TOTAL MAXIMUM DAILY LOAD (TMDL)

for

Pathogens

in the

Lower French Broad Watershed (HUC 06010107)

Cocke, Jefferson, and Sevier Counties, Tennessee

FINAL

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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
DEM	Digital Elevation Model
DMR	Discharge Monitoring Report
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
LSPC	Loading Simulation Program in C^{++}
LDC	Load Duration Curve
MGD	Million Gallons per Day
MOS	Margin of Safety
MRLC	Multi-Resolution Land Characteristic
MS4	Municipal Separate Storm Sewer System
MST	Microbial Source Tracking
NHD	National Hydrography Dataset
NMP	Nutrient Management Plan
NOV	Notice of Violation
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 Pathogens in Lower French Broad Watershed (HUC 06010107)

Impaired Waterbody Information

State: Tennessee
Counties: Cocke, Jefferson, and Sevier
Watershed: Lower French Broad (HUC 06010107)
Constituents of Concern: Pathogens

Impaired Waterbodies Addressed in This Document:

Waterbody ID	Waterbody	Miles/Acres Impaired
TN06010107003 – 1000	BOYDS CREEK	15.4
TN06010107007 – 1000 & 2000	LITTLE PIGEON RIVER	5.9
TN06010107010 – 0100	GNATTY BRANCH	1.8
TN06010107010 – 0200	KING BRANCH	2.5
TN06010107010 – 0300	BEECH BRANCH	1.0
TN06010107010 – 0400	DUDLEY CREEK	5.7
TN06010107010 – 0500	ROARING FORK	1.5
TN06010107010 – 0600	BASKINS CREEK	1.3
TN06010107010 – 1000	WEST PRONG LITTLE PIGEON RIVER	8.1
TN06010107010 – 1300	HOLY BRANCH	1.0
TN06010107010 – 1800	MILL CREEK	5.9
TN06010107010 – 1900	WALDEN CREEK	2.6
TN06010107010 – 2000	WEST PRONG LITTLE PIGEON RIVER	5.7
TN06010107010 – 3000	WEST PRONG LITTLE PIGEON RIVER	5.4
TN06010107029T – 0400*	LEADVALE CREEK	4.4
TN06010107029T – 1100	CLEAR CREEK	3.3
TN06010107029T – 1150	CLEAR CREEK	13.6

*TMDL could not be developed for Leadvale Creek. No monitoring data was available. Additional monitoring is recommended to allow for either development of a TMDL or delisting.

Designated Uses:

The designated use classifications for these waterbodies include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. Portions of Little Pigeon River and West Prong Little Pigeon River are also designated for domestic and/or industrial water supply. Baskins Creek, Dudley Creek, and West Prong Little Pigeon River (from mile 4.5 to 19.0) are designated as trout streams. Roaring Fork and West Prong Little Pigeon River (above mile 19.0) are designated as naturally reproducing trout streams.

Water Quality Goal:

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

The concentration of the E. coli group shall not exceed 126 colony forming units per 100 mL, as a geometric mean based on a minimum of 5 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. For the purposes of determining the geometric mean, individual samples having an E. coli concentration of less than 1 per 100 mL shall be considered as having a concentration of 1 per 100 mL. 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.

Additionally, consistent with current TMDL methodology, standards from *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, October 1999* for recreation use classification:

> The concentration of a fecal coliform group shall not exceed 200 per 100 mL nor shall the concentration of the *E. coli* group exceed 126 per 100 mL, as a geometric mean based on a minimum of 10 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. For the purposes of determining the geometric mean, individual samples having a fecal coliform group or *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 fecal coliform group in any individual sample shall not exceed 1,000 per 100 mL.

TMDL Scope:

Waterbodies identified on the Final 2004 303(d) list as impaired due to E. coli. TMDLs are generally developed for impaired waterbodies on a HUC-12 basis. A TMDL could not be developed for Leadvale Creek due to lack of monitoring data (see Section 9.4).

Analysis/Methodology:

The TMDLs for impaired waterbodies in the French Broad watershed were developed using the load duration curve methodology to assure compliance with the E. Coli 126 counts/100 mL geometric mean and 941 counts/100 mL maximum standards while also incorporating the fecal coliform 200 counts/100 mL geometric mean and 1,000 counts/100 mL maximum concentration as surrogates. 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 portion of the waterbody flow regime represented by these existing loads. Load duration curves were used to determine the load reductions required to meet the target maximum concentrations for E. coli and fecal coliform (standard - MOS). When sufficient data were available, load reductions were also determined based on geometric mean criteria.

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.

Seasonal Variation:

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

Margin of Safety (MOS):

Explicit – 10% of the water quality standard for each impaired subwatershed.

Summary of TMDLs, WLAs, & LAs for Impaired Waterbodies

HUC-12 Subwatershed (06010107__) or Drainage Area	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	WLAs				LAs	
				WWTFs[a] (Monthly Avg.) E. Coli	Leaking Collection Systems[b]	CAFOs	MS4s[c]	Precipitation Induced Nonpoint Sources	Other Direct Sources[d]
			[% Red.]	[cts./day]	[cts./day]	[cts./day]	[% Red.]	[% Red.]	[cts./day]
0202	Boyds Creek	TN06010107003 – 1000	**14.2**	**8.584×10^{7}**	**0**	**NA**	**14.2**	**14.2**	**0**
0315	Little Pigeon River	TN06010107007 – 1000 & – 2000	**88.2**	**3.374×10^{10}**	**0**	**NA**	**88.2**	**88.2**	**0**
Gnatty (0307)	Gnatty Branch	TN06010107010 – 0100	**61.7**	**NA***	**NA**	**NA**	**61.7**	**61.7**	**0**
Kings (0307)	Kings Branch	TN06010107010 – 0200	**90.7**	**NA***	**NA**	**NA**	**90.7**	**90.7**	**0**
Beech (0307)	Beech Branch	TN06010107010 – 0300	**85.9**	**NA***	**NA**	**NA**	**85.9**	**85.9**	**0**
0311	Dudley Creek	TN06010107010 – 0400	**93.4**	**NA***	**NA**	**NA**	**93.4**	**93.4**	**0**
0310	Roaring Fork	TN06010107010 – 0500	**96.0**	**NA***	**NA**	**NA**	**96.0**	**96.0**	**0**
0309	Baskins Creek	TN06010107010 – 0600	**92.2**	**NA***	**NA**	**NA**	**92.2**	**92.2**	**0**
0313	West Prong Little Pigeon River	TN06010107010 – 1000	**72.0**	**3.374×10^{10}**	**0**	**NA**	**72.0**	**72.0**	**0**
Holy (0307)	Holy Branch	TN06010107010 – 1300	**91.6**	**NA***	**NA**	**NA**	**91.6**	**91.6**	**0**
0312	Mill Creek	TN06010107010 – 1800	**74.7**	**NA***	**NA**	**NA**	**74.7**	**74.7**	**0**
0312	Walden Creek	TN06010107010 – 1900	**88.5**	**3.577×10^{8}**	**0**	**NA**	**88.5**	**88.5**	**0**
WPLPR (0307)	West Prong Little Pigeon River	TN06010107010 – 2000	**51.9**	**1.431×10^{10}**	**0**	**NA**	**51.9**	**51.9**	**0**
WPLPR (0307)	West Prong Little Pigeon River	TN06010107010 – 3000	**68.4**	**1.431×10^{10}**	**0**	**NA**	**68.4**	**68.4**	**0**
0103	Clear Creek	TN06010107029T – 1100 & – 1150	**NA**	**NA***	**NA**	**NA**	**NA**	**>65.0**	**0**

Note: NA = Not Applicable.

* *Future WWTFs must meet instream water quality standards at the point of discharge as specified in their NPDES permit.*

a. *WLAs for WWTFs expressed as E. coli loads (counts/day).*

b. *The objective for leaking collection systems is a waste load allocation of zero. It is recognized, however, that a WLA of 0 counts/day may not be practical. For these sources, the WLA is interpreted to mean a reduction in coliform loading to the maximum extent practicable, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.*

c. *Applies to any MS4 discharge loading in the subwatershed.*

d. *The objective for all "other direct sources" is a load allocation of zero. It is recognized, however, that for leaking septic systems a LA of 0 counts/day may not be practical. For these sources, the LA is interpreted to mean a reduction in coliform loading by the application of best management practices, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.*

PROPOSED PATHOGEN TOTAL MAXIMUM DAILY LOAD (TMDL) LOWER FRENCH BROAD WATERSHED (HUC 06010107)

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 Lower French Broad watershed, identified on the Final 2004 303(d) list as not supporting designated uses due to E. coli and/or fecal coliform. TMDL analyses are performed primarily on a 12-digit hydrologic unit area (HUC-12) basis. In some cases, where appropriate, TMDLs are developed for an impaired waterbody drainage area only.

3.0 WATERSHED DESCRIPTION

The Lower French Broad watershed (HUC 06010107) is located in East Tennessee (Figure 1), primarily in Cocke, Jefferson, and Sevier Counties. The watershed lies within two Level III ecoregions (Blue Ridge Mountains, Ridge and Valley) and contains seven Level IV ecoregions as shown in Figure 2 (USEPA, 1997):

- **The Southern Sedimentary Ridges (66e)** in Tennessee include some of the westernmost foothill areas of the Blue Ridges Mountains ecoregion, such as the Bean, Starr, Chilhowee, English, Stone, Bald, and Iron Mountain areas. Slopes are steep, and elevations are generally 1000-4500 feet. The rocks are primarily Cambrian-age sedimentary (shale, sandstone, siltstone, quartzite, conglomerate), although some lower stream reachs occur on limestone. Soils are predominantly friable loams and fine sandy loams with variable amounts of sandstone rock fragments, and support mostly mixed oak and oak-pine forests.

- **Limestone Valleys and Coves (66f)** are small but distinct lowland areas of the Blue Ridge, with elevations mostly between 1500 and 2500 feet. About 450 million years ago, older Blue Ridge rocks to the east were forced up and over younger rocks to the west. In places, the Precambrian rocks have eroded through to Cambrian or Ordovician-age limestones, as seen especially in isolated, deep cove areas that are surrounded by steep mountains. The main areas of limestone include the Mountain City lowland area and Shady Valley in the north; and Wear Cove, Tuckaleechee Cove, and

Cades Cove of the Great Smoky Mountains in the south. Hay and pasture, with some tobacco patches on small farms, are typical land uses.

- **The Southern Metasedimentary Mountains (66g)** are steep, dissected, biologically-diverse mountains that include Clingmans Dome (6643 feet), the highest point in Tennessee. The Precambrian-age metamorphic and sedimentary geologic materials are generally older and more metamorphosed than the Southern Sedimentary Ridges (66e) to the west and north. The Appalachian oak forests and, at higher elevations, the northern hardwoods forests include a variety of oaks and pines, as well as silverbell, hemlock, yellow poplar, basswood, buckeye, yellow birch, and beech. Spruce-fir forests, found generally above 5500 feet, have been affected greatly over the past twenty-five years by the balsam woolly aphid. The Copper Basin, in the southeast corner of Tennessee, was the site of copper mining and smelting from the 1850's to 1987, and once left more than fifty square miles of eroded earth.

- **The Southern Limestone/Dolomite Valleys and Low Rolling Hills (67f)** form a heterogeneous region composed predominantly of limestone and cherty dolomite. Landforms are mostly low rolling ridges and valleys, and the solids vary in their productivity. Landcover includes intensive agriculture, urban and industrial, or areas of thick forest. White oak forests, bottomland oak forests, and sycamore-ash-elm riparian forests are the common forest types, and grassland barrens intermixed with cedar-pine glades also occur here.

- **The Southern Shale Valleys (67g)** consist of lowlands, rolling valleys, and slopes and hilly areas that are dominated by shale materials. The northern areas are associated with Ordovician-age calcareous shale, and the well-drained soils are often slightly acid to neutral. In the south, the shale valleys are associated with Cambrian-age shales that contain some narrow bands of limestone, but the soils tend to be strongly acid. Small farms and rural residences subdivide the land. The steeper slopes are used for pasture or have reverted to brush and forested land, while small fields of hay, corn , tobacco, and garden crops are grown on the foot slopes and bottomland.

- **The Southern Sandstone Ridges (67h)** ecoregion encompasses the major sandstone ridges, but these ridges also have areas of shale and siltstone. The steep, forested chemistry of streams flowing down the ridges can vary greatly depending on the geologic material. The higher elevation ridges are in the north, including Wallen Ridge, Powell Mountain, Clinch Mountain, and Bays Mountain. White Oak Mountain in the south has some sandstone on the west side, but abundant shale and limestone as well. Grindstone Mountain, capped by the Gizzard Group sandstone, is the only remnant of Pennsylvanian-age strata in the Ridge and Valley of Tennessee.

- **The Southern Dissected Ridges and Knobs (67i)** contain more crenulated, broken, or hummocky ridges, compared to smoother, more sharply pointed sandstone ridges. Although shale is common, there is a mixture and interbedding of geologic materials. The ridges on the east side of Tennessee's Ridge and Valley tend to be associated with the Ordovician-age Sevier shale, Athens shale, and Holston and Lenoir limestones. These can include calcareous shale, limestone, siltstone, sandstone, and conglomerate. In the central and western part of the ecoregion, the shale ridges are associated with the Cambrian-age Rome Formation: shale and siltstone with beds of sandstone. Chestnut oak forests and pine forests are typical for the higher elevations of the ridges, with areas of white oak, mixed mesophytic forest, and tulip poplar on the lower slopes, knobs, and draws.

The Lower French Broad watershed, located in Cocke, Jefferson, and Sevier Counties, Tennessee, has a drainage area of approximately 800 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 Lower French Broad watershed have occurred since 1993 as a result of development, this is the most current land use data available. Land use for the Lower French Broad watershed is summarized in Table 1 and shown in Figure 3. Predominant land use in the Lower French Broad watershed is forest (73.6%) followed by agriculture (19.0%). Urban areas represent approximately 1.8% of the total drainage area of the watershed. Details of land use distribution of impaired subwatersheds in the Lower French Broad watershed are presented in Appendix A.

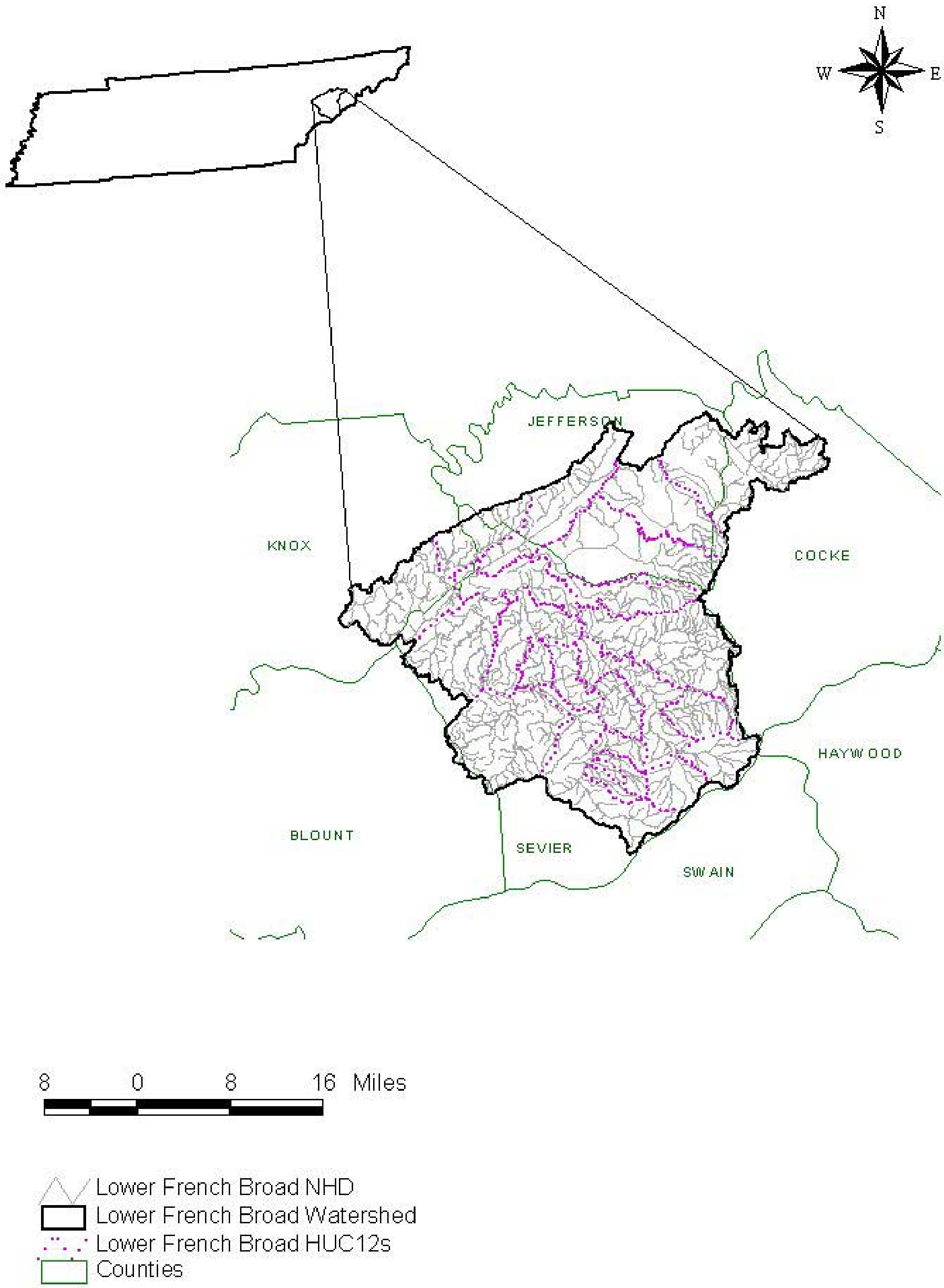

Figure 1. Location of the Lower French Broad Watershed.

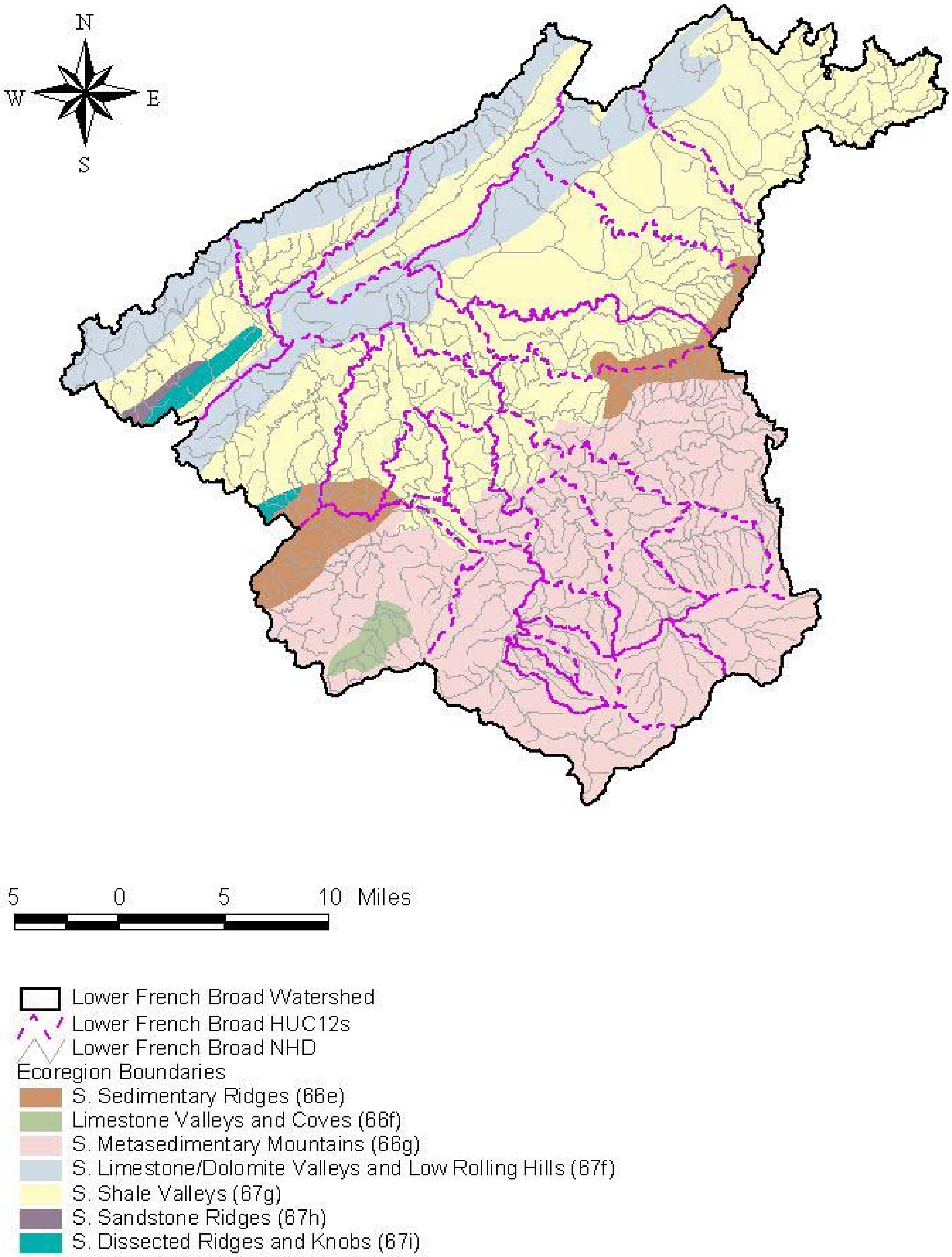

Figure 2. Level IV Ecoregions in the Lower French Broad Watershed.

