TOTAL MAXIMUM DAILY LOAD (TMDL)

for

E. Coli

in the

Old Hickory Lake Watershed (HUC 05130201)

Macon, Smith, Sumner, Trousdale, 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
LSPC	Loading Simulation Program in C^{++}
MGD	Million Gallons per Day
MOS	Margin of Safety
MRLC	Multi-Resolution Land Characteristic
MS4	Municipal Separate Storm Sewer System
MST	Microbial Source Tracking
NHD	National Hydrography Dataset
NMP	Nutrient Management Plan
NPS	Nonpoint Source
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
PCR	Polymerase Chain Reaction
PDFE	Percent of Days Flow Exceeded
PFGE	Pulsed Field Gel Electrophoresis
Rf3	Reach File v.3
RM	River Mile
SSO	Sanitary Sewer Overflow
STP	Sewage Treatment Plant
SWMP	Storm Water Management Program
TDA	Tennessee Department of Agriculture
TDEC	Tennessee Department of Environment & Conservation
TDOT	Tennessee Department of Transportation
TMDL	Total Maximum Daily Load
TWRA	Tennessee Wildlife Resources Agency
USGS	United States Geological Survey
UCF	Unit Conversion Factor
WCS	Watershed Characterization System
WLA	Waste Load Allocation
WWTF	Wastewater Treatment Facility

SUMMARY SHEET

Total Maximum Daily Load for E. coli in Old Hickory Lake Watershed (HUC 05130201)

Impaired Waterbody Information

State: Tennessee
Counties: Wilson
Watershed: Old Hickory Lake (HUC 05130201)
Constituents of Concern: E. coli

Impaired Waterbodies Addressed in This Document:

Waterbody ID	Waterbody	Miles Impaired
TN05130201013 – 4000	SPRING CREEK	9.0
TN05130201015 – 0200	JOHNSON BRANCH	7.6
TN05130201021 – 0300	NEAL BRANCH	3.7
TN05130201021 – 0400	BEECH LOG CREEK	8.5
TN05130201021 – 2000	ROUND LICK CREEK	8.7
TN05130201028 – 0100	LITTLE GOOSE CREEK	12.7
TN05130201028 – 0150	LITTLE GOOSE CREEK	10.0
TN05130201055 – 0200	SINKING CREEK	17.4
TN05130201055 – 1000	BARTONS CREEK	5.0

Designated Uses:

The designated use classifications for waterbodies in the Old Hickory Lake Watershed include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation.

Water Quality Targets:

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

> The concentration of the E. coli group shall not exceed 126 colony forming units per 100 mL, as a geometric mean based on a minimum of 5 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. For the purposes of determining the geometric mean, individual samples having an E. coli concentration of less than 1 per 100 mL shall be considered as having a concentration of 1 per 100 mL. In addition, the concentration of the E. coli group in any individual sample taken from a lake, reservoir, State Scenic River, or Tier II or III stream (1200-4-3-.06) shall not exceed 487 colony forming units per 100 mL. The concentration of the E. coli group in any individual sample taken from any other waterbody shall not exceed 941 colony forming units per 100 mL.

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

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

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

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

TMDL Scope:

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

Analysis/Methodology:

The TMDLs for impaired waterbodies in the Old Hickory Lake Watershed were developed using a load duration curve methodology to assure compliance with the E. Coli 126 CFU/100 mL geometric mean and the 487 CFU/100 mL maximum water quality criteria for lakes, reservoirs, State Scenic Rivers, or Tier II or Tier III waterbodies and 941 CFU/100 mL maximum water quality criteria 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 regime 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 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, for each hydrologic flow zone, to meet the target (TMDL) loading for E. coli. The percent load reduction goal of the greatest magnitude corresponds with the critical flow zone.

Seasonal Variation:

The 10-year period used for LSPC model simulation 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 Old Hickory Lake Watershed (HUC 05130201)

HUC-12 Subwatershed (05130201__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs			LAs
					WWTFs [a]	Collection Systems	MS4s	
			[CFU/day]	[CFU/day]	[CFU/day]	[CFU/day]	[CFU/day/acre]	[CFU/day/acre]
0105	Johnson Branch	TN05130201015 – 0200	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	6.893×10^{6} * Q
0106	Spring Creek	TN05130201013 – 4000	1.20×10^{10} * Q	1.20×10^{9} * Q	NA	NA	NA	7.653×10^{5} * Q
0107	Bartons Creek	TN05130201055 – 1000	*[b]	*[b]	*[b]	*[b]	*[b]	*[b]
	Sinking Creek	TN05130201055 – 0200	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	2.175×10^{6} * Q	2.175×10^{6} * Q
	Sinking Creek	TN05130201055 – 0250	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	2.175×10^{6} * Q	2.175×10^{6} * Q
0201	Beech Log Creek	TN05130201021 – 0400	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	5.692×10^{6} * Q	5.692×10^{6} * Q
	Neal Branch	TN05130201021 – 0300	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.723×10^{7} * Q	1.723×10^{7} * Q
	Round Lick Creek	TN05130201021 – 2000	2.30×10^{10} * Q	2.30×10^{9} * Q	9.617×10^{9}	0	1.194×10^{6} * Q – 5.546×10^{5}	1.194×10^{6} * Q – 5.546×10^{5}
0302	Little Goose Creek	TN05130201028 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	1.131×10^{6} * Q
	Little Goose Creek	TN05130201028 – 0150	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	1.651×10^{6} * Q

Notes: NA = Not Applicable.

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. Detailed TMDL analyses were not performed on Bartons Creek. It is assumed that water quality standards for E. coli will be attained in this waterbody when the requirements of the Commissioner's Order against Lebanon STP are complete and Lebanon STP complies with the terms of its NPDES permit.

E. COLI TOTAL MAXIMUM DAILY LOAD (TMDL)
OLD HICKORY LAKE WATERSHED (HUC 05130201)

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 Old Hickory Lake Watershed, identified on the Final 2006 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.

3.0 WATERSHED DESCRIPTION

The Old Hickory Lake Watershed (HUC 05130201) is located in Middle Tennessee (Figure 1), primarily in Macon, Smith, Sumner, Trousdale, and Wilson Counties. The Old Hickory Lake Watershed lies within one Level III ecoregion (Interior Plateau) and contains five Level IV ecoregions as shown in Figure 2 (USEPA, 1997):

- **Western Pennyroyal Karst (71e)** is a flatter area of irregular plains, with fewer perennial streams, compared to the open hills of the Western Highland Rim (71f). Small sinkholes and depressions are common. The productive soils of this notable agricultural area are formed mostly from a thin loess mantle over residuum of Mississippian-age limestones. Most of the region is cultivated or in pasture; tobacco and livestock are the principal agricultural products, with some corn, soybeans, and small grains. The natural vegetation consisted of oak-hickory forest with mosaics of bluestem prairie. The barrens of Kentucky, that extended south into Stewart, Montgomery, and Robertson counties, were once some of the largest natural grasslands in Tennessee.

- **Western Highland Rim (71f)** is characterized by dissected, rolling terrain of open hills, with elevations of 400 to 1000 feet. The geologic base of Mississippian-age limestone, chert, and shale is covered by soils that tend to be cherty, acidic and low to moderate in fertility. Streams are characterized by coarse chert gravel and sand substrates with areas of bedrock, moderate gradients, and relatively clear water. The oak-hickory natural vegetation was mostly deforested in the mid to late 1800's, in conjunction with the iron ore related mining and smelting of the mineral limonite, but now the region is again heavily forested. Some agriculture occurs on the flatter areas between streams and in the stream and river valleys: mostly hay, pasture, and cattle, with some cultivation of corn and tobacco.

- **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 Old Hickory Lake Watershed, located in Macon, Smith, Sumner, Trousdale, and Wilson Counties, Tennessee, has a drainage area of approximately 986 square miles (mi^2). Watershed land use distribution is based on the Multi-Resolution Land Characteristic (MRLC) databases derived from Landsat Thematic Mapper digital images from the period 1990-1993. Although changes in the land use of the Old Hickory Lake Watershed have occurred since 1993 as a result of development, this is the most current land use data available. Land use for the Old Hickory Lake Watershed is summarized in Table 1 and shown in Figure 3. Predominant land use in the Old Hickory Lake Watershed is forest (54.4%) followed by pasture (27.1%). Urban areas represent approximately 3.4% of the total drainage area of the watershed. Details of land use distribution of impaired subwatersheds in the Old Hickory Lake Watershed are presented in Appendix A.

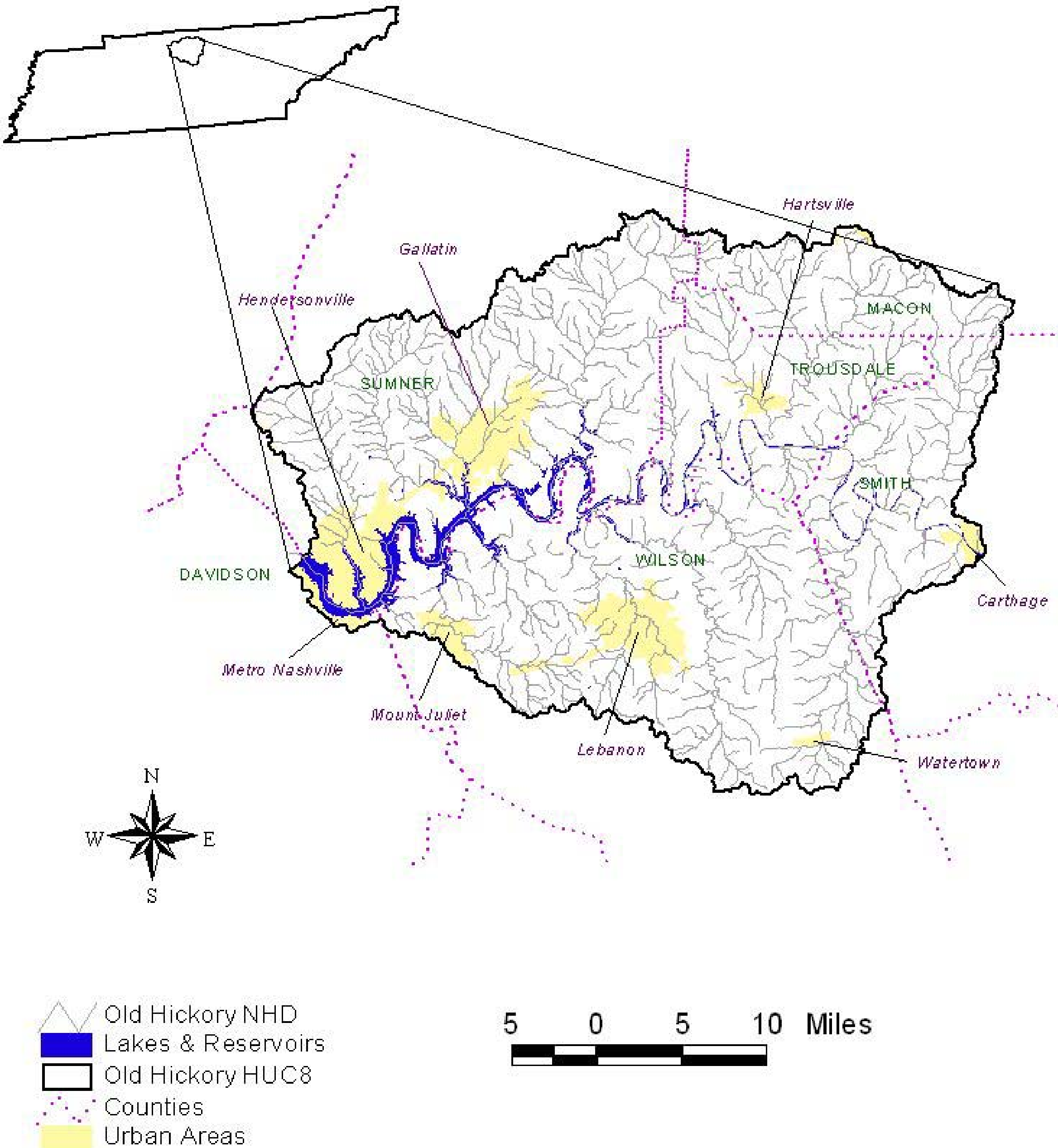

Figure 1. Location of the Old Hickory Lake Watershed.

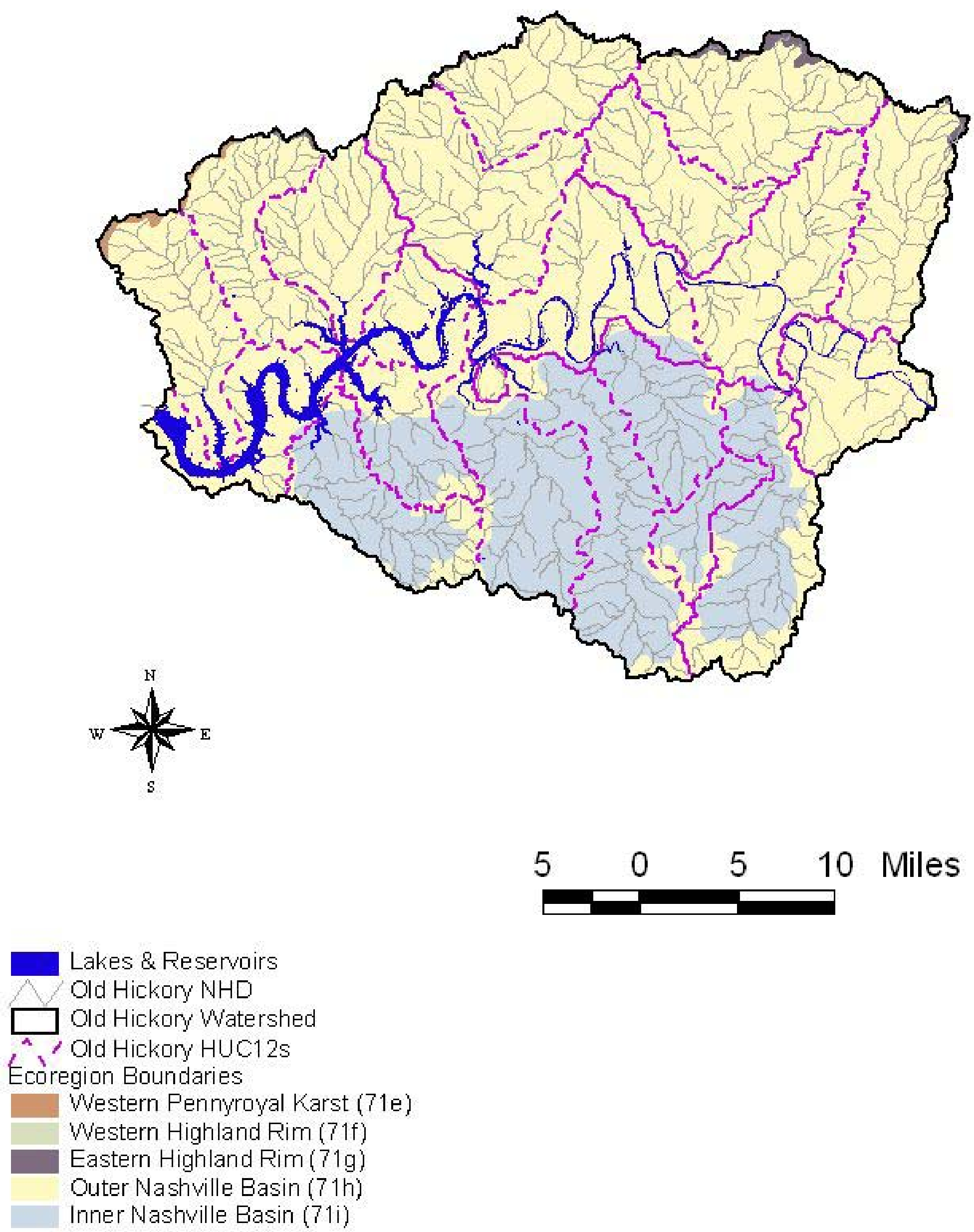

Figure 2. Level IV Ecoregions in the Old Hickory Lake Watershed.

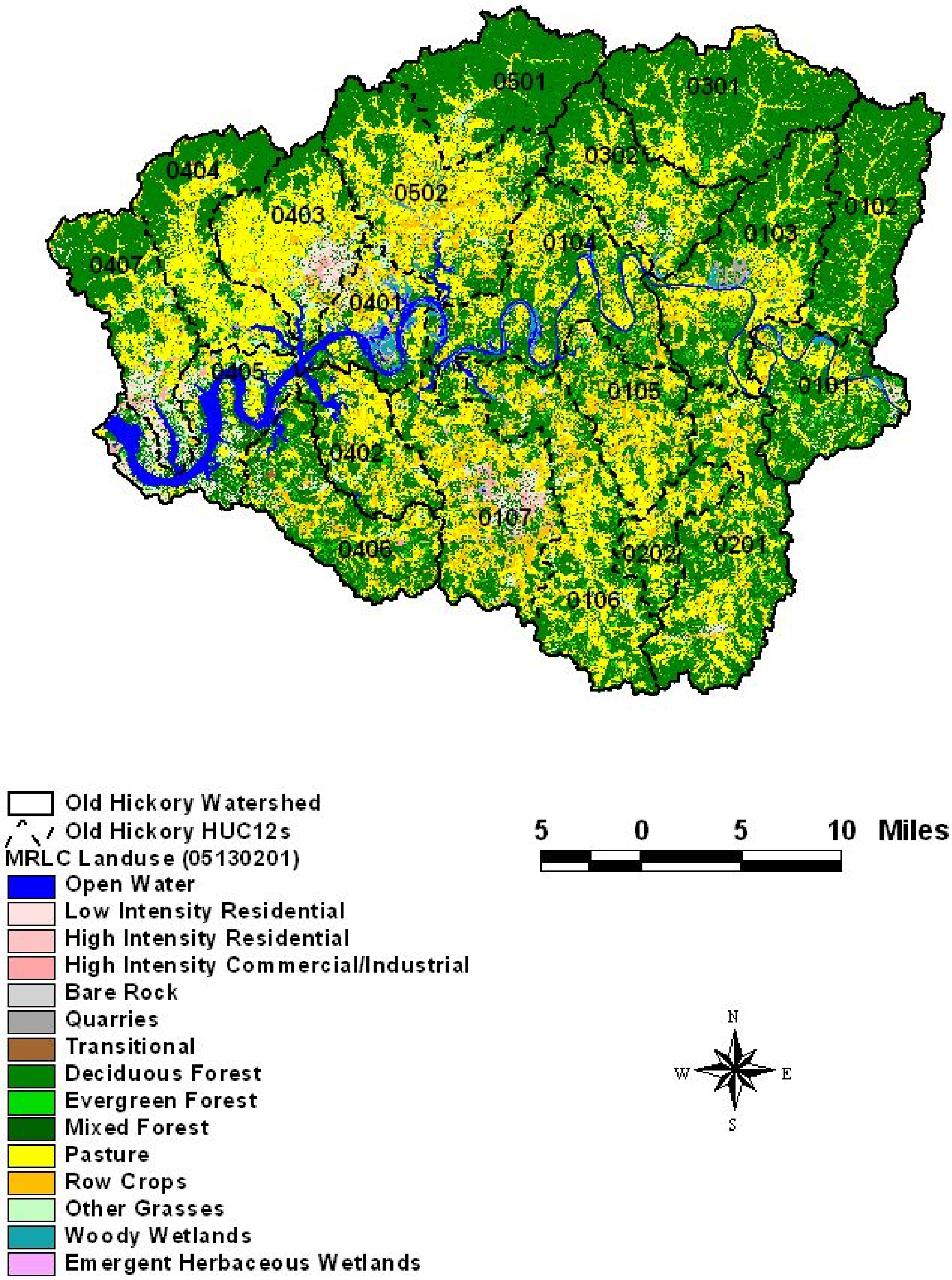

Figure 3. Land Use Characteristics of the Old Hickory Lake Watershed.

Table 1. MRLC Land Use Distribution – Old Hickory Lake Watershed

Land Use	Area	
	[acres]	[%]
Bare Rock/Sand Clay	2.9	0.0
Deciduous Forest	230,850.3	36.6
Emergent Herbaceous Wetlands	1,374.4	0.2
Evergreen Forest	27,561.1	4.4
High Intensity Commercial/Industrial/ Transportation	5,488.7	0.9
High Intensity Residential	1,787.8	0.3
Low Intensity Residential	14,073.4	2.2
Mixed Forest	84254.8	13.4
Open Water	19,788.5	3.1
Other Grasses (Urban/recreational)	9,140.9	1.4
Pasture/Hay	170,899.5	27.1
Quarries/Strip Mines/ Gravel Pits	1,093.1	0.2
Row Crops	59,507.5	9.4
Transitional	311.1	0.0
Woody Wetlands	4,678.8	0.7
Total	**630,813**	**100.0**

4.0 PROBLEM DEFINITION

The State of Tennessee's final 2006 303(d) list (TDEC, 2006), http://www.state.tn.us/environment/wpc/publications/303d2006.pdf , was approved by the U.S. Environmental Protection Agency (EPA), Region IV in October of 2006. This list identified portions of eight waterbodies in the Old Hickory Lake 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.

