488	1.45E+11	NR		
11/2/06		11.85	56.0%	150	4.35E+10	NR		

Table E-23 (cont'd). Calculated Load Reduction Based on Daily Loading – Stoners Creek – RM0.9

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
5/27/09	Mid-Range Flows (cont'd)	11.42	57.2%	150.0	4.19E+10	NR	**NR**	**NR**
5/8/07		10.62	59.0%	387	1.01E+11	NR		
2/17/09		10.12	60.6%	51.2	1.27E+10	NR		
5/29/09		9.32	62.5%	727.0	1.66E+11	NR		
11/18/08		9.07	63.2%	56.6	1.26E+10	NR		
6/26/07		8.45	64.5%	365	7.55E+10	NR		
4/25/07		8.33	64.8%	147	3.00E+10	NR		
3/13/07		8.14	65.4%	44	8.76E+09	NR		
10/11/06		7.78	66.2%	170	3.23E+10	NR		
5/10/07		7.70	66.5%	194	3.65E+10	NR		
10/1/06		7.21	68.0%	280	4.94E+10	NR		
5/30/09		7.11	68.9%	159.7	2.78E+10	NR		
11/10/08	Low Flows	6.30	70.9%	63.8	9.83E+09	NR		
11/4/08		6.09	71.6%	727.0	1.08E+11	NR		
6/5/08		5.76	72.4%	290.9	4.10E+10	NR		
2/12/07		5.49	72.8%	91	1.22E+10	NR		
11/11/08		5.52	73.1%	54.6	7.38E+09	NR		
5/22/07		5.09	74.0%	291	3.62E+10	NR		
8/10/09		5.04	74.7%	579.4	7.15E+10	NR		
11/6/08		4.95	74.9%	285.1	3.46E+10	NR		
7/18/06		3.72	77.8%	160	1.46E+10	NR		
10/12/06		3.32	79.3%	190	1.54E+10	NR		
6/16/08		3.26	79.8%	686.7	5.47E+10	NR		
8/13/09		3.17	80.0%	387.0	3.00E+10	NR		
8/4/08		2.87	81.0%	184.2	1.29E+10	NR		
6/17/08		2.79	81.3%	727.0	4.96E+10	NR		

Table E-23 (cont'd). Calculated Load Reduction Based on Daily Loading – Stoners Creek – RM0.9

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
6/18/08	Low Flows (cont'd)	2.46	82.6%	461.1	2.78E+10	NR	1.2	1.5
8/5/08		2.39	82.9%	172.5	1.01E+10	NR		
6/10/08		2.18	83.8%	325.5	1.74E+10	NR		
8/6/08		2.04	84.4%	122.4	6.10E+09	NR		
8/17/09		1.63	86.4%	410.6	1.64E+10	NR		
9/19/06		1.49	87.0%	1,400	5.09E+10	**32.8**		
5/29/07		1.41	87.5%	270	9.29E+09	NR		
8/24/09		1.36	88.1%	260.3	8.65E+09	NR		
8/25/09		1.11	89.8%	461.1	1.25E+10	NR		
5/31/07		1.01	90.1%	387	9.55E+09	NR		
8/14/08		0.643	92.5%	325.5	5.12E+09	NR		
8/3/06		0.331	95.0%	220	1.78E+09	NR		
8/19/08		0.290	95.6%	275.5	1.95E+09	NR		

Note: NR = No reduction required
NA = Not applicable

Table E-24. Calculated Load Reduction Based on Geomean Data – Stoners Creek – RM0.9

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 ml)	Calculated Reduction to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/19/06	1.49	87.0%	1400			
10/1/06	7.21	68.0%	280			
10/11/06	7.78	66.2%	170			
10/12/06	3.32	79.3%	190			
10/17/06	60.51	12.8%	2400	**497.2**	**74.7**	**77.3**
10/19/06	17.62	45.8%	130	**309.1**	**59.2**	**63.4**
10/26/06	46.00	18.1%	75	**237.5**	**46.9**	**52.4**
10/30/06	12.72	54.0%	140	**228.5**	**44.8**	**50.5**
11/2/06	11.85	56.0%	150	**217.9**	**42.2**	**48.1**
11/7/06	75.21	10.4%	1400	**195.6**	**35.6**	**42.2**
4/25/07	8.33	64.8%	147			
5/7/07	12.11	55.3%	488			
5/8/07	10.62	59.0%	387			
5/10/07	7.70	66.5%	194			
5/15/07	23.88	36.6%	387	**290.9**	**56.7**	**61.2**
5/22/07	5.09	74.0%	291	**333.5**	**62.2**	**66.1**
5/29/07	1.41	87.5%	270	**296.3**	**57.5**	**61.9**
5/31/07	1.01	90.1%	387	**296.3**	**57.5**	**61.9**
12/5/07	26.45	34.2%	143.9			
12/18/07	22.26	39.4%	290.9			
12/20/07	166.90	4.7%	185.0			
12/26/07	24.23	36.6%	93.3			
1/2/08	25.85	34.9%	72.7	**139.3**	**9.6**	**18.9**
6/5/08	5.76	72.4%	290.9			
6/10/08	2.18	83.8%	325.5			
6/16/08	3.26	79.8%	686.7			

Table E-24 (cont'd). Calculated Load Reduction Based on Geomean Data – Stoners Creek – RM0.9

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 ml)	Calculated Reduction to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
6/17/08	2.79	81.3%	727.0			
6/18/08	2.46	82.6%	461.1	**465.2**	**72.9**	**75.7**
8/4/08	2.87	81.0%	184.2			
8/5/08	2.39	82.9%	172.5			
8/6/08	2.04	84.4%	122.4			
8/14/08	0.643	92.5%	325.5			
8/19/08	0.290	95.6%	275.5	**203.5**	**38.1**	**44.5**
11/4/08	6.09	71.6%	727.0			
11/6/08	4.95	74.9%	285.1			
11/10/08	6.30	70.9%	63.8			
11/11/08	5.52	73.1%	54.6			
11/18/08	9.07	63.2%	56.6	**132.5**	**4.9**	**14.7**
2/3/09	32.54	27.5%	157.6			
2/4/09	29.56	30.6%	59.8			
2/9/09	18.58	44.9%	36.4			
2/10/09	16.58	47.9%	54.6			
2/17/09	10.12	60.6%	51.2	**62.6**		
5/20/09	26.13	34.6%	613.1			
5/21/09	21.96	39.7%	344.8			
5/27/09	11.42	57.2%	150.0			
5/29/09	9.32	62.5%	727.0			
5/30/09	7.11	68.9%	159.7	**326.0**	**61.3**	**65.3**
8/10/09	5.04	74.7%	579.4			
8/13/09	3.17	80.0%	387.0			
8/17/09	1.63	86.4%	410.6			
8/24/09	1.36	88.1%	260.3			
8/25/09	1.11	89.8%	461.1	**406.1**	**69.0**	**72.2**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-25. Calculated Load Reduction Based on Daily Loading – McCrory Creek – RM1.5

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
3/3/08	High Flows	94.09	2.2%	201.4	4.64E+11	NR		
12/20/07		52.88	4.5%	101.7	1.32E+11	NR	**NR**	**NR**
10/17/06	Moist Conditions	20.98	10.8%	920	4.72E+11	NR		
10/26/06		18.85	12.0%	56	2.58E+10	NR		
2/7/08		10.73	20.9%	80.9	2.12E+10	NR		
2/14/08		8.75	26.1%	71.7	1.53E+10	NR		
2/3/09		8.02	28.4%	73.8	1.45E+10	NR		
5/15/07		7.70	29.7%	1,414	2.66E+11	**33.5**		
2/4/09		7.31	31.4%	16.0	2.86E+09	NR		
10/19/06		6.83	33.2%	190	3.18E+10	NR		
5/20/09		6.44	35.1%	178.5	2.81E+10	NR		
2/11/08		6.13	36.7%	69.1	1.04E+10	NR		
12/26/07		6.03	37.2%	60.2	8.88E+09	NR		
12/18/07		5.49	39.7%	79.8	1.07E+10	NR	**2.8**	**4.0**
5/21/09	Mid-Range Flows	5.36	40.3%	461.1	6.05E+10	NR		
12/10/07		5.10	41.6%	48.3	6.03E+09	NR		
2/25/08		4.78	43.6%	218.7	2.56E+10	NR		
12/11/07		4.60	45.1%	93.2	1.05E+10	NR		
2/9/09		4.58	45.1%	49.6	5.56E+09	NR		
2/10/09		4.14	48.0%	145.5	1.47E+10	NR		
10/30/06		3.24	53.8%	160	1.27E+10	NR		
5/27/09		3.00	55.9%	816.4	5.98E+10	NR		
11/2/06		2.78	57.5%	160	1.09E+10	NR		
2/17/09		2.50	60.5%	85.5	5.22E+09	NR		
5/29/09		2.35	62.1%	387.3	2.22E+10	NR		
11/18/08		2.25	62.9%	90.8	5.01E+09	NR		
5/10/07		1.95	66.1%	1,120	5.34E+10	**16.0**		

Table E-25 (cont'd). Calculated Load Reduction Based on Daily Loading – McCrory Creek – RM1.5

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
10/1/06	Mid-Range Flows (cont'd)	1.86	67.2%	490	2.23E+10	NR		
5/30/09		1.71	68.9%	155.3	6.50E+09	NR	**1.1**	**1.6**
11/10/08	Low Flows	1.56	70.4%	105.0	4.01E+09	NR		
11/4/08		1.51	70.9%	218.7	8.08E+09	NR		
6/5/08		1.37	72.6%	435.2	1.46E+10	NR		
11/11/08		1.35	72.8%	93.2	3.09E+09	NR		
5/22/07		1.27	73.7%	228	7.08E+09	NR		
8/10/09		1.22	74.4%	344.8	1.03E+10	NR		
11/6/08		1.21	74.5%	129.1	3.82E+09	NR		
8/13/09		0.772	79.8%	214.0	4.04E+09	NR		
6/16/08		0.767	79.9%	613.1	1.15E+10	NR		
10/12/06		0.739	80.3%	820	1.48E+10	NR		
8/4/08		0.707	80.7%	387.3	6.70E+09	NR		
6/17/08		0.683	81.0%	613.1	1.02E+10	NR		
6/18/08		0.610	82.0%	980.4	1.46E+10	**4.0**		
8/5/08		0.588	82.5%	461.1	6.63E+09	NR		
6/10/08		0.539	83.2%	344.8	4.55E+09	NR		
8/6/08		0.509	83.8%	2,419.6	3.01E+10	**61.1**		
8/17/09		0.410	86.0%	224.7	2.25E+09	NR		
5/29/07		0.367	87.0%	326	2.93E+09	NR		
8/24/09		0.334	88.0%	228.2	1.86E+09	NR		
8/25/09		0.276	89.6%	238.2	1.61E+09	NR		
5/31/07		0.271	89.7%	276	1.83E+09	NR		
8/14/08		0.173	92.2%	108.6	4.60E+08	NR		
8/19/08		0.081	95.2%	78.9	1.56E+08	NR	**2.8**	**3.4**

Note: NR = No reduction required
NA = Not applicable

Table E-26. Calculated Load Reduction Based on Geomean Data – McCrory Creek – RM1.5

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 ml)	Calculated Reduction to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
10/1/06	1.86	67.2%	490			
10/12/06	0.739	80.3%	820			
10/17/06	20.98	10.8%	920			
10/19/06	6.83	33.2%	190			
10/26/06	18.85	12.0%	56	**330.3**	**61.9**	**65.8**
10/30/06	3.24	53.8%	160	**264.1**	**52.3**	**57.2**
5/10/07	1.95	66.1%	1120			
5/15/07	7.70	29.7%	1414			
5/22/07	1.27	73.7%	228			
5/29/07	0.367	87.0%	326			
5/31/07	0.271	89.7%	276	**503.9**	**75.0**	**77.6**
12/10/07	5.10	41.6%	48.3			
12/11/07	4.60	45.1%	93.2			
12/18/07	5.49	39.7%	79.8			
12/20/07	52.88	4.5%	101.7			
12/26/07	6.03	37.2%	60.2	**73.9**		
2/7/08	10.73	20.9%	80.9			
2/11/08	6.13	36.7%	69.1			
2/14/08	8.75	26.1%	71.7			
2/25/08	4.78	43.6%	218.7			
3/3/08	94.09	2.2%	201.4	**112.0**		
6/5/08	1.37	72.6%	435.2			
6/10/08	0.539	83.2%	344.8			
6/16/08	0.767	79.9%	613.1			
6/17/08	0.683	81.0%	613.1			
6/18/08	0.610	82.0%	980.4	**560.5**	**77.5**	**79.8**

Table E-26 (cont'd). Calculated Load Reduction Based on Geomean Data – McCrory Creek – RM1.5