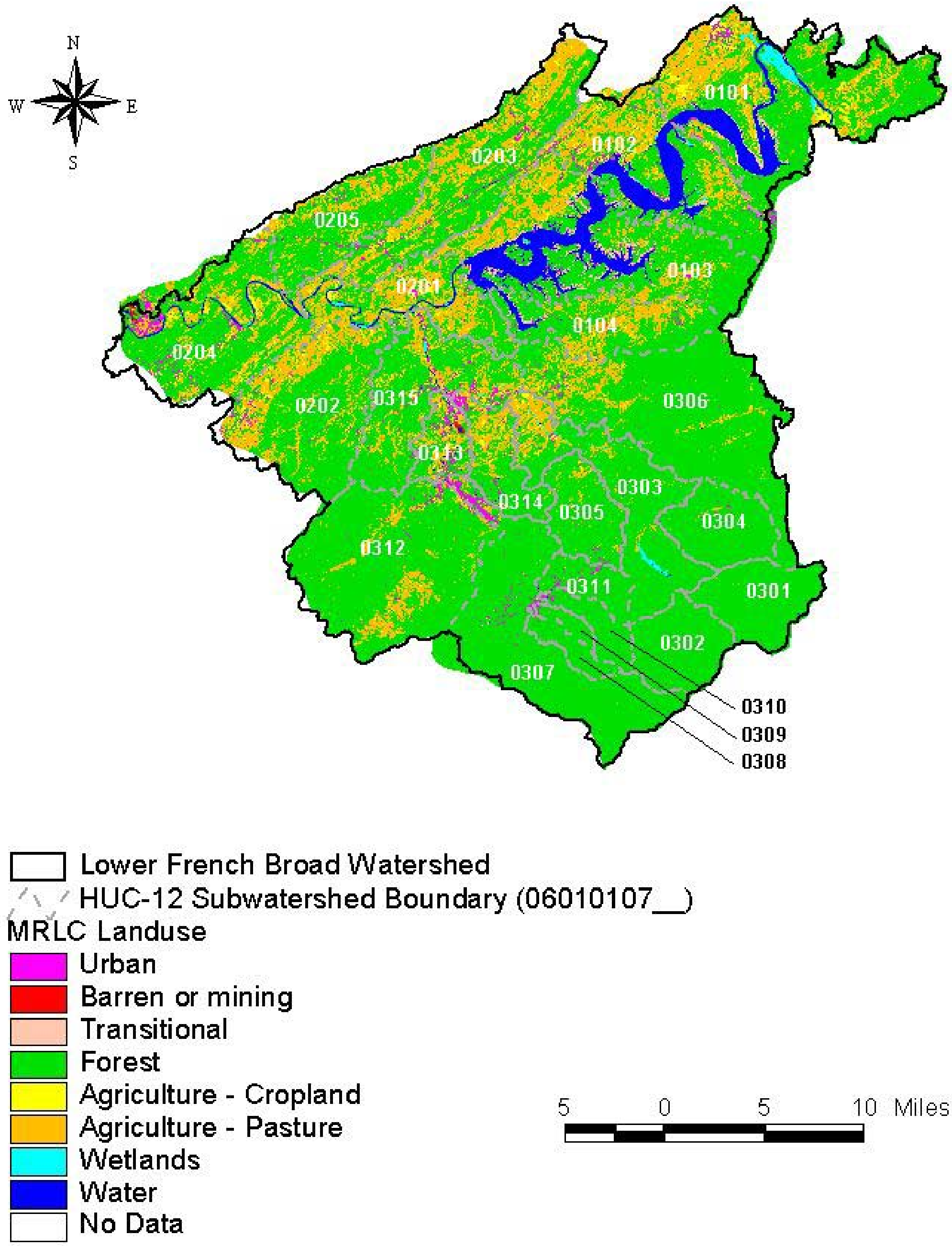

Figure 3. Land Use Characteristics of the Lower French Broad Wwatershed.

Table 1. MRLC Land Use Distribution – Lower French Broad Watershed

Land Use	Area	
	[acres]	[%]
Bare Rock/Sand/Clay	12	0.0
Deciduous Forest	159,157	31.1
Emergent Herbaceous Wetlands	562	0.1
Evergreen Forest	105,791	20.7
High Intensity Commercial/Industrial/ Transportation	5,161	8.1
High Intensity Residential	456	0.1
Low Intensity Residential	3,435	0.7
Mixed Forest	111,642	21.8
Open Water	20,627	4.0
Other Grasses (Urban/recreational)	2,642	0.5
Pasture/Hay	84,907	16.6
Quarries/Strip Mines/ Gravel Pits	203	0.0
Row Crops	12,246	2.4
Transitional	3,664	0.7
Woody Wetlands	1,352	0.3
Total	**511,857**	**100.00**

4.0 PROBLEM DEFINITION

The State of Tennessee's final 2004 303(d) list (TDEC, 2004a) was approved by the U.S. Environmental Protection Agency (EPA), Region IV in August of 2005. This list identified eighteen waterbody segments in the Lower French Broad watershed as not fully supporting designated use classifications due to E. coli (see Table 2). The designated use classifications for these waterbodies include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. Portions of Little Pigeon River and West Prong Little Pigeon River are also designated for domestic and/or industrial water supply. Baskins Creek, Dudley Creek, and West Prong Little Pigeon River (from mile 4.5 to 19.0) are designated as trout streams. Roaring Fork and West Prong Little Pigeon River (above mile 19.0) are designated as naturally reproducing trout streams.

When used in the context of waterbody assessments, the term pathogens is defined as disease-causing organisms such as bacteria or viruses that can pose an immediate and serious health threat if ingested or introduced into the body. The primary sources for pathogens are untreated or inadequately treated human or animal fecal matter. The fecal coliform and E. coli groups are indicators of the presence of pathogens in a stream.

The waterbody segments listed in Table 2 were assessed as impaired based on sampling data and/or biological surveys. The results of these assessment surveys are summarized in Table 3 and shown in Figure 4. The assessment information presented is excerpted from the EPA/TDEC Assessment Database (ADB) and is referenced to the waterbody ID in Table 2. ADB information may be accessed at:

http://gwidc.memphis.edu/website/wpc_arcmap

5.0 WATER QUALITY GOAL

As previously stated, the designated use classifications for the Lower French Broad waterbodies include fish & aquatic life, recreation, irrigation, and livestock watering & wildlife. Of the use classifications with numeric criteria for pathogens, 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, 2004b). Section 1200-4-3-.03 (4) (f) states:

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

Portions of the Little Pigeon River and West Prong Little Pigeon River located within the Great Smoky Mountains National Park are classified as Tier III. However, none of the impaired waterbodies in the Lower French Broad Watershed have been classified as either Tier II or Tier III streams.

Prior to January 2004, the coliform water quality criteria, for protection of the recreation use classification, established by *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, October 1999* (TDEC, 1999), Section 1200-4-3-.03 (4) (f) states:

> The concentration of a fecal coliform group shall not exceed 200 per 100 mL, nor shall the concentration of the *E. coli* group exceed 126 per 100 mL, as a geometric mean based on a minimum of 10 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. For the purposes of determining the geometric mean, individual samples having a fecal coliform group or *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 fecal coliform group in any individual sample shall not exceed 1,000 per 100 mL.

In addition to utilizing the E. coli water quality standards (with MOS) as the target, this TMDL utilizes a fecal coliform target as a surrogate for determining the attainment of the E. coli standard because of the demonstrated high correlation between E. coli and fecal coliform in this watershed. In the state of Tennessee, E. coli and fecal coliform are well correlated (R = 0.902) when evaluating all available ecoregion data (623 observations).

Therefore, this TMDL employs both the E. coli water quality standard and the surrogate fecal coliform criteria by determining the amount of load reduction required to comply with each of four criteria: 1) the geometric mean standard for E. coli of 126 counts/100mL, 2) the E. coli sample maximum of 941 counts/100 mL, 3) the geometric mean for fecal coliform of 200 counts/100 mL, and 4) the fecal coliform sample maximum of 1,000 counts/100 mL. The fecal coliform surrogate is most frequently used when insufficient monitoring data is available for E. coli or when analysis of E. coli monitoring data suggests that a listed segment is not impaired. The most protective (or highest percent of load reduction) of the four criteria will determine the percent reduction(s) required for impaired waterbodies. The analysis of fecal coliform data is only part of the methodology and is not included to comply with current water quality standards.

Note: In this document, the water quality standards are the instream goals. The term "target concentration" reflects the application of an explicit Margin of Safety (MOS) to the water quality standard. See Section 8.4 for an explanation of MOS.

Table 2. Final 2004 303(d) List for E. coli Impaired Waterbodies – Lower French Broad Watershed

Waterbody ID	Impacted Waterbody	RM Partially Supporting	RM Not Supporting	Cause (Pollutant)	Pollutant Source
TN06010107003 – 1000	BOYDS CREEK	15.4		Escherichia coli	Pasture Grazing
TN06010107007 – 1000 & 2000	LITTLE PIGEON RIVER		5.9	Escherichia coli	Septic Tanks Collection System Failure
TN06010107010 – 0100	GNATTY BRANCH		1.8	Escherichia coli	Septic Tanks
TN06010107010 – 0200	KINGS BRANCH		2.5	Escherichia coli	Septic Tanks
TN06010107010 – 0300	BEECH BRANCH		1.0	Escherichia coli	Septic Tanks
TN06010107010 – 0400	DUDLEY CREEK		5.7	Escherichia coli	Septic Tanks
TN06010107010 – 0500	ROARING FORK		1.5	Escherichia coli	Collection System Failure
TN06010107010 – 0600	BASKINS CREEK		1.3	Escherichia coli	Collection System Failure
TN06010107010 – 1000	WEST PRONG LITTLE PIGEON RIVER		8.1	Escherichia coli Siltation	Septic Tanks Collection System Failure Land Development Channelization

Table 2 (cont'd). Final 2004 303(d) List for E. coli Impaired Waterbodies – Lower French Broad Watershed

Waterbody ID	Impacted Waterbody	RM Partially Supporting	RM Not Supporting	Cause (Pollutant)	Pollutant Source
TN06010107010 – 1300	HOLY BRANCH		1.0	Escherichia coli	Collection System Failure
TN06010107010 – 1800	MILL CREEK	5.9		Other Habitat Alterations Escherichia coli	Collection System Failure Channelization
TN06010107010 – 1900	WALDEN CREEK	2.6		Siltation Escherichia coli	Pasture Grazing Land Development Septic Tanks
TN06010107010 – 2000	WEST PRONG LITTLE PIGEON RIVER		5.7	Unknown toxicity Escherichia coli	Septic Tanks Collection System Failure Urban Runoff/Storm Sewers
TN06010107010 –3000	WEST PRONG LITTLE PIGEON RIVER		5.4	Escherichia coli	Septic Tanks Collection System Failure
TN06010107029T – 0400	LEADVALE CREEK		4.4	Escherichia coli	Pasture Grazing
TN06010107029T – 1100	CLEAR CREEK	3.3		Escherichia coli	Pasture Grazing
TN06010107029T – 1150	CLEAR CREEK	13.6		Nutrients Escherichia coli	Pasture Grazing

Table 3. Water Quality Assessment of Waterbodies Impaired Due to E. coli - Lower French Broad Watershed

Waterbody ID	Segment Name	Comments
TN06010107003 – 1000	BOYDS CREEK	2001 TDEC biorecon at RM3.7 (Knob Creek Rd), 10 EPT, 7 intolerant, 35 total genera. Habitat score = 119. G.M. 267 E.coli. 2001 TVA survey at Wisons (?), 7 EPT, 3 intolerant, 18 total families. Passed biorecon criteria.
TN06010107007 – 1000	LITTLE PIGEON RIVER	2001 TDEC biorecon d/s Sanders Island, 20 EPT, 7 intolerant, 50 total genera. Habitat score = 152. Water contact advisory due to pathogens. TDEC pathogen monitoring station at Hwy 338. 2001 TVA survey at Cattletsburg, 14 EPT, 32 total families.
TN06010107007 – 2000	LITTLE PIGEON RIVER	Water contact advisory (pathogens). TDEC bacteriological monitoring station at Hwy 338. 2001 TDEC biorecon at gaging station, 20 EPT, 7 intolerant, 41 total genera. Habitat score = 111. Stream channelized through & below Sevierville.
TN06010107010 – 0100	GNATTY BRANCH	Water contact advisory. TDEC bacteriological monitoring station at mouth.
TN06010107010 – 0200	KINGS BRANCH	Water contact advisory. TDEC bacteriological monitoring station near mouth. G.M. 1954 E.coli.
TN06010107010 – 0300	BEECH BRANCH	Water contact advisory. TDEC bacteriological monitoring station near mouth. G.M. 179 E.coli.
TN06010107010 – 0400	DUDLEY CREEK	Water contact advisory. 2001 TDEC biorecon d/s Hwy 321, 13 EPT, 9 intolerant, 36 total genera. Habitat score = 152. TDEC bacteriological monitoring station at mouth. G.M. 113 E.coli.
TN06010107010 – 0500	ROARING FORK	Water contact advisory. Monitored by Gatlinburg.
TN06010107010 – 0600	BASKINS CREEK	Water contact advisory. Monitored by Gatlinburg.
TN06010107010 – 1000	WEST PRONG LITTLE PIGEON RIVER	Water contact advisory. 2001 TDEC biorecon at Sevierville City Park, 11 EPT, 2 intolerant, 34 total genera. Habitat score = 149. TDEC bacteriological monitoring station near Apple Barn. G.M. 152 E.coli.
TN06010107010 – 1300	HOLY BRANCH	Water contact advisory. TDEC bacteriological monitoring station at mouth.

Table 3 (cont'd). Water Quality Assessment of Waterbodies Impaired Due to E. coli - Lower French Broad Watershed

Waterbody ID	Segment Name	Comments
TN06010107010 – 1800	MILL CREEK	2001 TDEC biorecon at City Park, 13 EPT, 4 intolerant, 35 total genera. Habitat score = 106. Channelized. Did not pass biorecon criteria. TDEC bacteriological monitoring station near mouth. G.M. 203 E.coli.
TN06010107010 – 1900	WALDEN CREEK	2001 TDEC biorecon at Tiger Road, 13 EPT, 4 intolernat, 33 total genera. Habitat score = 119. TDEC bacteriological monitoring station near mouth. G.M. 264 E.coli.
TN06010107010 – 2000	WEST PRONG LITTLE PIGEON RIVER	Water contact advisory. 2001 TDEC biorecon u/s Waldens Cr., 9 EPT, 3 intolerant, 34 total genera. Habitat score = 146. 1997 TWRA survey at RM8.5, 12 EPT, 29 total genera. 2001 TVA survey at Buzzard Ridge Rd., 8 EPT, 20 total families.
TN06010107010 – 3000	WEST PRONG LITTLE PIGEON RIVER	Pathogen advisory. 2001 TDEC biorecon at u/s Pigeon Forge, 17 EPT, 5 intolerant, 37 total genera. Habitat score = 157. TDEC bacteriological station at Gatlinburg Visitors' Ctr. G.M. 47 E.coli. Nat. Reproducing trout stream.
TN06010107029T – 0400	LEADVALE CREEK	Water contact advisory. No new data to update assessment.
TN06010107029T – 1100	CLEAR CREEK	2001 TDEC biorecon at RM1.6 (Hwy 92), 8 EPT, 3 intolerant, 37 total genera. Habitat score = 126. Meets biorecon protocol. G.M. 924 E.coli at Rainwater School Rd.
TN06010107029T – 1150	CLEAR CREEK	TDEC G.M. 924 E.coli at Rainwater School Rd. 1997 TWRA survey at Rainwater Rd., 6 EPT, 19 total genera. Fish IBI score = 34, number of native fish species – 7.

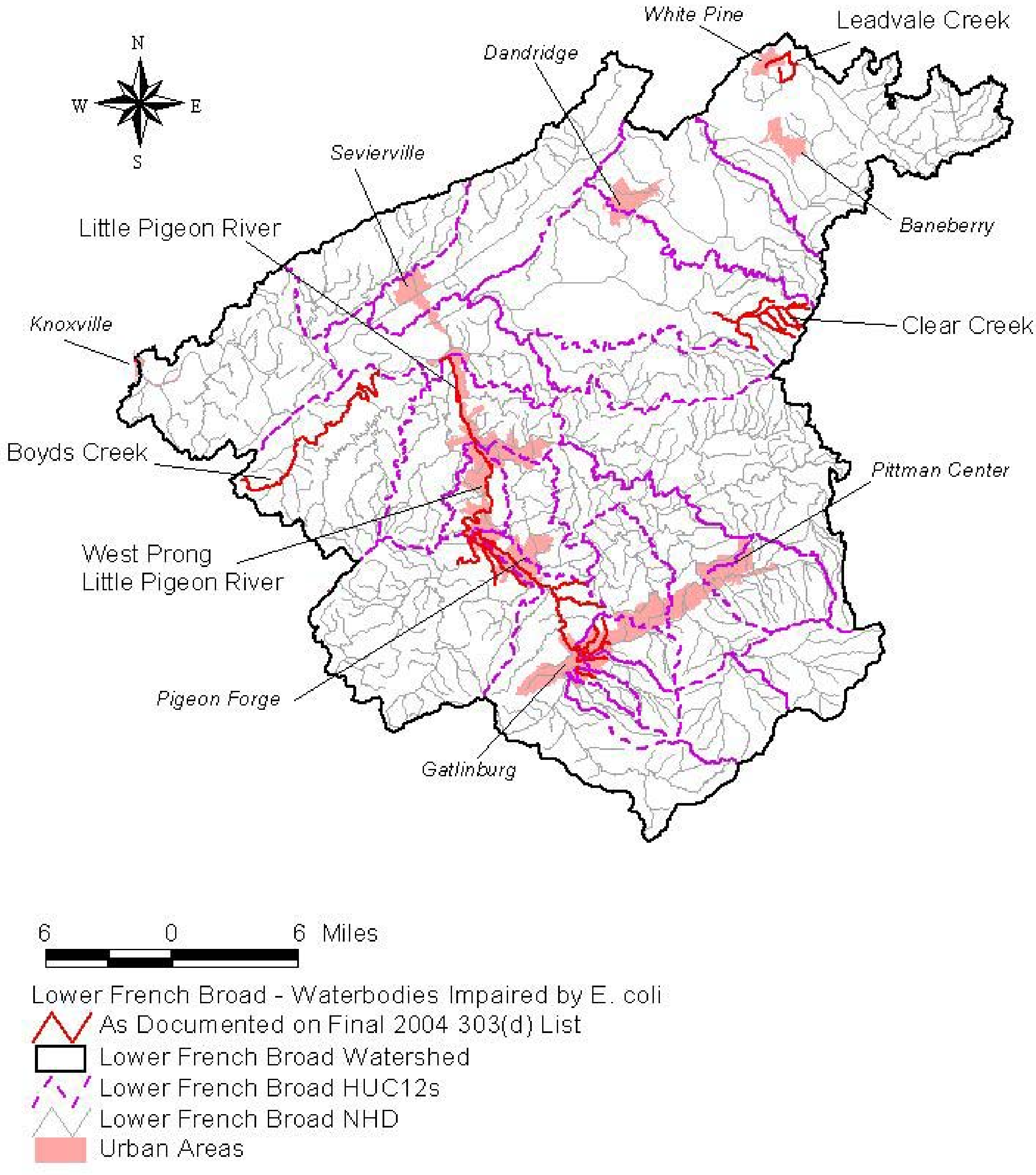

Figure 4. Waterbodies Impaired by E. coli (as documented on the Final 2004 303(d) List).

6.0 WATER QUALITY ASSESSMENT AND DEVIATION FROM GOAL

There are numerous water quality monitoring stations that provide data for waterbodies identified as impaired for pathogens in the Lower French Broad watershed:

- Boyds Creek Subwatershed:
  - BOYDS003.7SV – Boyds Creek at Knob Creek Rd bridge, just upstream of confluence with Knob Creek
- Clear Creek Subwatershed:
  - CLEAR002.7JE – Clear Creek at Rainwater School R BRE, downstream of Chestnut Hill
- Leadvale Creek Subwatershed:
  - No monitoring stations in Leadvale Creek Subwatershed
- Little Pigeon River Subwatershed:
  - LPR-RM0.8 – Little Pigeon River at Hwy 338 Bridge
- West Prong Little Pigeon River Subwatershed:
  - WPLPR-RM1.2 – West Prong Little Pigeon River, at intersection of Hwy 441 and Hwy 66 (Kentucky Fried Chicken)
  - WPLPR-RM4.6 – West Prong Little Pigeon River at lower city limits, Pigeon Forge (Apple Barn Restaurant)
  - WPLPR-RM12.4 – West Prong Little Pigeon River at upper city limits, Pigeon Forge (Pancake House Restaurant)
  - WPLPR-RM16.0 – West Prong Little Pigeon River at Gatlinburg Visitors Center
  - WPLPR-RM17.2 – West Prong Little Pigeon River at North Gatlinburg Park (Holt Park)
  - WPLPR-RM20.6 – West Prong Little Pigeon River at GSM National Park Headquarters
- Baskins Creek Subwatershed:
  - BASKIN – Baskins Creek, 25 ft. upstream of Parkway, adjacent to 1st foot bridge
- Beech Branch Subwatershed:
  - BEECH – Beech Branch, 90 ft. upstream of Hwy 441, intersection of Beech Branch Rd. and Hwy 441
- Dudley Creek Subwatershed:
  - DUDLEY – Dudley Creek at North Gatlinburg Park (Holt Park), 20 ft. upstream of Dudley Rd. bridge
- Gnatty Branch Subwatershed:
  - GNATTY – Gnatty Branch above confluence with West Prong Little Pigeon River, intersection of Gnatty Branch Rd. and Hwy 441

- Holy Branch Subwatershed:
  - HOLY – Holy Branch, discharge from pipe at confluence with West Prong Little Pigeon River
- Kings Branch Subwatershed:
  - KINGS – Kings Branch, 500 ft. above confluence with West Prong Little Pigeon River, 20 ft. on east side of 1st culvert of Kings Branch Rd., at Kings Branch Rd. and Hwy 441
- Mill Creek Subwatershed:
  - MILL – Mill Creek, 30 yds upstream of West Prong Little Pigeon River, at Pigeon Forge City Park
- Roaring Fork Subwatershed:
  - ROAR – Roaring Fork, 500 ft. upstream of Parkway, adjacent to Zoder Inn benches
- Waldens Creek Subwatershed:
  - WALDEN – Waldens Creek, 50 yds upstream of West Prong Little Pigeon River, at Pigeon Forge City Park

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 violations of the 941 counts/100 mL maximum E. coli standard and the 1,000 counts/100 mL maximum fecal coliform criterion at many monitoring stations. Water quality monitoring results for those stations with 10% of samples in violation of water quality standards are summarized in Table 4.