5.0 WATER QUALITY CRITERIA & TMDL TARGET

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

Portions of Spring Creek (within Old Hickory Wildlife Management Area and within Sellars Farm State Archaeological Area) have been classified as Tier II. As of February 8, 2008, none of the other impaired waterbodies in the Old Hickory Lake Watershed have been classified as high quality 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 487 CFU/100 ml have been selected as the appropriate numerical targets for TMDL development for impaired waterbodies classified as lakes, reservoirs, State Scenic Rivers, or Tier II or Tier III streams. 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 2006 303(d) List for E. coli Impaired Waterbodies – Old Hickory Lake Watershed

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	Cause (Pollutant)	Pollutant Source
TN05130201013 – 4000	SPRING CREEK	9.0	Escherichia coli	Pasture Grazing Livestock in Stream
TN05130201015 – 0200	JOHNSON BRANCH	7.6	Escherichia coli	Pasture Grazing
TN05130201021 – 0300	NEAL BRANCH	3.7	Phosphorus Loss of biological integrity due to siltation Escherichia coli	Livestock in Stream
TN05130201021 – 0400	BEECH LOG CREEK	8.5	Phosphorus Loss of biological integrity due to siltation Escherichia coli	Pasture Grazing
TN05130201021 – 2000	ROUND LICK CREEK	8.7	Nutrients Loss of biological integrity due to siltation Low dissolved oxygen Other habitat alterations Escherichia coli	Minor Municipal Point Source Pasture Grazing
TN05130201028 – 0100	LITTE GOOSE CREEK	12.7	Other Habitat Alteration Escherichia coli	Hydromodification Undetermined Source
TN05130201028 – 0150	LITTE GOOSE CREEK	10.0	Escherichia coli	Pasture Grazing
TN05130201055 – 0200	SINKING CREEK	7.4	Nutrients Other Anthropogenic Substrate Alterations Escherichia coli	Collection System Failure Discharges from MS4 Area
TN05130201055 – 0250	SINKING CREEK	10.0	Alteration in stream-side or littoral vegetative cover Other Anthropogenic Substrate Alterations Escherichia coli	Pasture Grazing Land Development Highway, Road, and Bridge Construction
TN05130201055 – 1000	BARTONS CREEK	5.0	Escherichia coli	Collection System Failure

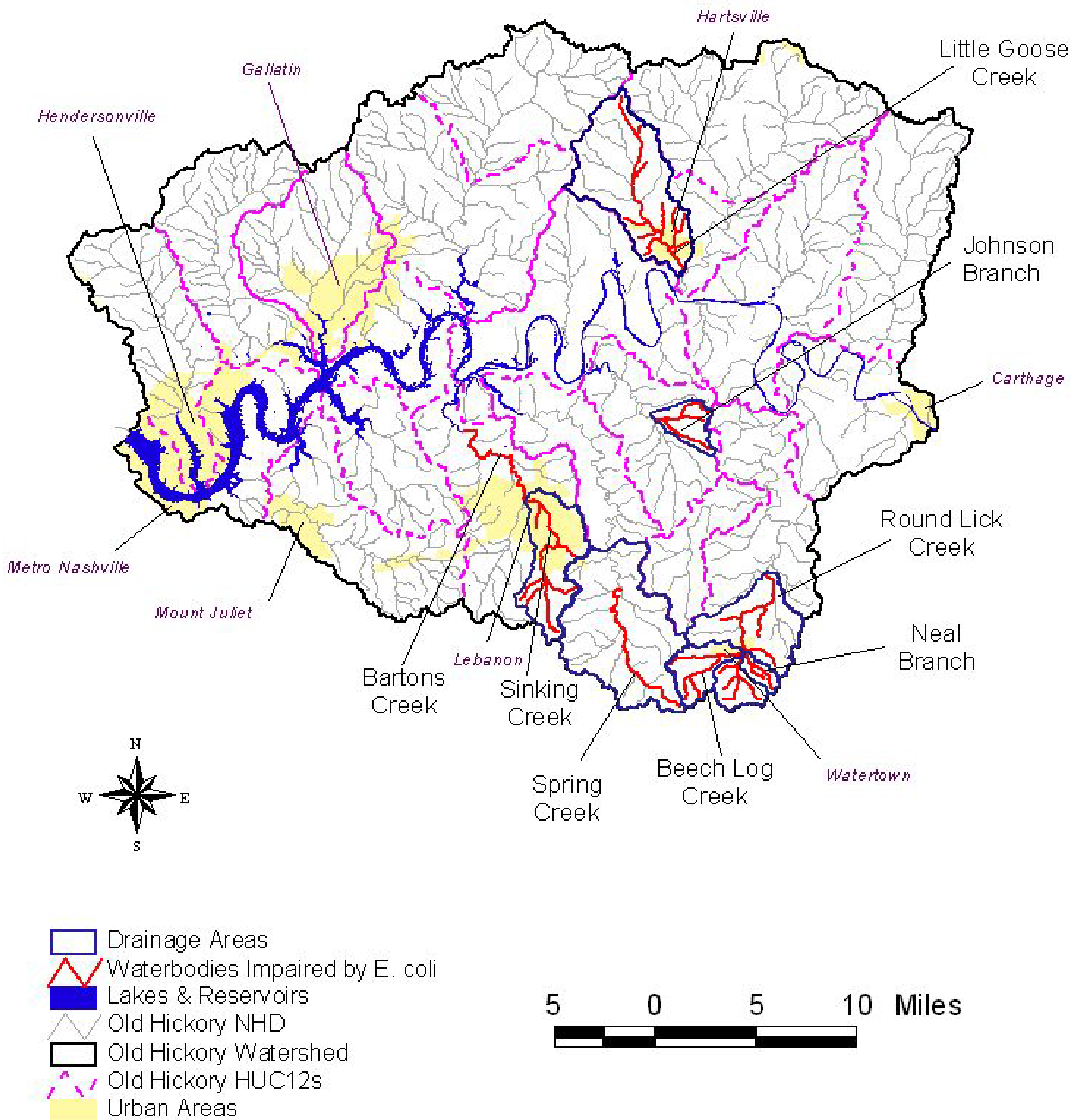

Figure 4. Waterbodies Impaired by E. Coli (as Documented on the Final 2006 303(d) List).

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 Old Hickory Lake Watershed. Monitoring stations located on lakes, reservoirs, State Scenic Rivers, or Tier II or Tier III waterbodies have been italicized:

- HUC-12 05130201_0105:
  - JOHNS000.1WS – Johnson Branch, at Big Springs Rd.
  - JOHNS000.4WS – Johnson Branch, 1.4 mi u/s Big Springs Rd.
- HUC-12 05130201_0106:
  - SPRIN016.0WS – Spring Creek, at Spring Creek Rd.
  - *SPRIN019.2WS – Spring Creek, at Eastover Rd.*
  - SPRIN027.0WS – Spring Creek, u/s Chicken Rd.
- HUC-12 05130201_0107:
  - BARTO007.4WS – Bartons Creek, at Maple Hill Rd. (off Trice Rd.)
  - BARTO009.6WS – Bartons Creek, at Hartmann Dr.
  - BARTO011.5WS – Bartons Creek, at Hidden Acres off Hwy 70/26
  - BARTO015.3WS – Bartons Creek, at Franklin Rd.
  - BARTO017.6WS – Bartons Creek, at Old Shannon Rd.
  - SINKI000.9WS – Sinking Creek, off Castle Heights N. @ J. Floud F.L.C.
  - SINKI004.0WS – Sinking Creek, at Highway 231 u/s Lebanon
- HUC-12 05130201_0201:
  - BEECH000.6WS/BLOG000.6WS – Beech Log Creek, at Old Statesville Rd. (Hwy 70)
  - NEAL000.1WS – Neal Branch, at Neal Rd.
  - RLICK017.1WS – Round Lick Creek, 200 yds u/s Wherley Rd.
  - RLICK018.7WS – Round Lick Creek, d/s Watertown STP at bridge
  - RLICK019.1WS – Round Lick Creek, 100 yds d/s Watertown STP, off Commerce Rd.
  - RLICK019.2WS/RLICK019.4WS – Round Lick Creek, 150 ft u/s Watertown STP
  - RLICK019.4WS – Round Lick Creek, approx. 150 ft u/s Watertown STP
  - RLICK020.2WS – Round Lick Creek, u/s of Hwy 267
- HUC-12-05130201_0302:
  - LGOOS004.7TR – Little Goose Creek, at E. Main Street, at ball fields
  - LGOOS007.5TR – Little Goose Creek, at Hwy 260

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 487 CFU/100 mL (lakes, reservoirs, State Scenic Rivers, or Tier II or Tier III waterbodies) and 941 CFU/100 mL (all other waterbodies) maximum E. coli standard at many 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
BARTO009.6WS	2000 – 2005	18	26	354	1,400	2
BARTO017.6WS	2000 – 2001	5	22	567	>2,400	1
BEECH000.6WS	2004 – 2005	9	80	476	>2,400	1
JOHNS000.1WS	2004 – 2004	11	93	524	1,600	2
JOHNS000.4WS	2000 – 2001	4	140	813	2,000	1
LGOOS004.7TR	2004 – 2005	11	96	661	2,400	2
LGOOS007.5TR	2004 – 2005	11	50	513	2,400	2
NEAL000.1WS	2001 – 2005	15	410	1,357	>2,400	8
RLICK018.7WS	2000 – 2005	16	36	721	>2,400	4
SINKI000.9WS	2004 – 2005	11	84	613	2,400	2
SINKI004.0WS	2000 – 2001	3	>2,400	2,400	>2,400	3
SPRIN019.2WS	*2004 – 2005*	*10*	*16*	*331*	*1,600*	*1*
SPRIN027.0WS	2000 – 2001	5	530	1,132	>2,400	3

** Maximum water quality target is 487 CFU/100 mL for lakes, reservoirs, State Scenic Rivers, or Tier II or Tier III 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 >2400. In addition, at six of these sites, the maximum E. coli sample value is >2400. 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) 2400. 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.

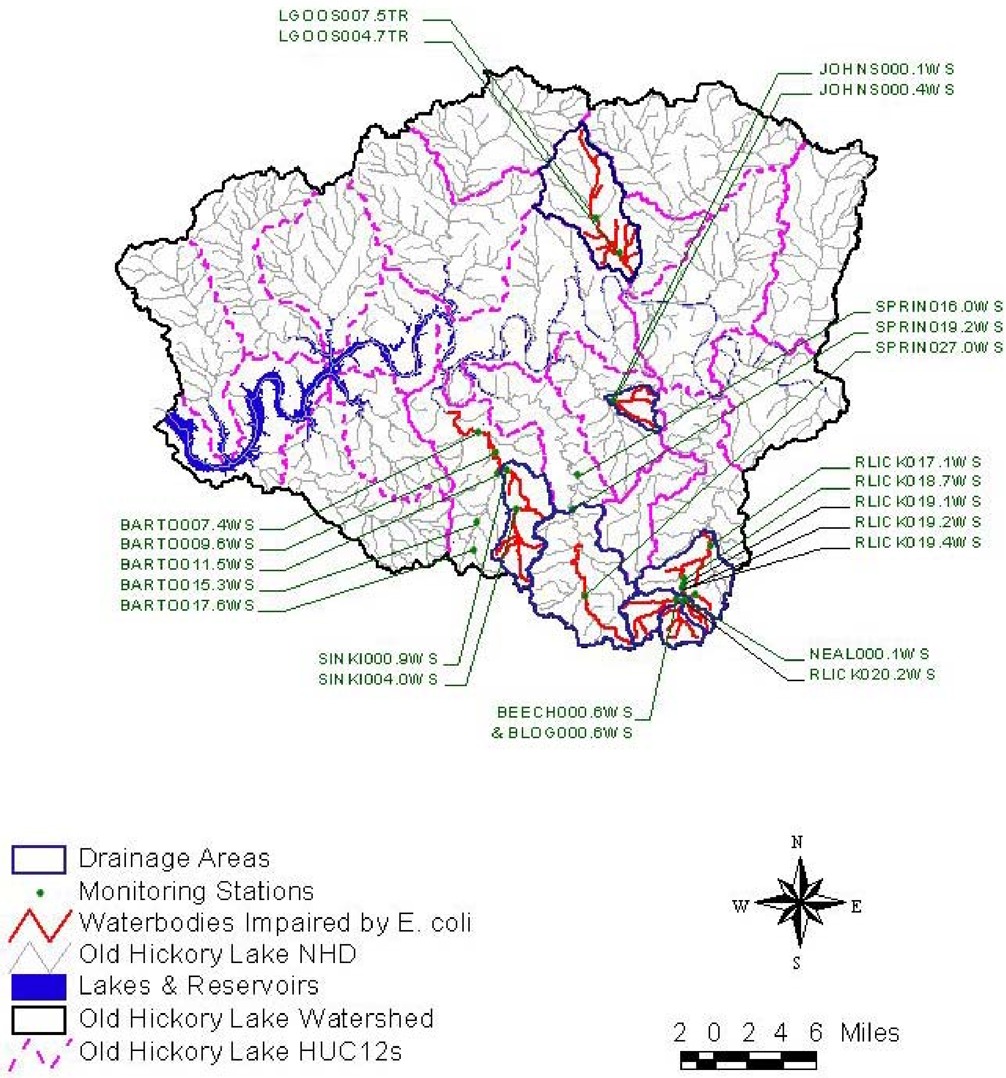

Figure 5. Water Quality Monitoring Stations in the Old Hickory Lake Watershed

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 WWTFs in the Old Hickory Lake Watershed that have NPDES permits authorizing the discharge of treated sanitary wastewater. Two of these facilities are located in an impaired subwatershed or drainage area (see Table 4 & Figure 6). 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 in Impaired Subwatersheds or Drainage Areas

NPDES Permit No.	Facility	Design Flow [MGD]	Receiving Stream
TN0025488	Watertown STP	0.27	Round Lick Creek at Mile 19.2
TN0028754	Lebanon STP	7.5	Old Hickory Lake at Mile 252.2

All treatment processes were in operation at the Watertown STP and the effluent was clear at the time of a Compliance Evaluation Inspection conducted in February 2000. However, insufficient documentation of sampling test results and standard instrument calibration was noted.

According to a Pretreatment Audit Inspection conducted at the Watertown STP in February 2005, there were numerous concerns regarding one of the industrial permittees, Technical Plating & Rubber (TPR). At the time of the inspection, a copy of the current permit application for the industrial permittee could not be located and several discharge violations had occurred for the permittee. It was also noted that the Watertown STP has a history of late submittals of Pretreatment Semi-Annual Reports (SARs).

The Lebanon STP serves the Lebanon municipality and discharges to Old Hickory Lake at mile 252.2. The sanitary sewer collection system has documented long-term wet-weather overflow problems and has historically been a significant contributor to E. coli impairment in the Bartons Creek watershed. The Lebanon STP is operating under Commissioner's Order 04-0146 for chronic violations of NPDES permit limits from May 2002 thru May 2004 (suspended solids, settleable solids, fecal, chlorine, CBOD, DO, Whole Effluent Toxicity, bypasses, and 160 collection system overflows). The Order mandates elimination of overflows by June 30, 2010. Lebanon has been pursuing significant infiltration and inflow reduction programs. The City also plans to begin a construction program at the STP in spring 2008 that will provide additional peak flow capacity. These efforts are intended to result in compliance with the Order.

7.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

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

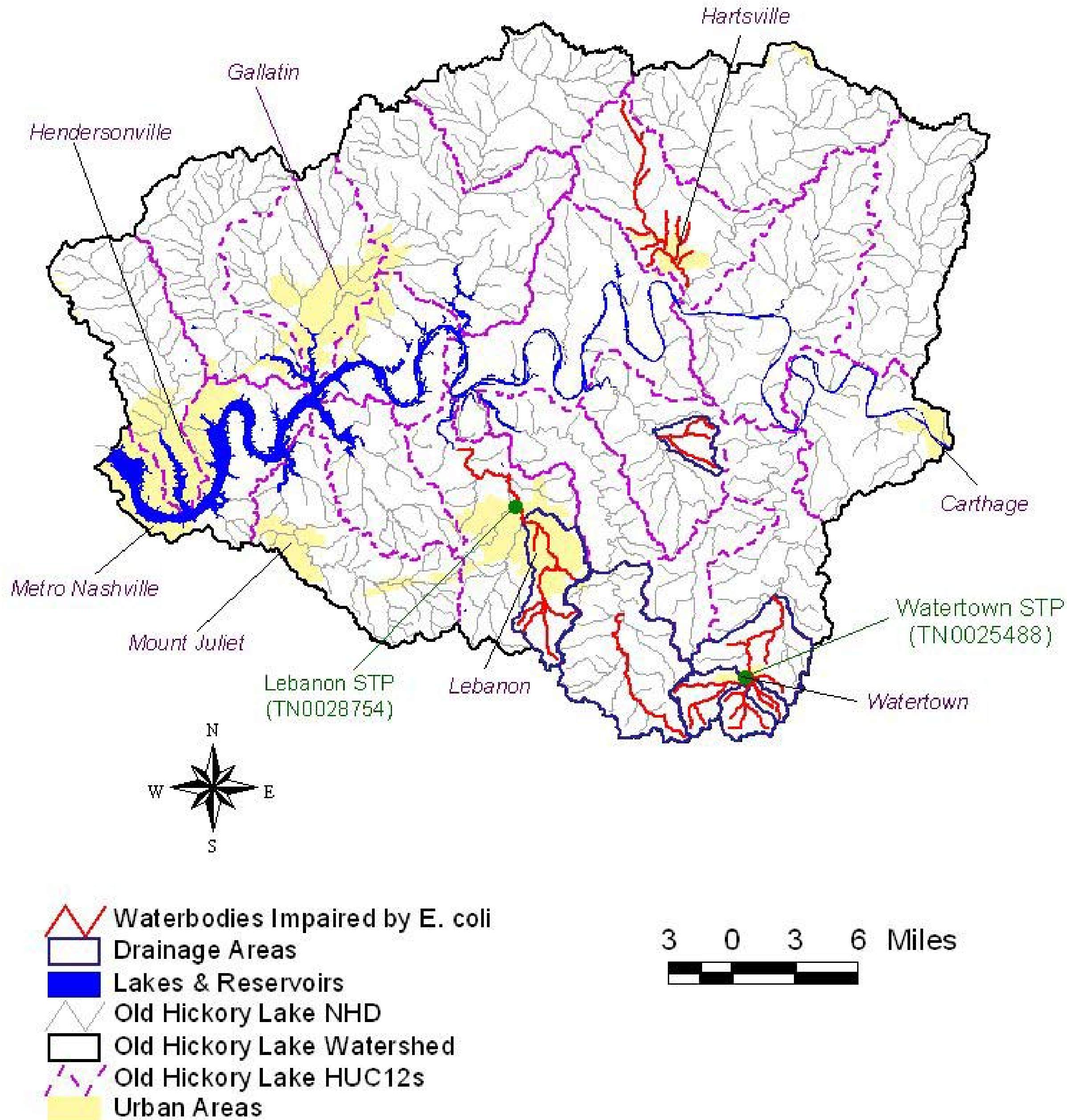

Figure 6. NPDES Regulated Point Sources in and near Impaired Subwatersheds and Drainage Areas of the Old Hickory Lake Watershed.

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). Gallatin, Hendersonville, Lebanon, Mount Juliet, Sumner County, and Wilson County 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. TDOT's individual MS4 permit may be obtained from the Tennessee Department of Environment and Conservation (TDEC) website: http://state.tn.us/environment/wpc/stormh2o/TNS077585.pdf .

For information regarding storm water permitting in Tennessee, see the TDEC website:

http://www.state.tn.us/environment/wpc/stormh2o/.

7.1.3 NPDES Concentrated Animal Feeding Operations (CAFOs)

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

As of November 26, 2007, there are no Class I CAFOs with individual permits and no Class II CAFOs with coverage under the general NPDES permit located in the Old Hickory Lake Watershed. There is one Class II CAFO with an application pending. Crooked Oaks Farms (TNA000150) is located near Goose Creek. This facility is not located in an impaired subwatershed or drainage area.

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. Many of the waterbodies identified on the Final 2006 303(d) list as impaired due to E. coli are attributed to nonpoint 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 2002 Census of Agriculture (http://www.nass.usda.gov/census/census02/volume1/tn/index2.htm). Livestock data for counties located within the Old Hickory Lake 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, 2004).

7.2.3 Failing Septic Systems

Some coliform loading in the Old Hickory Lake 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 Old Hickory Lake Watershed utilizing septic systems were compiled using the WCS and are summarized in Table 6. WCS is an Arcview geographic information system (GIS) based program developed by USEPA Region IV to facilitate watershed characterization and TMDL development. In middle and eastern Tennessee, it is estimated that there are approximately 2.37 people per household on septic systems, some of which can be reasonably assumed to be failing. As with livestock in streams, discharges of raw sewage provide a concentrated source of coliform bacteria directly to waterbodies.

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 Old Hickory Lake Watershed ranges from 0.1% to 19.3%. Land use for the Old Hickory Lake impaired drainage areas is summarized in Figures 7 through 10 and tabulated in Appendix A.