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 ml)	Calculated Reduction to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
8/4/08	0.707	80.7%	387.3			
8/5/08	0.588	82.5%	461.1			
8/6/08	0.509	83.8%	2419.6			
8/14/08	0.173	92.2%	108.6			
8/19/08	0.081	95.2%	78.9	**326.4**	**61.4**	**65.4**
11/4/08	1.51	70.9%	218.7			
11/6/08	1.21	74.5%	129.1			
11/10/08	1.56	70.4%	105.0			
11/11/08	1.35	72.8%	93.2			
11/18/08	2.25	62.9%	90.8	**120.2**		**6.0**
2/3/09	8.02	28.4%	73.8			
2/4/09	7.31	31.4%	16.0			
2/9/09	4.58	45.1%	49.6			
2/10/09	4.14	48.0%	145.5			
2/17/09	2.50	60.5%	85.5	**59.2**		
5/20/09	6.44	35.1%	178.5			
5/21/09	5.36	40.3%	461.1			
5/27/09	3.00	55.9%	816.4			
5/29/09	2.35	62.1%	387.3			
5/30/09	1.71	68.9%	155.3	**332.1**	**62.1**	**66.0**
8/10/09	1.22	74.4%	344.8			
8/13/09	0.772	79.8%	214.0			
8/17/09	0.410	86.0%	224.7			
8/24/09	0.334	88.0%	228.2			
8/25/09	0.276	89.6%	238.2	**246.0**	**48.8**	**54.1**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table E-27 Summary of TMDLs, WLAs, & LAs by Flow Regime for Impaired Waterbodies in the Stones River Watershed (HUC 05130203)

Waterbody Description (TN05130203__)	Hydrologic Condition			Flow[a]	PLRG	TMDL	MOS	WLAs			LAs [d]
	Flow Regime	PDFE Range	Flow Range					WWTFs [c]	CS	MS4s [d]	
		[%]	[cfs]	[cfs]	[%]	[CFU/d]	[CFU/d]	[CFU/d]		[CFU/d/ac]	[CFU/d/ac]
East Fork Stones River Waterbody ID: **026 – 2000** HUC-12: 0102	High Flows	0 – 10	125 – 1,049	212	NA	2.539×10^{12}	2.539×10^{11}	1.106×10^{10}	0	NA	8.082×10^{7}
	Moist	10 – 40	35.8 – 125	56.3	10.1	6.755×10^{11}	6.755×10^{10}				2.121×10^{7}
	Mid-Range	40 – 60	19.9 – 35.8	27.2	NR	3.265×10^{11}	3.265×10^{10}				1.005×10^{7}
	Dry	60 – 90	6.48 – 19.9	11.6	24.6	1.394×10^{11}	1.396×10^{10}				4.066×10^{6}
	Low Flows	90 – 100	3.52 – 6.48	5.48	39.9	6.576×10^{10}	6.576×10^{9}				1.710×10^{6}
Lytle Creek Waterbody ID: **022 – 1000** HUC-12: 0203	High Flows	0 – 10	49.6 – 485	84.9	49.1[b]	1.952×10^{12}	1.952×10^{11}	NA	0	1.552×10^{8}	1.552×10^{8}
	Moist	10 – 40	14.1 – 49.6	23.2		5.341×10^{11}	5.341×10^{10}			4.245×10^{7}	4.245×10^{7}
	Mid-Range	40 – 70	5.09 – 14.1	9.02		2.086×10^{11}	2.086×10^{10}			1.649×10^{7}	1.649×10^{7}
	Low Flows	70 – 100	0.79 – 5.09	2.49		5.727×10^{10}	5.727×10^{9}			4.552×10^{6}	4.552×10^{6}
Lytle Creek Waterbody ID: **022 – 2000** HUC-12: 0203	High Flows	0 – 10	17.5 – 151	30.4	9.9[b]	6.994×10^{11}	6.994×10^{10}	NA	NA	1.526×10^{8}	1.526×10^{8}
	Moist	10 – 40	4.87 – 17.5	7.75		1.783×10^{11}	1.783×10^{10}			3.890×10^{7}	3.890×10^{7}
	Mid-Range	40 – 70	4.77 – 4.87	3.08		7.084×10^{10}	7.084×10^{9}			1.546×10^{7}	1.546×10^{7}
	Low Flows	70 – 100	0.40 – 1.77	0.98		2.254×10^{10}	2.254×10^{9}			4.918×10^{6}	4.918×10^{6}
Town Creek Waterbody ID: **022 – 0100** HUC-12: 0203	High Flows	0 – 10	20.6 – 253	41.1	51.9[b]	9.448×10^{11}	9.448×10^{10}	NA	0	2.184×10^{8}	2.184×10^{8}
	Moist	10 – 40	4.49 – 20.6	7.98		1.835×10^{11}	1.835×10^{10}			4.243×10^{7}	4.243×10^{7}
	Mid-Range	40 – 70	1.10 – 4.49	2.56		5.888×10^{10}	5.888×10^{9}			1.361×10^{7}	1.361×10^{7}
	Low Flows	70 – 100	0.02 – 1.10	0.27		6.210×10^{9}	6.210×10^{8}			1.435×10^{6}	1.435×10^{6}
Christmas Creek Waterbody ID: **018 – 0210** HUC-12: 0205	High Flows	0 – 10	19.9 – 173	34.2	67.0[b]	7.875×10^{11}	7.875×10^{10}	NA	NA	1.541×10^{8}	1.541×10^{8}
	Moist	10 – 40	5.61 – 19.9	8.88		2.042×10^{11}	2.042×10^{10}			3.997×10^{7}	3.997×10^{7}
	Mid-Range	40 – 70	2.13 – 5.61	3.67		8.441×10^{10}	8.441×10^{9}			1.652×10^{7}	1.652×10^{7}
	Low Flows	70 – 100	0.47 – 2.13	1.12		2.576×10^{10}	2.576×10^{9}			5.042×10^{6}	5.042×10^{6}
Sinking Creek Waterbody ID: **018 – 0100** HUC-12: 0206	High Flows	0 – 10	21.7 – 228	42.2	74.7[b]	5.065×10^{11}	5.065×10^{10}	NA	NA	1.307×10^{8}	1.307×10^{8}
	Moist	10 – 40	4.21 – 21.7	7.67		9.204×10^{10}	9.204×10^{9}			2.375×10^{7}	2.375×10^{7}
	Mid-Range	40 – 70	0.97 – 4.21	2.29		2.748×10^{10}	2.748×10^{9}			7.090×10^{6}	7.090×10^{6}
	Low Flows	70 – 100	0.02 – 0.97	0.22		2.640×10^{9}	2.640×10^{8}			6.811×10^{5}	6.811×10^{5}
Stewarts Creek Waterbody ID: **010 – 2000** HUC-12: 0301	High Flows	0 – 10	123 – 1,395	223	77.1[b]	5.134×10^{12}	5.134×10^{11}	3.562×10^{9}	0	1.688×10^{8}	1.688×10^{8}
	Moist	10 – 40	29.8 – 123	48.8		1.123×10^{12}	1.123×10^{11}			3.681×10^{7}	3.681×10^{7}
	Mid-Range	40 – 60	15.6 – 29.8	21.9		5.028×10^{11}	5.028×10^{10}			1.641×10^{7}	1.641×10^{7}
	Dry	60 – 90	3.67 – 15.6	8.02		1.845×10^{11}	1.845×10^{10}			5.938×10^{6}	5.938×10^{6}
	Low Flows	90 – 100	1.75 – 3.67	2.91		6.693×10^{10}	6.693×10^{9}			2.072×10^{6}	2.072×10^{6}

Table E-27 (cont'd) Summary of TMDLs, WLAs, & LAs by Flow Regime for Impaired Waterbodies in the Stones River Watershed (HUC 05130203)

Waterbody Description **(TN05130203__)**	Hydrologic Condition			Flow[a]	PLRG	TMDL	MOS	WLAs			LAs [d]
	Flow Regime	PDFE Range	Flow Range					WWTFs [c]	CS	MS4s [d]	
		[%]	[cfs]	[cfs]	[%]	[CFU/d]	[CFU/d]	[CFU/d]		[CFU/d/ac]	[CFU/d/ac]
Hurricane Creek	High Flows	0 – 10	40.3 – 517	92.4	40.7[b]	1.108×10^{12}	1.108×10^{11}	NA	NA	1.444×10^{8}	1.444×10^{8}
Waterbody ID:	Moist	10 – 40	6.62 – 40.3	11.5		1.384×10^{11}	1.384×10^{10}			1.802×10^{7}	1.802×10^{7}
036 – 1000	Mid-Range	40 – 70	1.77 – 6.62	3.67		4.404×10^{10}	4.404×10^{9}			5.736×10^{6}	5.736×10^{6}
HUC-12: 0304	Low Flows	70 – 100	0.03 – 1.77	0.47		5.640×10^{9}	5.640×10^{8}			7.346×10^{5}	7.346×10^{5}
Finch Branch	High Flows	0 – 10	16.3 – 216	37.7	60.4[b]	8.664×10^{11}	8.664×10^{10}	NA	NA	2.690×10^{8}	2.690×10^{8}
Waterbody ID:	Moist	10 – 40	2.80 – 16.3	4.82		1.109×10^{11}	1.109×10^{10}			3.442×10^{7}	3.442×10^{7}
003T – 0100	Mid-Range	40 – 70	0.74 – 2.80	1.56		3.588×10^{10}	3.588×10^{9}			1.114×10^{7}	1.114×10^{7}
HUC-12: 0305	Low Flows	70 – 100	0.01 – 0.74	0.20		4.600×10^{9}	4.600×10^{8}			1.428×10^{6}	1.428×10^{6}
Stoners Creek	High Flows	0 – 10	78.0 – 1,009	156	74.7[b]	3.587×10^{12}	3.587×10^{11}	NA	NA	1.767×10^{8}	1.767×10^{8}
Waterbody ID:	Moist	10 – 40	21.6 – 78.0	35.2		8.085×10^{11}	8.085×10^{10}			3.983×10^{7}	3.983×10^{7}
035 – 1000	Mid-Range	40 – 70	6.58 – 21.6	12.3		2.822×10^{11}	2.822×10^{10}			1.390×10^{7}	1.390×10^{7}
HUC-12: 0308	Low Flows	70 – 100	0.06 – 6.58	1.92		4.278×10^{10}	4.278×10^{9}			2.108×10^{6}	2.108×10^{6}
McCrory Creek	High Flows	0 – 10	23.2 – 317	48.5	77.5[b]	1.116×10^{12}	1.116×10^{11}	NA	NA	2.034×10^{8}	2.034×10^{8}
Waterbody ID:	Moist	10 – 40	5.40 – 23.2	9.10		2.093×10^{11}	2.093×10^{10}			3.814×10^{7}	3.814×10^{7}
001 – 0150	Mid-Range	40 – 70	1.59 – 5.40	3.10		7.130×10^{10}	7.130×10^{9}			1.299×10^{7}	1.299×10^{7}
HUC-12: 0309	Low Flows	70 – 100	0.02 – 1.59	0.45		1.035×10^{10}	1.035×10^{9}			1.886×10^{6}	1.886×10^{6}

Notes: NA = Not Applicable.
NR = No Reduction Required.
PLRG = Percent Load Reduction Goal to achieve TMDL.
CS = 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 midpoint value in the respective hydrologic flow regime.
b. PLRG based on geomean data.
c. WLAs for WWTFs are expressed as E. coli loads (CFU/day). All current and future WWTFs must meet water quality standards as specified in their NPDES permit.
d. WLAs and LAs expressed on a "per acre" basis are calculated based on the drainage area at the specific monitoring point (see Table E-3).

APPENDIX F

Analysis of Monitoring Conducted by City of Murfreesboro

The City of Murfreesboro, as part of their MS4 permit, conducted water quality monitoring at several locations within the Murfreesboro MS4 area:

- Lytle Creek:
  - LC-1 – Overall Street near Old Fork Park; approx. 330 ft u/s greenway bridge (same as TDEC LYTLE000.6RU)
  - LC-2a – approx. 200 ft west of W. Main St at greenway (LYTLE001.1RU)
  - LC-2b – W. Main St (RM1.5)
  - LC-3 – approx. 175 ft west of Church St/Hwy 231 (Jennings and Ayers property) (LYTLE002.3RU)
  - LC-4 – at bridge to tennis courts in Saratoga subdivision (LYTLE003.8RU)
  - LC-5 – above Co-op (RM3.2)
  - LC-6 – at Mid TN Blvd (RM3.0)
    - 6a – at coop above flow
    - 6b – in flow at bridge
    - 6c – below bridge in pool
    - 6d – culvert outfall to Lytle at bridge
- Sinking Creek:
  - SC-1 – at Thompson Lane (same as TDEC SINKI000.2RU)
  - SC-2 – 100 ft. u/s W. Northfield Blvd. (SINKI003.2RU)
  - SC-3 – 350 ft. d/s of spring @Oakland Mansion; at footbridge crossing (SINKI1T0.1RU)
  - SC-4 – immediately d/s concrete-lined segment behind Dow St.; approx 675 ft. east of N. Highland (SINKI2T0.0RU)
- Town Creek:
  - TC-1 – at Cannonsburgh (same as TDEC TOWN000.1RU)
  - TC-2 – at KFC (outlet of wetland) (TOWN000.5RU)
  - TC-3 – at Murfree Spring; above Discovery Center; access via Discovery Center (TOWN000.9RU)

The location of these monitoring stations is shown in Figure F-1. Water quality monitoring results for these stations are tabulated in Appendix B, Table B-3.