There were not enough data to calculate the geometric mean at each monitoring station. 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.

Insufficient monitoring data were available to develop a load reduction for Leadvale Creek (see Section 9.4 for discussion of monitoring requirements). All other waterbodies listed on the Final 2004 303(d) List are provided a TMDL for pathogen loading.

Note that the three impaired segments of West Prong Little Pigeon River are represented by five water quality monitoring stations. The monitoring stations at miles 1.2 and 4.6 are located in segment –1000 (Little Pigeon River to Walden Creek). The monitoring station at mile 12.4 is located in segment –2000 (Walden Creek to Caney Creek). The monitoring stations at miles 16.0 and 17.2 are located in segment –3000 (Caney Creek to Roaring Fork). The monitoring station at mile 20.6 is actually located upstream of segment –3000, in an unimpaired segment.

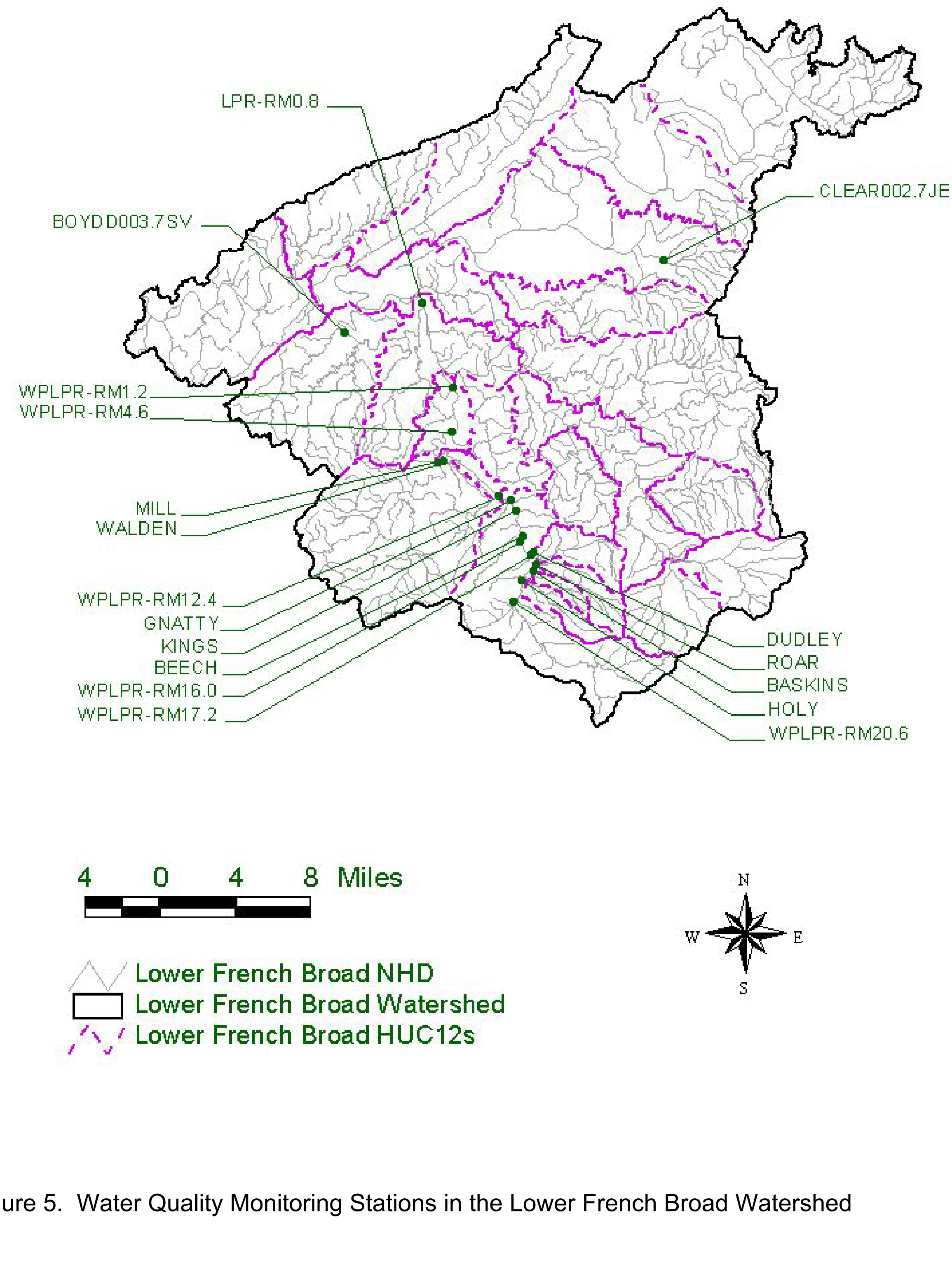

Figure 5. Water Quality Monitoring Stations in the Lower French Broad Watershed

Table 4. Summary of Water Quality Monitoring Data

Monitoring Station	Monitoring Dates	E. Coli						Fecal Coliform					
		Data Pts.	[Counts/100 mL]			No. Viol. WQ Crit.	Percent Viol. WQ Crit.	Data Pts.	[Counts/100 mL]			No. Viol. WQ Crit.	Percent Viol. WQ Crit.
			Min.	Avg.	Max.				Min.	Avg.	Max.		
BOYDS003.7SV	2001	10	93	382	1046	2	20.0%	0					
CLEAR002.7JE	2001	10	488	>1749	>2419	7	70.0%	0					
LPR-RM0.8	1992-1999	26	11	346	2419	2	7.7%	64	12	776	5,800	13	20.3%
WPLPR-RM1.2	1992-1994	0						38	35	1,482	17,000	6	15.8%
WPLPR-RM4.6	1992-1999	26	9	299	1733	2	7.7%	74	31	886	5,800	19	25.7%
WPLPR-RM12.4	1992-1999	40	1	>425	>2419	7	17.5%	88	14	773	12,300	12	13.6%
WPLPR-RM16.0	1992-1999	26	3	203	1,986	2	7.7%	46	36	1,086	15,400	6	13.0%
WPLPR-RM17.2	1993-1999	40	<1	>419	>2419	5	12.5%	79	10	943	8,400	16	20.3%
BASKINS	1992 - 1994	0						12	130	2,499	12,000	3	25.0%
BEECH	1992 - 1999	14	9	>670	>2419	3	21.4%	25	6	2,635	26,500	8	32.0%
DUDLEY	1992 - 1999	14	4	>916	>2419	4	28.6%	25	12	12,071	225,000	10	40.0%
GNATTY	1992 - 1999	14	1	>445	>2419	2	14.3%	25	2	1,455	10,200	6	24.0%
HOLY	1992	0						10	380	3,376	13,400	4	40.0%
KINGS	1992 - 1999	14	1553	>2326	>2419	14	100.0%	25	150	8,279	69,000	19	76.0%
MILL	1993 - 1999	26	7	>515	>2419	3	11.5%	38	62	906	9,900	8	21.1%
ROAR	1992 - 1994	0						22	100	2,655	8,700	15	68.2%
WALDEN	1993 - 1999	26	19	559	2,419	2	7.7%	38	56	876	7,700	12	31.6%

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, 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 regulates point source discharges. Point sources can be described by three broad categories: 1) NPDES regulated municipal and industrial wastewater treatment facilities (WWTFs); 2) NPDES regulated industrial and municipal storm water discharges; and 3) NPDES regulated Concentrated Animal Feeding Operations (CAFOs). 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 wastewaters contain coliform bacteria. There are 14 NPDES permitted WWTFs that require monitoring of fecal coliform and/or E. coli within the Lower French Broad watershed. The fecal coliform and E. coli permit limits for discharges from these WWTFs are in accordance with the criteria specified in the 1999 and 2004 State of Tennessee water quality standards (TDEC, 1999 and TDEC, 2004b, respectively) (ref.: Section 5.0).

Four of these facilities are located in impaired subwatersheds of the Lower French Broad watershed. The Gatlinburg Sewage Treatment Plant (STP) (TN0020117), with a design capacity of 3 MGD, discharges to the West Prong Little Pigeon River at mile 16.4. Discharges only occur between December 1st and April 30th. The Pigeon Forge STP (TN0021237), with a design capacity of 4 MGD, discharges to the West Prong Little Pigeon River at mile 7.7. The Harrison Chilhowee Baptist Academy (TN0022748), with a design capacity of 0.018 MGD, discharges to an unnamed tributary of Boyds Creek. The Cloisters in Shagbark (TN0061611), with a design capacity of 0.075 MGD, discharges to Clear Fork prior to its confluence with Walden Creek. The Gatlinburg and Pigeon Forge STPs have had numerous problems with collection system overflows, as has the Sevierville (McCrowkey Island) STP (TN0063959) which discharges directly to the French Broad River. These overflow problems can be a significant contributor to pathogen impairment in the watershed.

7.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

Municipal Separate Storm Sewer Systems (MS4s) are considered to be point sources of pathogens. Discharges from MS4s occur in response to storm events through road drainage systems, curb and gutter systems, ditches, and storm drains. Large and medium MS4s serving populations greater than 100,000 people are required to obtain NPDES storm water permits. At present, there are no MS4s of this size having any jurisdiction in the Lower French Broad Watershed. As of March 2003, small MS4s serving urbanized areas, or having the potential to exceed instream water quality standards, are required to obtain a permit under the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (TDEC, 2002). An urbanized area is defined as an entity with a residential population of at least 50,000 people and an overall population density of at least 1,000 people per square mile. Under the General Permit, an annual report must be submitted to the Director of TDEC Water Pollution Control Division.

Six permittees are covered under Phase II of the NPDES Storm Water Program (Figure 6). The six permitted MS4s in the Lower French Broad watershed are as follows:

NPDES Permit Number	Phase	Permittee Name	Issuance Date	Effective Date	Expiration Date
TNS075116	II	Blount County	10/17/03	10/20/03	2/26/08
TNS075329	II	City of Gatlinburg	10/30/03	10/30/03	2/26/08
TNS075485	II	City of Pigeon Forge	3/8/04	9/22/03	2/26/08
TNS075523	II	City of Sevierville	3/8/04	9/22/03	2/26/08
TNS075582	II	Knox County	10/2/03	10/2/03	2/26/08
TNS075655	II	Sevier County	3/8/04	9/30/03	2/26/08

The Tennessee Department of Transportation (TDOT) is also being issued MS4 permits for State roads in urban areas. Information regarding storm water permitting in Tennessee may be obtained from the TDEC website at http://www.state.tn.us/environment/wpc/stormh2o/.

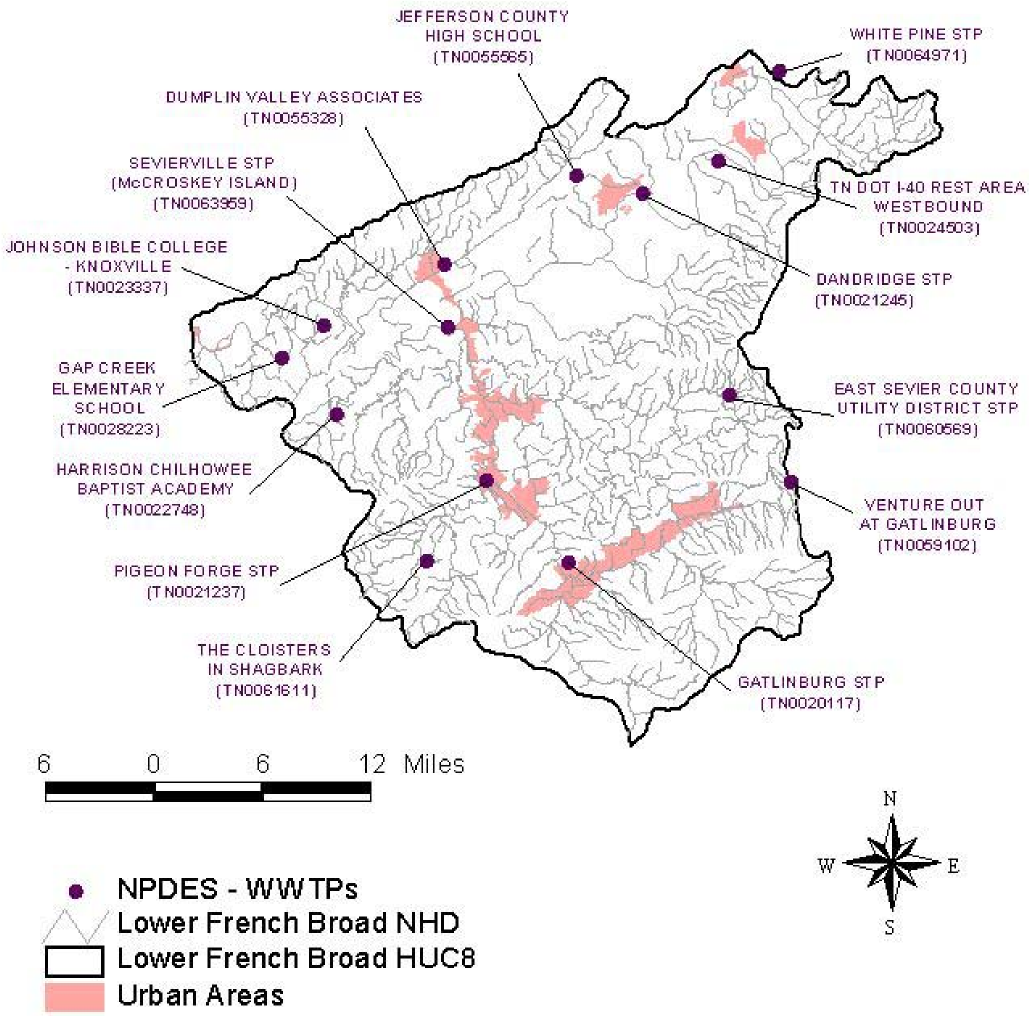

Figure 6. NPDES Regulated Point Sources in and near the Lower French Broad Watershed.

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*, while larger, Class I CAFOs are required to obtain an individual NPDES permit.

As of May 11, 2005, there are no Class II CAFOs in the Lower French Broad watershed with coverage under the general NPDES permit. There are also no Class I CAFOs with individual permits located in the watershed.

7.2 Nonpoint Sources

Nonpoint sources of coliform bacteria are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. These sources generally, but not always, involve accumulation of coliform bacteria on land surfaces and wash off as a result of storm events. Nonpoint sources of pathogen loading are primarily associated with agricultural and urban land uses. The majority of waterbodies identified on the Final 2004 303(d) list as impaired due to E. coli are attributed to nonpoint sources, such as improper connections to storm sewers, leaking sewers, failing septic tanks, and pasture grazing.

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. Fecal coliform loads due to deer are estimated by EPA to be 5.0×10^8 counts/animal/day.

Table 5. Livestock Distribution in the Lower French Broad Watershed

Subwatershed	Livestock Population (WCS)					
	Beef Cow	Milk Cow	Poultry	Hogs	Sheep	Horse
Boyds Creek	284	0	44,634	0	0	522
Clear Creek	387	45	45,247	0	0	14
Leadvale Creek	210	24	24,455	0	0	0
LPR	6,173	115	978,381	248	147	1,294
WPLPR-RM1.2	2,246	54	381,862	98	58	371
WPLPR-RM4.6	2,143	52	365,420	94	56	305
WPLPR-RM12.4	995	25	191,492	48	28	0
WPLPR-RM16.0	973	21	155,724	39	23	0
WPLPR-RM17.2	797	0	127,593	32	0	0
Baskins Creek	43	0	6,936	0	0	0
Beech Branch	0	0	1,790	0	0	0
Dudley Creek	144	0	23,069	0	0	0
Gnatty Branch	0	0	2,351	0	0	0
Holy Branch	0	0	1,453	0	0	0
Kings Branch	27	0	4,262	0	0	0
Mill Creek	214	0	34,048	0	0	29
Roaring Fork	116	0	18,602	0	0	0
Walden Creek	838	2,132	124,393	33	21	227

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.

Potential data sources related to livestock operations include the 2002 Census of Agriculture, which was compiled for the Lower French Broad Watershed utilizing the Watershed Characterization System (WCS). WCS is an Arcview geographic information system (GIS) based program developed by USEPA Region IV to facilitate watershed characterization and TMDL development. Livestock information provided in WCS is based on the ratio of watershed pasture area to county pasture area applied to the livestock population within the county. Livestock data for E. coli-impaired watersheds are summarized in Table 5. Populations were rounded to the nearest 25 cows, 50 poultry, and 5 hogs, sheep, and horses.

7.2.3 Failing Septic Systems

Some coliform loading in the Lower French Broad 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 Lower French Broad watershed utilizing septic systems were compiled using the WCS and are summarized in Table 6. In east Tennessee, it is estimated that there are approximately 2.37 people per household on septic systems, some of which can be reasonably assumed to be failing. As with livestock in streams, discharges of raw sewage provide a concentrated source of coliform bacteria directly to waterbodies.

Table 6. Population on Septic Systems in the Lower French Broad Watershed

Subwatershed	Population on Septic Systems	Subwatershed	Population on Septic Systems
Boyds Creek	1171	Baskins Creek	198
Clear Creek	769	Beech Branch	46
Leadvale Creek	468	Dudley Creek	737
Little Pigeon	26,641	Gnatty Branch	60
WPLPR- RM1.2	10,889	Holy Branch	64
WPLPR- RM4.6	10,343	Kings Branch	109
WPLPR-RM12.4	5,280	Mill Creek	941
WPLPR-RM16.0	4,358	Roaring Fork	513
WPLPR-RM17.2	3,444	Walden Creek	3,523

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. Leadvale Creek has the highest percentage of urban land area for impaired waterbodies in the Lower French Broad watershed, with 12.5%. Land use for the Lower French Broad impaired drainage areas is summarized in Figures 7 thru 12 and tabulated in Appendix A.

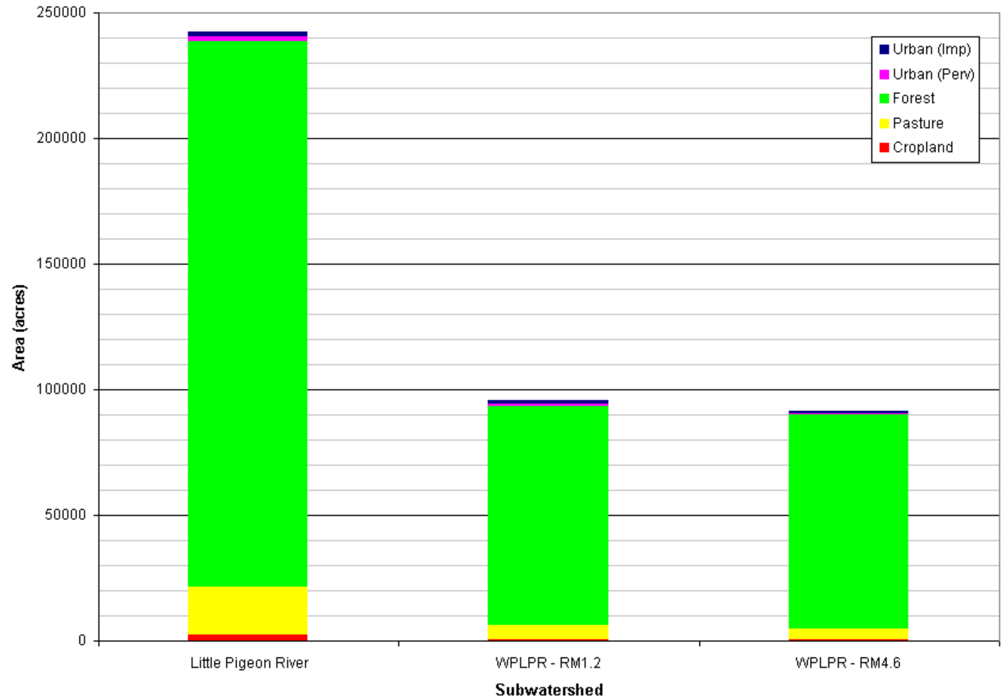

Figure 7. Land Use Area of Lower French Broad Pathogen-Impaired Subwatersheds – Drainage Areas Greater Than 50,000 Acres.

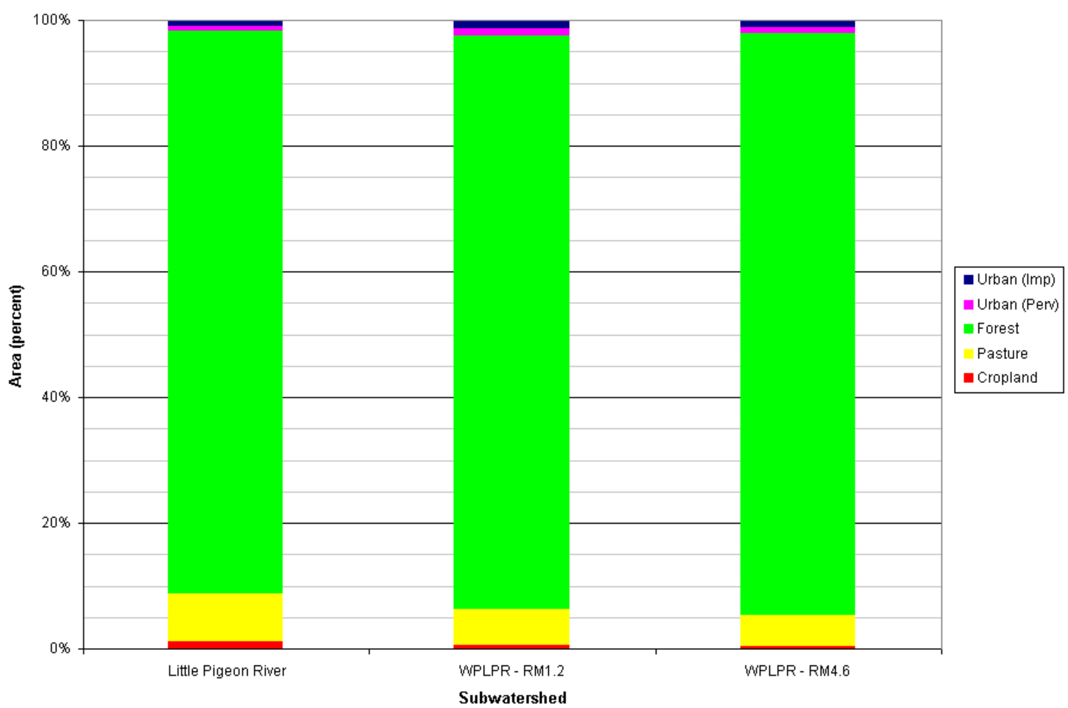

Figure 8. Land Use Percent of Lower French Broad Pathogen-Impaired Subwatersheds – Drainage Areas Greater Than 50,000 Acres.