Table 5 Livestock Distribution in the Old Hickory Lake Watershed

County	Livestock Population (2002 Census of Agriculture)						
	Beef Cow	Milk Cow	Poultry		Hogs	Sheep	Horse
			Layers	Broilers			
Macon	D	D	978	D	3,738	58	2,104
Smith	16,756	520	975	105	D	540	1,687
Sumner	22,246	884	1,451	336	592	537	3,590
Trousdale	5,807	64	119	D	27	167	468
Wilson	29,077	873	1,873	103	2,194	762	4,498

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

Table 6 Estimated Population on Septic Systems in the Old Hickory Lake Watershed

County	Total Population (2000 Census)	Population on Septic Systems
Macon	20,386	13,012
Smith	17,712	10,878
Sumner	130,449	55,440
Trousdale	7,259	3.861
Wilson	88,809	442

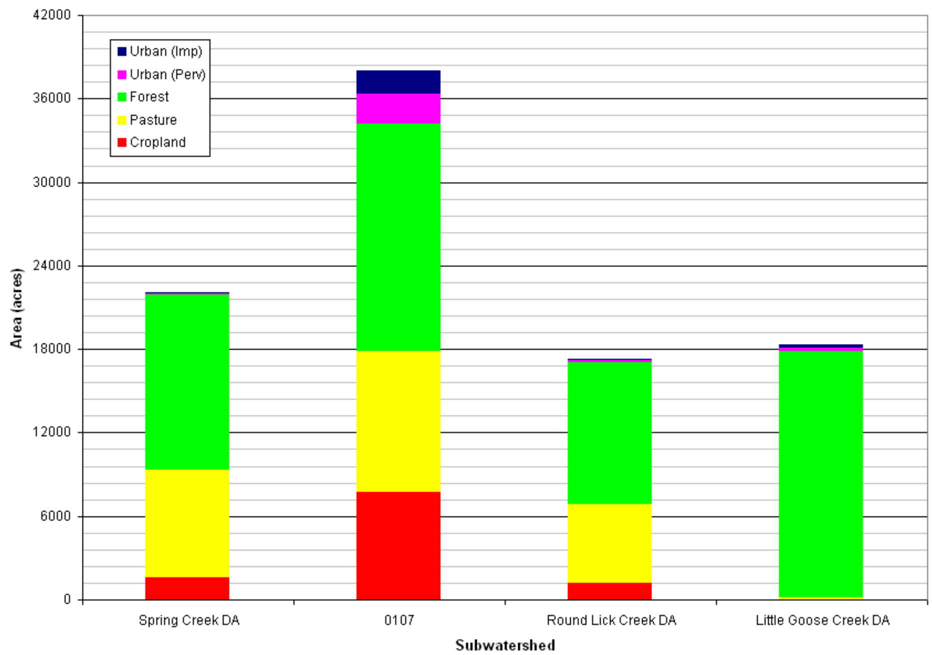

Figure 7. Land Use Area of Old Hickory Lake E. coli-Impaired Subwatersheds – Drainage Areas Greater Than 10,000 Acres

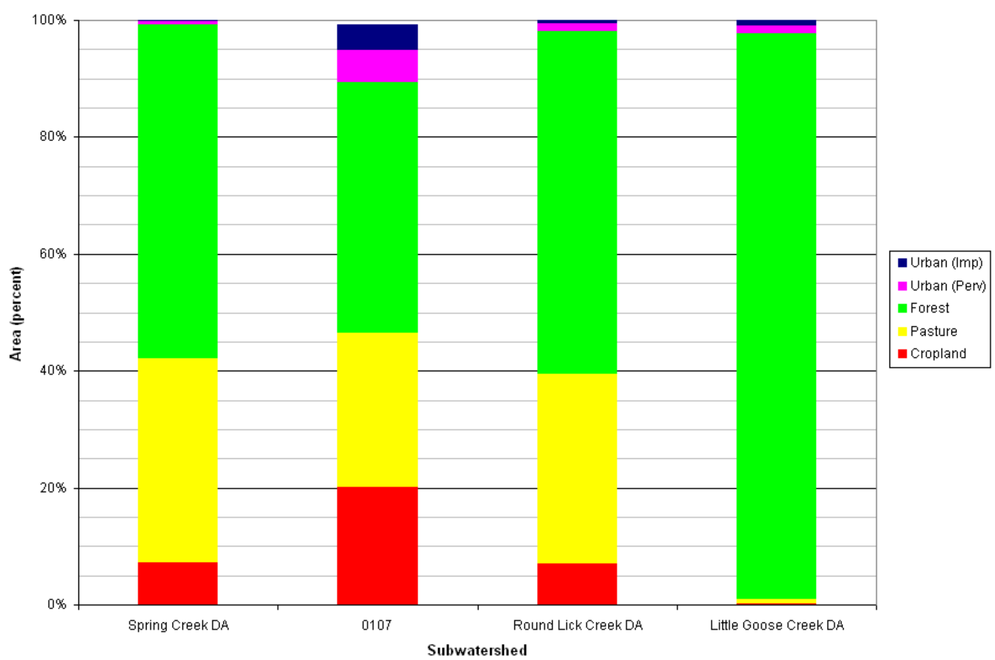

Figure 8. Land Use Percent of the Old Hickory Lake E. coli-Impaired Subwatersheds – Drainage Areas Greater Than 10,000 Acres

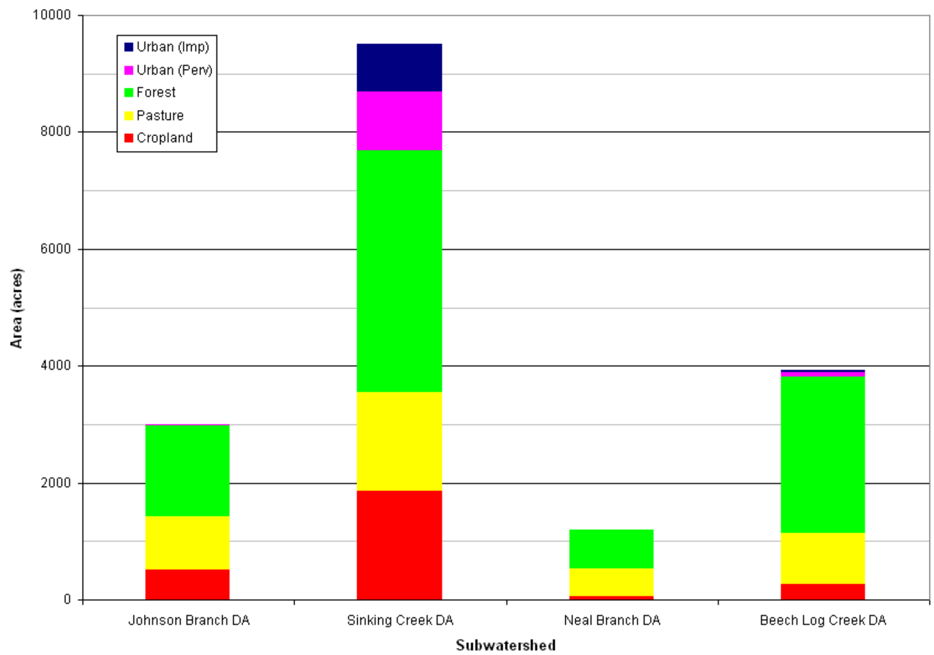

Figure 9. Land Use Area of Old Hickory Lake E. coli-Impaired Subwatersheds – Drainage Areas Less Than 10,000 Acres

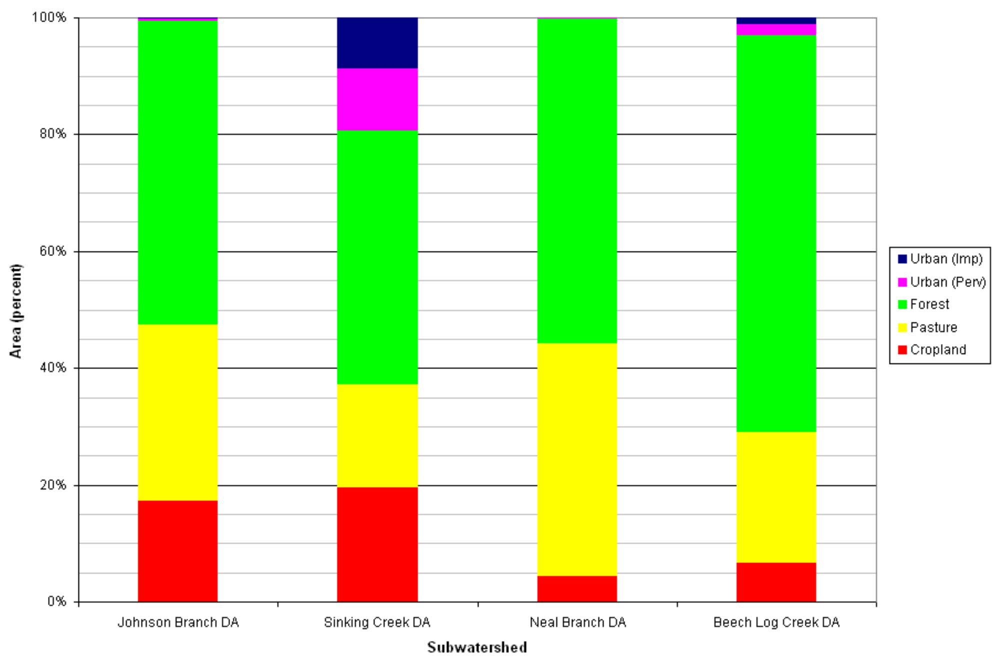

Figure 10. Land Use Percent of the Old Hickory Lake E. coli-Impaired Subwatersheds – Drainage Areas Less Than 10,000 Acres

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:

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

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) (http://www.epa.gov/epacfr40/chapt-I.info/chi-toc.htm) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measure.

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

8.1 Expression of TMDLs, WLAs, & LAs

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

8.2 Area Basis for TMDL Analysis

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

Table 7 Determination of Analysis Areas for TMDL Development

HUC-12 Subwatershed (05130201____)	Impaired Waterbody	Area
0105	Johnson Branch	DA
0106	Spring Creek	DA
0107	Sinking Creek	HUC-12
0201	Beech Log Creek Neal Branch Round Lick Creek	DA
0302	Little Goose Creek	DA

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

8.3 TMDL Analysis Methodology

TMDLs for the Old Hickory Lake 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 analysis.

The ten-year period from October 1, 1995 to September 30, 2005 was used to simulate flow. This 10-year period contained a range of hydrologic conditions that included both low and high streamflows. Critical conditions are accounted for in the load duration curve analyses by using the entire period of flow and water quality data available for the impaired waterbodies.

In 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 Old Hickory Lake watershed (see Section 9.3 and Table 8).

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. The water quality data were collected during all seasons.

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 E. coli TMDLs in the Old Hickory Lake 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 Tier II or Tier III 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 Old Hickory Lake 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 TMDLs, WLAs, & LAs for Impaired Subwatersheds and Drainage Areas in the Old Hickory Lake Watershed

HUC-12 Subwatershed (05130201__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs			LAs
					WWTFs [a]	Leaking Collection Systems	MS4s	
			[CFU/day]	[CFU/day]	[CFU/day]	[CFU/day]	[CFU/day/acre]	[CFU/day/acre]
0105	Johnson Branch	TN05130201015 – 0200	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	6.893×10^{6} * Q
0106	Spring Creek	TN05130201013 – 4000	1.20×10^{10} * Q	1.20×10^{9} * Q	NA	NA	NA	7.653×10^{5} * Q
0107	Bartons Creek	TN05130201055 – 1000	*[b]	*[b]	*[b]	*[b]	*[b]	*[b]
	Sinking Creek	TN05130201055 – 0200	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	2.175×10^{6} * Q	2.175×10^{6} * Q
	Sinking Creek	TN05130201055 – 0250	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	2.175×10^{6} * Q	2.175×10^{6} * Q
0201	Beech Log Creek	TN05130201021 – 0400	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	5.692×10^{6} * Q	5.692×10^{6} * Q
	Neal Branch	TN05130201021 – 0300	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.723×10^{7} * Q	1.723×10^{7} * Q
	Round Lick Creek	TN05130201021 – 2000	2.30×10^{10} * Q	2.30×10^{9} * Q	9.617×10^{9}	0	1.194×10^{6} * Q – 5.546×10^{5}	1.194×10^{6} * Q – 5.546×10^{5}
0302	Little Goose Creek	TN05130201028 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	1.131×10^{6} * Q
	Little Goose Creek	TN05130201028 – 0150	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	1.651×10^{6} * Q

Notes: NA = Not Applicable.

a. WLAs for WWTFs are expressed as E. coli loads (CFU/day). All current and future WWTFs must meet water quality standards at the point of discharge as specified in their NPDES permit; at no time shall concentration be greater than the appropriate E. coli standard (487 CFU/100 mL or 941 CFU/100 mL).

b. Detailed TMDL analyses were not performed on Bartons Creek. It is assumed that water quality standards for E. coli will be attained in this waterbody when the requirements of the Commissioner's Order against Lebanon STP are complete and Lebanon STP complies with the terms of its NPDES permit.

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 Old Hickory Lake 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 (LCD) 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.

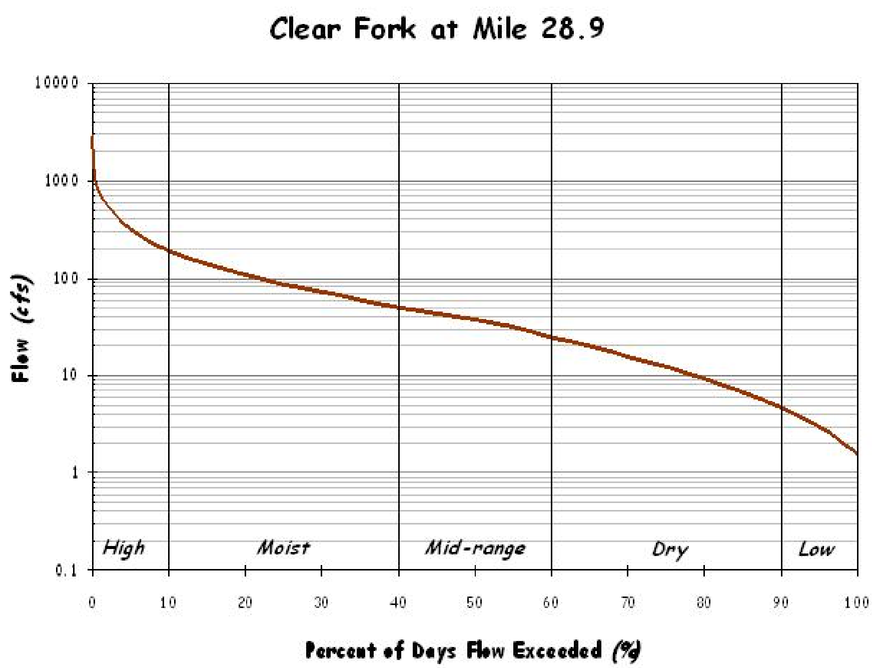

Figure 11. Five-Zone Flow Duration Curve for Clear Fork at RM 28.9

9.1.2 Existing Loads and Percent Load Reductions

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

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

9.1.3 Critical Conditions

The critical condition for each impaired waterbody is defined as the flow zone with the largest PLRG, excluding the “high flow” zone because these extremely high flows are not representative of recreational flow conditions, as described in Section 9.1.1. If the PLRG in this zone is greater than all the other zones, the zone with the second highest PLRG will be 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. 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 manatement systems. For further information, see: http://state.tn.us/environment/wpc/ppo/CAFO%20Final%20PDF%20Modified.pdf .

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 Cumberland River Coalition. The Cumberland River Compact is a non-profit group made up of businesses, individuals, community organizations, and agencies working in the Cumberland River watershed. Members of the Compact work with educators, landowners, contractors, marinas and other interested groups to coordinate informational education programs that encourage all of us to be better stewards of our water resources. The Compact works with local, state and federal agencies and officials to promote and strengthen cooperative working relationships and encourage the development of reliable, easy-to-understand data about water quality. Members of the Compact work with local communities to develop watershed forums where citizens come together to learn more about their watershed and participate in developing a shared vision for the future. The Compact also serves as a clearing-house of available public education programs to landowner assistance. Information regarding the accomplishments of the Cumberland River Compact is available at their website:

http://www.cumberlandrivercompact.org/.

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 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 Old Hickory Lake 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 Old Hickory Lake watershed E. coli-impaired subwatersheds during the TMDL evaluation period. The Tennessee Department of Agriculture (TDA) keeps a database of BMPs implemented in Tennessee. Those listed in the Old Hickory Lake 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.

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

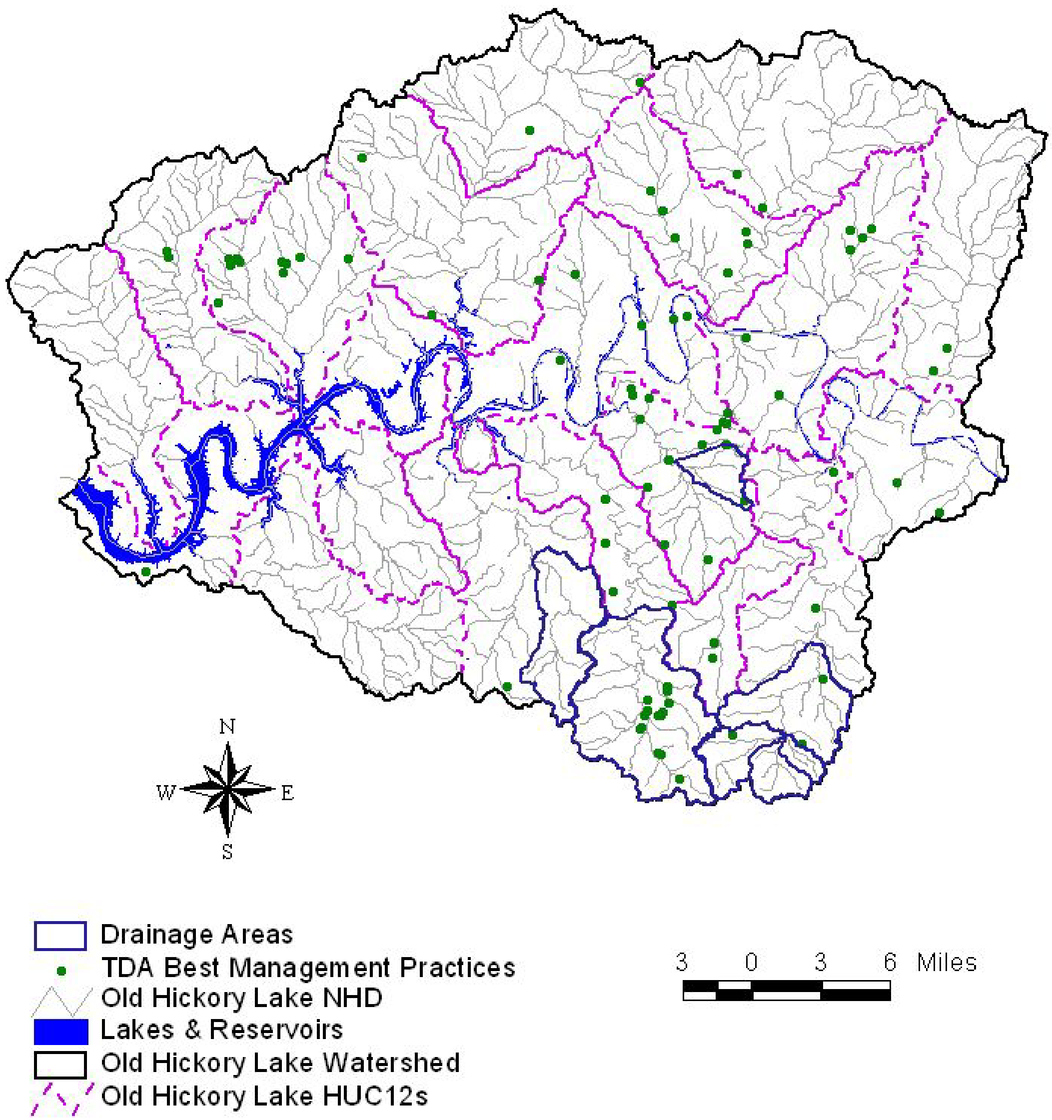

Figure 12. Tennessee Department of Agriculture Best Management Practices located in the Old Hickory Lake Watershed.

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.

Activities recommended for the Old Hickory Lake watershed:

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

Evaluate the effectiveness of implementation measures (see Sect. 9.6). Includes BMP performance analysis and monitoring by 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 Old Hickory Lake watershed suggest levels of impairment. Therefore, additional data are required for listing determination.

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

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

9.4.2 Source Identification

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

Bacterial Source Tracking is a collective term used for various 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 (McKay, 2005). The assays have been used in a study of fecal contamination and have proven useful in identification of areas where cattle represent a significant fecal input and in development of BMPs. It is expected that these types of assays could have broad applications in monitoring fecal impacts from Animal Feeding Operations, as well as from wildlife and human sources. Additional information can be found on the following UTK website: http://web.utk.edu/~hydro/Research?McKayAGU2004Abstract.pdf .

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 Old Hickory Lake watershed are summarized in Table E-12.

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

Waterbody ID	Source Area Type*			
	Urban	Agricultural	Mixed	Forested
Johnson Branch		✓		
Spring Creek		✓		
Sinking Creek			✓	
Beech Log Creek			✓	
Neal Branch		✓		
Round Lick Creek		✓		
Little Goose Creek			✓	

* 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.

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.

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 Old Hickory Lake watershed.

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

Management Practice	Duration Curve Zone (Flow Zone)				
	High	Moist	Mid-Range	Dry	Low
Bacteria source reduction					
Remove illicit discharges			L	M	H
Address pet & wildlife waste		H	M	M	L
Combined sewer overflow management					
Combined sewer separation		H	M	L	
CSO prevention practices		H	M	L	
Sanitary sewer system					
Infiltration/Inflow mitigation	H	M	L	L	
Inspection, maintenance, and repair		L	M	H	H
SSO repair/abatement	H	M	L		
Illegal cross-connections					
Septic system management					
Managing private systems		L	M	H	M
Replacing failed systems		L	M	H	M
Installing public sewers		L	M	H	M
Storm water infiltration/retention					
Infiltration basin		L	M	H	
Infiltration trench		L	M	H	
Infiltration/Biofilter swale		L	M	H	
Storm Water detention					
Created wetland		H	M	L	
Low impact development					
Disconnecting impervious areas		L	M	H	
Bioretention	L	M	H	H	
Pervious pavement		L	M	H	
Green Roof		L	M	H	
Buffers		H	H	H	

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
New/existing on-site wastewater treatment systems					
Permitting & installation programs		L	M	H	M
Operation & maintenance programs		L	M	H	M
Other					
Point source controls		L	M	H	H
Landfill control		L	M	H	
Riparian buffers		H	H	H	
Pet waste education & ordinances		M	H	H	L
Wildlife management		M	H	H	L
Inspection & maintenance of BMPs	L	M	H	H	L
Note: Potential relative importance of management practice effectiveness under given hydrologic condition (*H: High, M: Medium, L: Low*)					

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

Flow Condition	High	Moist	Mid-range	Dry	Low
% Time Flow Exceeded	0-10	10-40	40-60	60-90	90-100
Grazing Management					
Prescribed Grazing (528A)	**H**	**H**	**M**	**L**	
Pasture & Hayland Mgmt (510)	**H**	**H**	**M**	**L**	
Deferred Grazing (352)	**H**	**H**	**M**	**L**	
Planned Grazing System (556)	**H**	**H**	**M**	**L**	
Proper Grazing Use (528)	**H**	**H**	**M**	**L**	
Proper Woodland Grazing (530)	**H**	**H**	**M**	**L**	
Livestock Access Limitation					
Livestock Exclusion (472)			**M**	**H**	**H**
Fencing (382)			**M**	**H**	**H**
Stream Crossing			**M**	**H**	**H**

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
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**	
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**		

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
CAFO Management (cont'd)					
Mulching (484)	**H**	**H**	**M**		
Waste Utilization (633)	**H**	**H**	**M**		
Water & Sediment Control Basin (638)	**H**	**H**	**M**		
Filter Strip (393)	**H**	**H**	**M**		
Sediment Basin (350)	**H**	**H**	**M**		
Grassed Waterway (412)	**H**	**H**	**M**		
Diversion (362)	**H**	**H**	**M**		
Heavy Use Area Protection (561)					
Constructed Wetland (656)					
Dikes (356)	**H**	**H**	**M**		
Lined Waterway or Outlet (468)	**H**	**H**	**M**		
Roof Runoff Mgmt (558)	**H**	**H**	**M**		
Floodwater Diversion (400)	**H**	**H**	**M**		
Terrace (600)	**H**	**H**	**M**		
Potential for source area contribution under given hydrologic condition (H: High; M: Medium; L: Low)					

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

9.6 Evaluation of TMDL Implementation Effectiveness

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

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

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

In general, periods of record greater than 5 years (given adequate sampling frequency) can be evaluated for determination of relative change (trend analysis). For watershed 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 fecal coliform concentration data statistics for Oostanaula Creek at mile 28.4 (Hiwassee River watershed) for a historical (2002) TMDL analysis period versus a recent post-implementation period of sampling data (revised TMDL). The individual flow zone analyses are presented in a box and whisker plot of recent [2] versus historical [1] data. Figure 14 shows a load duration curve analysis (of recent versus historical data) of fecal coliform loading statistics for Oostanaula Creek. Lastly, Figure 15 shows best fit curve analyses of flow (percent time exceeded) versus fecal coliform loading relationships (regressions) plotted against the LDC of the single sample maximum water quality standard. Note that Figures 13-15 present the same data, from approved TMDLs (2 cycles), each clearly illustrating improving conditions between historical and recent periods.