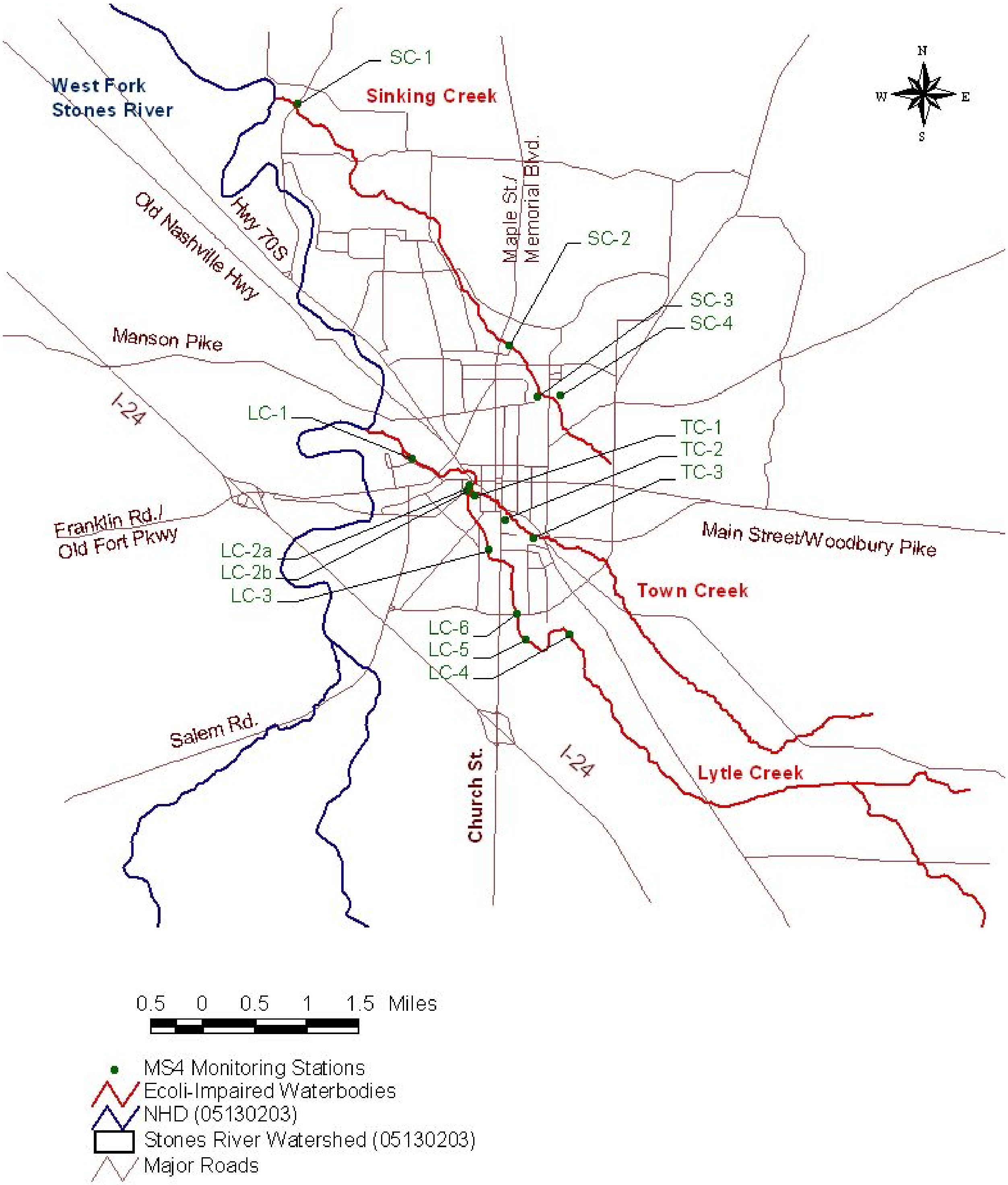

Figure F-1. Location of Water Quality Monitoring Stations for Murfreesboro MS4

Monitoring results for Sinking Creek are presented below. While there is insufficient data to form any definite conclusions, some observations can be made.

1. Whenever sampling occurred on the same day at locations SC-1 and SC-2, the concentration of E. coli was higher at SC-2. This suggests that the source of impairment is upstream of SC-1.

2. On June 12th, all four locations were sampled within one hour. The concentration of E. coli at location SC-4 was more than double the concentration of E. coli at any of the other locations. This suggests that the source of the impairment is located near SC-4.

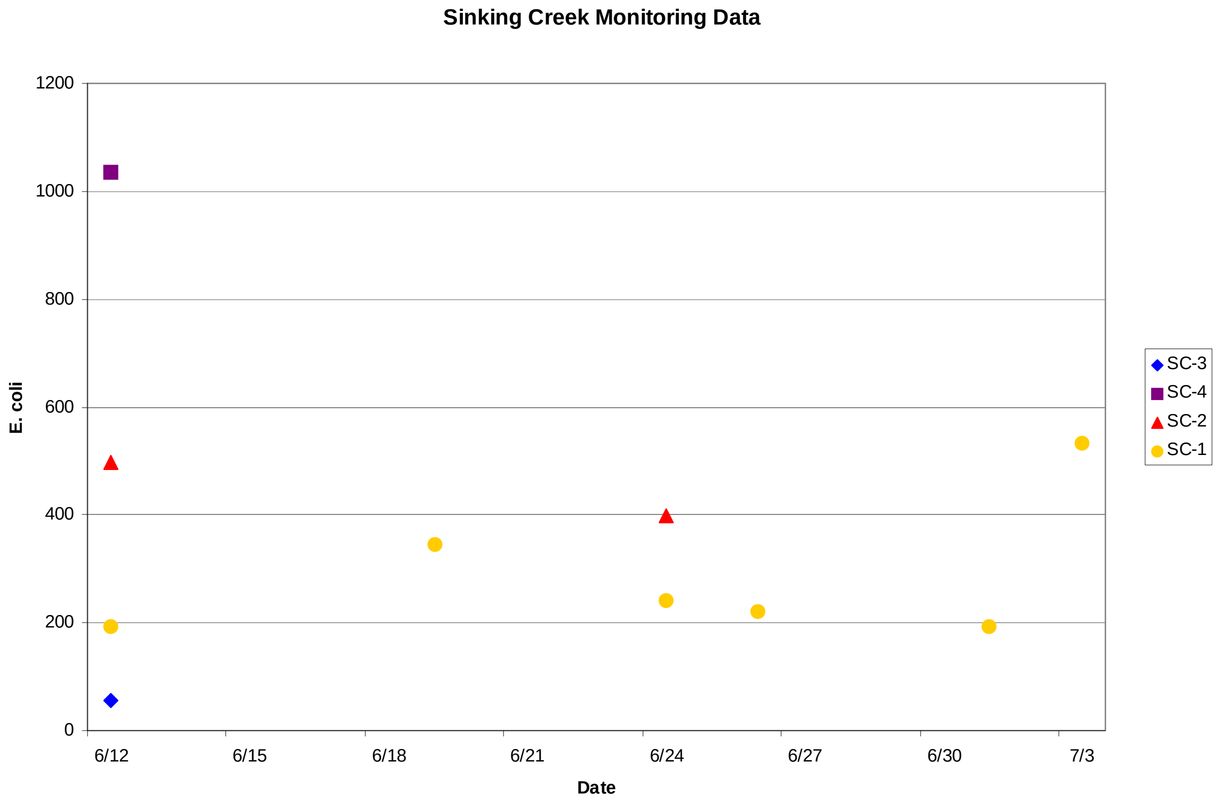

Figure F-2. E. coli Monitoring Data Collected by the City of Murfreesboro for Sinking Creek.

Monitoring results for Town Creek are presented below. While there is insufficient data to form any definite conclusions, some observations can be made.

1. Whenever sampling occurred on the same day at locations TC-2 and TC-3, the concentration of E. coli was higher at TC-2. This suggests that the source of impairment is between TC-2 and TC-3.

2. On July 1st, the concentration of E. coli at TC-3 was nearly double any of the other readings at TC-3. In the three days prior to the sampling on July 1st, approximately one-inch of rainfall was reported at the Murfreesboro weather station.

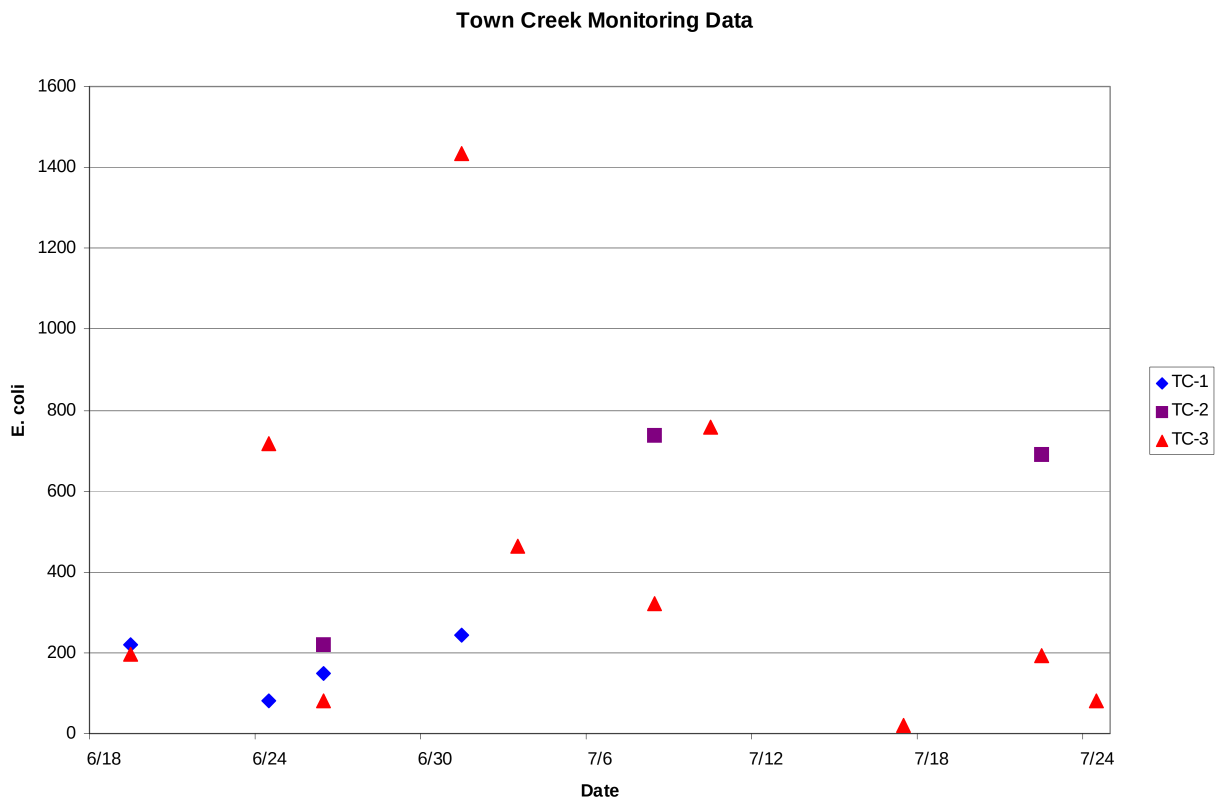

Figure F-3. E. coli Monitoring Data Collected by the City of Murfreesboro for Town Creek.

Monitoring results for Lytle Creek are presented below. While there is insufficient data to form any definite conclusions, some observations can be made.

1. Based on examination of rainfall reported at the Murfreesboro weather station, the high concentration of E. coli reported at LC-6b on July 24th was not due to a rainfall event.

2. Based on examination of rainfall reported at the Murfreesboro weather station, the high concentration of E. coli reported at LC-4 on August 26th may have been due to a rainfall event. Approximately 2.5 inches of rain was recorded on August 25th and 26th.

3. In general, when sampling occurred on the same day at locations LC-6a/b/c and either LC-4 or LC-5, the concentration of E. coli was higher at LC-6a/b/c. This suggests that the source of impairment is downstream of LC-4 and LC-5 and near LC-6a/b/c.