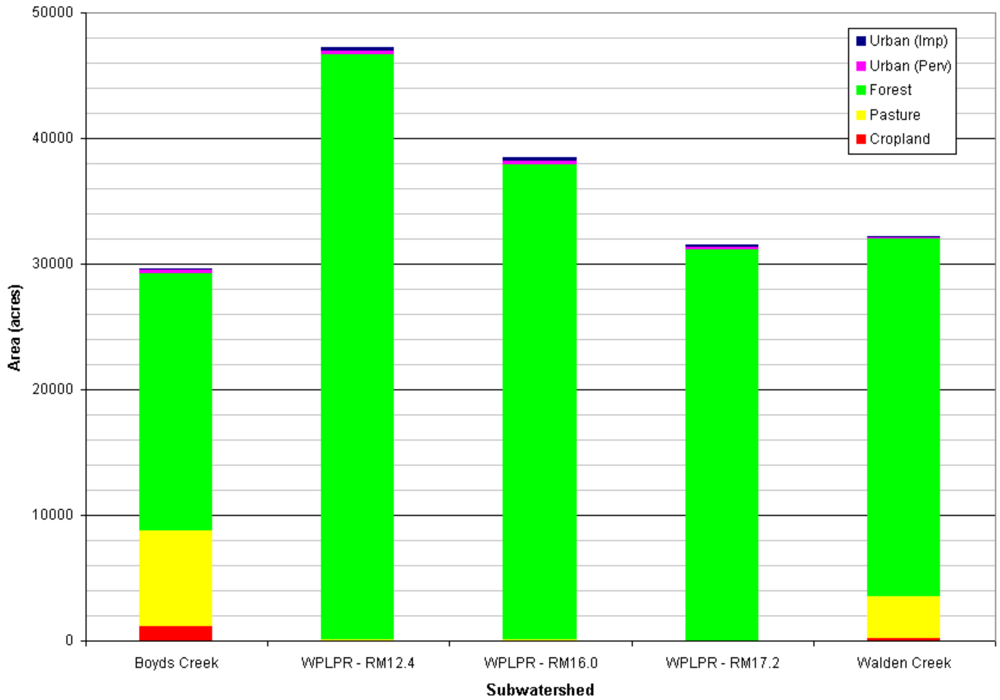

Figure 9. Land Use Area of Lower French Broad Pathogen-Impaired Subwatersheds – Drainage Areas Between 10,000 and 50,000 Acres.

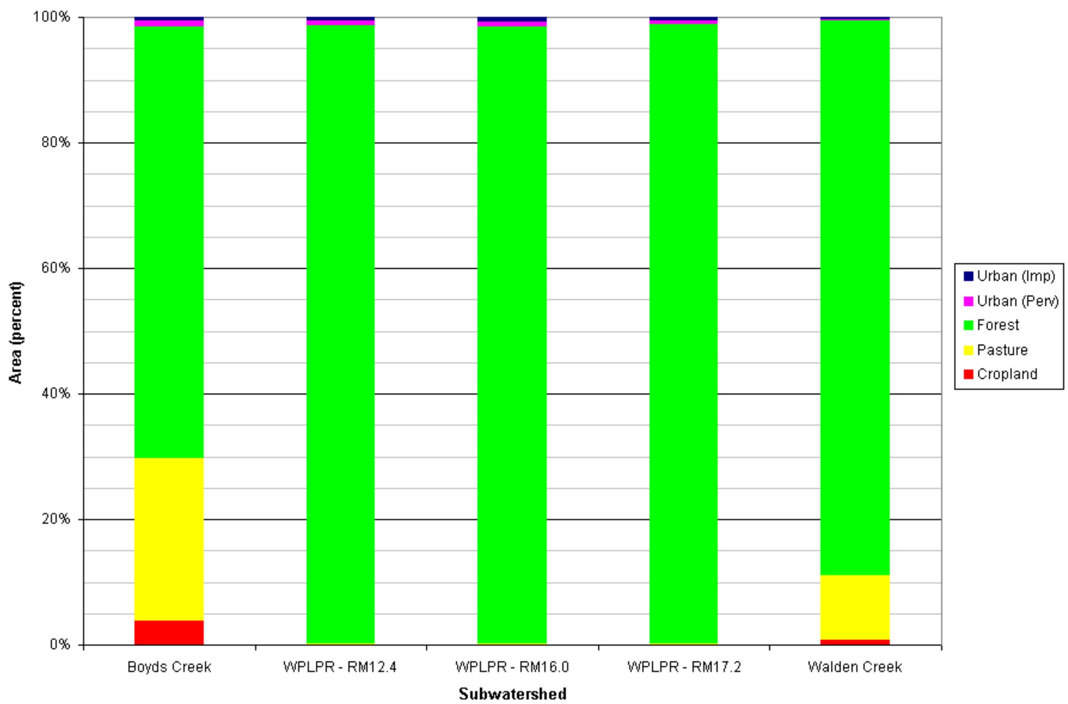

Figure 10. Land Use Percent of Lower French Broad Pathogen-Impaired Subwatersheds – Drainage Areas Between 10,000 and 50,000 Acres.

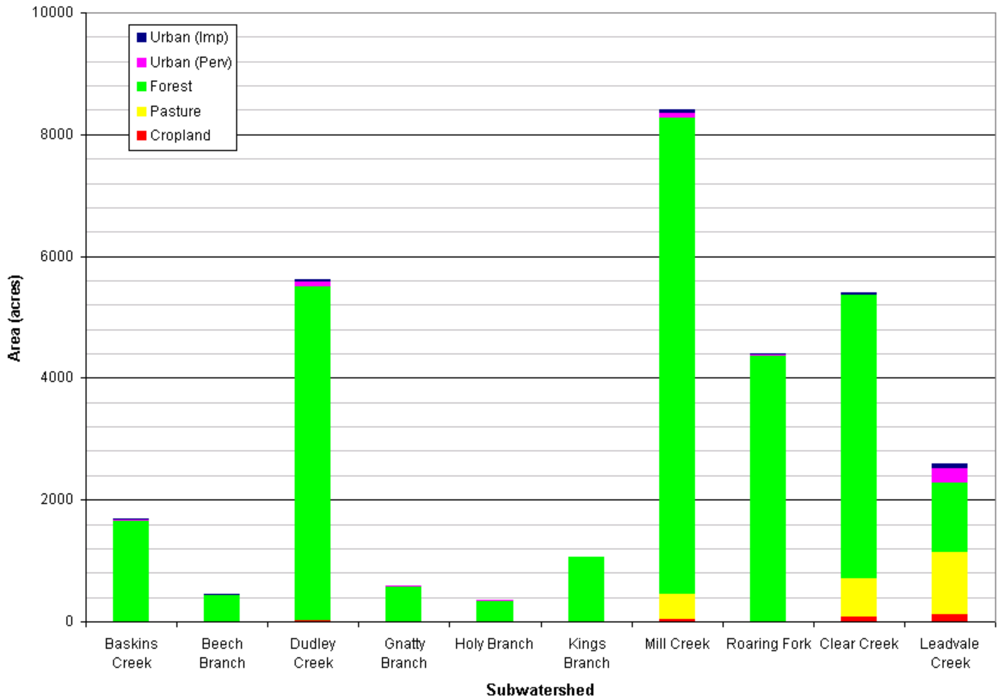

Figure 11. Land Use Area of Lower French Broad Pathogen-Impaired Subwatersheds – Drainage Areas Less Than 10,000 Acres.

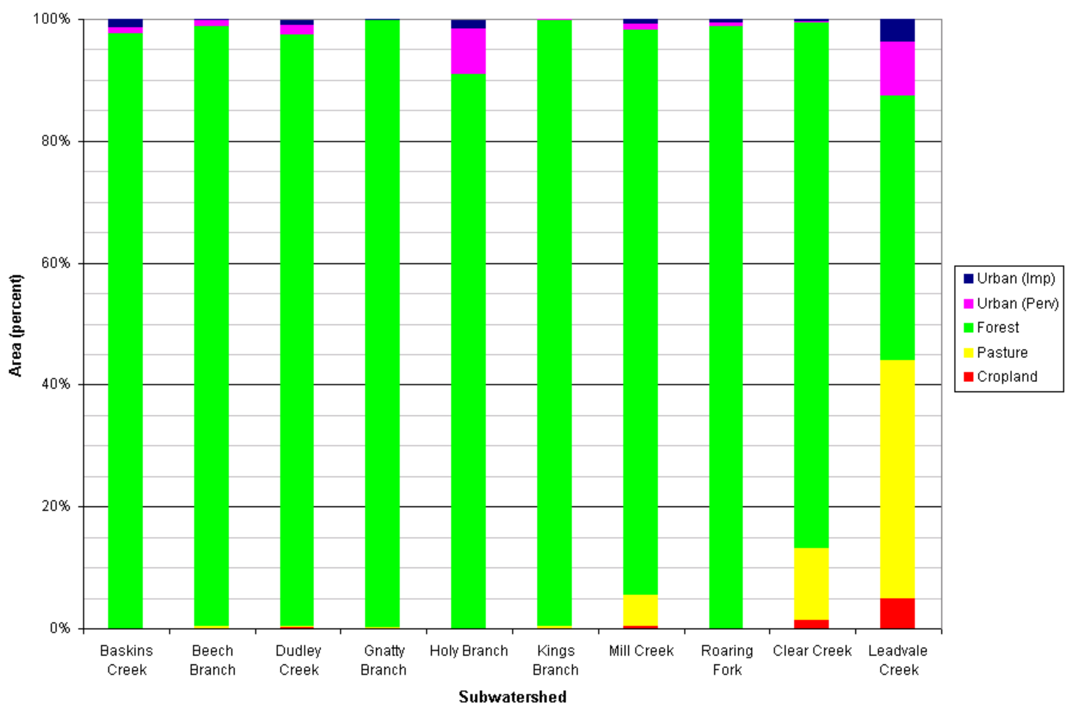

Figure 12. Land Use Percent of Lower French Broad Pathogen-Impaired Subwatersheds – Drainage Areas Less Than 10,000 Acres.

8.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOAD

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

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

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

This document describes pathogen TMDL, Waste Load Allocation (WLA), and Load Allocation (LA) development for waterbodies identified as impaired due to E. coli on the Final 2004 303(d) list. TMDL analyses are performed primarily on a 12-digit hydrologic unit area (HUC-12) basis for subwatersheds containing waterbodies identified as impaired due to E. coli on the Final 2004 303(d) list.

8.1 Expression of TMDLs, WLAs, & LAs

In this document, the pathogen TMDL is expressed as the percent reduction in instream loading required to decrease existing E. coli or fecal coliform concentrations to desired target levels. Target concentrations are equal to the desired water quality goals (see Section 5.0) minus the appropriate MOS. WLAs & LAs for precipitation-induced loading sources are also expressed as required percent reductions in pathogen loading. Allocations for loading that is independent of precipitation (WLAs for WWTFs and LAs for "other direct sources") are expressed as counts/day.

8.2 TMDL Analysis Methodology

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

TMDLs for the Lower French Broad Watershed were developed using load duration curves for analysis of impaired waterbodies. 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 regime represented by these existing loads. Load duration curves were 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 an overall load reduction calculated to meet E. coli and fecal coliform targets according to the methods described in Appendix C.

8.3 Critical Conditions and Seasonal Variation

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

The ten-year period from October 1, 1991 to September 30, 2001 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 analysis 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. Based on the location of the water quality exceedances on the load duration curves, the probably dominant delivery mode for pathogens varies depending on the subwatershed (see Section 9.3 and Table 10).

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 not collected during all seasons.

8.4 Margin of Safety

There are two methods for incorporating an MOS in the analysis: a) implicitly incorporate the MOS using conservative model assumptions; or b) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations.

An explicit MOS, equal to 10% of the E. coli and fecal coliform water quality goals (ref.: Section 5.0), was utilized for TMDL analysis. Explicit MOS and the resulting target concentrations are shown in Table 7.

Table 7. Explicit MOS and Target Concentrations

Pollutant	WQ Goal Type	WQ Goal [cts./100mL]	Explicit MOS [cts./100mL]	Target [cts./100mL]
E. coli	Maximum	941	94	847
	30-Day Geometric Mean	126	13	113
Fecal Coliform	Maximum	1,000	100	900
	30-Day Geometric Mean	200	20	180

8.5 Determination of TMDLs

E. coli and fecal coliform load reductions were calculated for impaired segments in the Lower French Broad Watershed using Load Duration Curves to evaluate compliance with the maximum target concentrations (Appendix C). When sufficient data were available, load reductions were also developed to achieve compliance with the 30-day geometric mean target concentrations (Appendix C). All of the instream load reductions for a particular waterbody were compared and the largest required load reduction was selected as the TMDL. These TMDL load reductions for the impaired segments are shown in Table 8 and are applied to the entire HUC-12 subwatershed in which the impaired waterbodies are located. In cases where the geometric mean could not be developed, it is assumed that achieving the load reduction based on the maximum target concentrations should result in attainment of the geometric mean criteria.

8.6 Determination of WLAs & LAs

WLAs & LAs are developed in Appendix F for point sources and nonpoint sources respectively. TMDLs, WLAs, & LAs for Lower French Broad Watershed impaired waterbodies are summarized in Table 9.

Table 8. Determination of TMDLs for Pathogen Impaired Waterbodies, Lower French Broad Watershed

HUC-12 Subwatershed (06010107__) or Drainage Area	Impaired Waterbody Name	Impaired Waterbody ID	Required Load Reduction [%]				
			Based on Target Maximum Concentration		Based on 30-day Geometric Mean Concentration		TMDL
			Fecal Coliform	E. Coli	Fecal Coliform	E. Coli	
0202	Boyds Creek	TN06010107003 – 1000		14.2			14.2
0315	Little Pigeon River	TN06010107007 – 1000 & – 2000	55.0	NR	88.2		88.2
Gnatty (0307)	Gnatty Branch	TN06010107010 – 0100	61.7	>54.0			61.7
Kings (0307)	Kings Branch	TN06010107010 – 0200	90.7	>65.0			90.7
Beech (0307)	Beech Branch	TN06010107010 – 0300	85.9	>59.3			85.9
0311	Dudley Creek	TN06010107010 – 0400	93.4	>65.0			93.4
0310	Roaring Fork	TN06010107010 – 0500	85.0		96.0		96.0
0309	Baskins Creek	TN06010107010 – 0600	92.2		92.2		92.2
0313	West Prong Little Pigeon River	TN06010107010 – 1000	NR	NR	72.0	53.0	72.0
Holy (0307)	Holy Branch	TN06010107010 – 1300	88.2		91.6		91.6
0312	Mill Creek	TN06010107010 – 1800	57.1	>10.4	74.7	71.6	74.7
0312	Walden Creek	TN06010107010 – 1900	16.7	NR	82.1	88.5	88.5
WPLPR (0307)	West Prong Little Pigeon River	TN06010107010 – 2000	51.9	>46.9	49.5	NR	51.9
WPLPR (0307)	West Prong Little Pigeon River	TN06010107010 – 3000	37.9	>21.6	68.4	36.6	68.4
0103	Clear Creek	TN06010107029T – 1100 & – 1150		>65.0			>65.0

Table 9. WLAs & LAs for Lower French Broad Watershed, Tennessee

HUC-12 Subwatershed (06010107__) or Drainage Area	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	WLAs				LAs	
				WWTFs[a] (Monthly Avg.) E. Coli	Leaking Collection Systems[b]	CAFOs	MS4s[c]	Precipitation Induced Nonpoint Sources	Other Direct Sources[d]
			[% Red.]	[cts./day]	[cts./day]	[cts./day]	[% Red.]	[% Red.]	[cts./day]
0202	Boyds Creek	TN06010107003 – 1000	**14.2**	**8.584×10^7**	**0**	**NA**	**14.2**	**14.2**	**0**
0315	Little Pigeon River	TN06010107007 – 1000 & – 2000	**88.2**	**3.374×10^{10}**	**0**	**NA**	**88.2**	**88.2**	**0**
Gnatty (0307)	Gnatty Branch	TN06010107010 – 0100	**61.7**	**NA***	**NA**	**NA**	**61.7**	**61.7**	**0**
Kings (0307)	Kings Branch	TN06010107010 – 0200	**90.7**	**NA***	**NA**	**NA**	**90.7**	**90.7**	**0**
Beech (0307)	Beech Branch	TN06010107010 – 0300	**85.9**	**NA***	**NA**	**NA**	**85.9**	**85.9**	**0**
0311	Dudley Creek	TN06010107010 – 0400	**93.4**	**NA***	**NA**	**NA**	**93.4**	**93.4**	**0**
0310	Roaring Fork	TN06010107010 – 0500	**96.0**	**NA***	**NA**	**NA**	**96.0**	**96.0**	**0**
0309	Baskins Creek	TN06010107010 – 0600	**92.2**	**NA***	**NA**	**NA**	**92.2**	**92.2**	**0**
0313	West Prong Little Pigeon River	TN06010107010 – 1000	**72.0**	**3.374×10^{10}**	**0**	**NA**	**72.0**	**72.0**	**0**
Holy (0307)	Holy Branch	TN06010107010 – 1300	**91.6**	**NA***	**NA**	**NA**	**91.6**	**91.6**	**0**
0312	Mill Creek	TN06010107010 – 1800	**74.7**	**NA***	**NA**	**NA**	**74.7**	**74.7**	**0**
0312	Walden Creek	TN06010107010 – 1900	**88.5**	**3.577×10^8**	**0**	**NA**	**88.5**	**88.5**	**0**
WPLPR (0307)	West Prong Little Pigeon River	TN06010107010 – 2000	**51.9**	**1.431×10^{10}**	**0**	**NA**	**51.9**	**51.9**	**0**
WPLPR (0307)	West Prong Little Pigeon River	TN06010107010 – 3000	**68.4**	**1.431×10^{10}**	**0**	**NA**	**68.4**	**68.4**	**0**
0103	Clear Creek	TN06010107029T – 1100 & – 1150	**NA**	**NA***	**NA**	**NA**	**NA**	**>65.0**	**0**

Note: NA = Not Applicable.
* *Future WWTFs must meet instream water quality standards at the point of discharge as specified in their NPDES permit.*
a. WLAs for WWTFs expressed as E. coli loads (counts/day).
b. The objective for leaking collection systems is a waste load allocation of zero. It is recognized, however, that a WLA of 0 counts/day may not be practical. For these sources, the WLA is interpreted to mean a reduction in coliform loading to the maximum extent practicable, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.
c. Applies to any MS4 discharge loading in the subwatershed.
d. The objective for all "other direct sources" is a load allocation of zero. It is recognized, however, that for leaking septic systems a LA of 0 counts/day may not be practical. For these sources, the LA is interpreted to mean a reduction in coliform loading by the application of best management practices, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.

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 Lower French Broad watershed through reduction of excessive pathogen 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.

9.1 Point Sources

9.1.1 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. 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 expressed as average loads in counts per day. WLAs are derived from facility design flows and permitted E. coli limits.

A total of 35 bypass/overflow events were reported on monthly Discharge Monitoring Reports (DMRs) by the Pigeon Forge STP from January 2001 through December 2004. A total of 46 bypass/overflow events were reported on monthly DMRs by the Gatlinburg STP from January 2001 through December 2004. In order to meet water quality criteria for West Prong Little Pigeon River, the Pigeon Forge and Gatlinburg STPs must meet the provisions of their NPDES permits, including elimination of bypasses and overflows.

9.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

For regulated discharges from municipal separate storm sewer systems, WLAs 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. The *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (TDEC, 2002) was issued on February 27, 2003 and requires SWMPs to include six minimum control measures:

- Public education and outreach on storm water impacts
- Public involvement/participation
- Illicit discharge detection and elimination
- Construction site storm water runoff control
- Post-construction storm water management in new development and re-development
- Pollution prevention/good housekeeping for municipal operations

For discharges into impaired waters, the proposed Small MS4 General Permit (ref: http://www.state.tn.us/environment/wpc/stormh2o/MS4II.php) requires that SWMPs include a section describing how discharges of pollutants of concern will be controlled to ensure that they do not cause or contribute to instream exceedances of water quality standards. Specific measures and BMPs to control pollutants of concern must also be identified. In addition, MS4s must implement the WLA provisions of an applicable TMDL and describe methods to evaluate whether storm water controls are adequate to meet the WLA.

Implementation of the coliform WLAs for MS4s in this TMDL document will require effluent or instream monitoring to evaluate SWMP effectiveness with respect to reduction of pathogen loading.

9.1.3 NPDES Regulated Concentrated Animal Feeding Operations (CAFOs)

WLAs provided to 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. Among the provisions of the general permit are:

- Development and implementation of a site-specific Nutrient Management Plan (NMP) that:
    - Includes best management practices (BMPs) and procedures necessary to implement applicable limitations and standards;
    - Ensures adequate storage of manure, litter, and process wastewater including provisions to ensure proper operation and maintenance of the storage facilities.
    - Ensures proper management of mortalities (dead animals);
    - Ensures diversion of clean water, where appropriate, from production areas;
    - Identifies protocols for manure, litter, wastewater and soil testing;
    - Establishes protocols for land application of manure, litter, and wastewater;
    - Identifies required records and record maintenance procedures.

  The NMP must submitted to the State for approval and a copy kept on-site.

- Requirements regarding manure, litter, and wastewater land application BMPs.

- Requirements for the design, construction, operation, and maintenance of CAFO liquid waste management systems that are constructed, modified, repaired, or placed into operation after April 13, 2006. The final design plans and specifications for these systems must meet or exceed standards in the NRCS Field Office Technical Guide and other guidelines as accepted by the Departments of Environment and Conservation, or Agriculture.