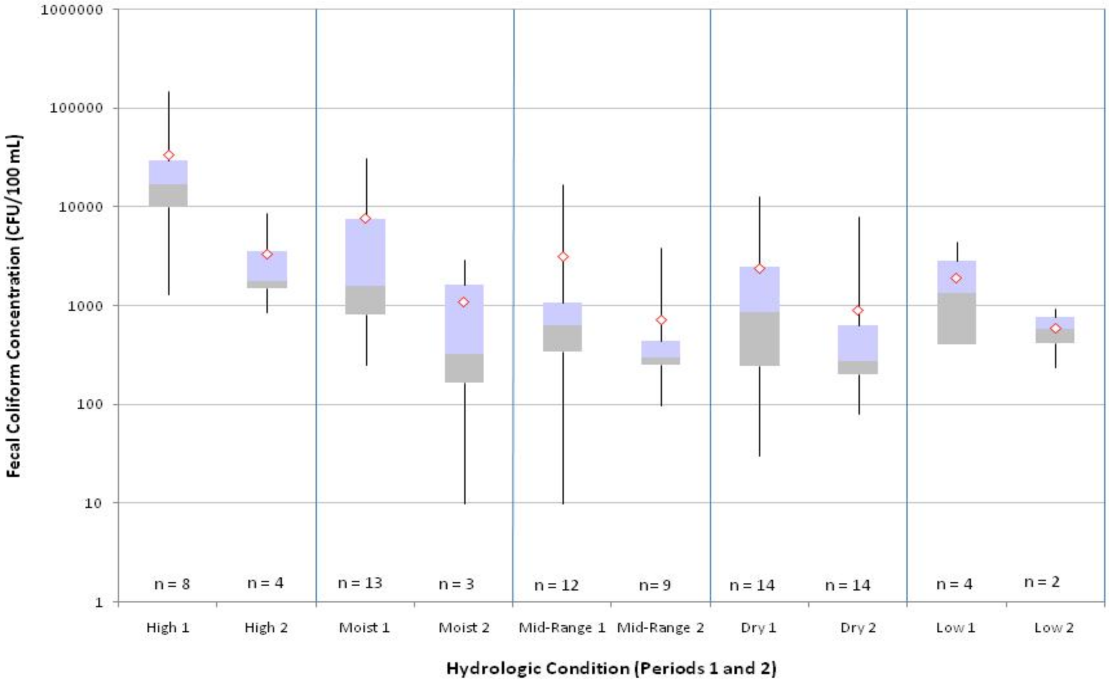

Figure 13. Oostanaula Creek TMDL implementation effectiveness (box and whisker plot).

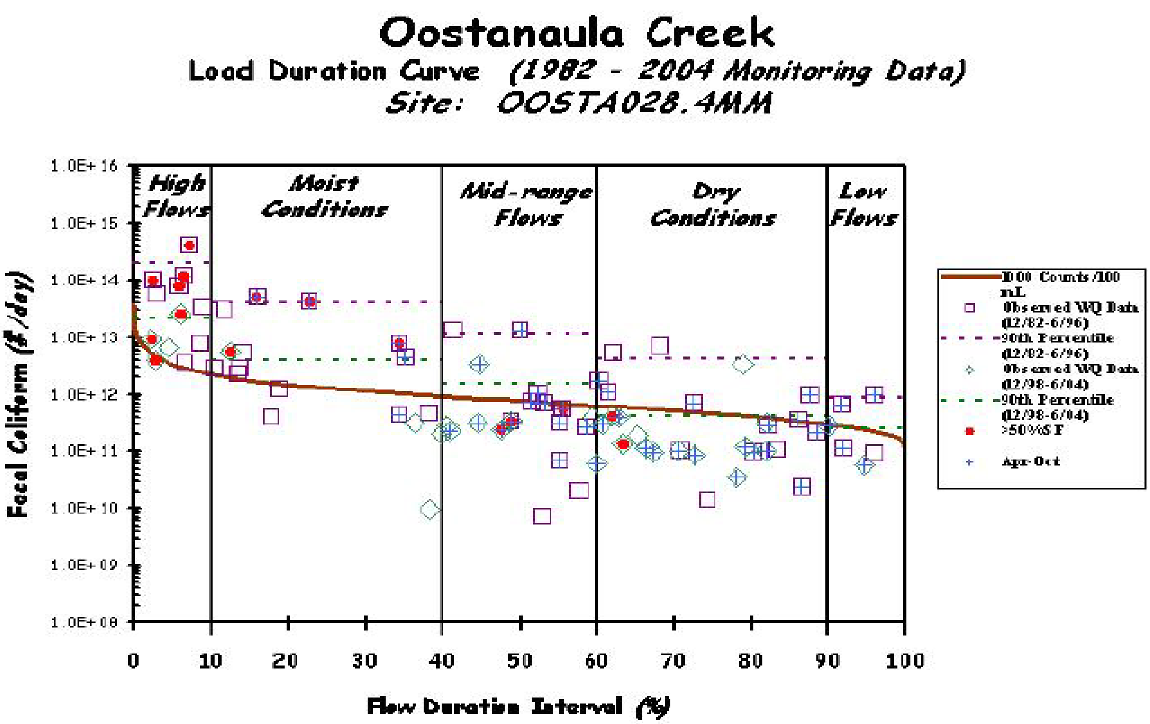

Figure 14. Oostanaula Creek TMDL implementation effectiveness (LDC analysis).

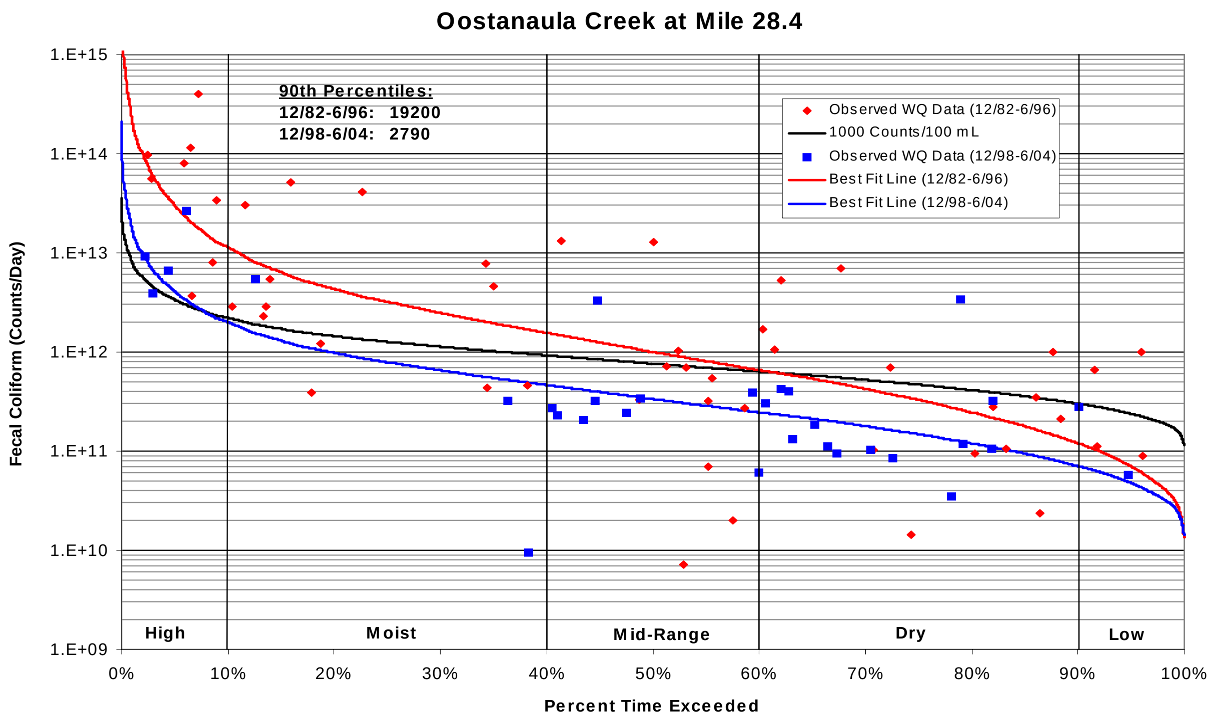

Figure 15. Oostanaula Creek TMDL implementation effectiveness (LDC regression analysis).

10.0 PUBLIC PARTICIPATION

In accordance with 40 CFR §130.7, the proposed pathogen TMDLs for the Old Hickory Lake Watershed was placed on Public Notice for a 35-day period and comments solicited. Steps that were taken in this regard include:

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 Old Hickory Lake 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:

   Watertown STP (TN0025488)

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 (TNS068047)
   City of Gallatin, Tennessee (TNS077534)
   City of Hendersonville, Tennessee (TNS075353)
   City of Lebanon, Tennessee (TNS075426)
   City of Mount Juliet, Tennessee (TNS075451)
   Sumner County, Tennessee (TNS075680)
   Wilson County, Tennessee (TNS075809)
   Tennessee Dept. of Transportation (TNS077585)

5) A letter was sent to water quality partners in the Old Hickory Lake 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:

Cumberland Coalition
Cumberland River Compact
Mid-Cumberland Watershed Committee
Natural Resources Conservation Service
Tennessee Valley Authority
United States Forest Service
Tennessee Department of Agriculture
Tennessee Wildlife Resources Agency
The Nature Conservancy

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 Old Hickory Lake Watershed

Table A-1. MRLC Land Use Distribution of Old Hickory Subwatersheds

Land Use	HUC-12 Subwatershed (05130201__) or Drainage Area					
	Johnson Branch DA		Spring Creek DA		0107	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Deciduous Forest	896.5	29.9	7,163.1	32.5	9,483.8	24.8
Emergent Herbaceous Wetlands	0.0	0.0	0.0	0.0	55.2	0.1
Evergreen Forest	173.9	5.8	1,385.1	6.3	1,218.3	3.2
High Intensity Commercial/ Industrial/Transp.	6.4	0.2	36.0	0.2	1,230.5	3.2
High Intensity Residential	0.0	0.0	0.2	0.0	596.0	1.6
Low Intensity Residential	8.7	0.3	140.3	0.6	1,980.4	5.2
Mixed Forest	493.9	16.4	3,798.5	17.2	4,533.8	11.8
Open Water	0.0	0.0	7.8	0.0	276.9	0.7
Other Grasses (Urban/recreation; e.g. parks)	0.0	0.0	202.4	0.9	831.8	2.2
Pasture/Hay	903.4	30.1	7,720.0	35.0	10,097.0	26.4
Quarries/Strip Mines/Gravel Pits	0.0	0.0	0.0	0.0	169.0	0.4
Row Crops	520.4	17.3	1,591.7	7.2	7,722.0	20.2
Transitional	0.0	0.0	16.5	0.1	1.1	0.0
Woody Wetlands	0.0	0.0	0.0	0.0	91.4	0.2
Total	3,003.2	100.0	22,061.6	100.0	38,287.2	100.0

Table A-1 (Cont.). MRLC Land Use Distribution of Old Hickory Subwatersheds

Land Use	HUC-12 Subwatershed (05130201__) or Drainage Area					
	Sinking Creek DA		Round Lick Creek DA		Beech Log Creek DA	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Deciduous Forest	2,461.7	25.9	5,732.5	33.1	1,675.5	42.6
Emergent Herbaceous Wetlands	0.0	0.0	0.0	0.0	0.0	0.0
Evergreen Forest	282.2	3.0	1119.1	6.5	235.3	6.0
High Intensity Commercial/ Industrial/Transp.	526.0	5.5	55.6	0.3	26.7	0.7
High Intensity Residential	414.3	4.4	45.4	0.3	13.3	0.3
Low Intensity Residential	893.4	9.4	215.1	1.2	81.4	2.1
Mixed Forest	1,093.3	11.5	3,143.8	18.1	652.1	16.6
Open Water	5.6	0.1	7.8	0.0	0.7	0.0
Other Grasses (Urban/recreation; e.g. parks)	291.6	3.1	163.0	0.9	110.3	2.8
Pasture/Hay	1,679.3	17.6	5,647.7	32.6	877.3	22.3
Quarries/Strip Mines/Gravel Pits	7.8	0.1	0.0	0.0	0.0	0.0
Row Crops	1,862.3	19.6	1,210.9	7.0	263.5	6.7
Transitional	1.1	0.0	0.0	0.0	0.0	0.0
Woody Wetlands	0.0	0.0	0.0	0.0	0.0	0.0
Total	9,518.5	100.0	17,340.9	100.0	3,936.2	100.0

Table A-1 (Cont.). MRLC Land Use Distribution of Old Hickory Subwatersheds

Land Use	HUC-12 Subwatershed (05130201__) or Drainage Area			
	Neal Branch DA		Little Goose Creek DA	
	[acres]	[%]	[acres]	[%]
Deciduous Forest	445.7	37.1	2,810.0	15.4
Emergent Herbaceous Wetlands	0.0	0.0	0.0	0.0
Evergreen Forest	40.3	3.4	5,569.9	30.4
High Intensity Commercial/ Industrial/Transp.	0.2	0.0	125.7	0.7
High Intensity Residential	0.0	0.0	40.0	0.2
Low Intensity Residential	0.9	0.1	261.3	1.4
Mixed Forest	184.1	15.3	1,230.5	6.7
Open Water	0.0	0.0	5.1	0.0
Other Grasses (Urban/recreation; e.g. parks)	0.0	0.0	4.7	0.0
Pasture/Hay	477.3	39.7	146.6	0.8
Quarries/Strip Mines/Gravel Pits	0.0	0.0	7,276.3	39.8
Row Crops	52.7	4.4	31.1	0.2
Transitional	0.0	0.0	798.0	4.4
Woody Wetlands	0.0	0.0	0.0	0.0
Total	1,201.2	100.0	18,299.2	100.0

APPENDIX B

Water Quality Monitoring Data

There are a number of water quality monitoring stations that provide data for waterbodies identified as impaired for pathogens in the Old Hickory Lake 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.

Table B-1. TDEC Water Quality Monitoring Data – Old Hickory Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
BARTO007.4WS	8/25/04	180
	9/7/04	56
	10/20/04	260
	11/16/04	100
	12/14/04	110
	1/5/05	330
	2/10/05	580
	3/8/05	230
	4/11/05	91
	5/18/05	80
	6/14/05	130
BARTO009.6WS	7/26/00	440
	8/2/00	1300
	9/26/00	410
	10/24/00	26
	11/29/00	370
	12/6/00	120
	1/22/01	82
	8/25/04	61
	9/7/04	160
	10/20/04	440
	11/16/04	120
	12/14/04	170
	1/5/05	390
	2/10/05	110
	3/8/05	580
	4/11/05	130
	5/18/05	1400
	6/14/05	62

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Old Hickory Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
BARTO011.5WS	8/25/04	920
	9/7/04	35
	10/20/04	610
	11/16/04	99
	12/14/04	86
	1/5/05	120
	2/10/05	110
	3/8/05	230
	4/11/05	160
	5/18/05	920
	6/14/05	87
BARTO015.3WS	8/25/04	47
	9/7/04	51
	10/20/04	920
	11/16/04	650
	12/14/04	150
	1/5/05	370
	2/10/05	120
	3/8/05	460
	4/11/05	170
	5/18/05	78
	6/14/05	52
BARTO017.6WS	1/4/00	>2400
	5/1/00	220
	7/20/00	64
	10/31/00	22
	6/12/01	130
BEECH000.6WS	9/8/04	190
	10/25/04	490
	11/15/04	190
	12/15/04	120
	1/13/05	>2400
	2/24/05	370
	3/30/05	290
	4/6/05	80
	5/25/05	150

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Old Hickory Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
BLOG000.6WS	8/2/00	650
	9/26/00	330
	10/24/00	370
	11/20/00	75
	12/6/00	520
	1/22/01	110
JOHNS000.1WS	8/25/04	460
	9/8/04	1600
	10/25/04	520
	11/15/04	390
	12/15/04	93
	1/13/05	410
	2/24/05	130
	3/30/05	460
	4/6/05	610
	5/25/05	1000
	6/22/05	93
JOHNS000.4WS	1/3/00	820
	4/19/00	140
	7/19/00	2000
	5/31/01	290
LGOOS004.7TR	8/23/04	820
	9/21/04	650
	10/19/04	2400
	11/29/04	490
	12/16/04	160
	1/10/05	920
	2/15/05	260
	3/14/05	130
	4/27/05	1200
	5/24/05	140
	6/21/05	96
LGOOS007.5TR	8/23/04	50
	9/21/04	140
	10/19/04	2400
	11/29/04	1000
	12/16/04	180

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Old Hickory Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
LGOOS007.5TR (cont'd)	1/10/05	390
	2/15/05	86
	3/14/05	190
	4/27/05	580
	5/24/05	260
	6/21/05	370
NEAL000.1WS	8/2/00	870
	9/26/00	650
	11/29/00	2400
	12/6/00	1100
	1/22/01	>2400
	9/8/04	550
	10/25/04	>2400
	11/15/04	2000
	12/15/04	410
	1/13/05	>2400
	2/24/05	490
	3/30/05	610
	4/6/05	1200
	5/25/05	870
	6/22/05	2000
RLICK017.1WS	11/17/99	34
RLICK018.7WS	7/26/00	600
	8/2/00	580
	9/26/00	1600
	10/24/00	36
	11/29/00	490
	12/6/00	130
	1/22/01	2000
	9/8/04	1200
	10/25/04	520
	12/15/04	160
	1/13/05	>2400
	2/24/05	150

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Old Hickory Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
RLICK018.7WS (cont'd)	3/30/05	550
	4/6/05	86
	5/25/05	920
	6/22/05	120
RLICK019.1WS	11/17/99	1
RLICK019.2WS	11/17/99	1
RLICK019.4WS	7/26/00	110
	8/2/00	58
	9/26/00	250
	10/24/00	24
	11/29/00	100
	12/6/00	330
	1/22/01	180
RLICK019.8WS	11/17/99	2
RLICK020.2WS	11/29/00	70
	1/22/01	160
SINKI000.9WS	8/25/04	520
	9/7/04	580
	10/20/04	2400
	11/16/04	100
	12/14/04	91
	1/5/05	550
	2/10/05	84
	3/8/05	1100
	4/11/05	250
	5/18/05	200
	6/14/05	870
SINKI004.0WS	1/4/00	>2400
	4/18/00	>2400
	5/31/01	>2400
SPRIN016.0WS	1/3/00	41
	4/19/00	240
	7/19/00	190
	11/1/00	190
	5/31/01	580

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Old Hickory Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
SPRIN019.2WS	9/8/04	1600
	10/25/04	130
	11/15/04	150
	12/15/04	140
	1/13/05	460
	2/24/05	180
	3/30/05	440
	4/6/05	140
	5/25/05	16
	6/22/05	49
SPRIN027.0WS	1/4/00	>2400
	4/18/00	530
	7/18/00	770
	11/2/00	960
	5/30/01	1000

APPENDIX C

Load Duration Curve Development
and
Determination of Daily Loading

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

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

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.

C.1 Development of TMDLs

E. coli TMDLs, WLAs, and LAs were developed for impaired subwatersheds and drainage areas in the Old Hickory Lake 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 Loading Simulation Program C++ (LSPC).

Flow duration curves for impaired waterbodies in the Old Hickory Lake Watershed were derived from LSPC hydrologic simulations based on parameters derived from calibrations at USGS Station No. 03430147 (see Appendix D for details of calibration). For example, a flow-duration curve for Neal Branch at RM 0.1 was constructed using simulated daily mean flow for the period from 10/1/95 through 9/30/05 (RM 0.1 corresponds to the location of monitoring station NEAL000.1WS). 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 Old Hickory Lake Watershed were developed from the flow duration curves developed in Section C.1.1, E. coli target concentrations, and available water quality monitoring data. LDCs and daily loading functions were developed using the following procedure (Neal Branch is shown as an example):

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

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

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

   TMDL = (2.30×10^{10}) x (Q) CFU/day

2. Daily loads were calculated for each of the water quality samples collected at monitoring station NEAL000.1WS (ref.: Table B-1) by multiplying the sample concentration by the daily mean flow for the sampling date and the required unit conversion factor. NEAL000.1WS was selected for LDC analysis because the sample were well distributed across the full range of flow conditions and there were 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 – 11/15/04 sampling event:
   Modelled Flow = 1.82 cfs
   Concentration = 2000 CFU/100 mL
   Daily Load = 8.88×10^{10} 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 and MOS

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

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

Expanding the terms:

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

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

- $[\sum \text{WLAs}]_{WWTF}$ 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.
- $[\sum \text{WLAs}]_{CAFO}$ 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:
    - All process wastewater resulting from the operation of the CAFO (such as wash water, parlor water, watering system overflow, etc.); plus,
    - All runoff from a 25-year, 24-hour rainfall event for the existing CAFO or new dairy or cattle CAFOs; or all runoff from a 100-year, 24-hour rainfall event for a new swine or poultry CAFO.