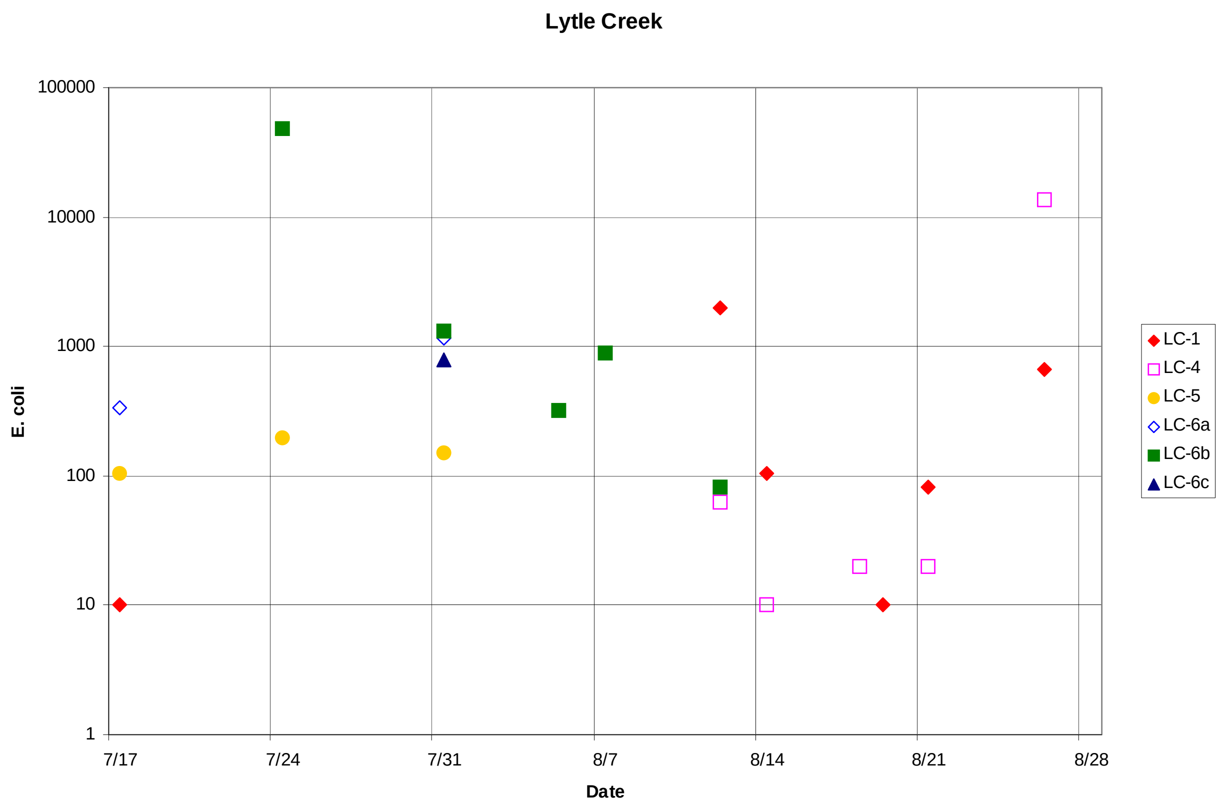

Figure F-4. E. coli Monitoring Data Collected by the City of Murfreesboro for Lytle Creek.

APPENDIX G

Impairment Analysis for Non-303(d) Listed Waterbodies

Water quality monitoring data were available for a number of waterbodies in the Stones River watershed that are not listed on the Final 2010 303(d) List as impaired due to E. coli. Subsequent analysis of the pathogen data (E. coli) suggests an existing condition of impairment for seven of these waterbody segments

This appendix documents the analyses of pathogen data for seven waterbody segments in the Stones River watershed. The analyses of water quality data for these waterbodies parallels the analyses of the waterbodies on Tennessee's Final 2010 303(d) list designated as not fully supporting designated use classifications due to E. coli.

G.1 WATERSHED DESCRIPTION

All of the waterbodies in this appendix lie within the 71h (Outer Nashville Basin) and 71i (Inner Nashville Basin) Level IV subecoregions. See Section 3.0 for descriptions of each. Landuse for the subwatersheds is summarized in Table G-1.

G.2 WATER QUALITY ASSESSMENT

The following water quality monitoring stations provided data for waterbodies evaluated in Appendix G:

- HUC-12 05130203_0101:
  - *ECO71H09 – Carson Fork, 2 mi NE of Bradyville, TN, alongside Burt-Burgen Rd.*
- HUC-12 05130203_0103:
  - CRIPP000.4RU – Cripple Creek, at Rob Taylor Rd.
- HUC-12 05130203_0202:
  - HURRI002.1RU – Hurricane Creek, off Cobbs Rd near intersection with Jacobs Rd
- HUC-12 05130203_0204:
  - OVERA005.1RU – Overall Creek, u/s Manson Rd.
- HUC-12 05130203_0301:
  - HARTS000.1RU – Harts Branch, at golf course (u/s Smyrna STP)
  - STEWA006.0RU – Stewarts Creek, d/s Sam Davis Dam (u/s Smyrna STP)
- HUC-12 05130203_0305:
  - STEWA005.3RU – Stewarts Creek, at gauge (d/s Smyrna STP)
- HUC-12 05130203_0306:
  - SUGGS007.1WS – Suggs Creek, off dead-end Stewarts Ferry Pike

The locations of these water quality monitoring stations are shown in Figure G-1. Water quality monitoring results for these stations are tabulated in Table G-2. Examination of the data shows exceedances of the 941 counts/100 mL maximum E. coli standard . Water quality monitoring results for those stations with 10% or more of samples exceeding water quality maximum criteria are summarized in Table G-3.

G.3 ANALYSIS METHODOLOGY

Analysis of water quality monitoring data was performed for seven segments in the Stones River Watershed. Load duration curves were used to evaluate compliance with the maximum target concentrations (see Appendix C). Percent load reduction goals were calculated and critical flow zones were determined.

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 concentration of 126 CFU/100 mL. 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.

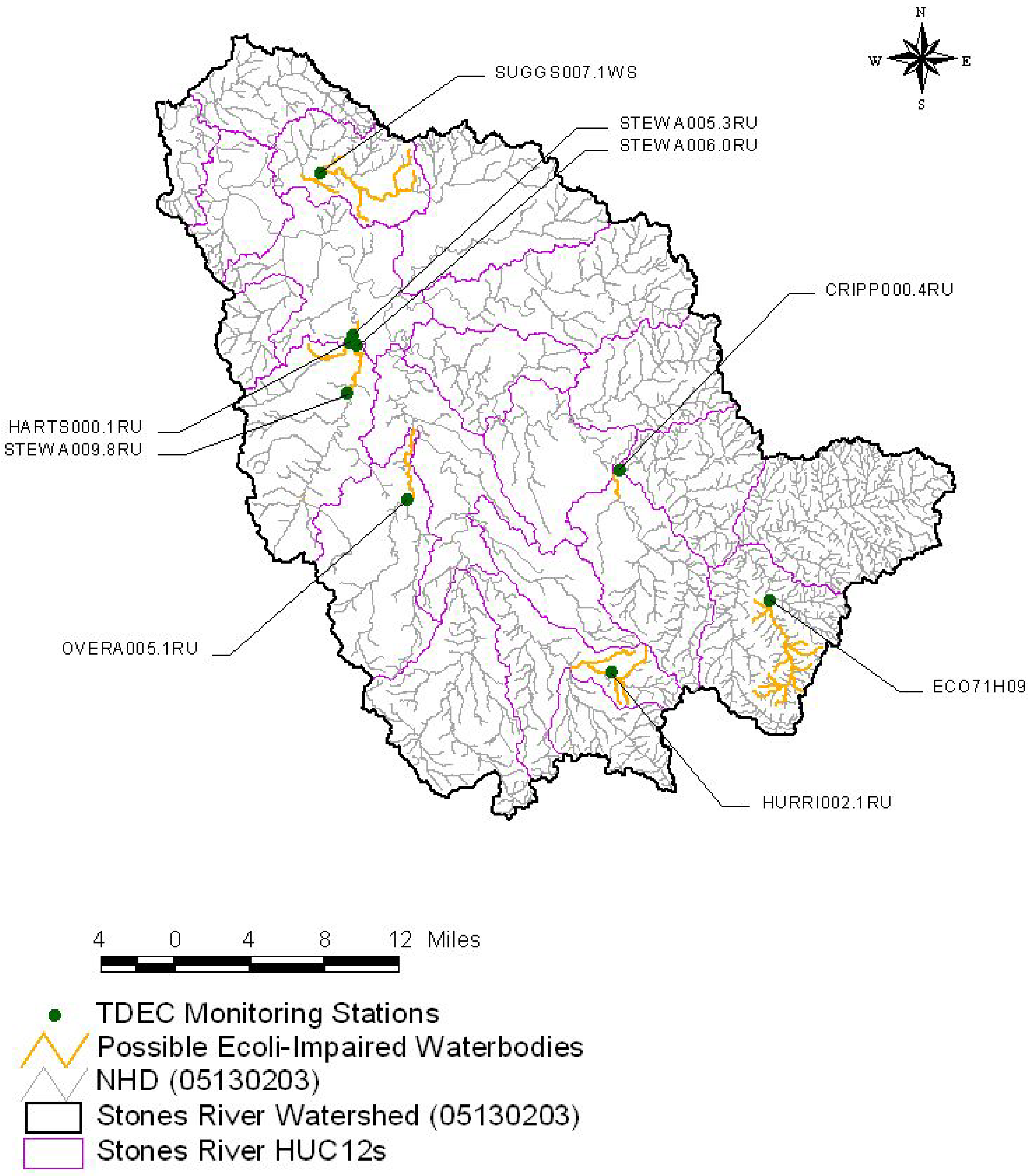

Figure G-1. Water Quality Monitoring Stations in the Stones River Watershed.