Provisions of individual CAFO permits are similar. NPDES Permit No. TNA000000, *Class II Concentrated Animal Feeding Operation General Permit* is available on the TDEC website at http://www.state.tn.us/environment/wpc/programs/cafo/.

9.2 Nonpoint Sources

The Tennessee Department of Environment & Conservation (TDEC) has no direct regulatory authority over most nonpoint source discharges. Reductions of pathogen loading from nonpoint sources (NPS) 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. Local citizen-led and implemented management measures offer the most efficient and comprehensive avenue for reduction of loading rates from nonpoint sources. 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.

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 nongovernmental levels to be successful.

BMPs have been utilized in the Lower French Broad 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 the Lower French Broad watershed during the TMDL evaluation period. The TDA keeps a database of BMPs implemented in Tennessee. Those listed in the Lower French Broad watershed are shown in Figure 13. 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 BMPs be utilized to reduce the amount of coliform bacteria transported to surface waters from agricultural sources. Demonstration sites for various types of BMPs should be established, maintained, and evaluated (performance in source reduction) 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.

Two projects are currently in progress within the Lower French Broad watershed. Both projects were funded, in part, through Tennessee Department of Agriculture (TDA) Nonpoint Source Program 319 grants. One project, located in King Branch, involves installation of a new STEP system. The objective of the project is to correct the sole source of impairment of King Branch, which is failing septic tank systems. The Sevier County Soil Conservation District is the lead organization for another project that concentrates on agriculture-related pollution sources that can be remediated by implementing BMPs. Work thus far has concentrated on East Fork – Dunn Creek. However, three other impaired tributaries of the French Broad were added in 2005.

9.3 Example Application of Load Duration Curves for Implementation Planning

The Load Duration Curve methodology (Appendix C) is a form of water quality analysis and presentation of data that aids in guiding implementation by targeting strategies to appropriate flow conditions. One of the strengths of this method is that it can be used to interpret possible delivery mechanisms of pathogens by differentiating between point and non-point problems. The E. coli load duration analysis was utilized for implementation planning. The E. coli load duration curve for each pathogen-impaired subwatershed (Figures 14 thru 26) was analyzed to determine the frequency with which water quality monitoring data exceed the E. coli target maximum concentration of 847 counts/100 mL (standard – MOS) under five flow conditions (low, dry, mid-range, moist, and high).

Table 10 presents Load Duration analysis statistics for E. coli in the Lower French Broad Watershed at mile 17.2 of West Prong Little Pigeon River and targeted implementation strategies for each source category covering the entire range of flow (Stiles, 2003). Each implementation strategy addresses a range of flow conditions and targets point sources, non-point sources, or a combination of each. Results indicate the West Prong Little Pigeon River (RM17.2) implementation strategy will require BMPs targeting primarily non-point sources (dominant under high flow/runoff conditions). The implementation strategies listed in Table 10 are a subset of the categories of BMPs and implementation strategies available for application to the pathogen-impaired Lower French Broad watersheds for reduction of pathogen loading and mitigation of water quality impairment.

See Appendix C for a detailed discussion of the Load Duration Curve Methodology applied to the Lower French Broad Watershed.

Appendix E presents Fecal Coliform Load Duration Curves comparing monitoring data for 1992-94 to monitoring data for 1998-99 for subwatersheds with monitoring data during both time periods. Examination of the plots suggests possible improvement during dry conditions for all subwatersheds except Beech Branch, Mill Creek, and Walden Creek. However, examination of the plots also suggests worsening of conditions during periods of high flow for all subwatersheds as indicated by the increased 90^{th} percentile.

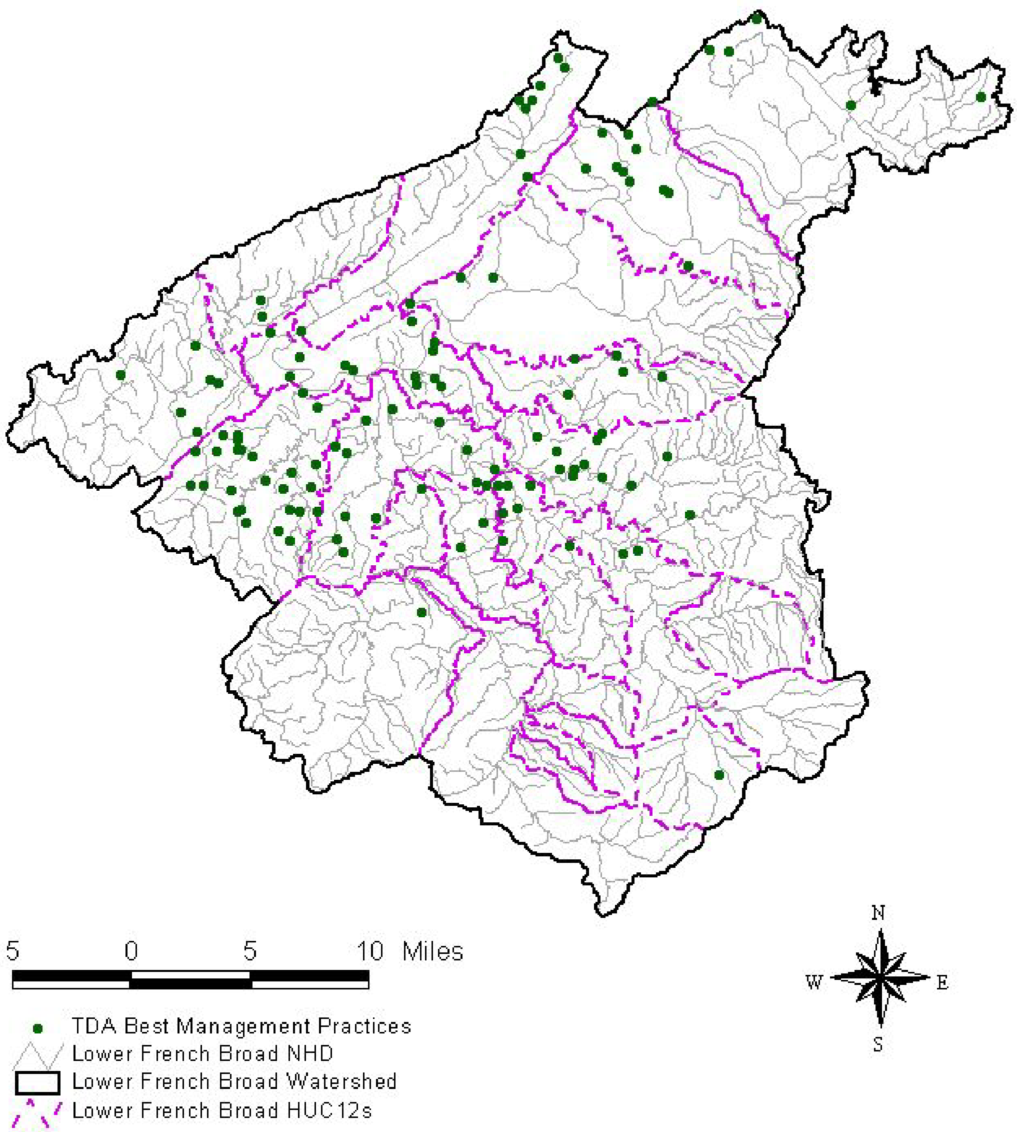

Figure 13. Tennessee Department of Agriculture Best Management Practices located in the Lower French Broad Watershed.