  Therefore, a WLA of zero has been assigned to this class of facilities.
- $[\sum \text{WLAs}]_{MS4}$ 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:

- $[\sum \text{LAs}]_{DS}$ 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, Tier II, and Tier III):

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

Target – MOS = 438 CFU/100 ml

Instantaneous Maximum (other):

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

Target – MOS = 847 CFU/100 ml

30-Day Geometric Mean: Target – MOS = (126 CFU/100 ml) – 0.1(126 CFU/100 ml)

Target – MOS = 113 CFU/100 ml

C.2.1 Daily Load Calculation

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

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

where: DA = waterbody drainage area (acres)

Using Neal Branch as an example:

$$TMDL_{Neal\ Branch} = (941\ CFU/100\ mL) \times (Q) \times (UCF)$$

$$= 2.30 \times 10^{10} \times Q$$

$MOS_{Neal\ Branch}$ = TMDL x 0.10 = $2.30x10^9$ x Q

MOS = ($2.30x10^9$) x (Q) CFU/day

$LA_{Neal\ Branch}$ = {TMDL – MOS – WLA[WWTFs]} / DA

= {($2.30x10^{10}$ x Q) – ($2.30x10^9$ x Q) – (0)} / ($1.20x10^4$)

LA = [$1.723x10^7$ x Q]

Since the Neal Branch drainage area does not include a WWTF, Round Lick Creek is also presented as an example that does include a WWTF:

$WLA[MS4]_{Round\ Lick\ Creek}$ = $LA_{Round\ Lick\ Creek}$

= {TMDL – MOS – WLA[WWTFs]} / DA

= {($2.30x10^{10}$ x Q) – ($2.30x10^9$ x Q) – ($9.617x10^9$)} / ($1.73x10^4$)

WLA[MS4] = LA = [$1.194x10^6$ x Q] – [$5.546x10^5$]

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

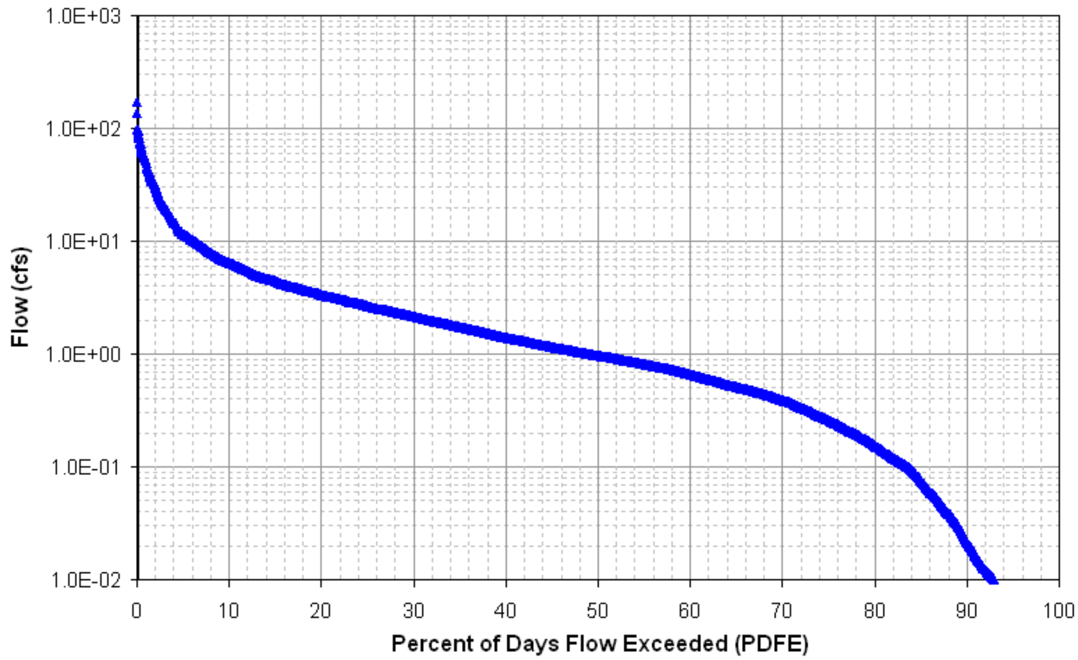

Figure C-1. Flow Duration Curve for Neal Branch at Mile 0.1

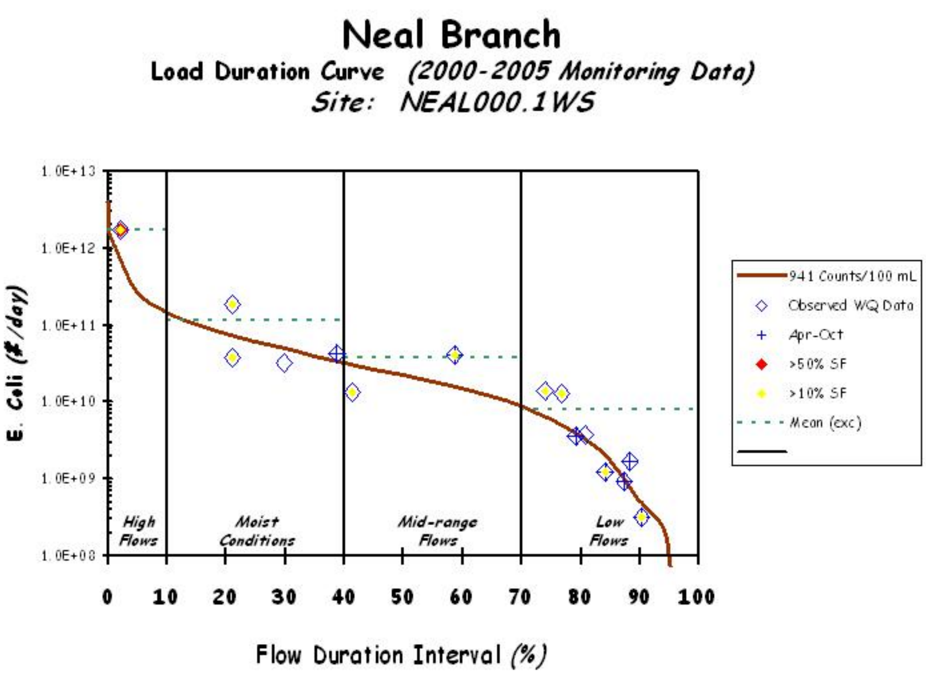

Figure C-2. E. Coli Load Duration Curve for Neal Branch at Mile 0.1

Table C-1 Summary of TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Old Hickory Lake Watershed (HUC 05130201)

HUC-12 Subwatershed (05130201__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs			LAs
					WWTFs [a]	Collection Systems	MS4s	
			[CFU/day]	[CFU/day]	[CFU/day]	[CFU/day]	[CFU/day/acre]	[CFU/day/acre]
0105	Johnson Branch	TN05130201015 – 0200	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	6.893×10^{6} * Q
0106	Spring Creek	TN05130201013 – 4000	1.20×10^{10} * Q	1.20×10^{9} * Q	NA	NA	NA	7.653×10^{5} * Q
0107	Bartons Creek	TN05130201055 – 1000	*[b]	*[b]	*[b]	*[b]	*[b]	*[b]
	Sinking Creek	TN05130201055 – 0200	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	2.175×10^{6} * Q	2.175×10^{6} * Q
	Sinking Creek	TN05130201055 – 0250	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	2.175×10^{6} * Q	2.175×10^{6} * Q
0201	Beech Log Creek	TN05130201021 – 0400	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	5.692×10^{6} * Q	5.692×10^{6} * Q
	Neal Branch	TN05130201021 – 0300	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.723×10^{7} * Q	1.723×10^{7} * Q
	Round Lick Creek	TN05130201021 – 2000	2.30×10^{10} * Q	2.30×10^{9} * Q	9.617×10^{9}	0	1.194×10^{6} * Q – 5.546×10^{5}	1.194×10^{6} * Q – 5.546×10^{5}
0302	Little Goose Creek	TN05130201028 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	1.131×10^{6} * Q
	Little Goose Creek	TN05130201028 – 0150	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	NA	NA	1.651×10^{6} * Q

Notes: NA = Not Applicable.

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. Detailed TMDL analyses were not performed on Bartons Creek. It is assumed that water quality standards for E. coli will be attained in this waterbody when the requirements of the Commissioner's Order against Lebanon STP are complete and Lebanon STP complies with the terms of its NPDES permit.

APPENDIX D

Hydrodynamic Modeling Methodology

HYDRODYNAMIC MODELING METHODOLOGY

D.1 Model Selection

The Loading Simulation Program C++ (LSPC) was selected for flow simulation of pathogen-impaired waters in the subwatersheds of the Old Hickory Lake Watershed. LSPC is a watershed model capable of performing flow routing through stream reaches. LSPC is a dynamic watershed model based on the Hydrologic Simulation Program - Fortran (HSPF)

D.2 Model Set Up

The Old Hickory Lake 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 LSPC 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 contained in the meteorological data files used in these simulations. Weather data from multiple meteorological stations were available for the time period from January 1970 through December 2005. 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 (10/1/95 – 9/30/05) used for TMDL analysis.

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. A USGS continuous record station located near the Old Hickory Lake Watershed with a sufficiently long and recent historical record was selected as the basis of the hydrology calibration. The USGS stations were selected based on similarity of drainage area, Level IV ecoregion, land use, and topography. The calibration involved comparison of simulated and observed hydrographs until statistical stream volumes and flows were within acceptable ranges as reported in the literature (Lumb, et al., 1994).

Initial values for hydrologic variables were taken from an EPA developed default data set. During the calibration process, model parameters were adjusted within reasonable constraints until acceptable agreement was achieved between simulated and observed streamflow. Model parameters adjusted include: evapotranspiration, infiltration, upper and lower zone storage, groundwater storage, recession, losses to the deep groundwater system, and interflow discharge.

The results of the hydrologic calibration for Stoners Creek near Hermitage, USGS Station 03430147, drainage area 20.67 square miles, are shown in Table D-1 and Figures D-1 and D-2.

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

		19.62910261	
Simulation Name:	USGS03430147	**Simulation Period:**	
		Watershed Area (ac):	12566.65
Period for Flow Analysis			
Begin Date:	**10/01/92**	**Baseflow PERCENTILE:**	2.5
End Date:	**09/30/02**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**198.55**	Total Observed In-stream Flow:	**206.51**
Total of highest 10% flows:	**121.77**	Total of Observed highest 10% flows:	**121.66**
Total of lowest 50% flows:	**12.65**	Total of Observed Lowest 50% flows:	**14.05**
Simulated Summer Flow Volume (months 7-9):	**12.42**	Observed Summer Flow Volume (7-9):	**10.18**
Simulated Fall Flow Volume (months 10-12):	**41.45**	Observed Fall Flow Volume (10-12):	**39.35**
Simulated Winter Flow Volume (months 1-3):	**87.27**	Observed Winter Flow Volume (1-3):	**101.24**
Simulated Spring Flow Volume (months 4-6):	**57.41**	Observed Spring Flow Volume (4-6):	**55.74**
Total Simulated Storm Volume:	**197.76**	Total Observed Storm Volume:	**204.72**
Simulated Summer Storm Volume (7-9):	**12.22**	Observed Summer Storm Volume (7-9):	**9.73**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**-3.85**	10	
Error in 50% lowest flows:	**-9.92**	10	
Error in 10% highest flows:	**0.10**	15	
Seasonal volume error - Summer:	**22.00**	30	
Seasonal volume error - Fall:	**5.35**	30	
Seasonal volume error - Winter:	**-13.80**	30	
Seasonal volume error - Spring:	**3.00**	30	
Error in storm volumes:	**-3.40**	20	
Error in summer storm volumes:	**25.54**	50	

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

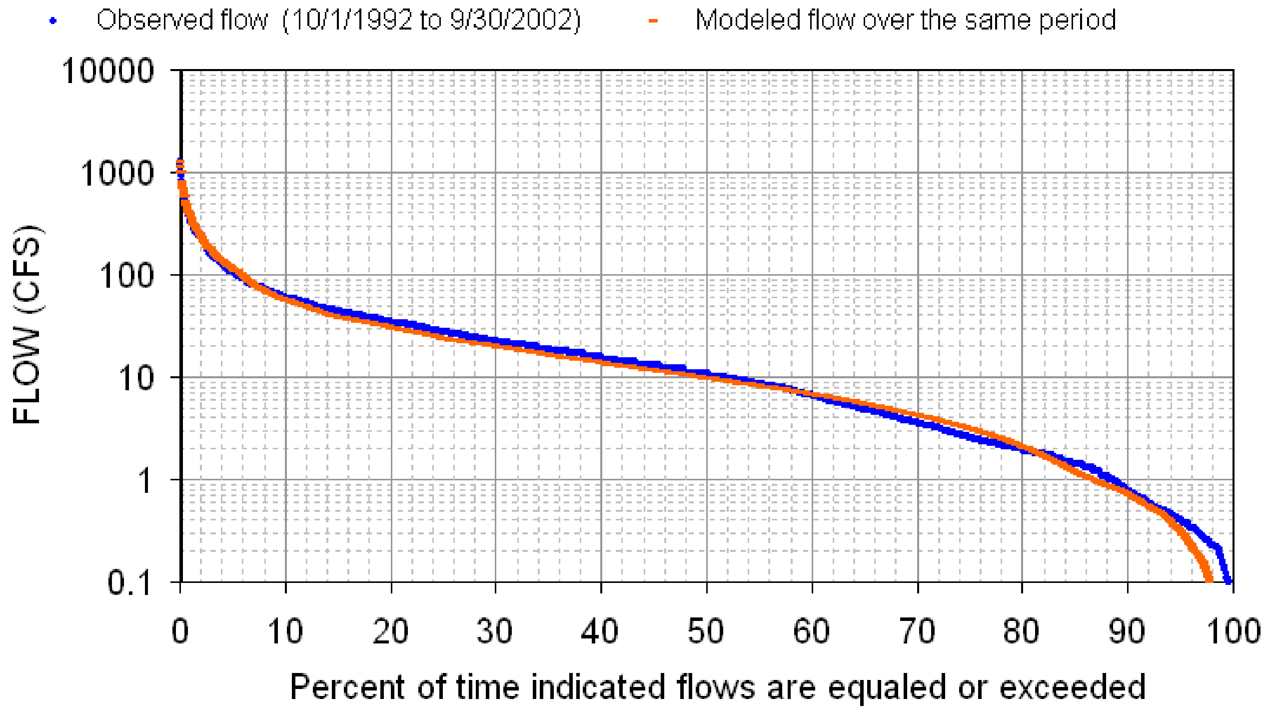

Figure D-1. Hydrologic Calibration: Stoners Creek, USGS 03430147 (WYs1993-2002)

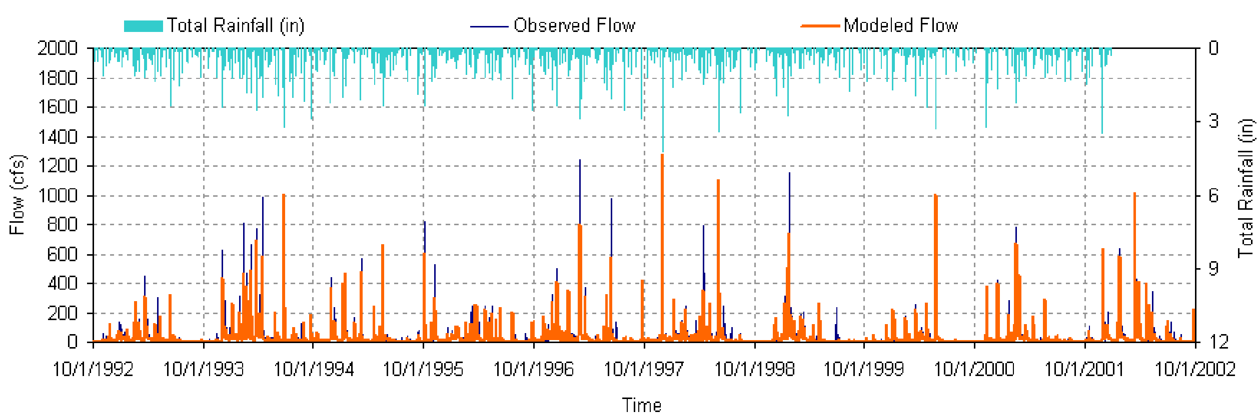

Figure D-2. 10-Year Hydrologic Comparison: Stoners Creek, USGS 03430147

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 10. 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, HUC-12 051302010107, lies near Lebanon. The drainage area for Sinking Creek at mile 0.9 is approximately 9,518 acres (14.9 mi^2); therefore, four flow zones were used for the duration curve analysis (see Sect. 9.1.1).

Note: The Final 2006 303(d) List includes Collection System Failure and Discharges from MS4 Area as Pollutant Source categories for Sinking Creek. However, based on the MRLC Land Use, the Sinking Creek watershed is approximately 37% agricultural. Therefore, Sinking Creek is listed in the Mixed source area type in Section 9.5, Table 10.

The flow duration curve for Sinking Creek at mile 0.9 was constructed using simulated daily mean flow for the period from 10/1/95 through 9/30/05 (mile 0.9 corresponds to the location of monitoring station SINKI000.9WS). 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 at Mile 0.9 (Figure E-2) was analyzed to determine the frequency with which observed daily water quality loads exceed the E. coli target maximum daily loading (941 CFU/100 mL x flow [cfs] x conversion factor) under four flow conditions (low, mid-range, moist, and high). Observation of the plot illustrates that exceedances occur under high flow and moist conditions indicating the Sinking Creek watershed may be impacted by non-point sources. LDCs for other impaired waterbodies were developed using a similar procedure (Appendix C) and are shown in Figures E-4 to E-10.

Critical conditions for the Sinking Creek watershed (HUC-12 051302010107) occur during moist conditions, typically indicative of non-point source contributions (see Table E-3, Section E.4). According to hydrograph separation analysis, the exceedances in the high flow range occur during stormflow events. These factors indicate that non-point sources are significant contributors to impairment in the Sinking Creek watershed. However, it is possible that both point and non-point type sources contribute to exceedances of the E. coli standard in Sinking Creek.

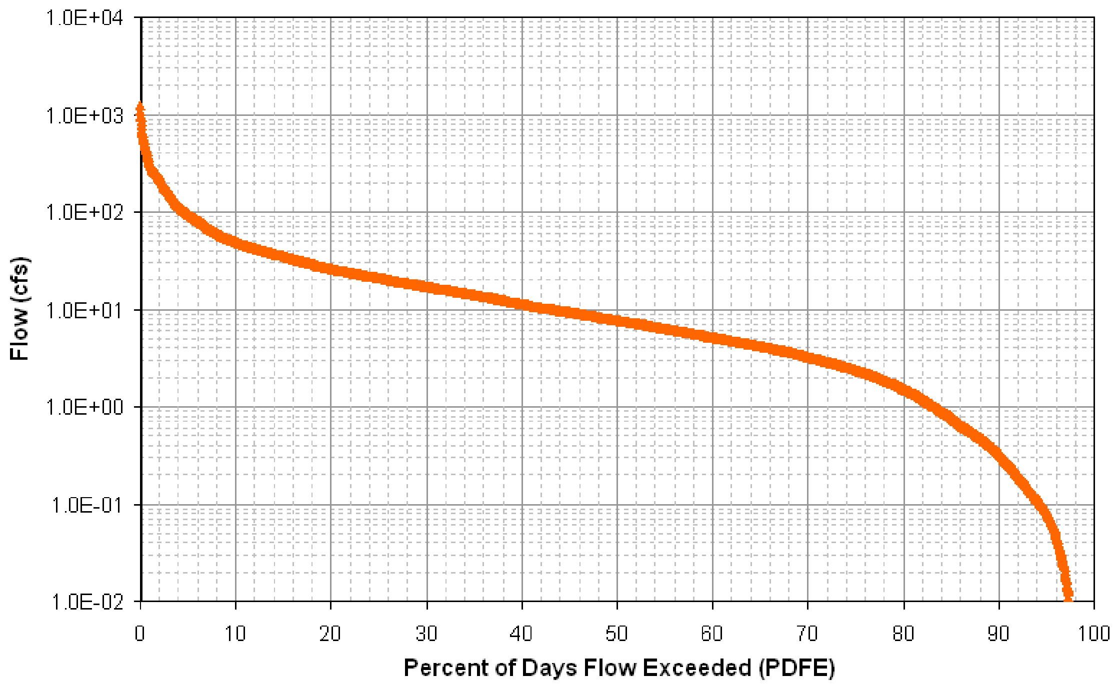

Figure E-1. Flow Duration Curve for Sinking Creek at Mile 0.9

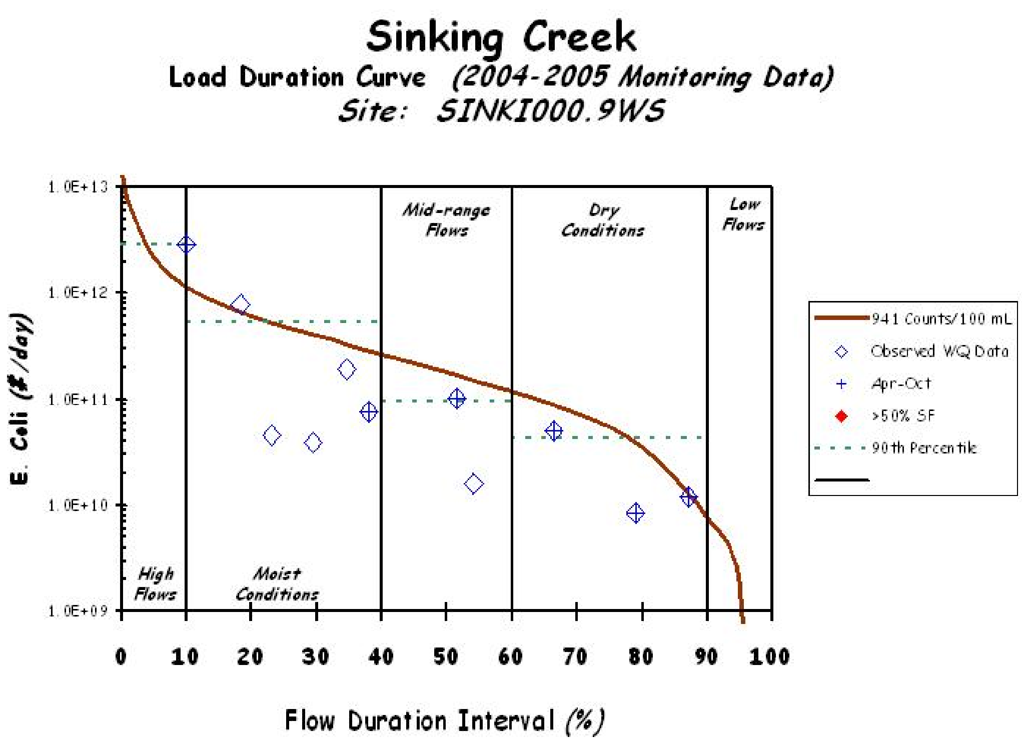

Figure E-2. E. Coli Load Duration Curve for Sinking Creek at Mile 0.9

Table E-1. Load Duration Curve Summary for Implementation Strategies (Example: Sinking Creek subwatershed, HUC-12 051302010107) (4 Flow Zones).