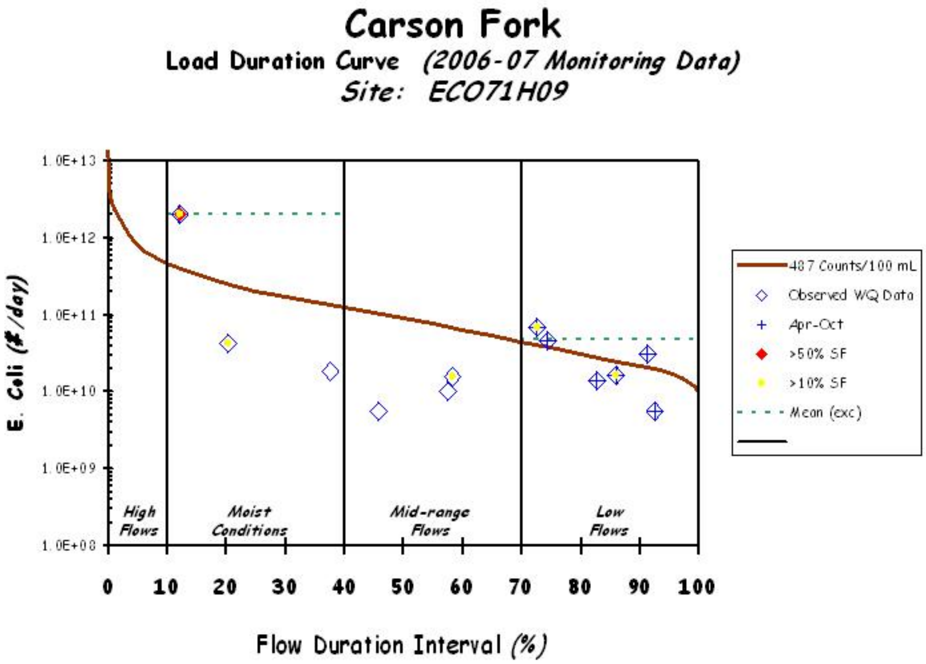

Figure G-2. E. Coli Load Duration Curve for Carson Fork – ECO71H09

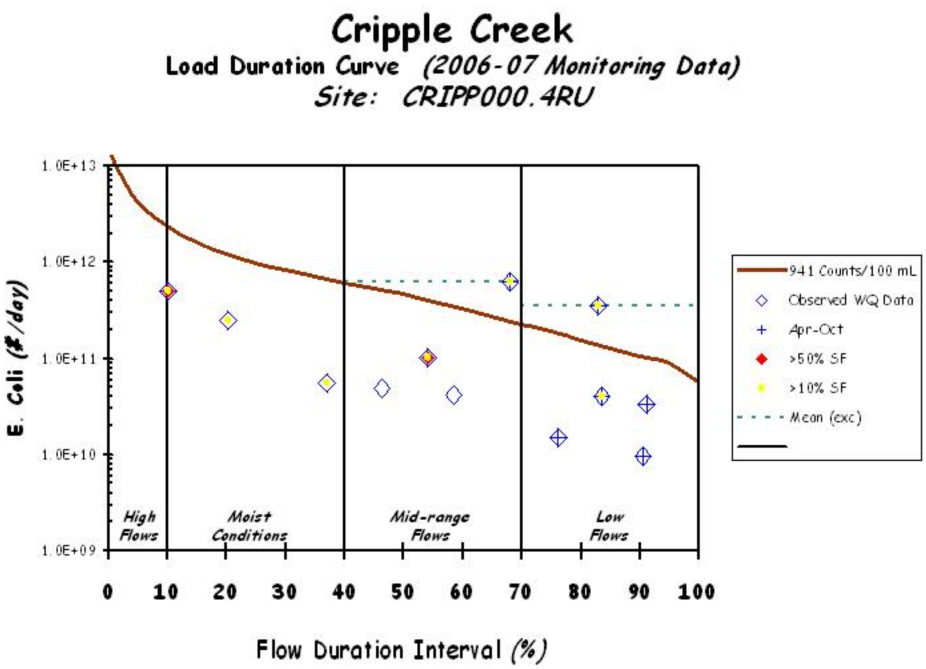

Figure G-3. E. Coli Load Duration Curve for Cripple Creek – RM0.4

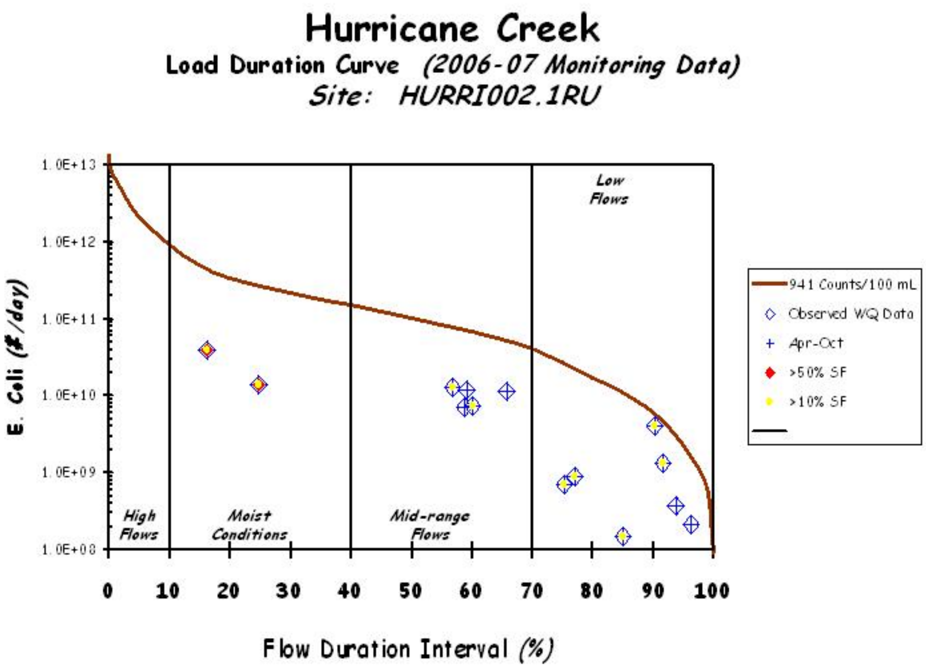

Figure G-4. E. Coli Load Duration Curve for Hurricane Creek – RM2.1 (segment 021-0100)