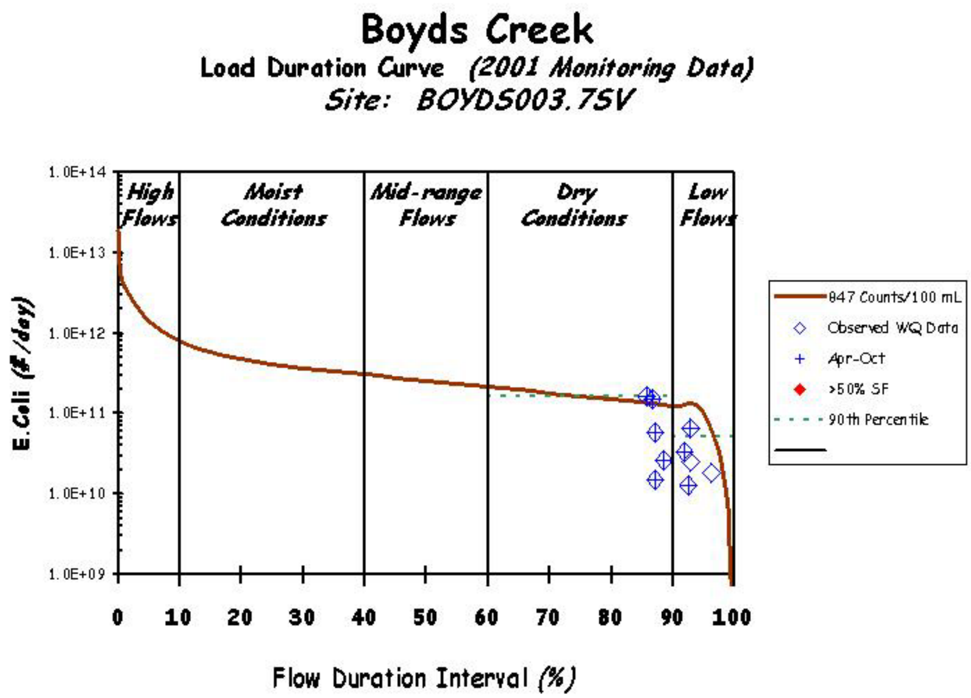

Figure 14. Load Duration Curve for Boyds Creek

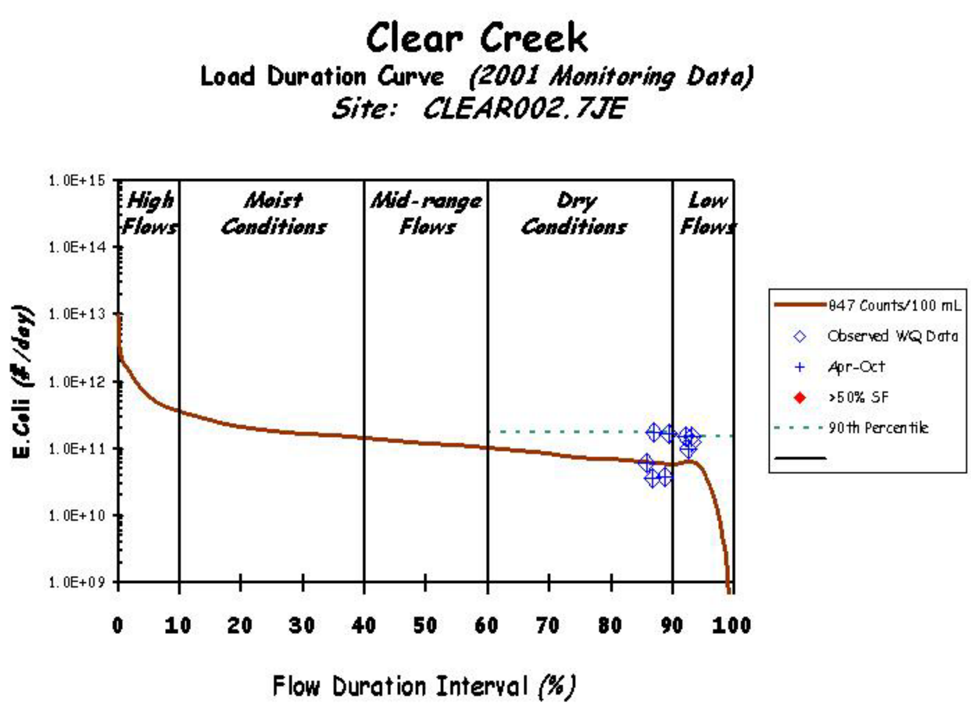

Figure 15. Load Duration Curve for Clear Creek

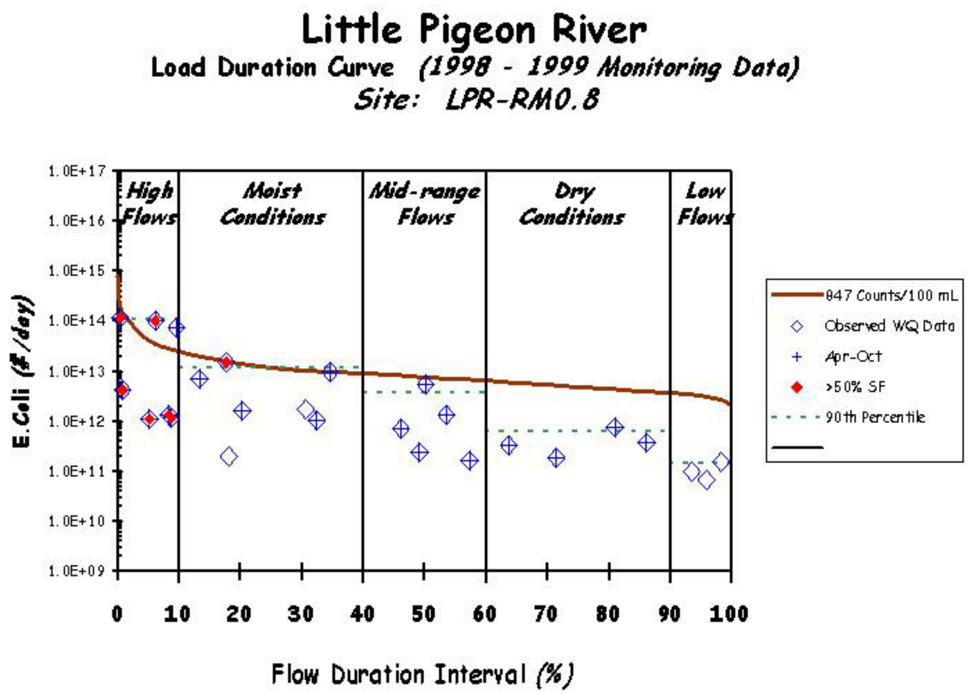

Figure 16. Load Duration Curve for Little Pigeon River

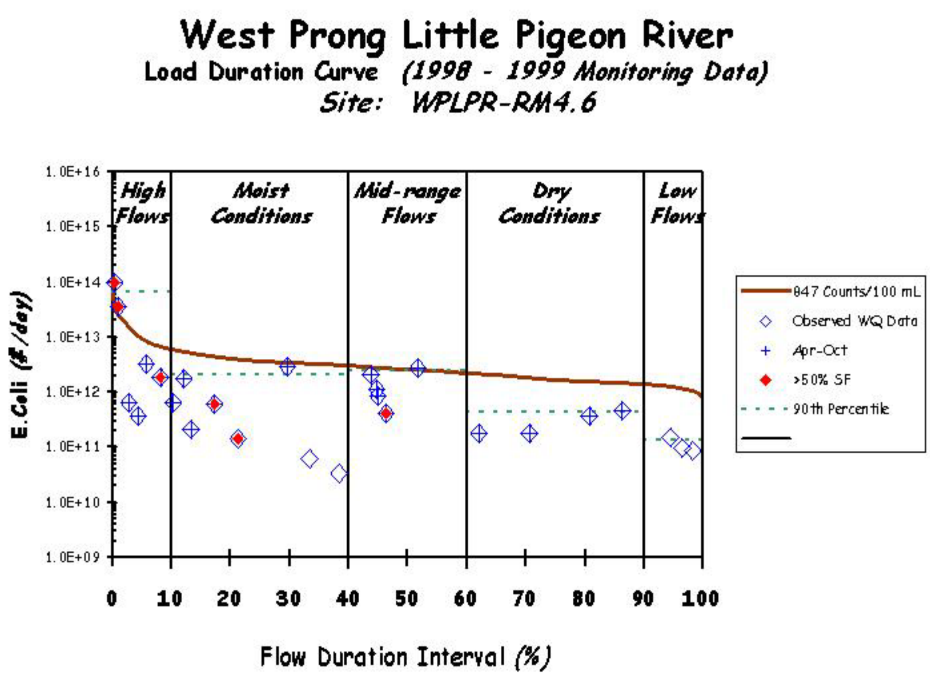

Figure 17. Load Duration Curve for West Prong Little Pigeon River – RM4.6

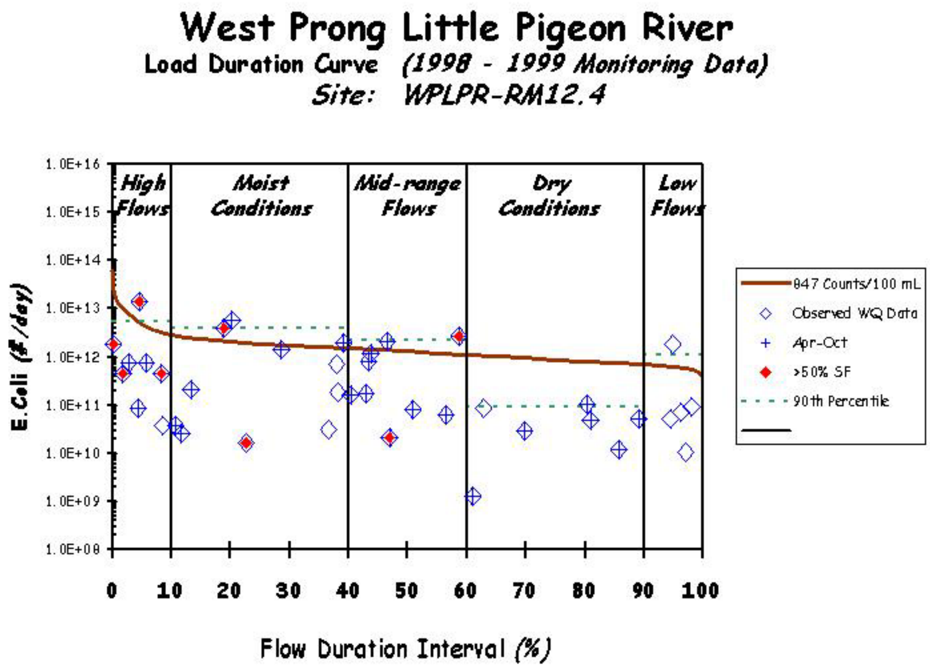

Figure 18. Load Duration Curve for West Prong Little Pigeon River – RM12.4

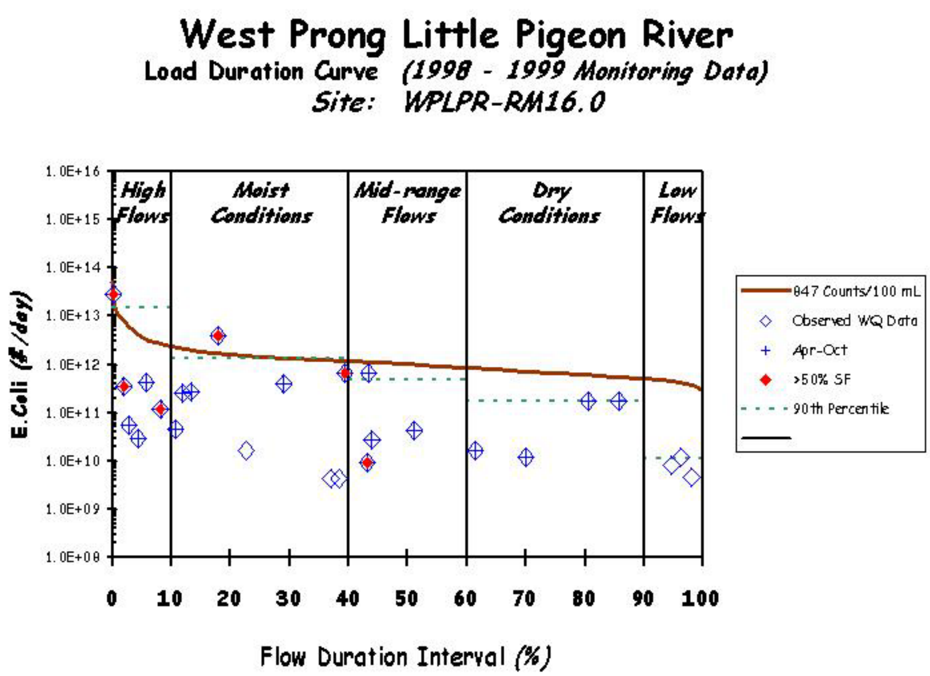

Figure 19. Load Duration Curve for West Prong Little Pigeon River – RM16.0

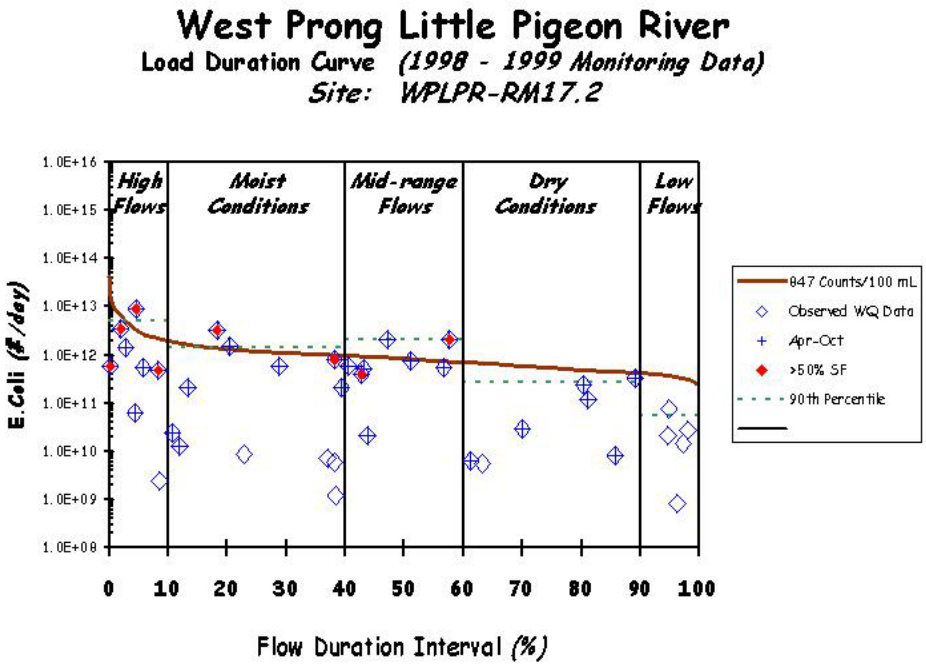

Figure 20. Load Duration Curve for West Prong Little Pigeon River – RM17.2

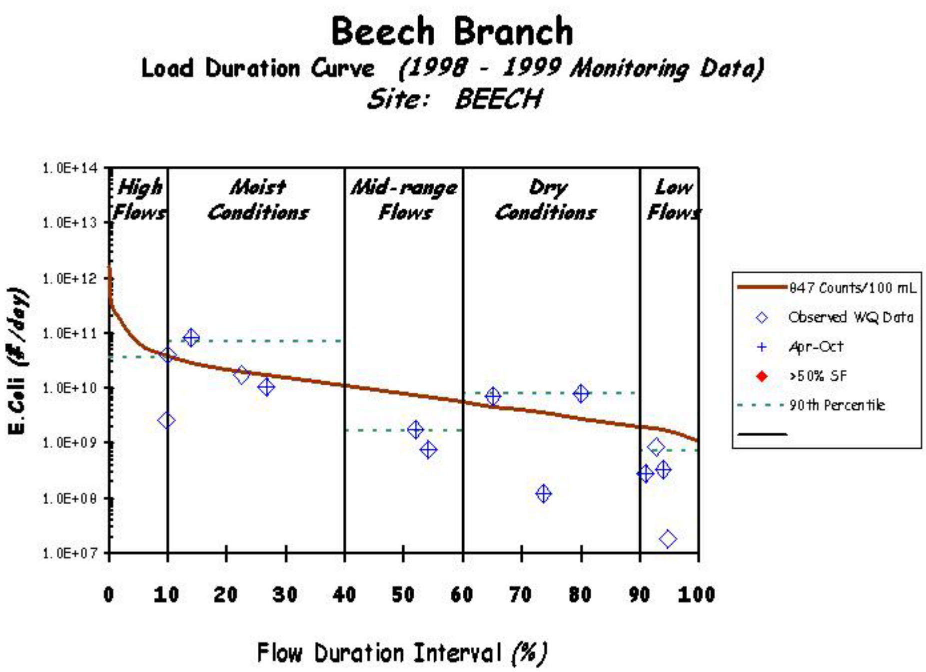

Figure 21. Load Duration Curve for Beech Branch

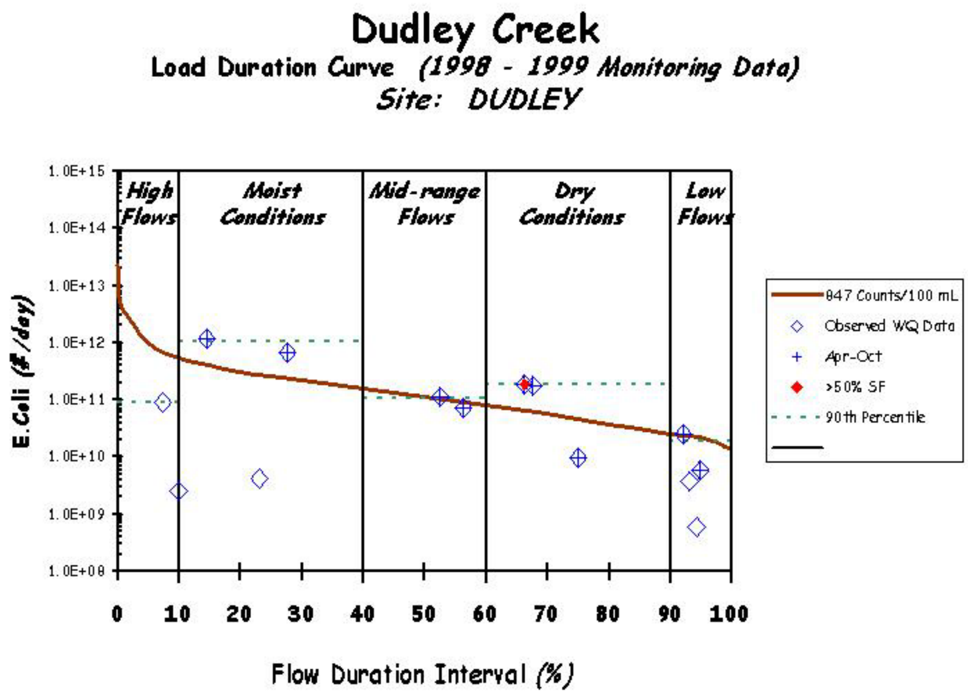

Figure 22. Load Duration Curve for Dudley Creek

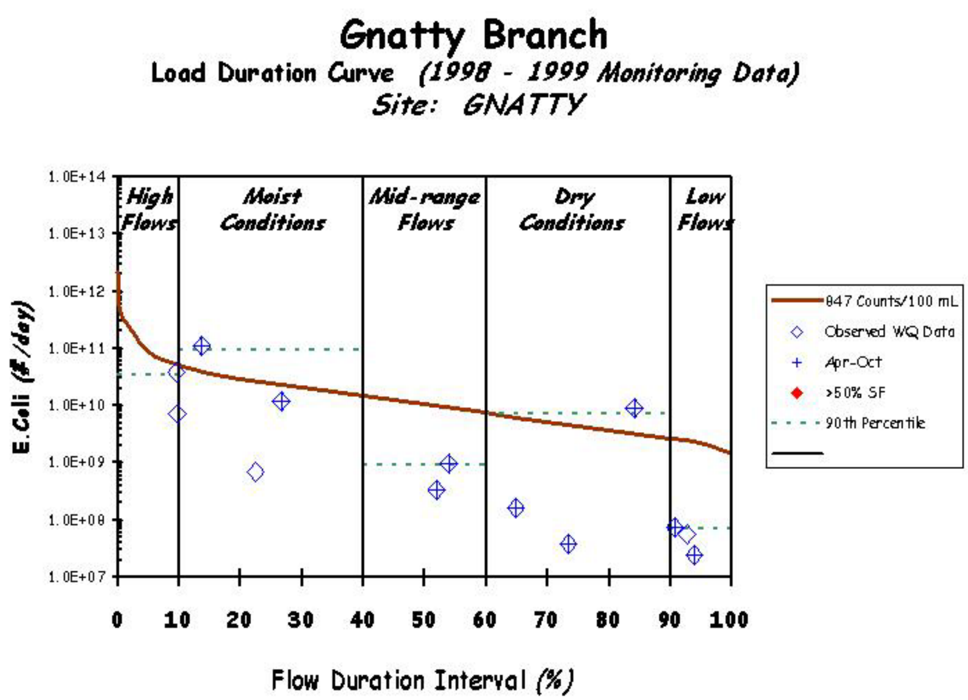

Figure 23. Load Duration Curve for Gnatty Branch

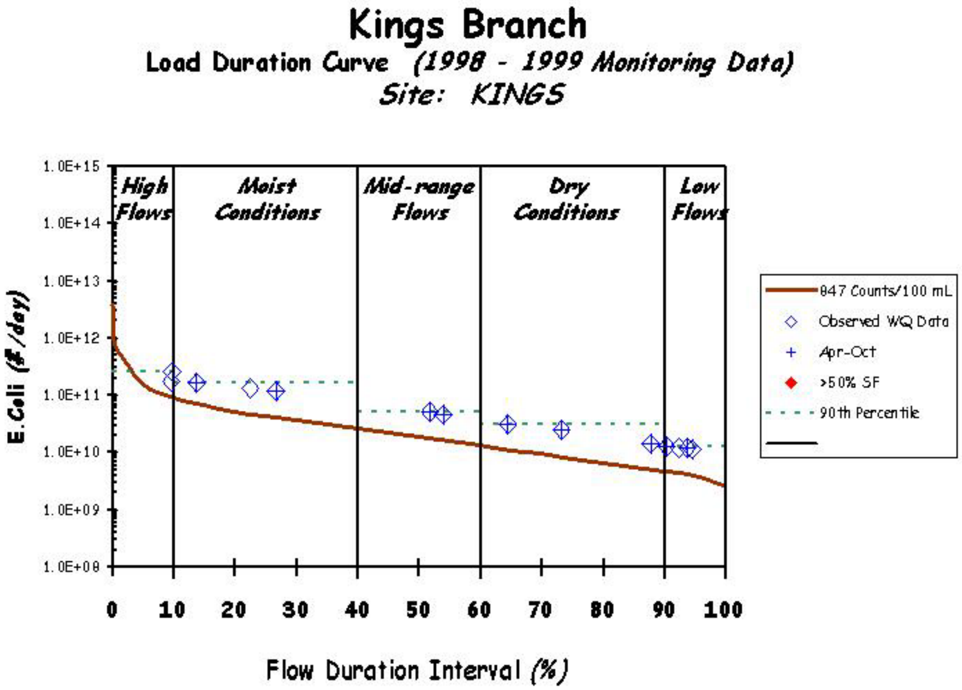

Figure 24. Load Duration Curve for Kings Branch

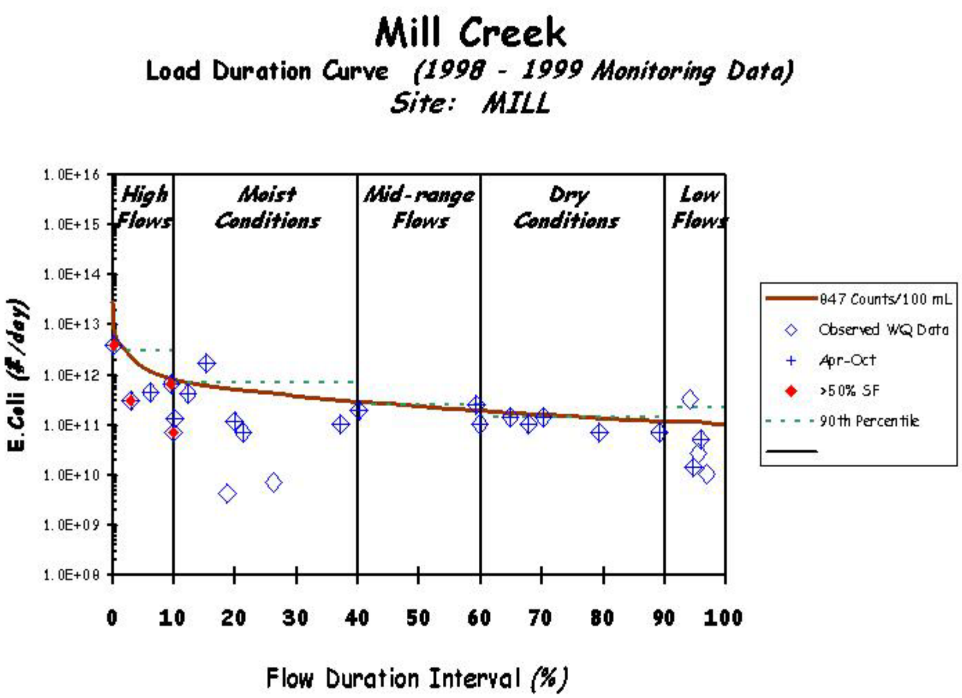

Figure 25. Load Duration Curve for Mill Creek

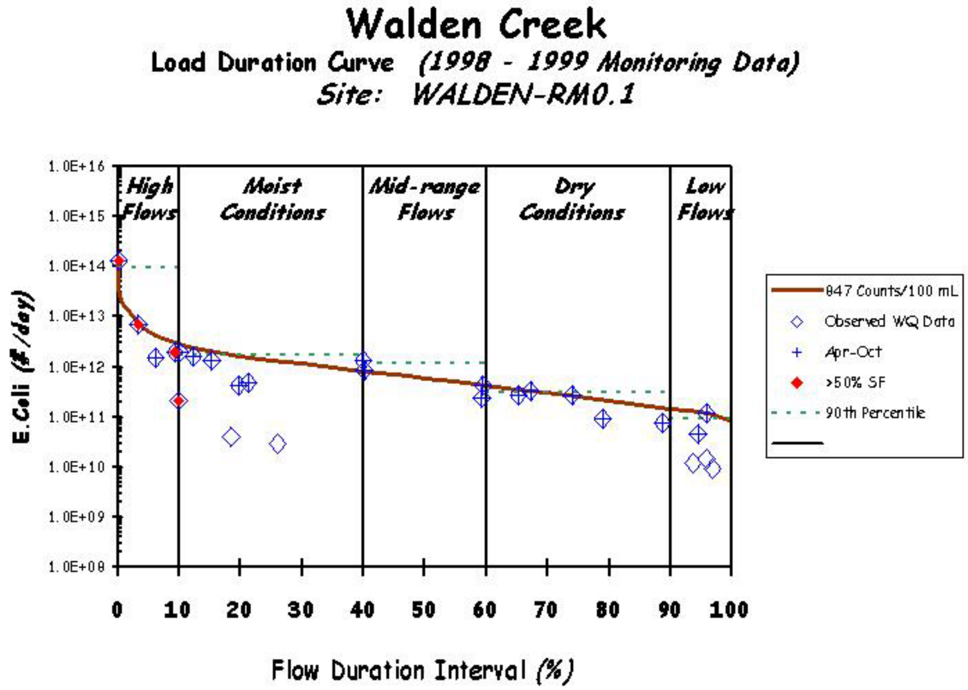

Figure 26. Load Duration Curve for Walden Creek

9.4 Additional Monitoring

Documenting progress in reducing the quantity of pathogens entering the Lower French Broad watershed is an essential element of the TMDL Implementation Plan. 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 instream water quality targets for fecal coliform and/or E. coli. Future monitoring activities should be representative of all seasons and a full range of flow and meteorological conditions. Monitoring activities should also be adequate to assess water quality using the 30-day geometric mean standard.

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

Additional sampling for both fecal coliform and E. coli is recommended to aid in a better understanding of the relationship between fecal coliform concentration and E. coli concentration.

Table 10. Load Duration Curve Summary for Example Implementation Strategies

Flow Condition		High	Moist	Mid-range	Dry	Low
% Time Flow Exceeded		0-10	10-40	40-60	60-90	90-100
West Prong Little Pigeon River at Mile 17.2	% Samples > 847 Counts/100 mL[1]	12.5	16.7	25.0	0.0	0.0
Example Implementation Strategies						
Municipal NPDES			L	M	H	H
Stormwater Management			H	H	H	
SSO Mitigation		H	H	M	L	
Collection System Repair			L	M	H	H
Septic System Repair			L	M	H	M
Livestock Exclusion[2]				M	H	H
Pasture Management/Land Application of Manure[2]		H	H	M	L	
Riparian Buffers[2]			H	H	H	
		Potential for source area contribution under given hydrologic condition (H: High; M: Medium; L: Low)				

[1] Tennessee maximum daily water quality standard for E.coli (941 Counts/100 mL) minus 10% MOS (94 counts/100 mL).
[2] Example Best Management Practices (BMPs) for Agricultural Source reduction. Actual BMPs applied may vary.

Additional monitoring and assessment activities are recommended for the Leadvale Creek subwatershed to verify the assessment status of the stream reach identified on Final 2004 303(d) list as impaired due to pathogens. Leadvale Creek has also been posted due to bacterial contamination from the White Pine STP. However, the White Pine STP is no longer discharging to Leadvale Creek. If it is determined that this stream reach is still not fully supporting designated uses, then sufficient data to enable development of a TMDL must be acquired.

Additional monitoring and assessment activities are also recommended for the Boyds Creek and Clear Creek subwatersheds. Examination of monitoring data indicates that all sampling events have occurred during dry conditions or periods of low flow. Once additional monitoring representing all seasons and a full range of flow and meteorological conditions has been obtained, the required load reductions may be revised.

9.5 Source Identification

An important aspect of pathogen load reduction activities is the accurate identification of the actual sources of pollution. In cases where the sources of pathogen impairment are not readily apparent, Microbial Source Tracking (MST) is one approach to determining the sources of fecal pollution and pathogens 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 is developing and testing 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. Other BST projects have been conducted or are currently in progress throughout the state of Tennessee, as presented in sessions of the Thirteenth Tennessee Water Resources Symposium (Lawrence, 2003) and the Fifteenth Tennessee Water Resources Symposium (Bailey, 2005; Baldwin, 2005; Farmer, 2005).

9.6 Evaluation of TMDL Effectiveness

The effectiveness of the TMDL will be assessed within the context of the State's rotating watershed management approach. Watershed monitoring and assessment activities will provide information by which the effectiveness of pathogen loading reduction measures can be evaluated. Additional monitoring data, ground-truthing activities, and bacterial source identification actions are recommended to enable implementation of particular types of BMPs to be directed to specific areas in impaired subwatersheds. This will optimize utilization of resources to achieve maximum reductions in pathogen loading. These TMDLs will be re-evaluated during subsequent watershed cycles and revised as required to assure attainment of applicable water quality standards.

10.0 PUBLIC PARTICIPATION

In accordance with 40 CFR §130.7, the proposed pathogen TMDLs for the Lower French Broad 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 or near pathogen-impaired subwatersheds in the Lower French Broad 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 will be provided on request. A letter was sent to the following facilities:

    Pigeon Forge STP (TN0021237)
    Gatlinburg STP (TN0020117)
    Harrison Chilhowee Baptist Academy (TN0022748)
    Cloisters in Shagbark (TN0061611).

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

    Blount County, Tennessee (TNS075116)
    City of Gatlinburg, Tennessee (TNS075329)
    City of Pigeon Forge, Tennessee (TNS075485)
    City of Sevierville, Tennessee (TNS075523)
    Knox County, Tennessee (TNS075582)
    Sevier County, Tennessee (TNS075655)
    Tennessee Dept. of Transportation (TNS077585)

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 Lower French Broad Watershed

Table A-1. MRLC Land Use Distribution of Lower French Broad Subwatersheds

Land Use	Lower French Broad Subwatersheds					
	Boyds Creek		Clear Creek		Leadvale Creek	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Bare Rock/Sand/Clay	0	0.0	0	0.0	0	0.0
Deciduous Forest	11,400	38.4	2,274	42.2	126	4.8
Emergent Herbaceous Wetlands	0	0.0	0	0.0	2	0.1
Evergreen Forest	3,416	11.5	1,153	21.4	232	8.9
High Intensity Commercial/Industrial/Transp.	112	0.4	28	0.5	57	2.2
High Intensity Residential	29	0.1	0	0.0	30	1.2
Low Intensity Residential	311	1.1	4	0.1	237	9.1
Mixed Forest	5,247	17.7	1,196	22.2	397	15.2
Open Water	8	0.0	1	0.0	0	0.0
Other Grasses (Urban/recreation; e.g. parks)	349	1.2	0	0.0	350	13.5
Pasture/Hay	7,640	25.8	636	11.8	1,021	39.2
Quarries/Strip Mines/Gravel Pits	0	0.0	0	0.0	0	0.0
Row Crops	1,144	3.9	75	1.4	126	4.9
Transitional	0	0.0	27	0.5	0	0.0
Woody Wetlands	0	0.0	0	0.0	24	0.9
Total	29,655	100.0	5,395	100.0	2,602	100.0

Table A-1 (Cont.). MRLC Land Use Distribution of Lower French Broad Subwatersheds

Land Use	Lower French Broad Subwatersheds					
	Little Pigeon River		West Prong Little Pigeon River-RM1.2		West Prong Little Pigeon River-RM4.6	
	[acres]	[%]	[acres]	[acres]	[acres]	[%]
Bare Rock/Sand/Clay	0	0.0	0	0.0	0	0.0
Deciduous Forest	91,242	37.6	38,407	40.1	37,594	41.0
Emergent Herbaceous Wetlands	5	0.0	0	0.0	0	0.0
Evergreen Forest	65,488	27.0	25,176	26.3	24,629	26.9
High Intensity Commercial/Industrial/Transp.	1804	0.7	1098	1.2	1014	1.1
High Intensity Residential	327	0.1	170	0.2	95	0.1
Low Intensity Residential	1750	0.7	942	1.0	644	0.7
Mixed Forest	58,965	24.3	23,456	24.5	22,598	24.6
Open Water	352	0.2	178	0.2	111	0.1
Other Grasses (Urban/recreation; e.g. parks)	821	0.3	304	0.3	195	0.2
Pasture/Hay	18,938	7.8	5,431	5.7	4,464	4.9
Quarries/Strip Mines/Gravel Pits	75	0.0	75	0.1	0	0.0
Row Crops	2,556	1.1	522	0.6	353	0.4
Transitional	48	0.0	26	0.0	25	0.0
Woody Wetlands	425	0.2	0	0.0	0	0.0
Total	242,796	100.0	95,784	100.0	91,722	100.0

Table A-1 (Cont.). MRLC Land Use Distribution of Lower French Broad Subwatersheds

Land Use	Lower French Broad Subwatersheds					
	West Prong Little Pigeon River-RM12.4		West Prong Little Pigeon River-RM16.0		West Prong Little Pigeon River-RM17.2	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Bare Rock/Sand/Clay	0	0.0	0	0.0	0	0.0
Deciduous Forest	22,387	47.3	18,599	48.4	15,363	48.8
Emergent Herbaceous Wetlands	0	0.0	0	0.0	0	0.0
Evergreen Forest	12,946	27.4	10,499	27.3	9,123	29.0
High Intensity Commercial/Industrial/Transp.	264	0.6	244	0.6	198	0.6
High Intensity Residential	46	0.1	46	0.1	33	0.1
Low Intensity Residential	291	0.6	270	0.7	120	0.4
Mixed Forest	11,247	23.8	8,707	22.6	6,624	21.0
Open Water	20	0.0	17	0.0	7	0.0
Other Grasses (Urban/recreation; e.g. parks)	14	0.0	13	0.0	5	0.0
Pasture/Hay	35	0.1	24	0.1	11	0.0
Quarries/Strip Mines/Gravel Pits	0	0.0	0	0.0	0	0.0
Row Crops	36	0.1	34	0.1	20	0.1
Transitional	14	0.0	12	0.0	10	0.0
Woody Wetlands	0	0.0	0	0.0	1	0.0
Total	47,301	100.0	38,464	100.0	31,515	100.0

Table A-1 (Cont.). MRLC Land Use Distribution of Lower French Broad Subwatersheds