Hydrologic Condition		High	Moist	Mid-range	Low*
% Time Flow Exceeded		0-10	10-40	40-70	70-100
Sinking Creek (051302010107)	Number of Samples	1	5	3	2
	% > 941 CFU/100 mL[1]	100.0	20.0	0.0	0.0
	Load Reduction[2]	60.8	2.9	NR	NR
TMDL (CFU/day)		2.190E+12	4.851E+11	1.454E+11	1.817E+10
Margin of Safety (CFU/day)		2.190E+11	4.851E+10	1.454E+10	1.817E+09
WLA (WWTFs) (CFU/day)		NA	NA	NA	NA
WLAs (MS4s) (CFU/day/acre)[3]		2.071E+08	4.586E+07	1.374E+07	1.718E+06
LA (CFU/day/acre)[3]		2.071E+08	4.586E+07	1.374E+07	1.718E+06
Implementation Strategies[4]					
Municipal NPDES			L	M	H
Stormwater Management			H	H	
SSO Mitigation		H	M	L	
Collection System Repair			H	M	L
Septic System Repair			L	M	H
Potential for source area contribution under given flow condition (H: High; M: Medium; L: Low)					

* The Moist Conditions Flow zone represents the critical conditions 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 non-point sources (dominant under high flow/runoff 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 Old Hickory Lake 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 11 and E-12.

Table E-12 presents LDC analyses (TMDLs, WLAs, LAs, and MOS) and PLRGs for all flow zones for all E. coli impaired waterbodies in the Old Hickory Lake 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 Neal Branch provides guidance for implementation analysis:

The Neal Branch subwatershed, HUC-12 051302010201, lies in a non-urbanized area near Watertown in Wilson county. The drainage area for Neal Branch at Mile 0.1 is approximately 1,200 acres (1.9 mi^2); therefore, four flow zones were used for the duration curve analysis (see Sect. 9.1.1). The landuse for Neal Branch is approximately 42% agricultural, with most of the remainder being forested. Urban areas make up less than 1% of the total area. Therefore, the predominant landuse type and sources are agricultural.

The flow duration curve for Neal Branch at Mile 0.1 was constructed using simulated daily mean flow for the period from 1/1/96 through 12/31/05. This flow duration curve is shown in Figure E-3 and represents the cumulative distribution of daily discharges arranged to show percentage of time specific flows were exceeded during the period of record. Flow duration curves for other impaired waterbodies were developed using a similar procedure (see Appendix C).

The E. coli LDC for Neal Branch at Mile 0.1 (Figure E-4) was analyzed to determine the frequency with which observed daily water quality loads exceed the E. coli target maximum daily loading (941 CFU/100 mL x flow [cfs] x conversion factor) under four flow conditions (low, mid-range, moist, and high). Observation of the plot illustrates that exceedances occur under all flow zones indicating the Neal Branch watershed is impacted by point and non-point-type sources. LDCs for other impaired waterbodies were developed using a similar procedure (Appendix C) and are shown in Figures E-2 thru E-10.

Critical conditions for the Neal Branch HUC-12 occur during mid-range flows, typically indicative of both point and non-point source contributions (see Table E-3, Section E.4). Exceedances of the E. coli water quality standard are fairly well distributed across the full range of flows and all flow zones, though the magnitude of exceedances varies. According to hydrograph separation analysis, most of the exceedances occur during stormflow events. Therefore, it is reasonable to say that non-point type sources contribute to exceedances of the E. coli standard in Neal Branch.

Results indicate the implementation strategy for the Neal Branch watershed will require BMPs targeting non-point sources (dominant under high flow/runoff conditions). Table E-2 presents an allocation table of Load Duration Curve analysis statistics for Neal Branch 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 Old Hickory Lake 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 12 and E-12.

Table E-12 presents LDC analyses (TMDLs, WLAs, LAs, and MOS) and PLRGs for all flow zones for all E. coli impaired waterbodies in the Old Hickory Lake watershed.

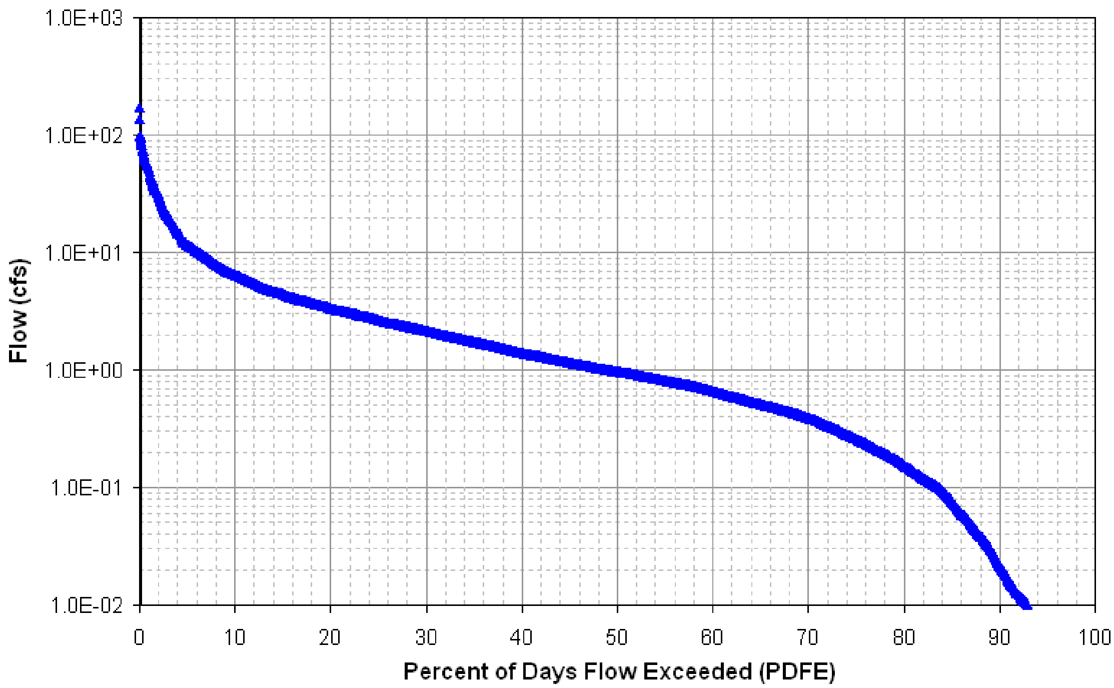

Figure E-3. Flow Duration Curve for Neal Branch at Mile 0.1

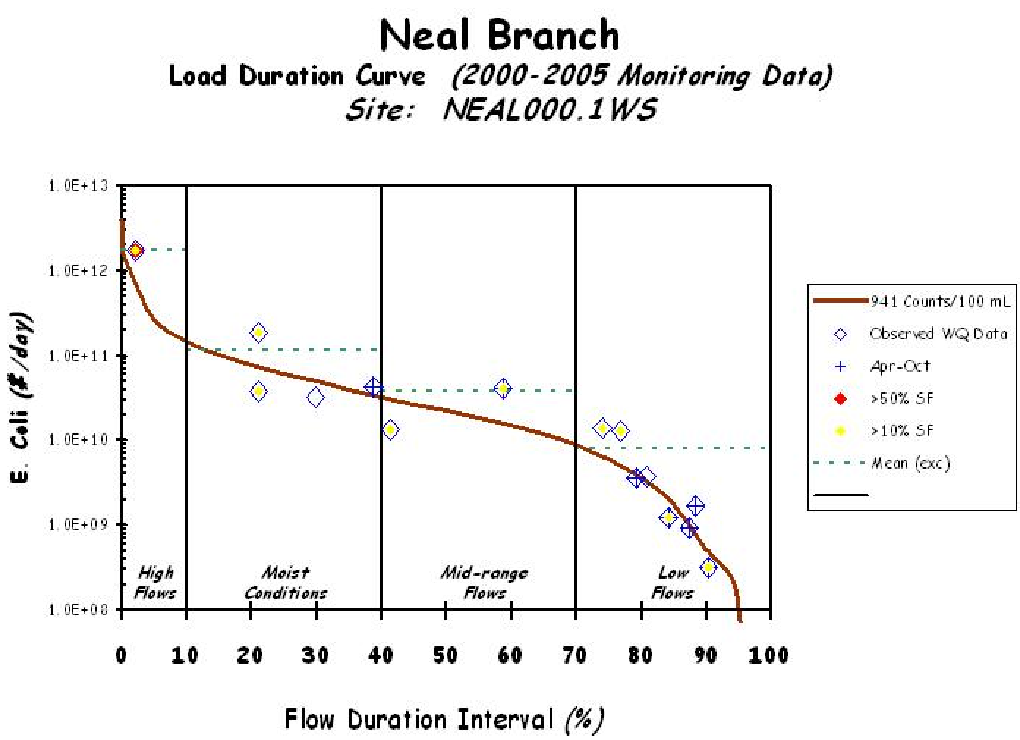

Figure E-4. E. Coli Load Duration Curve for Neal Branch at Mile 0.1

Table E-2. Load Duration Curve Summary for Implementation Strategies (Example: Neal Branch subwatershed, HUC-12 051302010201) (4 Flow Zones).

Hydrologic Condition		High	Moist	Mid-range*	Low
% Time Flow Exceeded		0-10	10-40	40-70	70-100
Neal Branch (051302010201)	Number of Samples	1	4	2	8
	% > 941 CFU/100 mL[1]	100	50.0	50.0	50.0
	Load Reduction[2]	60.8	20.6	30.4	22.6
TMDL (CFU/day)		2.663E+11	6.095E+10	1.863E+10	1.610E+09
Margin of Safety (CFU/day)		2.663E+10	6.095E+09	1.863E+09	1.610E+08
WLA (WWTFs) (CFU/day)		NA	NA	NA	NA
WLA (MS4s) (CFU/day/acre)[3]					
LAs (CFU/day/acre)[3]		1.956E+08	4.388E+07	1.315E+07	1.423E+06
Implementation Strategies[4]					
Pasture and Hayland Management		H	H	M	L
Livestock Exclusion				M	H
Fencing				M	H
Manure Management		H	H	M	L
Riparian Buffers		L	M	H	M
Potential for source area contribution under given flow condition (H: High; M: Medium; L: Low)					

* The Mid-range flow zone represents the critical conditions for E. coli loading in the Neal Branch 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 Old Hickory Lake watershed.

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

In order to facilitate implementation, corresponding percent reductions in loading required to decrease existing, in-stream E. coli loads to TMDL target levels (percent load reduction goals) were calculated. The following example is from Neal Branch at mile 0.1.

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
1/22/01	2400	3.19	1.87E+11	7.34E+10	60.8
2/24/05	490	3.19	3.82E+10	7.34E+10	0 (-92)
3/30/05	610	2.17	3.23E+10	4.99E+10	0 (-54.3)
4/6/05	1200	1.47	4.31E+10	3.38E+10	21.6
Percent Load Reduction Goal (PLRG) for Moist Flow Zone (Mean)					**20.6**

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

Example – *Moist Conditions Flow Zone Percent Load Reduction Goal =20.6*
Mid-Range Flow Zone Percent Load Reduction Goal = 30.4
Low Flow Zone Percent Load Reduction Goal = 22.6

Therefore, the critical flow zone for prioritization of Neal Branch implementation activities is the Mid-Range Zone and subsequently actions targeting point source controls.

PLRGs and critical flow zones of the other impaired waterbodies were derived in a similar manner and are shown in Table E-12.

Table E-3. Summary of Critical Conditions for Impaired Waterbodies in the Old Hickory Lake Watershed.

Waterbody ID	Moist	Mid-range	Dry	Low
Johnson Branch		✓		
Spring Creek				✓
Sinking Creek	✓			
Beech Log Creek				
Neal Branch		✓		
Round Lick Creek	✓			
Little Goose Creek	✓			

* All Waterbody(ies) have 4 flow zones.

Geometric Mean Data

For cases where five or more samples were collected over a period of not more than 30 consecutive days, the geometric mean E. coli concentration was determined and compared to the target geometric mean E. coli concentration of 126 CFU/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: *Insufficient monitoring data were available for all Old Hickory Lake watershed impaired waterbody monitoring stations. The following example is from the Clear Fork of the Cumberland River watershed:*

Monitoring Location = Little Elk Creek
Sampling Period = 7/1/04 – 7/29/04
Geometric Mean Concentration = 1128.4 CFU/100 mL
Target Concentration = 126 CFU/100 mL
Reduction to Target = 88.8%

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.