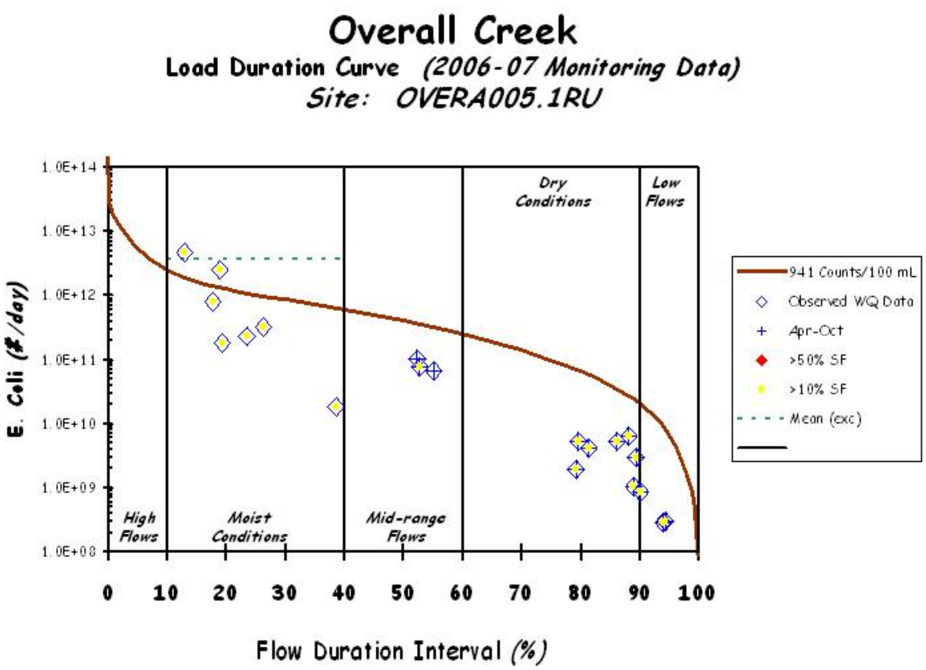

Figure G-5. E. Coli Load Duration Curve for Overall Creek – RM5.1

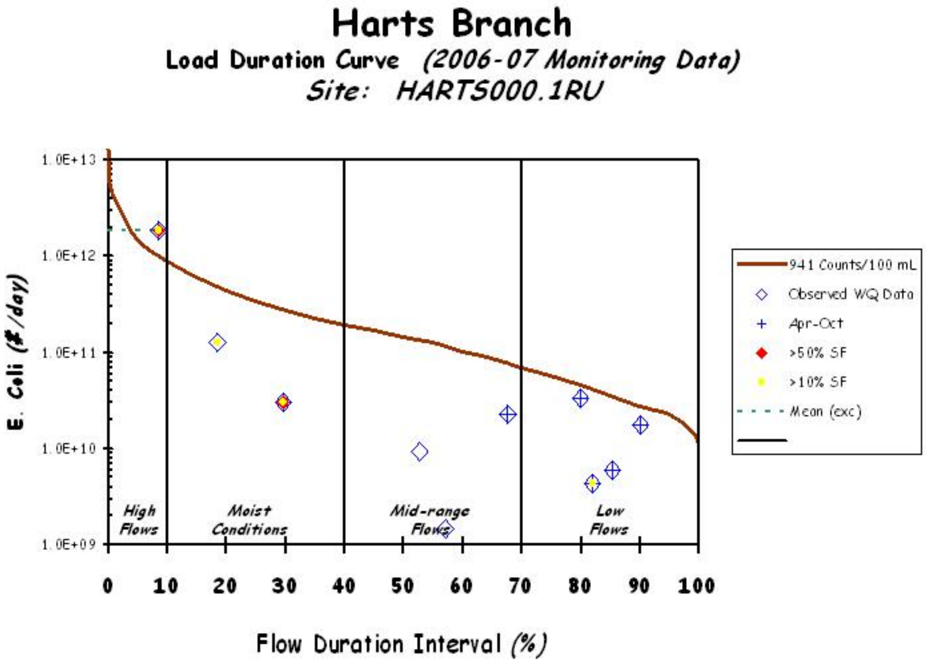

Figure G-6. E. Coli Load Duration Curve for Harts Branch

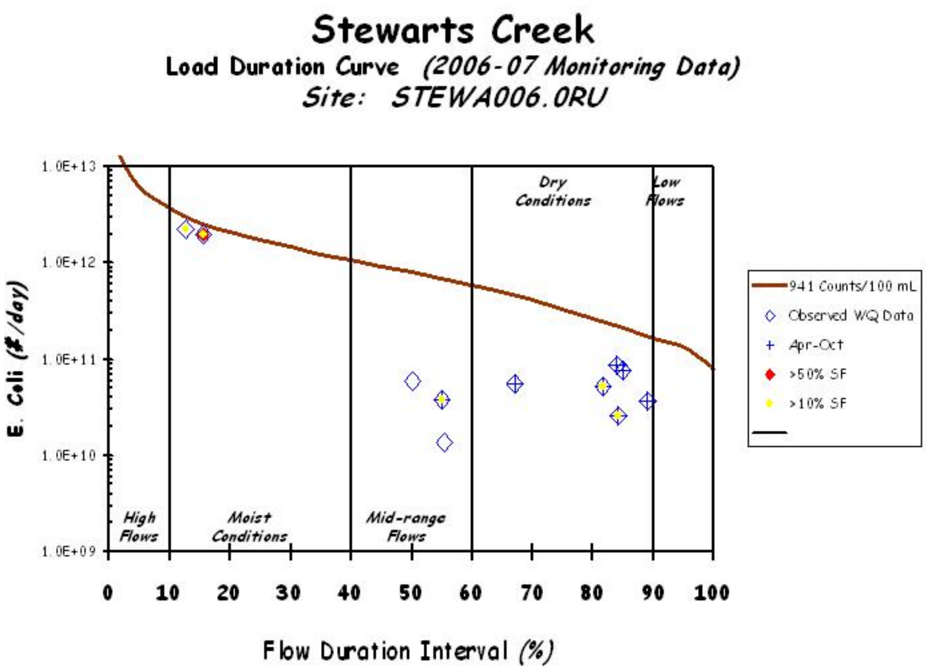

Figure G-7. E. Coli Load Duration Curve for Stewarts Creek – RM6.0

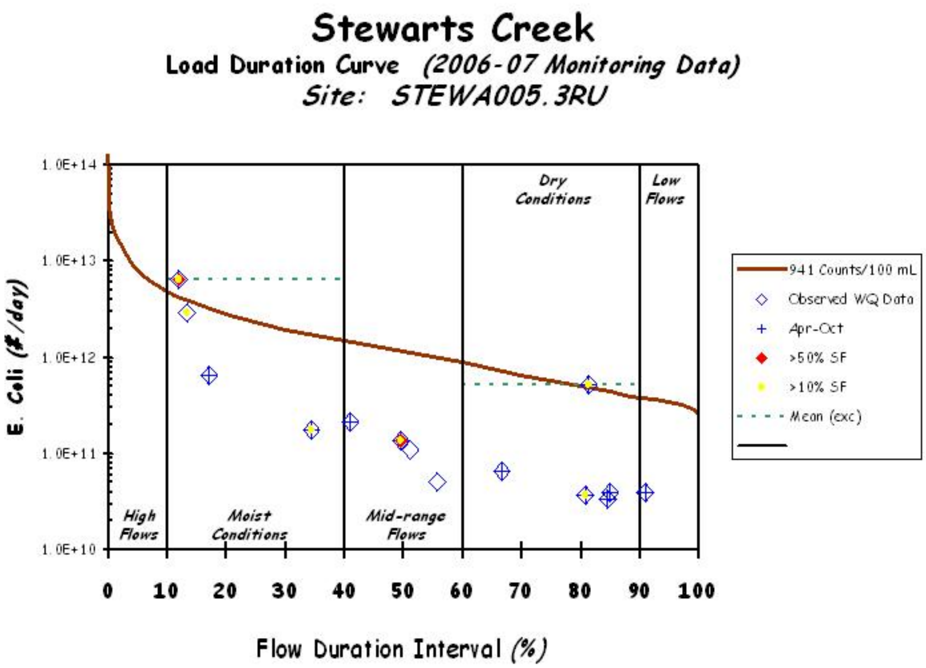

Figure G-8. E. Coli Load Duration Curve for Stewarts Creek – RM5.3

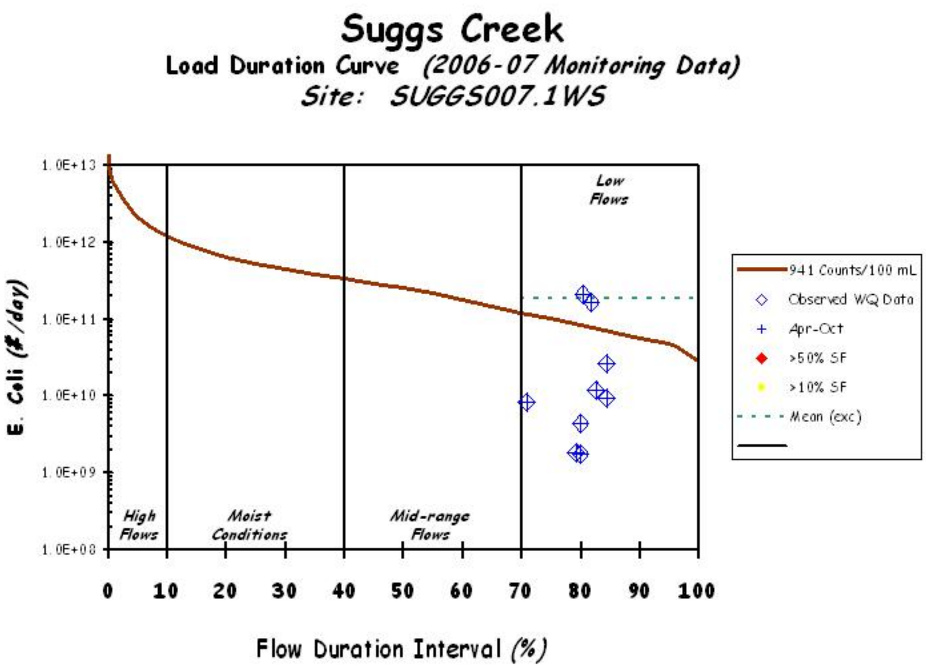

Figure G-9. E. Coli Load Duration Curve for Suggs Creek – RM7.1

Table G-1 2001 MRLC Land Use Distribution of Impaired HUC-12s & Drainage Areas

Land Use	Impaired Subwatershed (05130203____)							
	Carson Fork (in 0101)		0103 (Cripple Creek)		Hurricane Creek (021-0100) (in 0202)		0204 (Overall Creek)	
	[acres]	[%]	[acres]	[%]	[acres]	[%]	[acres]	[%]
Unclassified	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
Open Water	0.0	0.00	24.9	0.08	0.0	0.00	98.1	0.27
Developed Open Space	259.7	2.84	1,262.2	4.05	194.8	3.19	3,721.7	10.24
Low Intensity Development	8.2	0.09	289.8	0.93	4.3	0.07	2,039.0	5.61
Medium Intensity Development	0.0	0.00	81.0	0.26	0.6	0.01	348.9	0.96
High Intensity Development	0.0	0.00	6.2	0.02	0.0	0.00	101.8	0.28
Bare Rock	0.0	0.00	24.9	0.08	4.3	0.07	87.2	0.24
Deciduous Forest	5,899.6	64.51	7,121.2	22.85	1,927.7	31.57	7,145.4	19.66
Evergreen Forest	596.3	6.52	4,839.9	15.53	878.7	14.39	2,722.2	7.49
Mixed Forest	436.2	4.77	2,321.8	7.45	466.5	7.64	1,381.1	3.80
Shrub/Scrub	185.6	2.03	1,539.6	4.94	172.8	2.83	1,184.8	3.26
Grassland/Herbaceous	93.3	1.02	782.2	2.51	103.2	1.69	632.4	1.74
Pasture/Hay	1,532.7	16.76	11,400.2	36.58	2,175.6	35.63	12,415.5	34.16
Row Crops	130.8	1.43	1,402.4	4.50	174.6	2.86	4,310.5	11.86
Woody Wetlands	2.7	0.03	71.7	0.23	1.8	0.03	149.0	0.41
Emergent Herbaceous Wetland	0.0	0.00	3.1	0.01	0.0	0.00	7.3	0.02
Subtotal – Urban	268.0	2.93	1,639.3	5.26	199.7	3.27	6,211.4	17.09
Subtotal - Agriculture	1,663.5	18.19	12,802.6	41.08	2,350.3	38.49	16,726.0	46.02
Subtotal – Forest	7,213.7	78.88	16,704.4	53.60	3,555.0	58.22	13,309.5	36.62
Total	**9,145**	**100.00**	**31,171**	**100.00**	**6,105**	**100.0**	**36,345**	**100.0**

Table G-1 (cont'd) 2001 MRLC Land Use Distribution of Impaired HUC-12s & Drainage Areas

Land Use	Impaired Subwatershed (05130203____)					
	Stewarts Creek (0301 + portion of 0305)		Harts Branch (in 0301)		Suggs Creek (in 0306)	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Unclassified	0.0	0.00	0.0	0.00	0.0	0.00
Open Water	30.2	0.09	2.8	0.04	12.1	0.08
Developed Open Space	4,864.0	11.13	1,298.3	18.61	748.7	4.95
Low Intensity Development	3,902.6	8.93	1,455.9	20.87	77.1	0.51
Medium Intensity Development	830.3	1.90	264.4	3.79	9.1	0.06
High Intensity Development	428.3	0.98	82.3	1.18	0.0	0.21
Bare Rock	61.2	0.14	1.4	0.02	31.8	16.73
Deciduous Forest	12,442.0	28.47	1,241.7	17.80	2,530.6	10.49
Evergreen Forest	3,347.6	7.66	426.2	6.11	1,586.7	5.84
Mixed Forest	3,793.3	8.68	482.7	6.92	883.4	6.75
Shrub/Scrub	1,276.1	2.92	167.4	2.40	1,021.0	2.78
Grassland/Herbaceous	1,180.0	2.70	217.0	3.11	420.5	45.14
Pasture/Hay	10,510.4	24.05	1,258.5	18.04	6,827.9	6.19
Row Crops	970.2	2.22	76.7	1.10	936.3	0.26
Woody Wetlands	61.2	0.14	0.0	0.00	39.3	0.01
Emergent Herbaceous Wetland	4.4	0.01	0.0	0.00	1.5	0.00
Subtotal – Urban	10,025.3	22.94	3,100.9	44.45	835.0	5.73
Subtotal - Agriculture	11,480.5	26.27	1,335.2	19.14	7,764.2	6.45
Subtotal – Forest	22,165.7	50.72	2,536.5	36.36	6,514.8	87.74
Total	**43,702**	**100.00**	**6,975**	**100.0**	**15,126**	**100.00**

Table G-2. TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100 mL]
CRIPP000.4RU	7/24/06	2400
	8/21/06	290
	9/13/06	310
	10/17/06	2400
	11/28/06	115
	12/12/06	240
	1/10/07	192
	2/6/07	91
	3/8/07	79
	4/11/07	201
	5/22/07	77
	6/12/07	86
ECO71H09	7/24/06	240
	8/21/06	330
	9/13/06	140
	10/17/06	820
	11/28/06	70
	12/12/06	110
	1/10/07	83
	2/6/07	26
	3/8/07	67
	4/11/07	2420
	5/22/07	579
	6/12/07	727
HARTS000.1RU	7/18/06	610
	8/3/06	160
	9/19/06	100
	11/7/06	1700
	1/23/07	249
	2/12/07	12
	3/13/07	66
	4/25/07	102
	5/7/07	276
	6/26/07	687

Table G-2 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100 mL]
HURRI002.1RU	9/6/06	650
	9/11/06	110
	9/13/06	280
	9/21/06	110
	9/25/06	160
	9/26/06	91
	9/28/06	210
	5/8/07	158
	5/9/07	101
	5/15/07	82
	5/16/07	50
	5/23/07	25
	5/24/07	37
	5/29/07	13
OVERA005.1RU	9/6/06	26
	9/11/06	140
	9/13/06	220
	9/21/06	39
	9/25/06	260
	9/26/06	200
	9/28/06	190
	1/8/07	2419
	1/10/07	517
	1/17/07	127
	1/18/07	192
	1/23/07	1733
	1/25/07	308
	1/30/07	27
	5/8/07	74
	5/9/07	68
	5/15/07	40
	5/16/07	119
	5/23/07	31
	5/24/07	36
	5/29/07	12

Table G-2 (cont'd). TDEC Water Quality Monitoring Data

Monitoring Station	Date	E. Coli [cts./100 mL]
STEWA005.3RU	7/18/06	99
	8/3/06	84
	9/19/06	1000
	10/11/06	70
	11/7/06	1400
	1/23/07	687
	2/12/07	47
	3/13/07	91
	4/25/07	108
	5/7/07	84
	6/26/07	71
	5/11/10	96
	5/13/10	141
	5/19/10	190
STEWA006.0RU	7/18/06	200
	8/3/06	340
	9/19/06	110
	10/11/06	370
	11/7/06	730
	1/23/07	687
	2/12/07	19
	3/13/07	69
	4/25/07	52
	5/7/07	116
	6/26/07	201
SUGGS007.1WS	10/2/06	49
	10/9/06	2400
	10/11/06	2000
	10/18/06	150
	10/23/06	20
	10/25/06	20
	10/31/06	65
	6/4/07	130
	6/5/07	365

Table G-3 Summary of TDEC Water Quality Monitoring Data

Monitoring Station	Date Range	E. Coli (Max WQ Target = 941 CFU/100 mL)**				
		Data Pts.	Min. [CFU/100 ml]	Avg. [CFU/100 ml]	Max. [CFU/100 ml]	No. Exceed. WQ Max. Target
CRIPP000.4RU	2006 – 2007	12	77	540	2,400	2
ECO71H09	*2006 – 2006*	*12*	*26*	*468*	*2,420*	*4*
HARTS000.1RU	2006 – 2007	10	12	396	1,700	1
HURRI004.2RU	*2006 – 2010*	*25*	*20*	*564*	*4,610*	*6*
OVERA005.1RU	2006 – 2007	21	12	323	2,419	2
STEWA005.3RU	2006 – 2010	14	47	298	1,400	2
SUGGS007.1WS	2006 – 2007	9	20	578	2,400	2

** Maximum water quality target is 487 CFU/100 mL for lakes, reservoirs, State Scenic Rivers, or Exceptional Tennessee Waters waterbodies and 941 CFU/100 mL for other waterbodies. Waterbodies utilizing the 487 CFU/100 mL target are italicized.

Table G-4. Calculated Load Reduction Based on Daily Loading – Carson Fork – ECO71H09

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
4/11/07	Moist Conditions	33.80	12.1%	2,420	2.00E+12	**79.7**	**26.6**	**27.3**
1/10/07		21.09	20.3%	83	4.28E+10	NR		
3/8/07		11.47	37.6%	67	1.88E+10	NR		
2/6/07	Mid-Range Flows	8.78	45.9%	26	5.59E+09	NR	**NR**	**NR**
11/28/06		5.94	57.5%	70	1.02E+10	NR		
12/12/06		5.76	58.3%	110	1.55E+10	NR		
10/17/06	Low Flows	3.41	72.7%	820	6.83E+10	**40.6**	**14.9**	**18.4**
5/22/07		3.22	74.5%	579	4.56E+10	**15.9**		
7/24/06		2.34	82.9%	240	1.38E+10	NR		
8/21/06		2.07	86.0%	330	1.67E+10	NR		
6/12/07		1.71	91.5%	727	3.04E+10	**33.0**		
9/13/06		1.65	92.7%	140	5.64E+09	NR		

Note: NR = No reduction required
NA = Not applicable

Table G-5. Calculated Load Reduction Based on Daily Loading – Cripple Creek – RM0.4

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
4/11/07	Moist Conditions	101.90	10.1%	201	5.01E+11	NR	**NR**	**NR**
1/10/07		52.44	20.3%	192	2.46E+11	NR		
3/8/07		28.84	37.1%	79	5.57E+10	NR		
2/6/07	Mid-Range Flows	22.29	46.4%	91	4.96E+10	NR	**15.2**	**16.2**
12/12/06		17.48	54.2%	240	1.03E+11	NR		
11/28/06		15.00	58.6%	115	4.22E+10	NR		
10/17/06		10.54	68.2%	2,400	6.19E+11	**60.8**		
5/22/07	Low Flows	7.99	76.3%	77	1.50E+10	NR	**12.2**	**12.9**
7/24/06		5.90	83.0%	2,400	3.47E+11	**60.8**		
8/21/06		5.72	83.6%	290	4.06E+10	NR		
6/12/07		4.51	90.7%	86	9.49E+09	NR		
9/13/06		4.43	91.3%	310	3.36E+10	NR		

Note: NR = No reduction required
NA = Not applicable

Table G-6. Calculated Load Reduction Based on Daily Loading – Hurricane Creek – RM2.1 (segment 021-0100)

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
5/15/07	Moist Conditions	19.72	16.4%	82	3.96E+10	NR		
5/16/07		11.62	24.8%	50	1.42E+10	NR	**NR**	**NR**
5/8/07	Mid-Range Flows	3.39	56.8%	158	1.31E+10	NR		
9/26/06		3.13	58.8%	91	6.97E+09	NR		
9/25/06		3.07	59.3%	160	1.20E+10	NR		
5/9/07		2.94	60.2%	101	7.26E+09	NR		
9/28/06		2.25	65.8%	210	1.16E+10	NR	**NR**	**NR**
5/23/07	Low Flows	1.17	75.4%	25	7.17E+08	NR		
5/24/07		1.00	77.1%	37	9.04E+08	NR		
5/29/07		0.468	85.1%	13	1.49E+08	NR		
9/6/06		0.251	90.3%	650	3.99E+09	NR		
9/13/06		0.194	91.7%	280	1.33E+09	NR		
9/11/06		0.138	93.7%	110	3.71E+08	NR		
9/21/06		0.078	96.3%	110	2.10E+08	NR	**NR**	**NR**

Note: NR = No reduction required
NA = Not applicable

Table G-7. Calculated Load Reduction Based on Geomean Data – Hurricane Creek – RM2.1 (segment 021-0100)