Land Use	Lower French Broad Subwatersheds					
	Baskins Creek		Beech Branch		Dudley Creek	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Bare Rock/Sand/Clay	0	0.0	0	0.0	0	0.0
Deciduous Forest	775	45.7	184	41.7	2720	48.3
Emergent Herbaceous Wetlands	0	0.0	0	0.0	0	0.0
Evergreen Forest	404	23.8	108	24.35	1046	18.6
High Intensity Commercial/Industrial/Transp.	19	1.1	1	0.2	39	0.7
High Intensity Residential	10	0.6	0	0.0	11	0.2
Low Intensity Residential	10	0.6	4	0.9	84	1.5
Mixed Forest	477	28.1	143	32.3	1694	30.1
Open Water	0	0.0	0	0.0	9	0.2
Other Grasses (Urban/recreation; e.g. parks)	1	0.0	0	0.1	8	0.1
Pasture/Hay	0	0.0	1	0.3	12	0.2
Quarries/Strip Mines/Gravel Pits	0	0.0	0	0.0	0	0.0
Row Crops	1	0.1	0	0.1	14	0.2
Transitional	0	0.0	0	0.1	0	0.0
Woody Wetlands	0	0.0	0	0.0	0	0.0
Total	1697	100.0	442	100.0	5637	100.0

Table A-1 (Cont.). MRLC Land Use Distribution of Lower French Broad Subwatersheds

Land Use	Lower French Broad Subwatersheds					
	Gnatty Branch		Holy Branch		Kings Branch	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Bare Rock/Sand/Clay	0	0.0	0	0.0	0	0.0
Deciduous Forest	240	41.4	142	39.7	468	44.4
Emergent Herbaceous Wetlands	0	0.0	0	0.0	0	0.0
Evergreen Forest	163	28.1	70	19.4	284	27.0
High Intensity Commercial/Industrial/Transp.	1	0.2	2	0.7	1	0.1
High Intensity Residential	0	0.0	0	0.0	0	0.0
Low Intensity Residential	0	0.0	30	8.4	0	0.0
Mixed Forest	175	30.1	113	31.4	296	28.2
Open Water	0	0.0	0	0.0	0	0.0
Other Grasses (Urban/recreation; e.g. parks)	0	0.0	0	0.0	0	0.0
Pasture/Hay	1	0.2	0	0.0	3	0.3
Quarries/Strip Mines/Gravel Pits	0	0.0	0	0.0	0	0.0
Row Crops	0	0.0	0	0.0	1	0.1
Transitional	0	0.0	2	0.4	0	0.0
Woody Wetlands	0	0.0	0	0.0	0	0.0
Total	581	100.0	359	100.0	1053	100.0

Table A-1 (Cont.). MRLC Land Use Distribution of Lower French Broad Subwatersheds

Land Use	Lower French Broad Subwatersheds					
	Mill Creek		Roaring Fork Creek		Walden Creek	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Bare Rock/Sand/Clay	0	0.0	0	0.0	0	0.0
Deciduous Forest	3561	42.3	2010	45.6	10996	34.2
Emergent Herbaceous Wetlands	0	0.0	0	0.0	0	0.0
Evergreen Forest	2089	24.8	1417	32.2	8893	27.6
High Intensity Commercial/Industrial/Transp.	54	0.6	22	0.5	87	0.3
High Intensity Residential	8	0.1	10	0.2	4	0.0
Low Intensity Residential	81	1.0	17	0.4	104	0.3
Mixed Forest	2128	25.3	927	21.0	8489	26.4
Open Water	1	0.0	3	0.1	9	0.0
Other Grasses (Urban/recreation; e.g. parks)	23	0.3	2	0.0	50	0.2
Pasture/Hay	427	5.1	0	0.0	3324	10.3
Quarries/Strip Mines/Gravel Pits	0	0.0	0	0.0	0	0.0
Row Crops	34	0.4	4	0.1	222	0.7
Transitional	6	0.1	0	0.0	5	0.0
Woody Wetlands	0	0.0	0	0.0	0	0.0
Total	8412	100.0	4412	100.0	32183	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 Lower French Broad watershed. The locations of these monitoring stations are shown in Figure 5. Monitoring data recorded at these stations for Escherichia Coli (E. Coli), Fecal Coliform, and Fecal Strep are tabulated in Table B-1.

Table B-1. Water Quality Monitoring Data – Lower French Broad Subwatersheds

Monitoring Station	Date	E. Coli	Fecal Coliform	Fecal Strep
		[cts./100 mL]	[cts./100 mL]	[cts./100 mL]
BOYDS003.7SV	8/16/01	980		
	8/29/01	488		
	9/10/01	1046		
	9/12/01	365		
	9/17/01	173		
	10/16/01	96		
	10/23/01	238		
	10/31/01	93		
	11/1/01	186		
	11/15/01	157		
CLEAR002.7JE	8/16/01	488		
	8/29/01	>2419		
	9/10/01	816		
	9/17/01	548		
	10/12/01	>2419		
	10/16/01	>2419		
	10/16/01	>2419		
	10/23/01	>2419		
	10/31/01	1553		
	11/1/01	1986		
LPR-RM0.8	8/11/92		1400	2400
	8/13/92		1800	2700
	8/17/92		3700	13000
	8/19/92		700	690
	8/25/92		770	560
	8/26/92		660	450
	8/27/92		5700	21000
	9/2/92		430	700
	9/3/92		520	690
	9/4/92		1150	280
	3/29/93		190	47
	3/30/93		60	21
	3/31/93		165	91
	4/19/93		170	22

Monitoring Station	Date	E. Coli	Fecal Coliform	Fecal Strep
		[cts./100 mL]	[cts./100 mL]	[cts./100 mL]
LPR-RM0.8 (continued)	4/20/93		140	22
	4/21/93		220	190
	4/22/93		190	67
	4/23/93		12	14
	4/26/93		1470	3600
	4/27/93		250	860
	8/23/93		280	200
	8/24/93		270	330
	8/25/93		270	220
	8/30/93		320	400
	8/31/93		220	350
	9/1/93		2000	2100
	11/22/93		76	
	11/23/93		90	
	11/29/93		300	
	11/30/93		370	
	12/1/93		660	
	12/6/93		680	
	12/8/93		94	
	12/9/93		120	
	12/13/93		98	
	12/14/93		170	
	12/16/93		5800	
	8/26/94		490	290
	6/8/98	2419	3200	
	6/24/98	866	1120	
	7/13/98	74	250	
	7/27/98	613	210	
	8/10/98	157	244	
	8/31/98	47	76	
	9/14/98	31	80	
	10/5/98	144	190	
	10/19/98	80	490	
	11/9/98	25	60	
	11/23/98	18	32	
	12/7/98	47	220	
	1/11/99	11	94	
	2/1/99	816	2000	
	2/22/99	142	104	

Monitoring Station	Date	E. Coli	Fecal Coliform	Fecal Strep
		[cts./100 mL]	[cts./100 mL]	[cts./100 mL]
LPR-RM0.8 (continued)	6/2/99	26	130	
	6/24/99	21	170	
	7/1/99	39	440	
	7/6/99	88	230	
	7/7/99	435	600	
	7/8/99	23	440	
	7/15/99	23	270	
	7/19/99	96	440	
	7/20/99	2419	4200	
	7/21/99	38	390	
	7/22/99	308	2000	
WPLPR-RM1.2	8/11/92		1160	610
	8/13/92		5800	4800
	8/17/92		17000	7500
	8/19/92		1000	6500
	8/25/92		1600	1300
	8/26/92		6500	720
	8/27/92		8500	18000
	9/2/92		1350	1400
	9/3/92		940	710
	9/4/92		960	520
	3/29/93		90	38
	3/30/93		110	41
	3/31/93		380	64
	4/19/93		150	37
	4/20/93		220	73
	4/21/93		1000	200
	4/22/93		220	63
	4/23/93		35	20
	4/26/93		2300	2600
	4/27/93		117	82
	8/23/93		790	280
	8/24/93		760	190
	8/25/93		570	150
	8/30/93		530	330
	8/31/93		600	340
	9/1/93		500	580
	11/22/93		84	
	11/23/93		90	

Monitoring Station	Date	E. Coli	Fecal Coliform	Fecal Strep
		[cts./100 mL]	[cts./100 mL]	[cts./100 mL]
WPLPR-RM1.2 (continued)	11/29/93		210	
	11/30/93		160	
	12/1/93		200	
	12/6/93		250	
	12/8/93		310	
	12/9/93		212	
	12/13/93		350	
	12/14/93		162	
	12/16/93		300	
	8/30/94		810	214
WPLPR-RM4.6	7/29/92		2000	2400
	8/5/92		2200	1400
	8/6/92		2300	3000
	8/11/92		4600	3500
	8/13/92		5700	7500
	8/17/92		2800	9700
	8/19/92		1300	1350
	8/25/92		1000	2400
	8/26/92		1700	790
	8/27/92		5800	7800
	3/29/93		240	60
	3/30/93		110	27
	3/31/93		230	94
	4/19/93		190	29
	4/20/93		210	37
	4/21/93		610	220
	4/22/93		320	61
	4/23/93		31	23
	4/26/93		480	1700
	4/27/93		98	93
	7/8/93		670	330
	7/14/93		3300	1900
	7/19/93		1200	570
	7/20/93		1140	1000
	7/21/93		1400	1500
	7/22/93		1100	2100
	7/26/93		540	510
	7/27/93		500	330
	7/28/93		610	410

Monitoring Station	Date	E. Coli	Fecal Coliform	Fecal Strep
		[cts./100 mL]	[cts./100 mL]	[cts./100 mL]
WPLPR-RM4.6 (continued)	7/29/93		450	300
	8/23/93		890	530
	8/24/93		920	740
	8/25/93		1190	790
	8/30/93		910	510
	8/31/93		970	600
	9/1/93		1300	2000
	11/22/93		310	
	11/23/93		180	
	11/29/93		150	
	11/30/93		220	
	12/1/93		360	
	12/6/93		190	
	12/8/93		170	
	12/9/93		152	
	12/13/93		240	
	12/14/93		270	
	12/16/93		260	
	8/30/94		610	380
	6/8/98	328	240	
	6/24/98	727	740	
	7/13/98	613	800	
	7/27/98	344	120	
	8/10/98	921	3000	
	8/31/98	70	160	
	9/14/98	81	82	
	10/5/98	200	350	
	10/19/98	270	280	
	11/9/98	101	118	
	11/23/98	70	100	
	12/7/98	71	84	
	1/11/99	16	120	
	2/1/99	31	200	
	2/22/99	9	84	
	6/2/99	261	250	
	6/24/99	130	630	
	7/1/99	30	460	
	7/6/99	121	260	
	7/7/99	1733	2100	

Monitoring Station	Date	E. Coli	Fecal Coliform	Fecal Strep
		[cts./100 mL]	[cts./100 mL]	[cts./100 mL]
WPLPR-RM4.6 (continued)	7/8/99	980	700	
	7/15/99	37	290	
	7/19/99	276	280	
	7/20/99	238	1200	
	7/21/99	93	500	
	7/22/99	35	320	
WPLPR-RM12.4	7/29/92		700	900
	8/5/92		300	600
	8/6/92		1500	3400
	8/11/92		1050	8100
	8/13/92		10300	18000
	8/17/92		1000	2700
	8/19/92		1000	480
	8/25/92		1600	1030
	8/26/92		570	330
	8/27/92		850	690
	3/29/93		90	37
	3/30/93		200	13
	3/31/93		40	17
	4/19/93		84	49
	4/20/93		150	33
	4/21/93		98	48
	4/22/93		85	27
	4/23/93		170	25
	4/26/93		140	390
	4/27/93		34	17
	7/8/93		820	360
	7/14/93		510	880
	7/19/93		810	950
	7/20/93		1060	3200
	7/21/93		400	1000
	7/22/93		440	1300
	7/26/93		380	1500
	7/27/93		420	1070
	7/28/93		400	790
	7/29/93		420	760
	8/23/93		340	300
	8/24/93		1120	190

Monitoring Station	Date	E. Coli [cts./100 mL]	Fecal Coliform [cts./100 mL]	Fecal Strep [cts./100 mL]
WPLPR-RM12.4 (continued)	8/25/93		380	210
	8/30/93		560	480
	8/31/93		460	320
	9/1/93		590	450
	11/22/93		114	
	11/23/93		370	
	11/29/93		114	
	11/30/93		112	
	12/1/93		78	
	12/6/93		160	
	12/8/93		38	
	12/9/93		22	
	12/13/93		28	
	12/14/93		140	
	12/16/93		760	
	9/1/94		5600	6900
	6/2/98	>2419	12300	
	6/8/98	157	86	
	6/15/98	>2419	2500	
	6/24/98	687	270	
	7/6/98	1046	472	
	7/13/98	99	168	
	7/20/98	1300	1800	
	7/27/98	461	360	
	8/3/98	93	120	
	8/10/98	54	230	
	8/24/98	46	60	
	8/31/98	1	14	
	9/14/98	27	94	
	9/21/98	1986	5200	
	10/5/98	114	210	
	10/13/98	51	60	
	10/19/98	14	54	
	10/26/98	62	30	
	11/9/98	70	70	
	11/16/98	2419	690	
	11/23/98	99	66	

Monitoring Station	Date	E. Coli	Fecal Coliform	Fecal Strep
		[cts./100 mL]	[cts./100 mL]	[cts./100 mL]
WPLPR-RM12.4 (continued)	11/30/98	16	50	
	12/7/98	150	100	
	12/14/98	67	100	
	1/11/99	16	20	
	1/25/99	10	60	
	2/1/99	7	190	
	2/8/99	387	360	
	2/22/99	99	104	
	6/2/99	687	570	
	6/24/99	13	178	
	7/1/99	14	134	
	7/6/99	1553	2800	
	7/7/99	52	410	
	7/8/99	39	210	
	7/15/99	88	240	
	7/19/99	8	94	
	7/20/99	120	300	
	7/21/99	11	290	
	7/22/99	71	330	
WPLPR-RM16.0	8/11/92		1400	570
	8/13/92		15400	9400
	8/17/92		1900	20000
	8/19/92		900	280
	8/25/92		15000	4200
	8/26/92		940	320
	8/27/92		1020	600
	9/2/92		200	160
	9/3/92		330	390
	9/4/92		60	40
	11/22/93		180	
	11/23/93		116	
	11/30/93		66	
	12/1/93		58	
	12/6/93		42	
	12/8/93		60	
	12/9/93		220	
	12/13/93		100	

Monitoring Station	Date	E. Coli	Fecal Coliform	Fecal Strep
		[cts./100 mL]	[cts./100 mL]	[cts./100 mL]
WPLPR-RM16.0 (continued)	12/14/93		240	
	12/16/93		740	
	6/8/98	108	180	
	6/24/98	248	360	
	7/13/98	488	340	
	7/27/98	479	240	
	8/10/98	36	410	
	8/31/98	16	170	
	9/14/98	14	120	
	10/5/98	248	430	
	10/19/98	272	270	
	11/9/98	15	92	
	11/23/98	23	200	
	12/7/98	10	140	
	1/11/99	3	92	
	2/1/99	9	200	
	2/22/99	3	36	
	6/2/99	21	420	
	6/24/99	7	770	
	7/1/99	6	174	
	7/6/99	1986	3800	
	7/7/99	980	510	
	7/8/99	38	230	
	7/15/99	8	290	
	7/19/99	99	200	
	7/20/99	37	340	
	7/21/99	17	430	
	7/22/99	112	540	
WPLPR-RM17.2	3/29/93		30	3
	3/30/93		130	5
	3/31/93		18	4
	4/19/93		860	9
	4/20/93		310	23
	4/21/93		210	34
	4/22/93		820	28
	4/23/93		290	17
	4/26/93		10	350

Monitoring Station	Date	E. Coli	Fecal Coliform	Fecal Strep
		[cts./100 mL]	[cts./100 mL]	[cts./100 mL]
WPLPR-RM17.2 (continued)	4/27/93		10	16
	7/8/93		2200	1500
	7/12/93		8400	8800
	7/14/93		880	990
	7/19/93		1160	150
	7/20/93		8400	2800
	7/21/93		3000	600
	7/22/93		3900	850
	7/26/93		920	920
	7/27/93		1800	710
	7/28/93		850	690
	7/29/93		810	560
	8/23/93		500	720
	8/24/93		990	1290
	8/25/93		580	1440
	8/30/93		610	470
	8/31/93		960	630
	9/1/93		770	380
	11/22/93		2100	
	11/23/93		90	
	11/29/93		112	
	11/30/93		40	
	12/1/93		52	
	12/6/93		22	
	12/8/93		420	
	12/9/93		270	
	12/13/93		102	
	12/14/93		134	
	12/16/93		510	
	9/15/94		3200	1200
	6/2/98	>2419	2000	
	6/8/98	173	122	
	6/15/98	980	600	
	6/24/98	435	220	
	7/6/98	178	320	
	7/13/98	479	530	
	7/20/98	1986	1700	

Monitoring Station	Date	E. Coli	Fecal Coliform	Fecal Strep
		[cts./100 mL]	[cts./100 mL]	[cts./100 mL]
WPLPR-RM17.2 (continued)	7/27/98	689	670	
	8/3/98	517	550	
	8/10/98	770	610	
	8/24/98	613	470	
	8/31/98	8	360	
	9/14/98	42	240	
	9/21/98	>2419	7500	
	10/5/98	410	1420	
	10/13/98	201	310	
	10/19/98	15	580	
	10/26/98	649	460	
	11/9/98	46	330	
	11/16/98	172	154	
	11/23/98	2	270	
	11/30/98	36	444	
	12/7/98	74	260	
	12/14/98	7	100	
	1/11/99	6	96	
	1/25/99	<1	40	
	2/1/99	6	186	
	2/8/99	5	82	
	2/22/99	<1	72	
	6/2/99	20	226	
	6/24/99	365	1150	
	7/1/99	16	170	
	7/6/99	1986	2900	
	7/7/99	24	260	
	7/8/99	461	280	
	7/15/99	249	340	
	7/19/99	6	146	
	7/20/99	192	1200	
	7/21/99	11	250	
	7/22/99	111	410	
WPLPR-RM20.6	7/29/92		14	120
	8/5/92		20	200
	8/6/92		80	1500
	8/11/92		<2	210

Monitoring Station	Date	E. Coli [cts./100 mL]	Fecal Coliform [cts./100 mL]	Fecal Strep [cts./100 mL]
WPLPR-RM20.6 (continued)	8/13/92		20	540
	8/17/92		280	22
	8/19/92		14	92
	8/25/92		8	72
	8/26/92		6	96
	8/27/92		42	140
	9/2/92		10	80
	9/3/92		130	160
	9/4/92		20	70
	9/17/92		20	50
	3/29/93		3	1
	3/30/93		0	0
	3/31/93		1	0
	4/19/93		7	1
	4/20/93		3	4
	4/21/93		2	5
	4/22/93		4	0
	4/23/93		1	0
	4/26/93		13	32
	4/27/93		0	2
	7/8/93		8	154
	7/14/93		2	300
	7/19/93		72	720
	7/20/93		10	400
	7/21/93		4	180
	7/22/93		60	350
	7/26/93		2	130
	7/27/93		6	560
	7/28/93		2	540
	7/29/93		4	580
	8/23/93		10	150
	8/24/93		20	190
	8/25/93		8	96
	8/30/93		2	88
	8/31/93		6	106
	9/1/93		32	190
	11/22/93		2	

Monitoring Station	Date	E. Coli	Fecal Coliform	Fecal Strep
		[cts./100 mL]	[cts./100 mL]	[cts./100 mL]
WPLPR-RM20.6 (continued)	11/23/93		8	
	11/29/93		2	
	11/30/93		2	
	12/1/93		8	
	12/6/93		6	
	12/8/93		2	
	12/9/93		2	
	12/13/93		4	
	12/14/93		2	
	12/16/93		1	
	9/15/94		470	300
	6/2/98	1120	650	
	6/8/98	9	10	
	6/15/98	17	12	
	6/24/98	16	8	
	7/6/98	7	6	
	7/13/98	4	2	
	7/20/98	4	10	
	7/27/98	6	66	
	8/3/98	2	8	
	8/10/98	<1	2	
	8/24/98	14	8	
	8/31/98	4	4	
	9/14/98	4	4	
	9/21/98	866	850	
	10/5/98	2	14	
	10/13/98	13	6	
	10/19/98	<1	<2	
	10/26/98	4	2	
	11/9/98	<1	<2	
	11/16/98	4	12	
	11/23/98	<1	<2	
	11/30/98	<1	2	
	12/7/98	<1	<2	
	12/14/98	2	16	
	1/11/99	<1	16	
	1/25/99	<1	2	

Monitoring Station	Date	E. Coli [cts./100 mL]	Fecal Coliform [cts./100 mL]	Fecal Strep [cts./100 mL]
WPLPR-RM20.6 (continued)	2/1/99	1	30	
	2/8/99	<1	<2	
	2/22/99	<1	2	
	6/2/99	2	<2	
	6/24/99	2	78	
	7/1/99	3	22	
	7/6/99	8	58	
	7/7/99	26	30	
	7/8/99	24	20	
	7/15/99	4	12	
	7/19/99	2	8	
	7/20/99	1	12	
	7/21/99	2	20	
	7/22/99	<1	16	
BASKINS	7/29/92		12000	1600
	8/5/92		500	2000
	8/6/92		800	3000
	8/11/92		1200	2700
	8/13/92		11400	8200
	8/17/92		790	1900
	8/19/92		420	430
	8/25/92		530	570
	8/26/92		960	380
	8/27/92		700	690
	9/1/93		560	830
	9/13/94		130	930
BEECH	7/29/92		2500	4000
	8/5/92		240	1000
	8/6/92		1600	7600
	8/11/92		590	1500
	8/13/92		6800	25000
	8/17/92		10200	10300
	8/19/92		1800	2000
	8/25/92		1000	3200
	8/26/92		610	580
	8/27/92		810	1100
	9/13/94		64	470