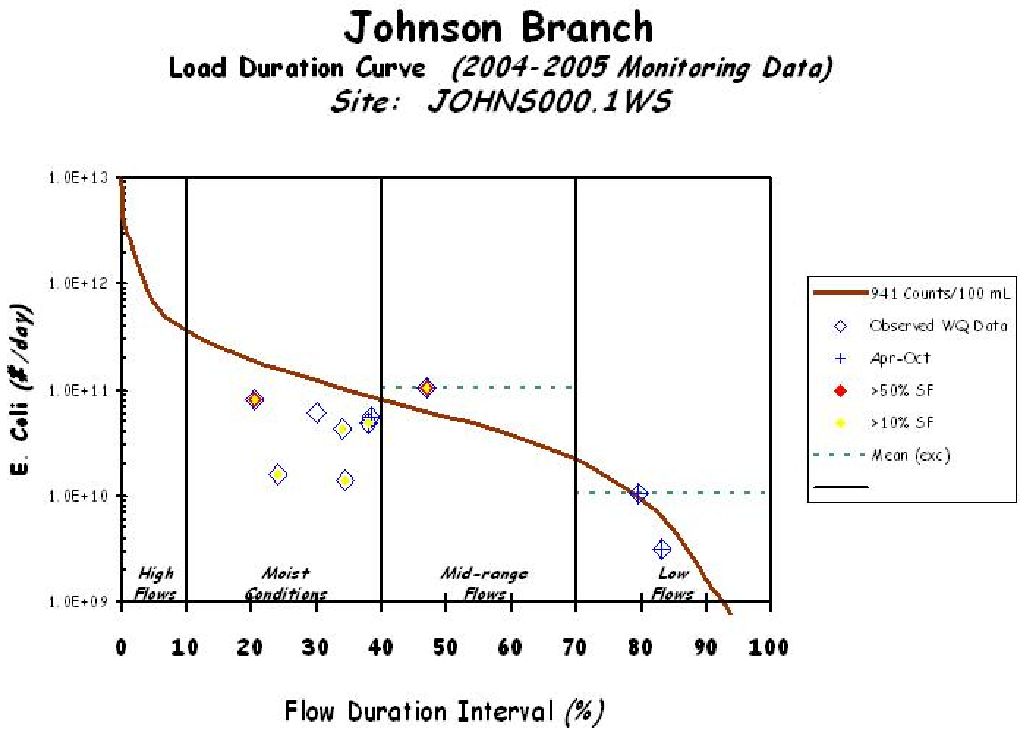

Figure E-5. E. Coli Load Duration Curve for Johnson Branch at Mile 0.1

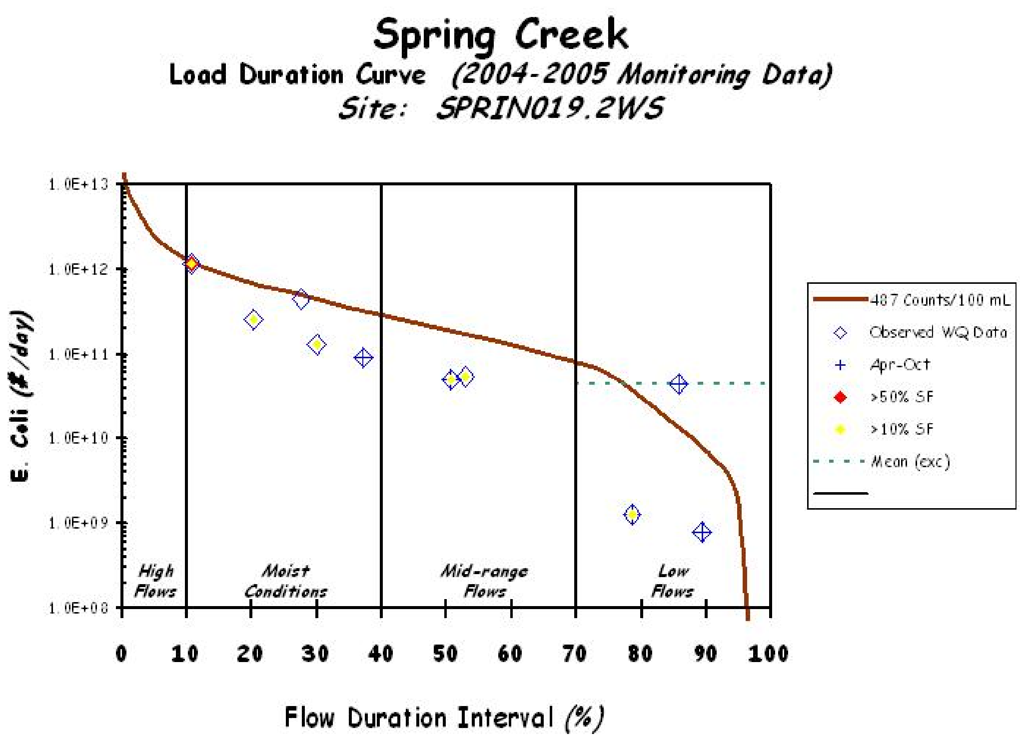

Figure E-6. E. Coli Load Duration Curve for Spring Creek at Mile 19.2

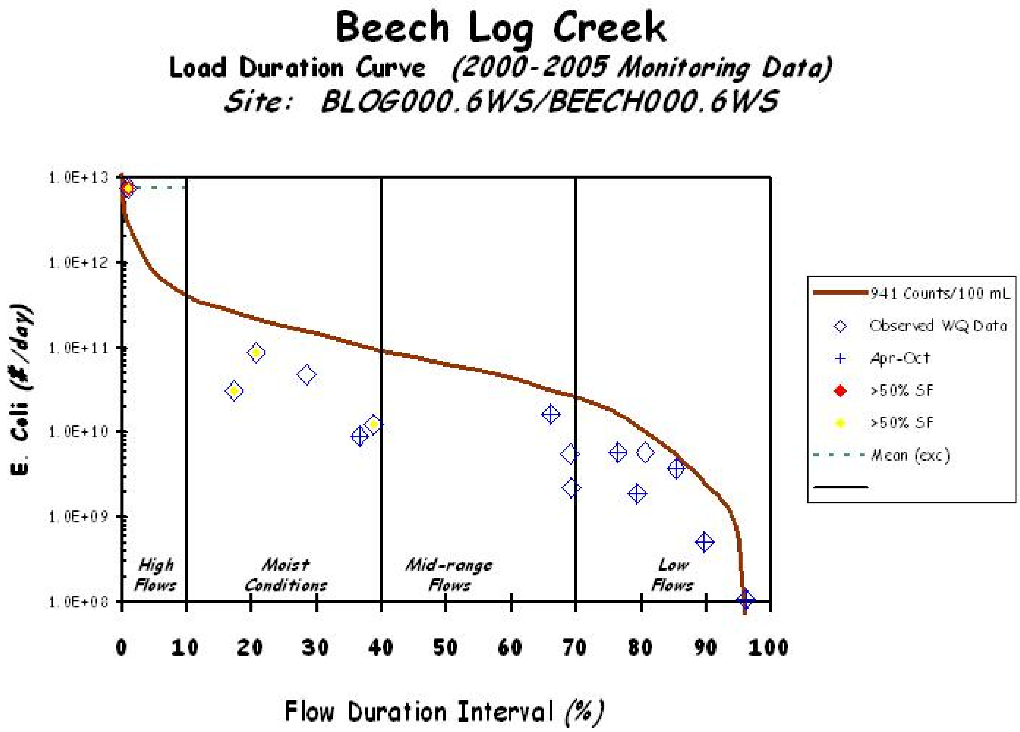

Figure E-7. E. Coli Load Duration Curve for Beech Log Creek at Mile 0.6

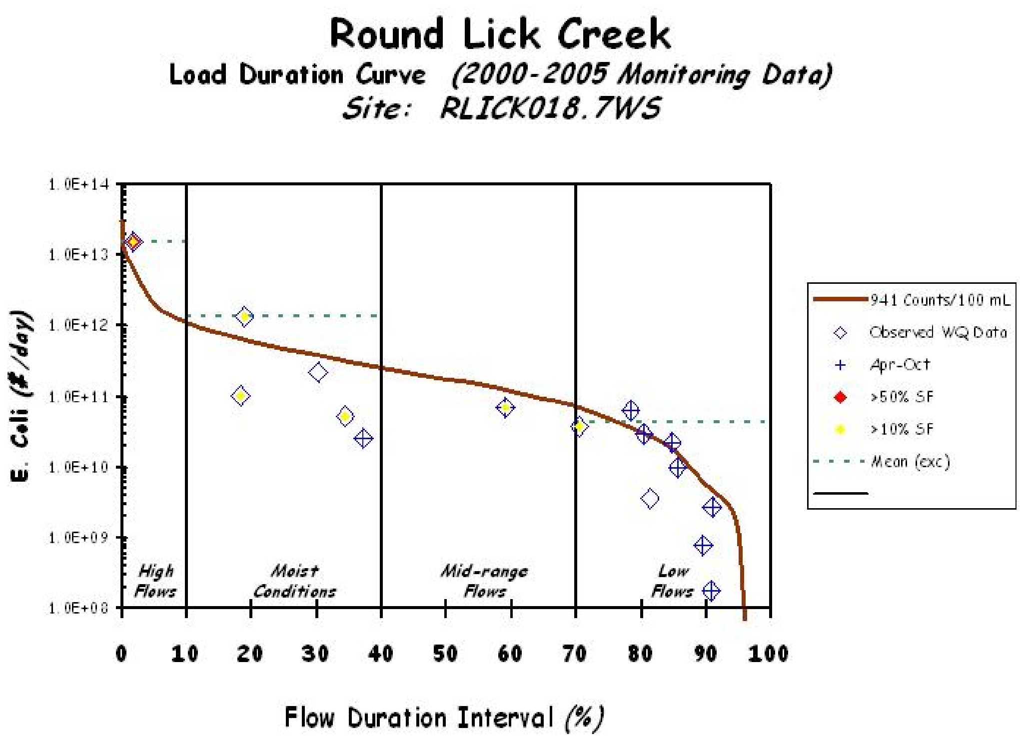

Figure E-8. E. Coli Load Duration Curve for Round Lick Creek at Mile 18.7

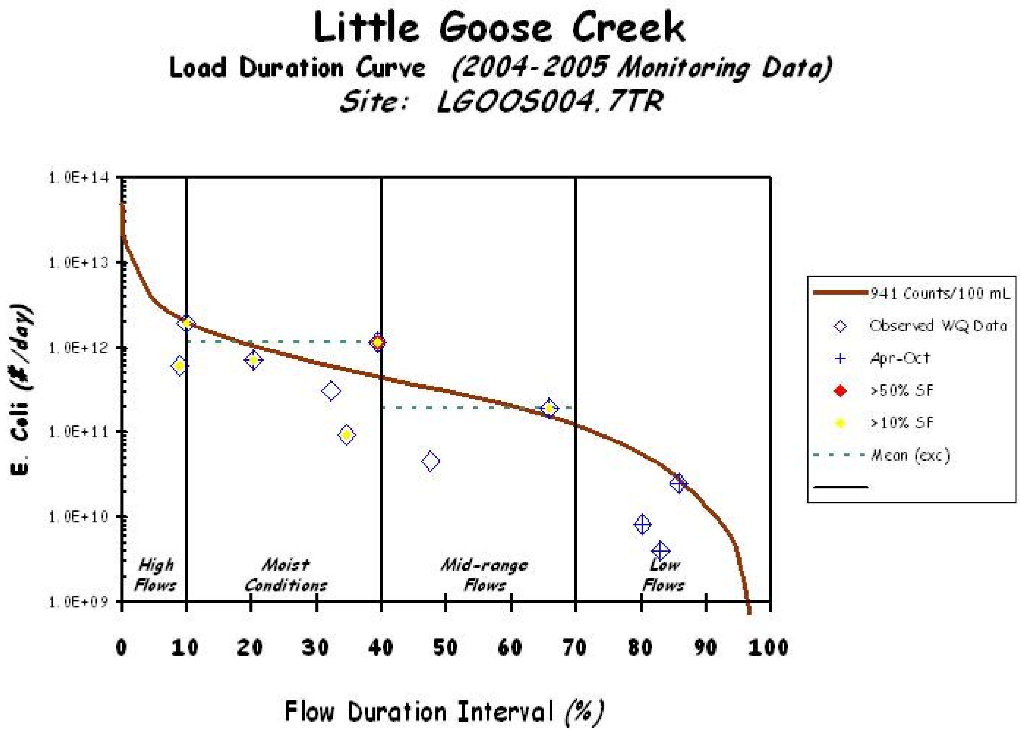

Figure E-9. E. Coli Load Duration Curve for Little Goose Creek at Mile 4.7

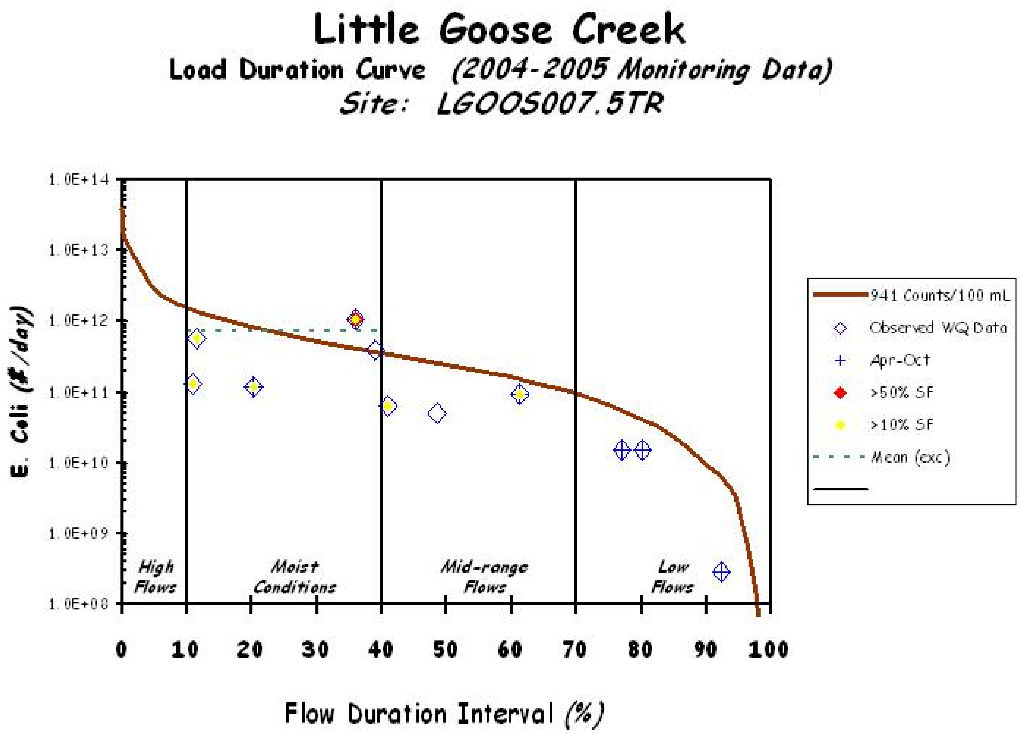

Figure E-10. E. Coli Load Duration Curve for Little Goose Creek at Mile 7.5

Table E-4. Calculated Load Reduction Based on Daily Loading – Johnson Branch – Mile 0.1

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 [%]
1/13/05	Moist Conditions	8.14	20.6%	410	8.17E+10	**0.0**	**NR**	**NR**
12/15/04		6.96	24.2%	93	1.58E+10	0.0		
3/30/05		5.41	30.0%	460	6.09E+10	0.0		
11/15/04		4.55	34.0%	390	4.34E+10	0.0		
2/24/05		4.44	34.5%	130	1.41E+10	0.0		
10/25/04		3.82	38.1%	520	4.86E+10	0.0		
4/6/05		3.74	38.5%	610	5.58E+10	0.0		
9/8/04	Mid-Range	2.71	47.0%	1600	1.06E+11	**41.2**	**41.2**	**47.1**
5/25/05	Low Flows	0.43	79.6%	1000	1.05E+10	5.9	**2.0**	**5.1**
8/25/04		0.28	83.2%	460	3.11E+09	0.0		
6/22/05		0.09	89.2%	93	1.97E+08	0.0		

Note: NR = No reduction required
NA = Not applicable

Table E-5. Calculated Load Reduction Based on Daily Loading – Spring Creek – Mile 19.2

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 [%]
1/13/05	Moist Conditions	104.16	10.7%	460	1.17E+12	0.0	**NR**	**1.0**
2/24/05		58.23	20.3%	180	2.56E+11	0.0		
3/30/05		41.55	27.7%	440	4.47E+11	0.0		
12/15/04		37.50	30.0%	140	1.28E+11	0.0		
4/6/05		27.02	37.3%	140	9.26E+10	0.0		
10/25/04	Mid-Range Flows	16.03	50.7%	130	5.10E+10	0.0	**NR**	**NR**
11/15/04		14.56	53.0%	150	5.34E+10	0.0		
5/25/05	Low Flows	3.22	78.7%	16	1.26E+09	0.0	**23.2**	**24.2**
9/8/04		1.15	85.9%	1600	4.50E+10	69.6		
6/22/05		0.67	89.5%	49	7.99E+08	0.0		

Note: NR = No reduction required
NA = Not applicable

Table E-6. Calculated Load Reduction Based on Daily Loading – Sinking Creek – Mile 0.9

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]	[%]	[%]	[%]
10/20/04	High Flow	49.79	9.9%	2400	2.92E+12	**60.8**	**60.8**	**64.7**
3/8/05	Moist Conditions	28.68	18.4%	1100	7.72E+11	**14.5**	**2.9**	**4.6**
2/10/05		22.53	23.2%	84	4.63E+10	0.0		
12/14/04		17.58	29.4%	91	3.91E+10	0.0		
1/5/05		14.34	34.7%	550	1.93E+11	0.0		
4/11/05		12.43	38.0%	250	7.61E+10	0.0		
9/7/04	Mid-Range Flows	7.27	51.6%	580	1.03E+11	0.0	**NR**	**NR**
11/16/04		6.56	54.1%	100	1.60E+10	0.0		
8/25/04		3.93	66.6%	520	5.00E+10	0.0		
5/18/05	Low Flows	1.71	79.1%	200	8.37E+09	0.0	**NR**	**NR**
6/14/05		0.56	87.2%	870	1.19E+10	0.0		

Note: NR = No reduction required
NA = Not applicable

Table E-7. Calculated Load Reduction Based on Daily Loading – Beech Log Creek – Mile 0.6

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]	[%]	[%]	[%]
1/13/05	High Flow	130.00	0.9%	2400	7.63E+12	**60.8**	**60.8**	**64.7**
1/22/01	Moist Conditions	11.39	17.3%	110	3.07E+10	0.0	**NR**	**NR**
2/24/05		9.50	20.8%	370	8.60E+10	0.0		
3/30/05		6.68	28.5%	290	4.74E+10	0.0		
4/6/05		4.66	36.6%	80	9.12E+09	0.0		
12/15/04		4.20	38.9%	120	1.23E+10	0.0		
10/25/04	Mid-Range Flows	1.39	66.2%	490	1.67E+10	0.0	**NR**	**NR**
11/15/04		1.21	69.1%	190	5.62E+09	0.0		
11/20/00		1.20	69.3%	75	2.20E+09	0.0		
9/26/00	Low Flows	0.73	76.4%	330	5.89E+09	0.0	**NR**	**NR**
5/25/05		0.52	79.5%	150	1.91E+09	0.0		
12/6/00		0.45	80.7%	520	5.73E+09	0.0		
8/2/00		0.24	85.4%	650	3.74E+09	0.0		
9/8/04		0.11	89.9%	190	5.11E+08	0.0		
10/24/00		0.01	96.2%	370	1.08E+08	0.0		

Note: NR = No reduction required
NA = Not applicable

Table E-8. Calculated Load Reduction Based on Daily Loading – Neal Branch– Mile 0.1

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 [%]
1/13/05	High Flow	30.00	2.1%	2400	1.76E+12	**60.8**	**60.8**	**64.7**
1/22/01	Moist Conditions	3.19	21.2%	2400	1.87E+11	**60.8**		
2/24/05		3.19	21.2%	490	3.82E+10	0.0		
3/30/05		2.17	29.9%	610	3.23E+10	0.0		
4/6/05		1.47	38.8%	1200	4.31E+10	**21.6**	**20.6**	**23.5**
12/15/04	Mid-Range Flows	1.33	41.4%	410	1.33E+10	0.0		
10/25/04		0.70	58.8%	2400	4.11E+10	**60.8**	**30.4**	**32.4**
11/15/04	Low Flows	0.28	74.2%	2000	1.37E+10	**53.0**		
11/29/00		0.22	76.8%	2400	1.29E+10	**60.8**		
5/25/05		0.17	79.2%	870	3.66E+09	0.0		
12/6/00		0.14	80.9%	1100	3.77E+09	**14.5**		
9/8/04		0.09	84.3%	550	1.21E+09	0.0		
8/2/00		0.04	87.4%	870	9.45E+08	0.0		
6/22/05		0.03	88.5%	2000	1.71E+09	**53.0**		
9/26/00		0.02	90.4%	650	3.18E+08	0.0	**22.6**	**26.0**

Note: NR = No reduction required
NA = Not applicable

Table E-9. Calculated Load Reduction Based on Daily Loading – Round Lick Creek– Mile 18.7

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]	[%]	[%]	[%]
1/13/05	High Flow	260.00	1.8%	2400	1.53E+13	**60.8**	**60.8**	**64.7**
2/24/05	Moist Conditions	28.27	18.4%	150	1.04E+11	0.0	**10.6**	**11.5**
1/22/01		27.62	19.0%	2000	1.35E+12	53.0		
3/30/05		16.70	30.2%	550	2.25E+11	0.0		
12/15/04		13.68	34.5%	160	5.36E+10	0.0		
4/6/05		12.33	37.3%	86	2.59E+10	0.0		
10/25/04	Mid-Range	5.44	59.1%	520	6.92E+10	0.0	**NR**	**NR**
11/29/00	Low Flows	3.07	70.5%	490	3.68E+10	0.0	**7.0**	**9.4**
9/26/00		1.61	78.5%	1600	6.30E+10	**41.2**		
5/25/05		1.32	80.5%	920	2.98E+10	0.0		
12/6/00		1.14	81.4%	130	3.63E+09	0.0		
9/8/04		0.76	84.9%	1200	2.23E+10	**21.6**		
8/2/00		0.68	85.6%	580	9.62E+09	0.0		
6/22/05		0.27	89.6%	120	7.99E+08	0.0		
10/24/00		0.20	90.8%	36	1.76E+08	0.0		
7/26/00		0.19	91.0%	600	2.72E+09	0.0		

Note: NR = No reduction required
NA = Not applicable

Table E-10. Calculated Load Reduction Based on Daily Loading – Little Goose Creek– Mile 4.7

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]	[%]	[%]	[%]
2/15/05	High Flow	97.74	8.9%	260	6.22E+11	0.0		
1/10/05		86.78	10.0%	920	1.95E+12	**0.0**	**NR**	**NR**
9/21/04	Moist Conditions	45.02	20.3%	650	7.16E+11	0.0		
11/29/04		26.39	32.3%	490	3.16E+11	0.0		
12/16/04		23.80	34.7%	160	9.32E+10	0.0		
10/19/04		19.64	39.4%	2400	1.15E+12	**60.8**	**15.2**	**16.2**
3/14/05	Mid-Range	14.42	47.6%	130	4.59E+10	0.0		
4/27/05		6.69	66.0%	1200	1.96E+11	**21.6**	**10.8**	**14.7**
5/24/05	Low Flows	2.37	80.3%	140	8.13E+09	0.0		
6/21/05		1.71	83.1%	96	4.01E+09	0.0		
8/23/04		1.24	85.8%	820	2.49E+10	0.0	**NR**	**NR**

Note: NR = No reduction required
NA = Not applicable

Table E-11. Calculated Load Reduction Based on Daily Loading – Little Goose Creek– Mile 7.5

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]	[%]	[%]	[%]
2/15/05	Moist Conditions	62.86	11.0%	86	1.32E+11	0.0	15.2	16.2
1/10/05		59.77	11.5%	390	5.70E+11	0.0		
9/21/04		35.30	20.4%	140	1.21E+11	0.0		
10/19/04		17.80	36.1%	2400	1.05E+12	**30.8**		
11/29/04		15.84	39.1%	1000	3.88E+11	**5.9**		
12/16/04	Mid-Range	14.59	41.0%	180	6.43E+10	0.0	NR	NR
3/14/05		10.89	48.7%	190	5.06E+10	0.0		
4/27/05		6.69	61.3%	580	9.49E+10	0.0		
5/24/05	Low Flows	2.37	77.1%	260	1.51E+10	0.0	NR	NR
6/21/05		1.71	80.3%	370	1.54E+10	0.0		
8/23/04		0.23	92.5%	50	2.81E+08	0.0		

Note: NR = No reduction required
NA = Not applicable

Table E-12 Summary of TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Old Hickory Lake Watershed (HUC 05130201)

Waterbody Description	Hydrologic Condition			Flow[a]	PLRG	TMDL	MOS	WLAs			LAs
	Flow Regime	PDFE Range	Flow Range					WWTFs [b]	CS	MS4s	
		[%]	[cfs]	[cfs]	[%]	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d/ac]	[CFU/d/ac]
Johnson Branch	High Flows	0 – 10	16.02 – 124.5	29.14	NA	6.702×10^{11}	6.702×10^{10}	NA	NA	NA	2.009×10^{8}
Waterbody ID:	Moist	10 – 40	3.51 – 16.02	6.64	NR	1.527×10^{11}	1.527×10^{10}				4.577×10^{7}
TN05130201015 – 0200	Mid-Range	40 – 60	0.98 – 3.51	2.43	41.2	5.589×10^{10}	5.589×10^{9}				1.675×10^{7}
HUC-12: 0105	Low Flows	90 – 100	0 – 0.98	0.21	2.0	4.830×10^{9}	4.830×10^{8}				1.447×10^{6}
Spring Creek	High Flows	0 – 10	108.9 – 674.9	205.82	NA	2.470×10^{12}	2.470×10^{11}	NA	NA	NA	1.008×10^{8}
Waterbody ID:	Moist	10 – 40	24.10 – 108.9	46.75	NR	5.610×10^{11}	5.610×10^{10}				2.289×10^{7}
TN05130201013 – 4000	Mid-Range	40 – 70	6.74 – 24.10	13.40	NR	1.608×10^{11}	1.608×10^{10}				6.560×10^{6}
HUC-12: 0106	Low Flows	70 – 100	0 – 6.74	1.27	23.2	1.524×10^{10}	1.524×10^{9}				6.217×10^{5}
Sinking Creek	High Flows	0 – 10	49.37 – 312.5	95.22	60.8	2.190×10^{12}	2.190×10^{11}	NA	0	2.071×10^{8}	2.071×10^{8}
Waterbody IDs:	Moist	10 – 40	11.37 – 49.37	21.09	2.9	4.851×10^{11}	4.851×10^{10}			4.586×10^{7}	4.586×10^{7}
TN05130201055 – 0200	Mid-Range	40 – 70	3.25 – 11.37	6.32	NR	1.454×10^{11}	1.454×10^{10}			1.374×10^{7}	1.374×10^{7}
TN05130201055 – 0250 HUC-12: 0107	Low Flows	70 – 100	0 – 3.25	0.79	NR	1.817×10^{10}	1.817×10^{9}			1.718×10^{6}	1.718×10^{6}
Beech Log Creek	High Flows	0 – 10	18.28 – 122.3	34.36	60.8	7.903×10^{11}	7.903×10^{10}	NA	0	2.071×10^{8}	2.071×10^{8}
Waterbody ID:	Moist	10 – 40	4.01 – 18.28	7.71	NR	1.773×10^{11}	1.773×10^{10}			4.586×10^{7}	4.586×10^{7}
TN05130101021 – 0400	Mid-Range	40 – 70	1.16 – 4.01	2.31	NR	5.313×10^{10}	5.313×10^{9}			1.374×10^{7}	1.374×10^{7}
HUC-12: 0201	Low Flows	70 – 100	0 – 1.16	0.25	NR	5.750×10^{9}	5.750×10^{8}			1.718×10^{6}	1.718×10^{6}
Neal Branch	High Flows	0 – 10	6.41 – 49.68	11.58	60.8	2.663×10^{11}	2.663×10^{10}	NA	0	1.956×10^{8}	1.956×10^{8}
Waterbody ID:	Moist	10 – 40	1.40 – 6.41	2.65	20.6	6.095×10^{10}	6.095×10^{9}			4.388×10^{7}	4.388×10^{7}
TN05130201021 – 0300	Mid-Range	40 – 70	0.39 – 1.40	0.81	30.4	1.863×10^{10}	1.863×10^{9}			1.315×10^{7}	1.315×10^{7}
HUC-12: 0201	Low Flows	70 – 100	0 – 0.39	0.07	22.6	1.610×10^{9}	1.610×10^{8}			1.423×10^{6}	1.423×10^{6}
Round Lick Creek	High Flows	0 – 10	49.63 – 386.9	90.19	60.8	2.074×10^{12}	2.074×10^{11}	9.617×10^{9}	0	1.982×10^{8}	1.982×10^{8}
Waterbody ID:	Moist	10 – 40	10.92 – 49.64	20.62	10.6	4.743×10^{11}	4.743×10^{10}			4.453×10^{7}	4.453×10^{7}
TN05130201021 – 2000	Mid-Range	40 – 70	3.18 – 10.92	6.38	NR	1.467×10^{11}	1.467×10^{10}			1.307×10^{7}	1.307×10^{7}
HUC-12: 0201	Low Flows	70 – 100	0 – 3.18	0.74	7.0	1.702×10^{10}	1.702×10^{9}			6.084×10^{6}	6.084×10^{6}
Little Goose Creek	High Flows	0 – 10	86.66 – 613.4	162.03	NR	3.727×10^{12}	3.727×10^{11}	NA	NA	NA	2.107×10^{8}
Waterbody ID:	Moist	10 – 40	19.13 – 86.66	36.39	15.2	8.370×10^{11}	8.370×10^{10}				4.731×10^{7}
TN05130201028 – 0100	Mid-Range	40 – 70	5.37 – 19.13	11.07	10.8	2.546×10^{11}	2.546×10^{10}				1.439×10^{7}
HUC-12: 0302	Low Flows	70 – 100	0 – 5.37	1.36	NR	3.128×10^{10}	3.128×10^{9}				1.768×10^{6}

Table E-12 (cont'd) Summary of TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Old Hickory Lake Watershed (HUC 05130201)

Waterbody Description	Hydrologic Condition			Flow[a]	PLRG	TMDL	MOS	WLAs			LAs
	Flow Regime	PDFE Range	Flow Range					WWTFs [b]	CS	MS4s	
		[%]	[cfs]	[cfs]	[%]	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d]	[CFU/d/ac]	[CFU/d/ac]
Little Goose Creek Waterbody ID: **TN05130201028 – 0150** HUC-12: 0302	High Flows	0 – 10	68.25 – 497.4	127.74	NA	2.938×10^{12}	2.938×10^{11}	NA	NA	NA	2.109×10^{8}
	Moist	10 – 40	15.15 – 68.25	28.82	15.2	6.629×10^{11}	6.629×10^{10}				4.758×10^{7}
	Mid-Range	40 – 70	8.81 – 15.15	8.81	NR	2.026×10^{11}	2.026×10^{10}				1.455×10^{7}
	Low Flows	70 – 100	0 – 8.81	1.03	NR	2.369×10^{10}	2.369×10^{9}				1.701×10^{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. WLAs for WWTFs are expressed as E. coli loads (CFU/day). All current and future WWTFs must meet water quality standards at the point of discharge as specified in their NPDES permit; at no time shall concentration be greater than the appropriate E. coli standard (487 CFU/100 mL or 941 CFU/100 mL).

APPENDIX F

Supplemental Load Duration Curve Analysis of E. Coli Data

Load duration curve (LDC) methodology is a form of water quality analysis and presentation of data that aids in guiding implementation by targeting strategies to appropriate flow conditions. The LDC can be analyzed to determine the frequency with which water quality monitoring data exceed the target maximum concentration under five flow "zones" (low, dry, mid-range, moist, and high). LDC zones can provide insight about conditions and patterns associated with the impairment.