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 ml)	Calculated Reduction to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/6/06	0.251	90.3%	650			
9/11/06	0.138	93.7%	110			
9/13/06	0.194	91.7%	280			
9/21/06	0.078	96.3%	110			
9/25/06	3.07	59.3%	160	**203.9**	**38.2**	**44.6**
9/26/06	3.13	58.8%	91	**137.6**	**8.4**	**17.9**
9/28/06	2.25	65.8%	210	**156.6**	**19.5**	**27.8**
5/8/07	3.39	56.8%	158			
5/9/07	2.94	60.2%	101			
5/15/07	19.72	16.4%	82			
5/16/07	11.62	24.8%	50			
5/23/07	1.17	75.4%	25	**69.6**	**NR**	**NR**
5/24/07	1.00	77.1%	37	**52.1**	**NR**	**NR**
5/29/07	0.468	85.1%	13	**34.6**	**NR**	**NR**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table G-8. Calculated Load Reduction Based on Daily Loading – Overall Creek – RM5.1

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
1/8/07	Moist Conditions	80.80	13.0%	2,419	4.78E+12	**61.1**	**15.3**	**16.6**
1/10/07		61.79	17.8%	517	7.82E+11	NR		
1/23/07		58.30	18.9%	1,733	2.47E+12	**45.7**		
1/17/07		57.24	19.4%	127	1.78E+11	NR		
1/18/07		48.09	23.6%	192	2.26E+11	NR		
1/25/07		43.20	26.3%	308	3.26E+11	NR		
1/30/07		27.71	38.7%	27	1.83E+10	NR		
9/25/06	Mid-Range Flows	16.12	52.3%	260	1.03E+11	NR	**NR**	**NR**
9/26/06		15.89	52.7%	200	7.78E+10	NR		
9/28/06		14.19	55.1%	190	6.60E+10	NR		
9/6/06	Dry Conditions	3.00	79.3%	26	1.91E+09	NR	**NR**	**NR**
5/8/07		2.93	79.6%	74	5.31E+09	NR		
5/9/07		2.50	81.5%	68	4.16E+09	NR		
9/11/06		1.51	86.3%	140	5.17E+09	NR		
9/13/06		1.20	88.2%	220	6.48E+09	NR		
5/15/07		1.09	89.0%	40	1.06E+09	NR		
5/16/07		1.01	89.5%	119	2.93E+09	NR		
9/21/06	Low Flows	0.894	90.2%	39	8.53E+08	NR	**NR**	**NR**
5/23/07		0.383	94.1%	31	2.90E+08	NR		
5/24/07		0.339	94.5%	36	2.99E+08	NR		
5/29/07		0.171	96.5%	12	5.02E+07	NR		

Note: NR = No reduction required
NA = Not applicable

Table G-9. Calculated Load Reduction Based on Geomean Data – Overall Creek – RM5.1

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction	
					to Target GM (126 CFU/100 ml)	to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
9/6/06	3.00	79.3%	26			
9/11/06	1.51	86.3%	140			
9/13/06	1.20	88.2%	220			
9/21/06	0.894	90.2%	39			
9/25/06	16.12	52.3%	260	**95.9**	**NR**	**NR**
9/26/06	15.89	52.7%	200	**144.3**	**12.7**	**21.7**
9/28/06	14.19	55.1%	190	**153.3**	**17.8**	**26.3**
1/8/07	80.80	13.0%	2419			
1/10/07	61.79	17.8%	517			
1/17/07	57.24	19.4%	127			
1/18/07	48.09	23.6%	192			
1/23/07	58.30	18.9%	1733	**555.4**	**77.3**	**79.7**
1/25/07	43.20	26.3%	308	**367.8**	**65.7**	**69.3**
1/30/07	27.71	38.7%	27	**203.8**	**38.2**	**44.5**
5/8/07	2.93	79.6%	74			
5/9/07	2.50	81.5%	68			
5/15/07	1.09	89.0%	40			
5/16/07	1.01	89.5%	119			
5/23/07	0.383	94.1%	31	**59.4**	**NR**	**NR**
5/24/07	0.339	94.5%	36	**51.5**	**NR**	**NR**
5/29/07	0.171	96.5%	12	**36.4**	**NR**	**NR**

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table G-10. Calculated Load Reduction Based on Daily Loading – Harts Branch – RM0.1

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
11/7/06	High Flows	44.85	8.5%	1,700	1.87E+12	**44.6**	**44.6**	**50.2**
1/23/07	Moist Conditions	20.94	18.6%	249	1.28E+11	NR	**NR**	**NR**
4/25/07		12.19	29.7%	102	3.04E+10	NR		
3/13/07	Mid-Range Flows	5.82	52.8%	66	9.40E+09	NR	**NR**	**NR**
2/12/07		5.00	57.2%	12	1.47E+09	NR		
5/7/07		3.32	67.8%	276	2.24E+10	NR		
6/26/07	Low Flows	1.99	80.1%	687	3.34E+10	NR	**NR**	**NR**
9/19/06		1.78	82.0%	100	4.35E+09	NR		
8/3/06		1.51	85.4%	160	5.90E+09	NR		
7/18/06		1.20	90.3%	610	1.78E+10	NR		

Note: NR = No reduction required
NA = Not applicable

Table G-11. Calculated Load Reduction Based on Daily Loading – Stewarts Creek – RM6.0

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
1/23/07	Moist Conditions	132.90	12.8%	687	2.23E+12	NR	**NR**	**NR**
11/7/06		111.80	15.7%	730	2.00E+12	NR		
3/13/07	Mid-Range Flows	34.88	50.3%	69	5.89E+10	NR	**NR**	**NR**
4/25/07		30.04	55.1%	52	3.82E+10	NR		
2/12/07		29.73	55.5%	19	1.38E+10			
5/7/07		19.77	67.2%	116	5.61E+10	NR		
6/26/07	Low Flows	10.64	81.7%	201	5.23E+10	NR	**NR**	**NR**
10/11/06		9.61	84.0%	370	8.69E+10	NR		
9/19/06		9.51	84.2%	110	2.56E+10			
8/3/06		9.12	85.0%	340	7.59E+10	NR		
7/18/06		7.49	89.1%	200	3.66E+10	NR		

Note: NR = No reduction required
NA = Not applicable

Table G-12. Calculated Load Reduction Based on Daily Loading – Stewarts Creek – RM5.3

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
11/7/06	Moist Conditions	186.80	12.0%	1,400	6.40E+12	**32.8**		
1/23/07		170.80	13.3%	687	2.87E+12	NR		
5/19/10		138.60	17.1%	190	6.44E+11	NR		
5/11/10		73.95	34.4%	96	1.74E+11	NR	**8.2**	**9.9**
5/13/10	Mid-Range Flows	62.46	41.1%	141	2.15E+11	NR		
4/25/07		50.93	49.7%	108	1.35E+11	NR		
3/13/07		49.17	51.1%	91	1.09E+11	NR		
2/12/07		43.57	55.7%	47	5.01E+10	NR		
5/7/07		31.78	66.7%	84	6.53E+10	NR	**NR**	**NR**
6/26/07	Dry Conditions	21.34	80.9%	71	3.71E+10	NR		
9/19/06		21.11	81.4%	1,000	5.16E+11	**5.9**		
10/11/06		19.41	84.6%	70	3.32E+10	NR		
8/3/06		19.19	85.1%	84	3.94E+10	NR	**1.5**	**3.8**
7/18/06	Low Flows	16.29	91.1%	99	3.95E+10	NR	**NR**	**NR**

Note: NR = No reduction required
NA = Not applicable

Table G-13. Calculated Load Reduction Based on Daily Loading – Suggs Creek – RM7.1

Sample Date	Flow Regime	Flow	PDFE	Concentration	Load	% Reduction to Achieve TMDL	Average of Load Reductions	% Reduction to TMDL – MOS
		[cfs]	[%]	[CFU/100 ml]	[CFU/day]	[%]	[%]	[%]
10/31/06	Low Flows	5.18	71.0%	65	8.23E+09	NR	12.6	13.6
10/23/06		3.73	79.3%	20	1.83E+09	NR		
10/2/06		3.65	80.0%	49	4.37E+09	NR		
10/25/06		3.64	80.0%	20	1.78E+09	NR		
10/9/06		3.60	80.4%	2,400	2.11E+11	**60.8**		
10/11/06		3.38	81.9%	2,000	1.65E+11	**53.0**		
10/18/06		3.26	82.7%	150	1.20E+10	NR		
6/4/07		3.01	84.5%	130	9.57E+09	NR		
6/5/07		3.01	84.5%	365	2.69E+10	NR		

Note: NR = No reduction required
NA = Not applicable

Table G-14. Calculated Load Reduction Based on Geomean Data – Suggs Creek – RM7.1

Sample Date	Flow	PDFE	Concentration	Geometric Mean	Calculated Reduction to Target GM (126 CFU/100 ml)	Calculated Reduction to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[CFU/100 ml]	[%]	[%]
10/2/06	3.65	80.0%	49			
10/9/06	3.60	80.4%	**2400**			
10/11/06	3.38	81.9%	**2000**			
10/18/06	3.26	82.7%	150			
10/23/06	3.73	79.3%	20	**234.3**	**46.2**	**51.8**
10/25/06	3.64	80.0%	20	**195.8**	**35.7**	**42.3**
10/31/06	5.18	71.0%	65	**95.2**		

Note: Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table G-15. Summary of Critical Conditions for Possible Ecoli-Impaired Non-Listed Waterbodies in the Stones River Watershed.

Waterbody ID	Moist	Mid-range	Dry	Low	PLRG
Carson Fork (027-2000) [b]	ò				26.6
Cripple Creek [b]		ò			15.2
Hurricane Creek (021-0100) [b]					44.6 [c]
Overall Creek [a]	ò				79.7 [c]
Harts Branch [b]					44.6
Stewarts Creek (010-1000) [a]	ò				8.2
Suggs Creek [b]				ò	46.2 [c]

[a] Waterbody(ies) with 5 flow zones.
[b] Waterbody(ies) with 4 flow zones.
[c] PLRG based on geomean data.

APPENDIX H

Public Notice Announcement

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

PUBLIC NOTICE OF AVAILABILITY OF PROPOSED TOTAL MAXIMUM DAILY LOAD (TMDL) FOR E. COLI IN STONES RIVER WATERSHED (HUC 05130203), TENNESSEE

Announcement is hereby given of the availability of Tennessee's proposed Total Maximum Daily Load (TMDL) for E. coli in the Stones 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 in the Stones River watershed are listed on Tennessee's Final 2010 303(d) list as not supporting designated use classifications due, in part, to discharges from MS4 areas and pasture grazing. The TMDL utilizes Tennessee's general water quality criteria, continuous flow data from a USGS discharge monitoring station located in proximity to the watershed, site specific water quality monitoring data, a calibrated hydrologic model, load duration curves, and an appropriate Margin of Safety (MOS) to establish allowable loadings of pathogens which will result in the reduced in-stream concentrations and attainment of water quality standards. The TMDL requires reductions of pathogen loading on the order of 8.2-77.5% in the listed waterbodies.

The Stones River E. coli TMDL may be downloaded from the Department of Environment and Conservation website:

http://www.tennesse.gov/environment/wpc/tmdl/

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

Vicki S. Steed, P.E., Watershed Management Section
Telephone: 615-532-0707

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

Persons wishing to comment on the proposed TMDLs are invited to submit their comments in writing no later than May 29, 2012 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, 6th Floor, L & C Annex, 401 Church Street, Nashville, Tennessee. They may be inspected during normal office hours. Copies of the information on file are available on request.

APPENDIX I

Public Comments Received

FW: Metro Nashville questions relating to draft Stones E Coli TMDL

Sherry Wang
Sent: Thursday, May 24, 2012 2:15 PM
To: Vicki Steed; Bruce Evans
Importance: High

FYI

From: Hunt, Michael (WS) [mailto:Michael.Hunt@nashville.gov]
Sent: Thursday, May 24, 2012 1:09 PM
To: Sherry Wang
Cc: Winesett, Steve (WS); Stallard, Megan (WS); Hayes, Joshua (WS)
Subject: Metro Nashville questions relating to draft Stones E Coli TMDL
Importance: High

Hi Sherry, Now that TMDL compliance is more complicated than us simply being compliant with our MS4 permit, we took a bit more detailed approached when reviewing the Stones *E Coli* draft TMDL. In doing so, we came up with some questions – not necessarily as official comments - but more as reference info to help us better understand the TMDL WLAs and also how we can translate our sampling data into terms that relate to our MS4 WLAs. If easier for us to meet and discuss, let us know. Thanks, Michael

1. Are MS4 WLA's related to all flow conditions (high flow through low flow)?
2. As it relates to MS4 WLA, do dry days count as zero in calculating an overall average (CFU/d/ac) in determining TMDL compliance or is the MS4 WLA value a "not to exceed" value. This would seem an important distinction as obviously on dry days, no *E Coli* will be discharged from MS4.
3. Why does TDEC report DA acres in the TMDL and not for subwatersheds?
4. If an MS4 gets a geometric mean of 500 cfu/100 ml on a wet weather sample from an MS4 outfall (or a series of values that average 500), how would an MS4 mathematically know if that value equates to meeting the MS4 WLA? We've tried some calculations and even with low CFU #s (well below single sample max), we get a value factors above the MS4 WLA. Would we need to categorize all samples as either HF, M, MR, or LF?
5. Summary table on page xiii notes that Q = mean daily in-stream flow (cfs). Help us understand how that equates/is related to rain event-generated discharges from MS4?
6. There appears to be a difference in MS4 WLA's within the draft document between those stated on pages xiii and E-43. See below. How were values on page xiii derived from those on page E-43?