One of the strengths of the LDC methodology is that it can be used to identify possible delivery mechanisms of pathogens by differentiating between point source and nonpoint source problems. Once the delivery mechanism has been identified, best management practices and potential implementation actions can be applied to effectively address water quality concerns.

However, the LDC is only as good as the data used to create it. If data is not representative of all seasons and flow conditions, incorrect conclusions can be drawn. The following two examples are presented to illustrate the importance of having sampling data that are representative of all seasons and flow conditions.

Figure F-1 is a load duration curve for Beech Log Creek at Mile 0.6. The data appear to be representative of all flow conditions. Figure F-2 displays E. coli concentrations with known rain events highlighted. The only occasion when the E. coli concentration exceeded 2000 CFU/100 mL coincided with a rain event. This suggests that stormwater runoff is a likely source of E. coli. Figures F-3 and F-4 display E. coli concentrations and rainfall measured at the Nashville Airport, confirming that the sampling event in which E. coli concentration exceeded 2000 CFU/100 mL occurred during or immediately following rain events.

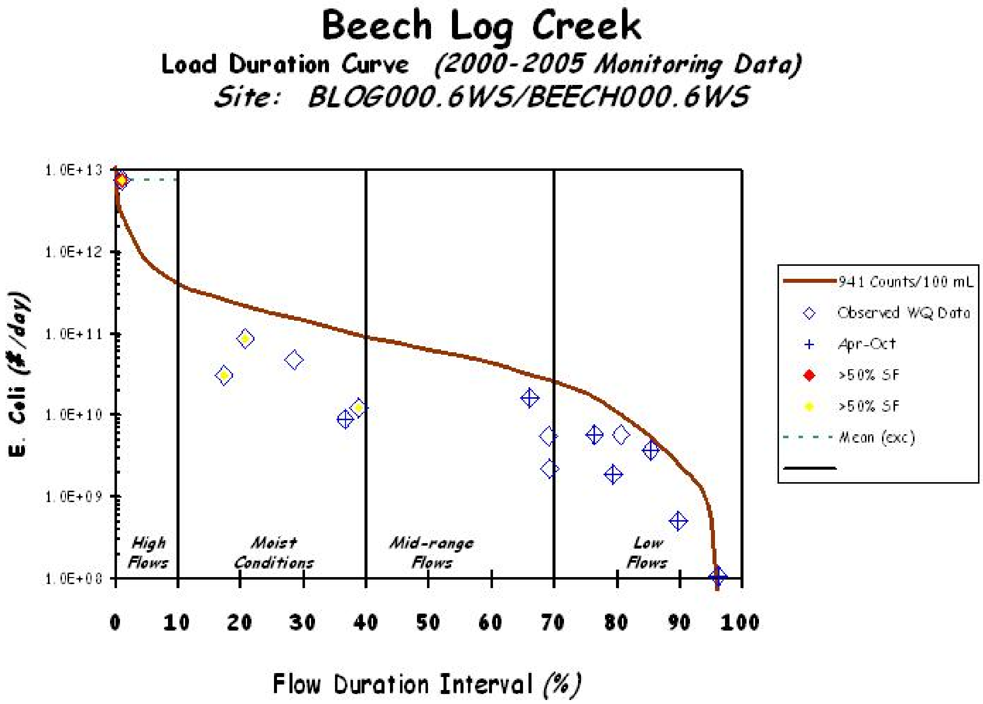

Figure F-1. E. coli Load Duration Curve for Beech Log Creek at RM0.6

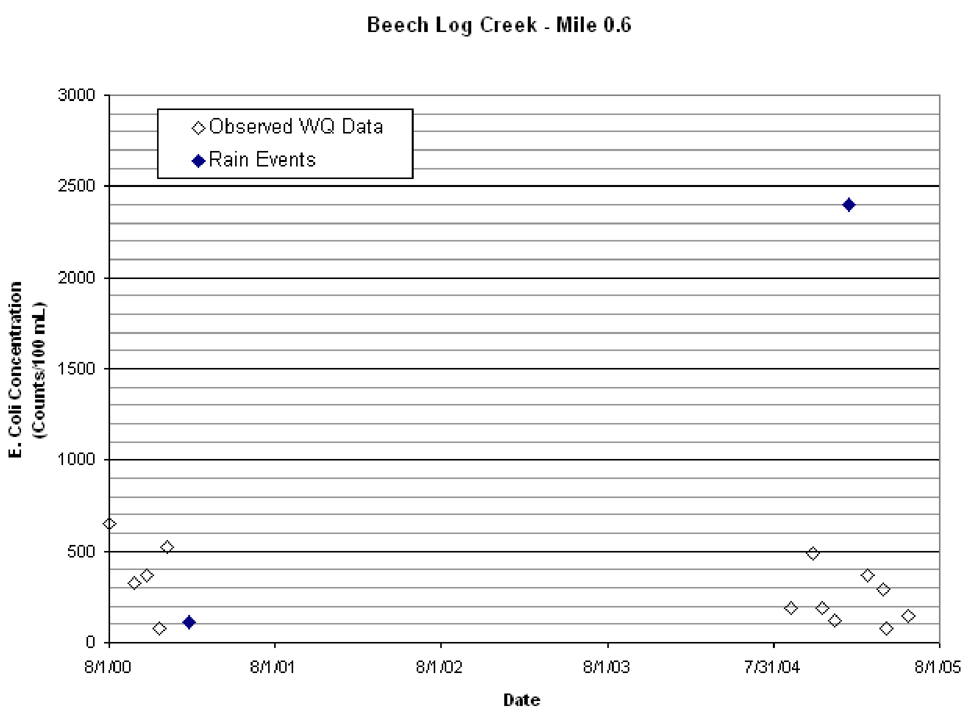

Figure F-2. E. coli Concentrations for Beech Log Creek at RM0.6 (2000-2005)

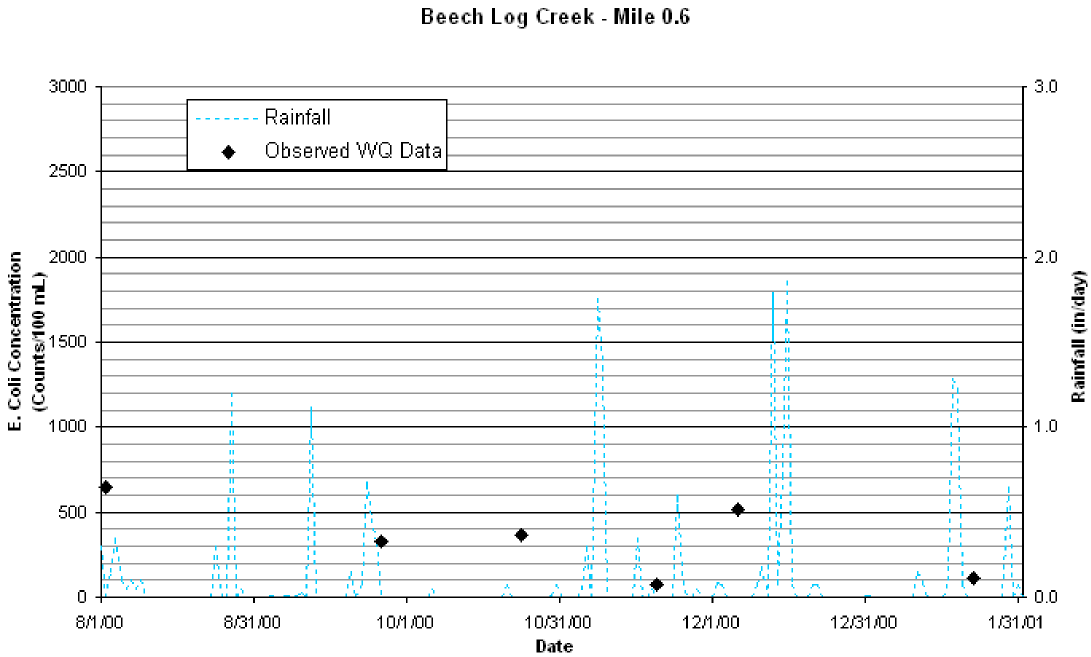

Figure F-3. E. coli Concentrations for Beech Log Creek at RM0.6 and Measured Rainfall at Nashville Airport (08/00-01/01)

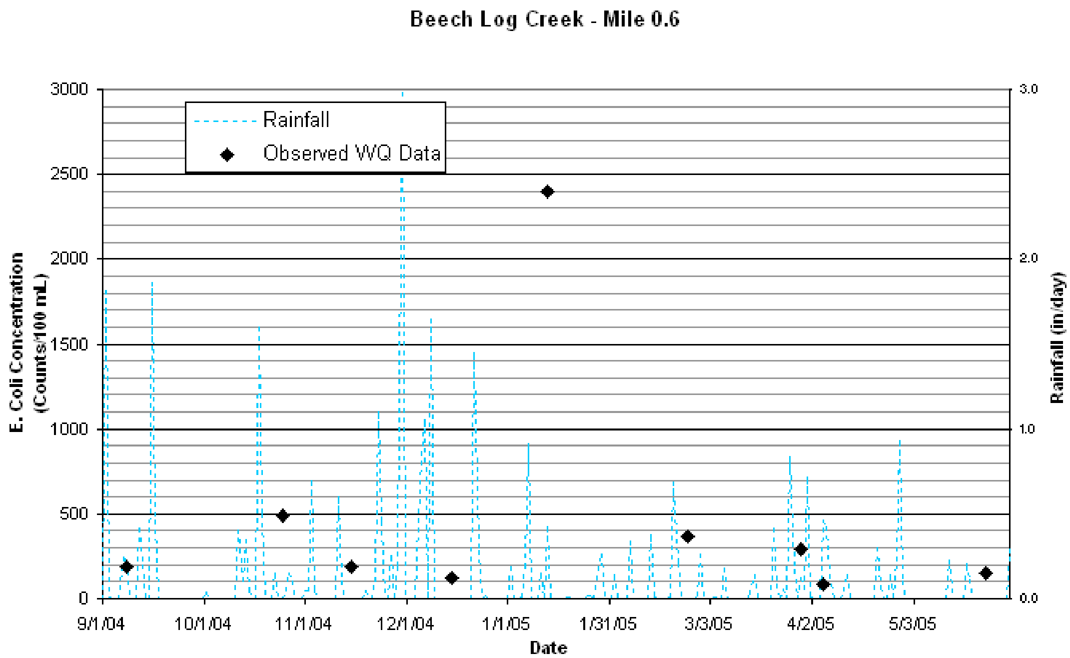

Figure F-4. E. coli Concentrations for Beech Log Creek at RM0.6 and Measured Rainfall at Nashville Airport (09/04-06/05)

Figure F-5 is a load duration curve forJohnson Branch at Mile 0.1. The data are not representative of all flow conditions. Figures F-6 displays E. coli concentrations with known rain events highlighted. None of the sampling events coincided with known rain events. Figure F-7 displays E. coli concentrations and rainfall measured at the Nashville Airport, confirming that none of the sampling events occurred during or immediately following rain events.

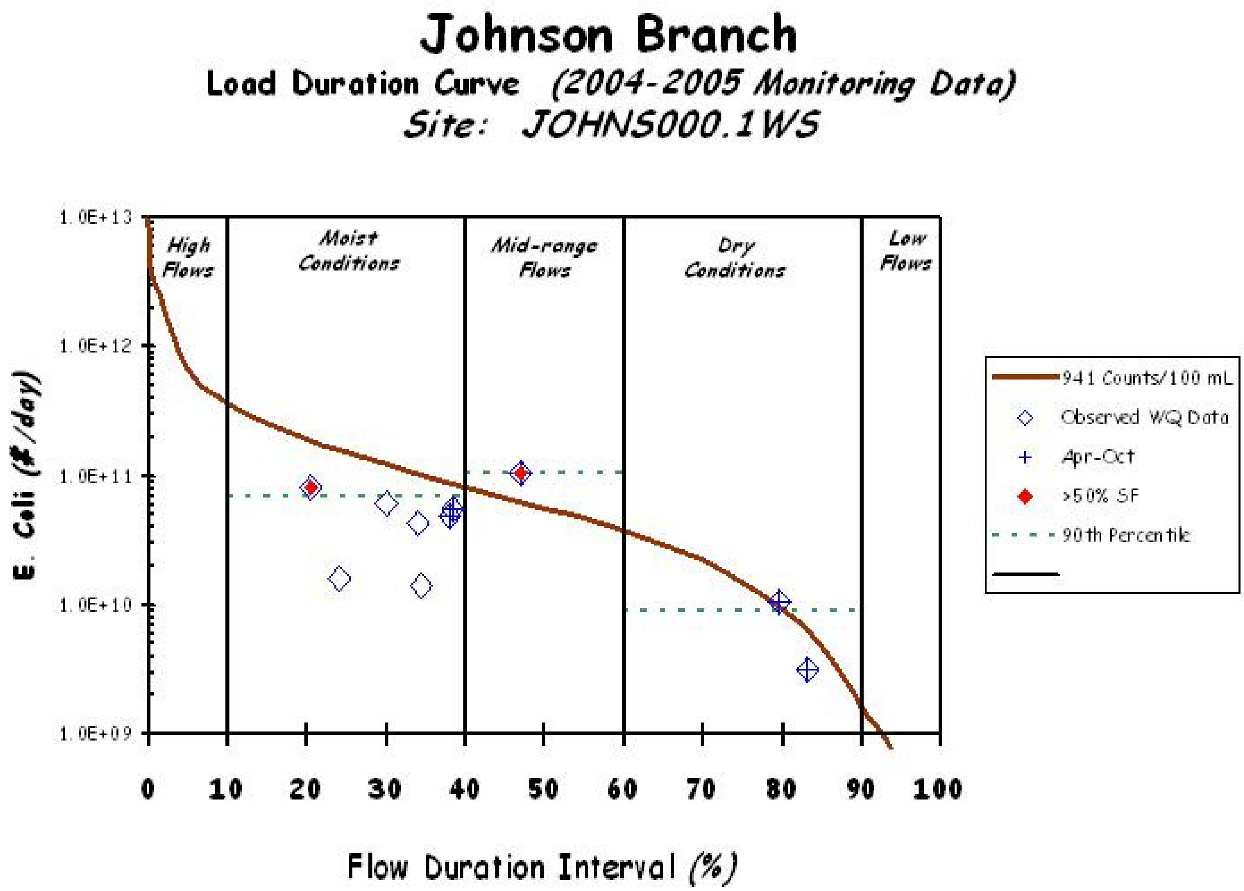

Figure F-5. E. coli Load Duration Curve for Johnson Branch at RM0.1

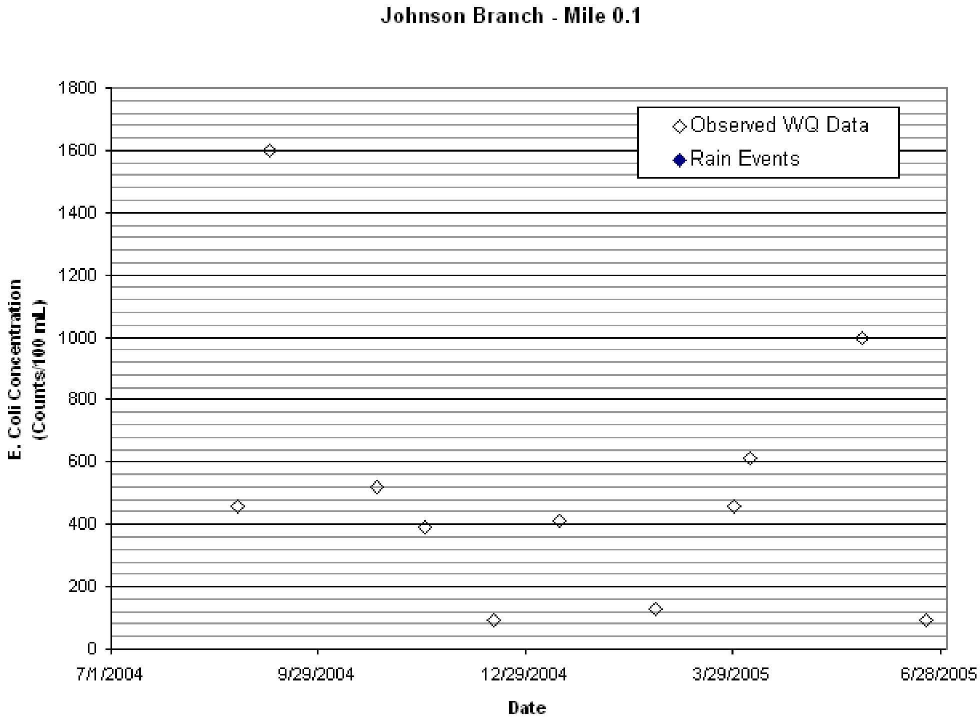

Figure F-6. E. coli Concentrations for Johnson Branch at RM0.1 (07/04-04/05)

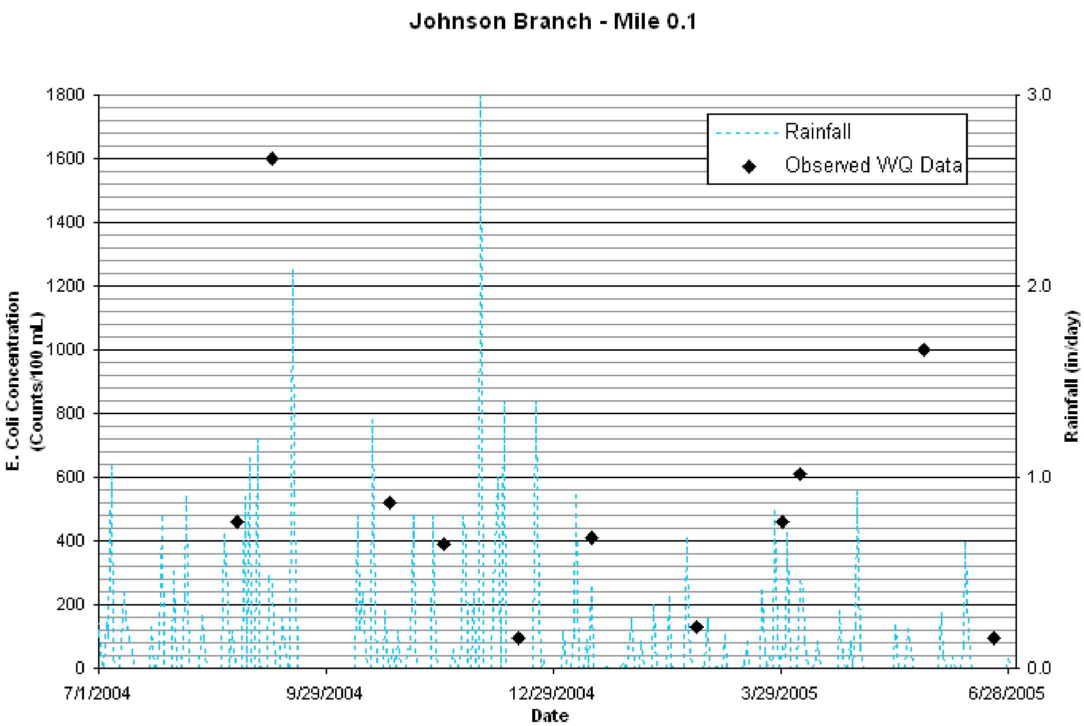

Figure F-7. E. coli Concentrations for Johnson Branch at RM0.1 and Measured Rainfall at Nashville Airport (07/04-07/05)

APPENDIX G

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 OLD HICKORY LAKE WATERSHED (HUC 05130201), TENNESSEE

Announcement is hereby given of the availability of Tennessee's proposed Total Maximum Daily Load (TMDL) for E. coli in the Old Hickory Lake watershed, located in middle 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 Old Hickory Lake watershed are listed on Tennessee's Final 2006 303(d) list as not supporting designated use classifications due, in part, to pasture grazing and collection system failure. 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 3-41% in the listed waterbodies.

Old Hickory Lake E. coli TMDL may be downloaded from the 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:

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 March 17, 2008 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 H

Public Comments Received

FEB 2 0 2008

SUITE 401
2 INTERNATIONAL PLAZA
NASHVILLE, TENNESSEE 37217

TELEPHONE: 615/366-6088
FAX: 615/366-6203

Water Management Services, LLC

ENGINEERING • PLANNING • OPERATIONS • RATE STUDIES

February 19, 2008

Dr. Sherry Wang, Ph.D.
Tennessee Division of Water Pollution Control
Watershed Management Section
7th Floor, L & C Annex
401 Church Street
Nashville, TN 37243-1534

Re: TMDL for E. coli, Old Hickory Lake Watershed, Tennessee

Dear Ms. Wang:

I have reviewed the above document and wish to provide the Division with comments. Our firm is a consultant to the City of Lebanon, and it is in their interest that I have reviewed this document and am making these comments.

On page ix, on the Summary Sheet, concerning the table entitled: Impaired Waterbodies Addressed in This Document: Under the Waterbody Bartons Creek, the miles impaired is listed as 16.9. However, on page 8, in Table 2, the miles of Bartons Creek that are Impaired is listed as 5.0 miles. (The other milages in this table match with the Summary Sheet table).

In Section 7, Source Assessment, under subsection 7.1.1, the only municipality specifically mentioned is Watertown. It is well known that Lebanon's municipal sewer collection system, which is located on Barton's Creek, has wet weather SSO's. These are all reported to the Division. These overflows would constitute a significant E. coli source, when those overflows are occurring. It should also be noted that Lebanon is under a Consent Order that mandates elimination of these overflows by June 30, 2010. Lebanon has been pursuing significant infiltration and inflow reduction programs. The City will also implement a construction program at the WWTP this spring that will provide additional peak flow capacity. The two efforts are intended to result in compliance with the Order.

Section 9.2.1: This section states that all NPDES dischargers are in compliance, and no additional reduction is required. The above noted situation with Lebanon and the expected reduction of E. coli after the elimination of the ongoing SSO may be worth noting here.

Thank you for this opportunity to comment. If you have questions, please feel free to call.

Sincerely,

Robert Slayden, Jr.

Cc: Chuck Boyett, City of Lebanon

APPENDIX I

Response to Public Comments

Note: responses correspond to comments (see Appendix H).

1. The "miles impaired" listed for Bartons Creek has been corrected.

2. Information relating to the Lebanon STP and the Commissioner's Order have been incorporated into Section 7.1.1.

3. Section 9.2.1 states that "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 time". While the Lebanon STP is not currently in compliance with their permit, compliance with the Commissioner's Order will result in future compliance with the NPDES permit.