Page xiii

Summary of TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Stones River Watershed (HUC 05130203)

HUC-12 Subwatershed (05130203__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs			LAs
					WWTFs [a]	Collection Systems	MS4s [b]	
			[CFU/day]	[CFU/day]	[CFU/day]	[CFU/day]	[CFU/d/ac]	[CFU/d/ac]
0308	Stoners Creek	TN05130203035 – 1000	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	$1.081 \times 10^{6} \times Q$	$1.081 \times 10^{6} \times Q$
0309	McCrory Creek	TN05130203001 – 0100	$2.30 \times 10^{10} \times Q$	$2.30 \times 10^{9} \times Q$	NA	NA	$2.264 \times 10^{6} \times Q$	$2.264 \times 10^{6} \times Q$

Table E-27 (cont'd) Summary of TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Stones River Watershed (HUC 05130203)

Waterbody Description (TN05130203__)	Hydrologic Condition			Flow[a]	PLRG	TMDL	MOS	WLAs			LAs
	Flow Regime	PDFE Range	Flow Range					WWTFs [c]	CS	MS4s	
		[%]	[cfs]	[cfs]	[%]	[CFU/d]	[CFU/d]	[CFU/d]		[CFU/d/ac]	[CFU/d/ac]
Stoners Creek Waterbody ID: **035 – 1000** HUC-12: 0308	High Flows	0 – 10	78.0 – 1,009	156	74.7[b]	3.587×10^{12}	3.587×10^{11}	NA	NA	1.767×10^{8}	1.767×10^{8}
	Moist	10 – 40	21.6 – 78.0	35.2		8.085×10^{11}	8.085×10^{10}			3.983×10^{7}	3.983×10^{7}
	Mid-Range	40 – 70	6.58 – 21.6	12.3		2.822×10^{11}	2.822×10^{10}			1.390×10^{7}	1.390×10^{7}
	Low Flows	70 – 100	0.06 – 6.58	1.92		4.278×10^{10}	4.278×10^{9}			2.108×10^{6}	2.108×10^{6}
McCrory Creek Waterbody ID: **001 – 0150** HUC-12: 0309	High Flows	0 – 10	23.2 – 317	48.5	77.5[b]	1.116×10^{12}	1.116×10^{11}	NA	NA	2.034×10^{8}	2.034×10^{8}
	Moist	10 – 40	5.40 – 23.2	9.10		2.093×10^{11}	2.093×10^{10}			3.814×10^{7}	3.814×10^{7}
	Mid-Range	40 – 70	1.59 – 5.40	3.10		7.130×10^{10}	7.130×10^{9}			1.299×10^{7}	1.299×10^{7}
	Low Flows	70 – 100	0.02 – 1.59	0.45		1.035×10^{10}	1.035×10^{9}			1.886×10^{6}	1.886×10^{6}

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May 25, 2012

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Re: Comments on Proposed E. Coli Total Maximum Daily Load for the Stones River Watershed

TDEC has recently issued a draft document for public comment presenting a proposed Total Maximum Daily Load (TMDL) for E. coli in the Stones River Watershed (HUC 05130203). In Section 7.1.2 of that document, the Tennessee Department of Transportation (TDOT) Municipal Separate Storm Sewer System (MS4), regulated under Permit TNS077585, is listed as a possible point source for the pollutant loading that is the subject of the TMDL. Inclusion as a possible point source will trigger requirements in the TDOT MS4 Permit that could include stormwater effluent monitoring, in-stream monitoring, and the implementation of control measures at the discharge points. TDOT does not believe that the inclusion of its MS4 as a point source for the pollutant loading which is the subject of this TMDL is appropriate and requests that the document be modified to remove the TDOT MS4 as a possible point source. The rationale for this request includes the following points:

1. The subject TMDL affects a total of 11 impaired stream segments in the Stones River Watershed. However, Table 2 of the subject document identifies that only five of those stream segments include as a pollutant source "Discharges from MS4 area." Those five stream segments include designated portions of:

    - McCory Creek
    - Stewarts Creek
    - Sinking Creek
    - Lytle Creek (W. Fork Stones River to Dilton Rd.)
    - Hurricane Creek

    Data from TDOT's outfall mapping program has determined that the TDOT MS4 has point source discharges to these five stream segments at approximately 14 locations. The total area within the TDOT MS4 that drains to these 14 point source outfalls is calculated to be 340 acres. However, the total drainage area of the five impaired stream segments (see subject document Table A-1) is 62,631 acres. The TDOT MS4 drainage area is less than 0.5% of the drainage area contributing to these stream segments and thus, is a negligible contributor to this hydrologic system.

2. The TDOT MS4 Program has been acquiring and analyzing samples of stormwater runoff from state highways over the past two years. These samples have been acquired from a variety of highway scenarios across the State, ranging from high traffic volume interstate highways in urban commercial areas to low traffic volume highways in rural agricultural areas. To date, a total of 117 stormwater samples from the TDOT MS4 have been evaluated for E. coli. Of these 117 analyses, only 14 have detected the presence of E. coli, and only six of the measured E. coli results have exceeded the sample maximum value selected as the appropriate numerical target for TMDL development in Tennessee (see subject document Section 5.0). Based on these stormwater sampling results from the TDOT MS4, only about 5% of the stormwater discharges from the TDOT MS4 would be expected to contribute E. coli contamination at levels that could impact the watershed. Again, the TDOT MS4 is obviously a negligible contributor to the E. coli contamination observed in this watershed.

3. The California Department of Transportation (Caltrans), when faced with similar issues, sponsored an extensive investigation into the presence of human pathogens in urban highway storm drains. The study focused on the validity of the use of organisms, such as coliforms and E. coli, as indicators of the presence of actual human pathogens in drainage systems. The study evaluated stormwater runoff from highways and controlled discharges of sterile water through the systems as a means to evaluate the source and presence of these organisms. In summary, the study had the following conclusions:

   - The use of total coliforms, fecal coliforms, and E. coli as indicator organisms for human pathogens is based on the assumption that these organisms do not compete well in the natural environment. However, these organisms have been shown to reproduce and compete in warm soils, and to be normal members of the microbial community;
   - Significant concentrations of indicator organisms, such as E. coli, are nearly ubiquitous in urban drainage;
   - Pathogens can be found in urban drainage, but there does not appear to be a relationship between the presence of pathogens and the concentration of indicator organisms, such as E. coli;
   - Highway facilities, including maintenance stations, do not appear to be a significant source of pathogens in urban drainage.

   The complete report for this study can be found at:

   http://www.dot.ca.gov/hq/env/stormwater/pdf/CTSW-RT-02-025.pdf

From this evaluation of the proposed TMDL, the stormwater runoff from the TDOT MS4 has been shown to be a negligible contributor to the hydrologic regime of the subject watershed, and two independent studies have demonstrated that highway stormwater runoff is not a significant vector of E. coli or human pathogens. Based on this information, TDOT respectfully requests that this draft TMDL document be revised to remove the TDOT MS4 as a possible source for the subject contamination.

If you have any questions, or require additional information and documentation, please call me at 615-741-4732 or email me at Barry.Brown@tn.gov.

Sincerely,

Barry C. Brown
Director, Environmental Compliance Office
TDOT Environmental Division

Cc: John Nichols, TDOT
Project Files

APPENDIX J

Response to Public Comments Received

Subject: **Response to Questions and Comments**
Draft of Proposed Total Maximum Daily Load (TMDL)
For E. coli
Stones River Watershed, Tennessee

1. Are MS4 WLA's related to all flow conditions (high flow through low flow)?

Yes, the WLA applies under all flow conditions.

2. As it relates to MS4 WLA, do dry days count as zero in calculating an overall average (CFU/d/ac) in determining TMDL compliance or is the MS4 WLA value a "not to exceed" value. This would seem an important distinction as obviously on dry days, no E Coli will be discharged from MS4.

   The WLA, like the TMDL, is based on the daily maximum water quality criteria (minus the MOS). Therefore, it is a "not to exceed" value. Assessment and compliance are based on water quality criteria.

3. Why does TDEC report DA acres in the TMDL and not for subwatersheds?

   The drainage areas included in Table A-1are for HUC-12s and drainage areas of impaired segments. These are the drainage areas used in calculating the TMDLs provided in the summary section as well as Table 8 and Table C-1. We have added drainage areas for specific monitoring points to Table E-3. (See response to question 6.)

4. If an MS4 gets a geometric mean of 500 cfu/100 ml on a wet weather sample from an MS4 outfall (or a series of values that average 500), how would an MS4 mathematically know if that value equates to meeting the MS4 WLA? We've tried some calculations and even with low CFU #s (well below the single sample max), we get a value factors above the MS4 WLA. Would we need to categorize all samples as either HF, M, MR, or LF?

   The TMDL, MOS, WLA, and LA are based on the daily maximum water quality criteria. A geometric mean value is not intended to be compared with the WLA. A geometric mean value can only be compared to the geometric mean water quality criteria (126 cfu/100 ml). To determine if an individual sample is less than the WLA, multiply the sample concentration times the in-stream flow at the time the sample was taken times a conversion factor (2.45×10^7) and divide by the drainage area for the segment. The resulting value can be compared to the WLA determined in the TMDL document. For instance, when sampling at the mouth of McCrory Creek, if the instream flow is 1 cfs and the measured concentration is 200 cfu/100 mL and the entire drainage area is within the MS4, the actual load is 8.508×10^5 cfu/d/ac. The target WLA determined in the TMDL document is 3.595×10^6 cfu/d/ac. Therefore, based on this single sample, the MS4 is in compliance with its WLA.

5. Summary table on page xiii notes the Q = mean daily in-stream flow (cfs). Help us understand how that equates/is related to rain event-generated discharges from MS4?

   Q refers to the mean daily in-stream flow as opposed to the discharge from a specific outlet. Our calculations are based on the daily mean flow as generated by our hydrologic model. If the in-stream flow is measured at the time a sample is collected, that "instantaneous" flow can be used in place of a "mean daily" in-stream flow.

6. There appears to be a difference in MS4 WLA's within the draft document between those stated on pages xiii and E-43. How were values on page xiii derived from those on page E-43.

The values on page E-43 (Table E-27) are derived from the values on page xiii.

The table on page xiii (which is the same as Table 8 and Table C-1) has a variable of Q (the mean daily in-stream flow discussed in the answer to question 5). Table E-27 is intended to be an aid to implementation. In Table E-27, the values of the TMDL, MOS, and WLA/LA are calculated for each impaired segment at a specific monitoring point and for a specific flow regime. The midpoint of the flow range for each flow regime is substituted for Q in order to produce a numeric value for the TMDL, MOS, and WLA/LA instead of an equation. For example, the TMDL for McCrory Creek in the table on page xiii is 2.30 x 10^{10} x Q cfu/d. In Table E-27, the TMDL for McCrory Creek at monitoring station MCCRO001.5DA for the moist flow regime is 2.03 x 10^{11} cfu/d [or (2.30 x 10^{10}) x 9.10]

The WLA for an MS4 is equal to the WLA (expressed on a per acre basis) multiplied by the number of acres in the drainage area which are within the jurisdiction of the MS4. For example, if 50% of the McCrory Creek drainage area is within the MS4, the total WLA for the MS4 would be (3.595 x 10^{6} x Q cfu/d/ac) multiplied by (50% of 5,759 ac) – or 1.071 x 10^{10} x Q cfu/d. The total WLA for the MS4 at monitoring station MCCRO001.5DA for the moist flow regime (assuming 50% of the drainage area is within the specific MS4) would be (3.814 x 10^{7} cfu/d/ac) multiplied by (50% of 4,939.1 ac) – or 9.419 x 10^{10} cfu/d. There is a slight difference between the WLA at MCCRO001.5DA and the WLA for the entire segment because MCCRO001.5DA is slightly upstream of the pour point of the drainage area for the entire segment.

Table E-3, which identifies the critical conditions for each impaired segment, has been expanded to include the name of the specific monitoring station and the associated drainage area used to determine the critical condition. The Flow and Flow Range included in Table E-27 are also for the monitoring station identified in Table E-3.

Response to Comments Received from TDOT:

TDEC has considered the comments submitted by TDOT. The TDOT MS4 will not be considered as a potential source of E. coli loading. Changes have been made to Section 7.1.2 summarizing the arguments made by TDOT.