Monitoring Station	Date	E. Coli [cts./100 mL]	Fecal Coliform [cts./100 mL]	Fecal Strep [cts./100 mL]
BEECH (continued)	6/2/98	>2419	8300	
	6/15/98	517	450	
	7/6/98	96	220	
	7/20/98	1300	1900	
	8/3/98	205	260	
	8/24/98	29	32	
	9/21/98	>2419	26500	
	10/13/98	129	150	
	10/26/98	166	140	
	11/16/98	411	220	
	11/30/98	9	6	
	12/14/98	866	840	
	1/25/99	56	70	
	2/8/99	770	580	
DUDLEY	7/29/92		1200	1100
	8/5/92		600	500
	8/6/92		5000	14000
	8/11/92		820	680
	8/13/92		12000	22000
	8/17/92		1400	5400
	8/19/92		225000	44000
	8/25/92		900	550
	8/26/92		930	400
	8/27/92		1140	530
	9/15/94		12	20
	6/2/98	>2419	18700	
	6/15/98	>2419	16000	
	7/6/98	687	770	
	7/20/98	>2419	8000	
	8/3/98	921	800	
	8/24/98	172	160	
	9/21/98	>2419	6700	
	10/13/98	866	870	
	10/26/98	228	180	
	11/16/98	135	114	
	11/30/98	22	134	
	12/14/98	104	180	

Monitoring Station	Date	E. Coli	Fecal Coliform	Fecal Strep
		[cts./100 mL]	[cts./100 mL]	[cts./100 mL]
DUDLEY (continued)	1/25/99	4	28	
	2/8/99	13	126	
GNATTY	8/11/92		820	2800
	8/13/92		8300	2000
	8/17/92		4000	6000
	8/19/92		900	940
	8/25/92		1000	710
	8/26/92		970	400
	8/27/92		750	2200
	9/2/92		730	1400
	9/3/92		3500	760
	9/4/92		260	60
	9/13/94		2	420
	6/2/98	>2419	10200	
	6/15/98	435	600	
	7/6/98	91	420	
	7/20/98	23	32	
	8/3/98	30	40	
	8/24/98	7	18	
	9/21/98	>2419	3100	
	10/13/98	25	14	
	10/26/98	9	6	
	11/16/98	20	18	
	11/30/98	1	<2	
	12/14/98	121	140	
	1/25/99	613	490	
	2/8/99	22	54	
HOLY	7/29/92		900	500
	8/5/92		450	380
	8/6/92		900	3500
	8/11/92		630	840
	8/13/92		13400	5000
	8/17/92		5700	2500
	8/19/92		7000	2900
	8/25/92		3600	3300
	8/26/92		380	580
	8/27/92		800	870

Monitoring Station	Date	E. Coli	Fecal Coliform	Fecal Strep
		[cts./100 mL]	[cts./100 mL]	[cts./100 mL]
KINGS	8/11/92		1600	2800
	8/13/92		2500	11000
	8/17/92		52000	30000
	8/19/92		990	1750
	8/25/92		4800	3200
	8/26/92		320	550
	8/27/92		1500	2500
	9/2/92		1500	480
	9/3/92		800	1750
	9/4/92		150	90
	9/13/94		69000	330
	6/2/98	1986	1160	
	6/15/98	>2419	4200	
	7/6/98	>2419	4900	
	7/20/98	>2419	2500	
	8/3/98	>2419	10000	
	8/24/98	>2419	3900	
	9/21/98	>2419	6500	
	10/13/98	>2419	10000	
	10/26/98	>2419	6000	
	11/16/98	>2419	8500	
	11/30/98	>2419	4100	
	12/14/98	2419	460	
	1/25/99	1553	700	
	2/8/99	>2419	8900	
MILL	7/14/93		510	440
	7/19/93		1270	1510
	7/20/93		320	390
	7/21/93		400	900
	7/22/93		2300	3100
	7/26/93		670	690
	7/27/93		670	910
	7/28/93		780	660
	7/29/93		400	270
	8/4/93		440	660
	8/24/93		600	260
	8/30/94		420	360

Monitoring Station	Date	E. Coli [cts./100 mL]	Fecal Coliform [cts./100 mL]	Fecal Strep [cts./100 mL]
MILL (continued)	6/8/98	140	194	
	6/24/98	579	700	
	7/13/98	461	780	
	7/27/98	687	260	
	8/10/98	517	1700	
	8/31/98	436	230	
	9/14/98	488	170	
	10/5/98	387	270	
	10/19/98	104	220	
	11/9/98	206	230	
	11/23/98	>2419	9900	
	12/7/98	80	134	
	1/11/99	7	62	
	2/1/99	73	250	
	2/22/99	14	62	
	6/2/99	1120	620	
	6/24/99	770	1000	
	7/1/99	501	880	
	7/6/99	276	260	
	7/7/99	291	1500	
	7/8/99	127	210	
	7/15/99	326	460	
	7/19/99	124	220	
	7/20/99	649	2500	
	7/21/99	2419	2600	
	7/22/99	189	250	
ROAR	7/29/92		6000	1250
	8/5/92		2000	650
	8/6/92		2800	2600
	8/11/92		6500	1050
	8/13/92		8700	13000
	8/17/92		770	350
	8/19/92		920	350
	8/25/92		100	150
	8/26/92		200	230
	8/27/92		670	250
	7/8/93		1060	1500

Monitoring Station	Date	E. Coli	Fecal Coliform	Fecal Strep
		[cts./100 mL]	[cts./100 mL]	[cts./100 mL]
ROAR (continued)	7/14/93		5900	2700
	7/19/93		2000	1820
	7/20/93		1560	2600
	7/21/93		3800	1500
	7/22/93		2300	2600
	7/26/93		3200	1000
	7/27/93		2800	1100
	7/28/93		3200	960
	7/29/93		3100	1540
	8/25/93		370	460
	9/13/94		460	250
WALDEN	7/14/93		960	1880
	7/19/93		510	390
	7/20/93		570	3000
	7/21/93		1200	200
	7/22/93		300	360
	7/26/93		1200	1700
	7/27/93		1090	1000
	7/28/93		1340	1140
	7/29/93		1100	670
	8/4/93		7700	9800
	8/23/93		1100	370
	9/6/94		1200	4900
	6/8/98	579	470	
	6/24/98	1414	1520	
	7/13/98	816	700	
	7/27/98	649	104	
	8/10/98	866	1150	
	8/31/98	365	320	
	9/14/98	411	270	
	10/5/98	816	490	
	10/19/98	299	330	
	11/9/98	101	120	
	11/23/98	77	56	
	12/7/98	66	60	
	1/11/99	19	94	
	2/1/99	62	330	

Monitoring Station	Date	E. Coli	Fecal Coliform	Fecal Strep
		[cts./100 mL]	[cts./100 mL]	[cts./100 mL]
WALDEN (continued)	2/22/99	19	102	
	6/2/99	461	570	
	6/24/99	866	1010	
	7/1/99	575	950	
	7/6/99	866	490	
	7/7/99	2419	2400	
	7/8/99	866	900	
	7/15/99	308	330	
	7/19/99	272	390	
	7/20/99	579	900	
	7/21/99	548	540	
	7/22/99	219	410	

APPENDIX C

Load Duration Curve Development
and
Determination of Required Load Reductions

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. When a water quality target (or criteria) 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).

C.1 Development of Flow Duration Curves

Flow duration curves are developed for a waterbody from daily discharges of flow over a 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 USGS continuous-record stations 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 Lower French Broad Watershed were derived from LSPC hydrologic simulations based on parameters derived from calibration at USGS Station No. 03535000, located on Bullrun Creek near Halls Crossroads, in the Lower Clinch watershed (see Appendix D for details of calibration). Flow duration curves for impaired waterbodies with drainage areas of greater than 50 square miles were derived from hydrologic simulations based on parameters derived from calibration at USGS Station No. 03469175, located on Little Pigeon River above Sevierville, in the Lower French Broad watershed. For example, a flow-duration curve for Dudley Creek was constructed using simulated daily mean flow for the period from 10/1/91 through 9/31/01. This flow duration curve is shown in Figure C-11 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 and are shown in Figures C-1 thru C-17.

C.2 Development of Load Duration Curves and Determination of Required Load Reductions

E. coli and fecal coliform load duration curves for impaired waterbodies in the Lower French Broad Watershed were developed from the flow duration curves developed in Section C.1 and available water quality monitoring data. Load duration curves were developed using the following procedure (Dudley Creek is shown as an example):

1. A target load-duration curve was generated for Dudley Creek by applying the fecal coliform target concentration of 900 cts./100 mL (1,000 cts./100mL - MOS) to each of the ranked flows used to generate the flow duration curve (ref.: Section D.1) and plotting the results. The fecal coliform target maximum load corresponding to each ranked daily mean flow is:

   $(\text{Target Load})_{\text{Dudley Creek}}$ = (900 cts./100 mL) x (Q) x (UCF)

   where: Q = daily mean flow
   UCF = the required unit conversion factor

   For E. coli, the target concentration of 847 cts./100 mL was applied to generate load duration curves corresponding to the E. coli water quality standard (see Section 5.0).

2. Daily loads were calculated for each of the water quality samples collected at monitoring station DUDLEY (ref.: Table B-1) by multiplying the sample concentration by the daily mean flow for the sampling date and the required unit conversion factor. DUDLEY was selected for LDC analysis because it was the monitoring station on Dudley Creek with the most 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.

3. Using the flow duration curves developed in C.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 fecal coliform and E. coli load duration curves for are shown in Figures C-34 and C-35.

4. For cases where the existing load exceeded the target maximum load at a particular PDFE, the reduction required to reduce the sample load to the target load was calculated.

5. The 90^{th} percentile value for all of the fecal coliform sampling data at DUDLEY monitoring site was determined. If the 90^{th} percentile value exceeded the target maximum fecal coliform concentration, the reduction required to reduce the 90^{th} percentile value to the target maximum concentration was calculated.

6. Step 5 was repeated for E. coli data at DUDLEY.

7. For cases where five or more samples were collected over a period of not more than 30 consecutive days, the geometric mean fecal coliform concentration was determined and compared to the target geometric mean fecal coliform concentration of 180 cts/100 mL (200 cts/100mL – MOS). 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.

8. Step 7 was repeated for the E. coli data at DUDLEY.

9. The load reductions required to meet the target maximum and target 30-day geometric mean concentrations of both fecal coliform and E. coli were compared and the load reduction of the greatest magnitude selected as the TMDL for Dudley Creek. The determination of required load reductions for Dudley Creek is shown in Tables C-17 and C-18.

Load reduction curves and required load reductions of other impaired waterbodies were derived in a similar manner and are shown in Figures C-18 through C-45 and Tables C-1 through C-28.

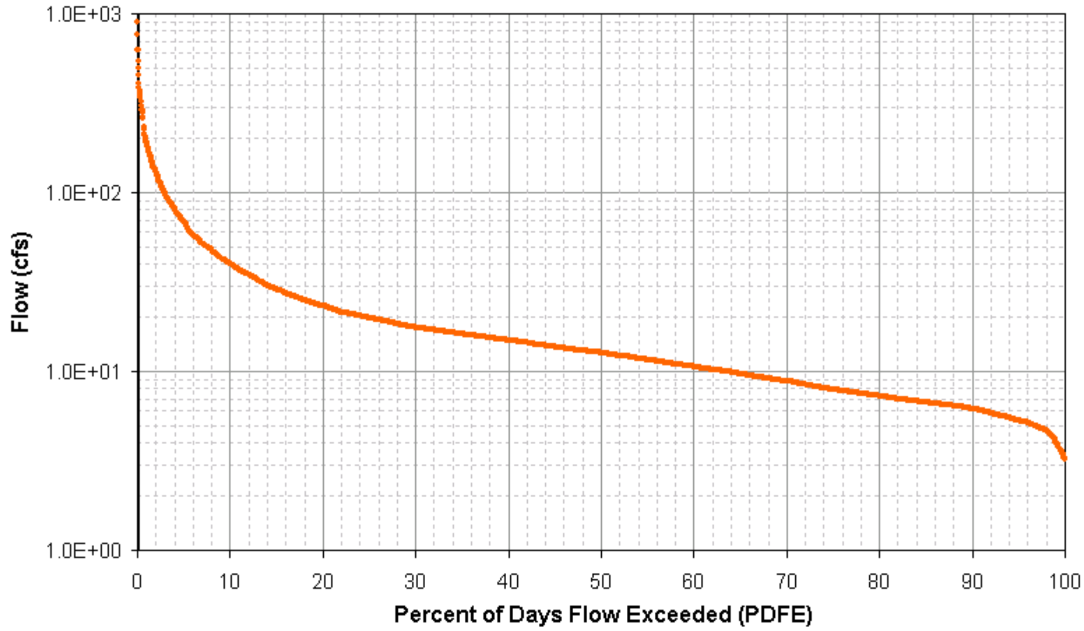

Figure C-1. Flow Duration Curve for Boyds Creek

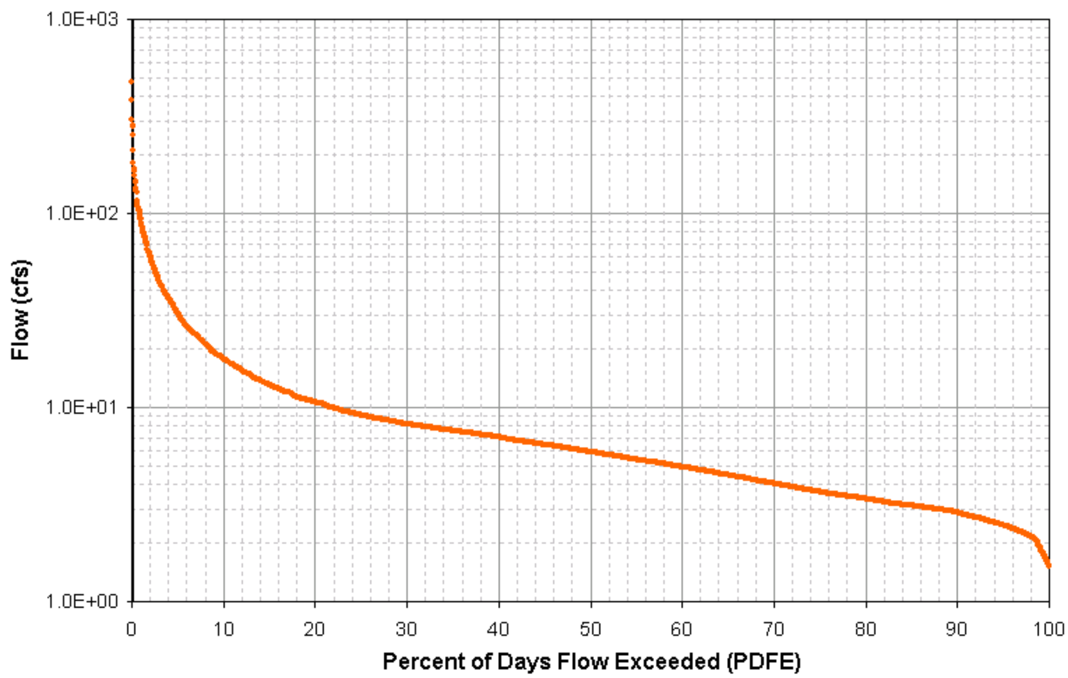

Figure C-2. Flow Duration Curve for Clear Creek

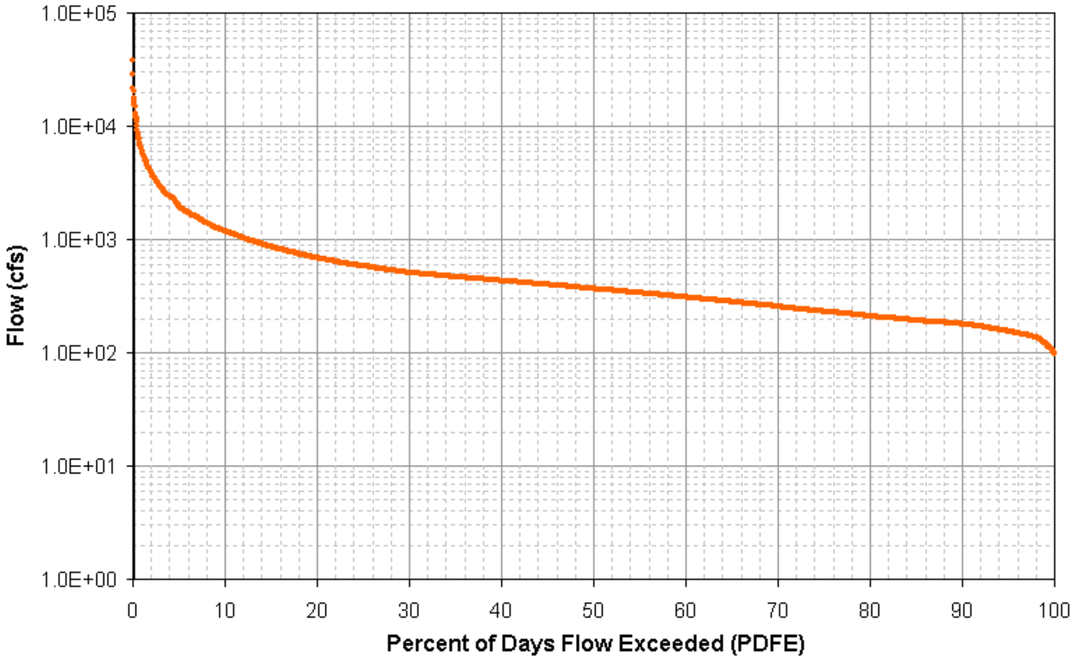

Figure C-3. Flow Duration Curve for Little Pigeon River at Mile 0.8

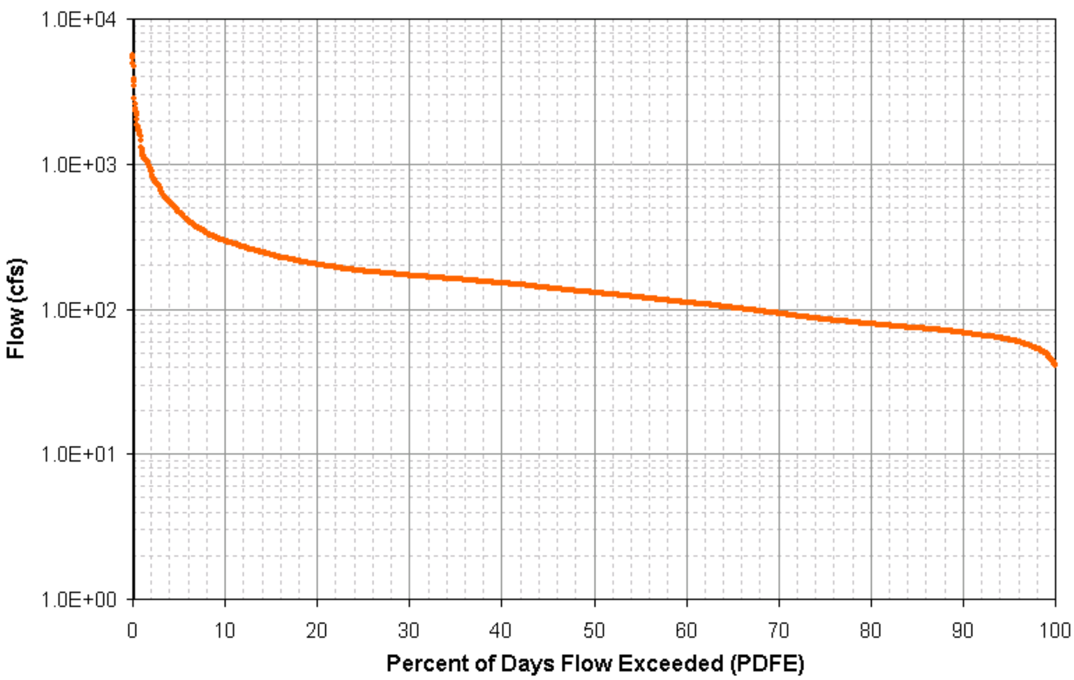

Figure C-4. Flow Duration Curve for West Prong Little Pigeon River at Mile 1.2

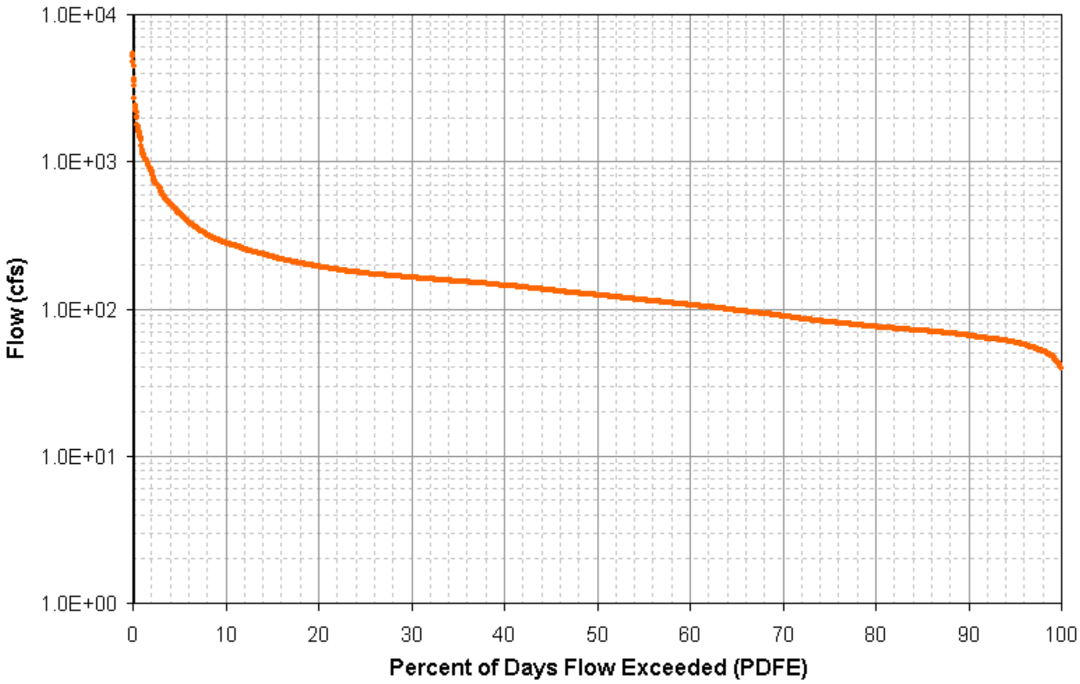

Figure C-5. Flow Duration Curve for West Prong Little Pigeon River at Mile 4.6

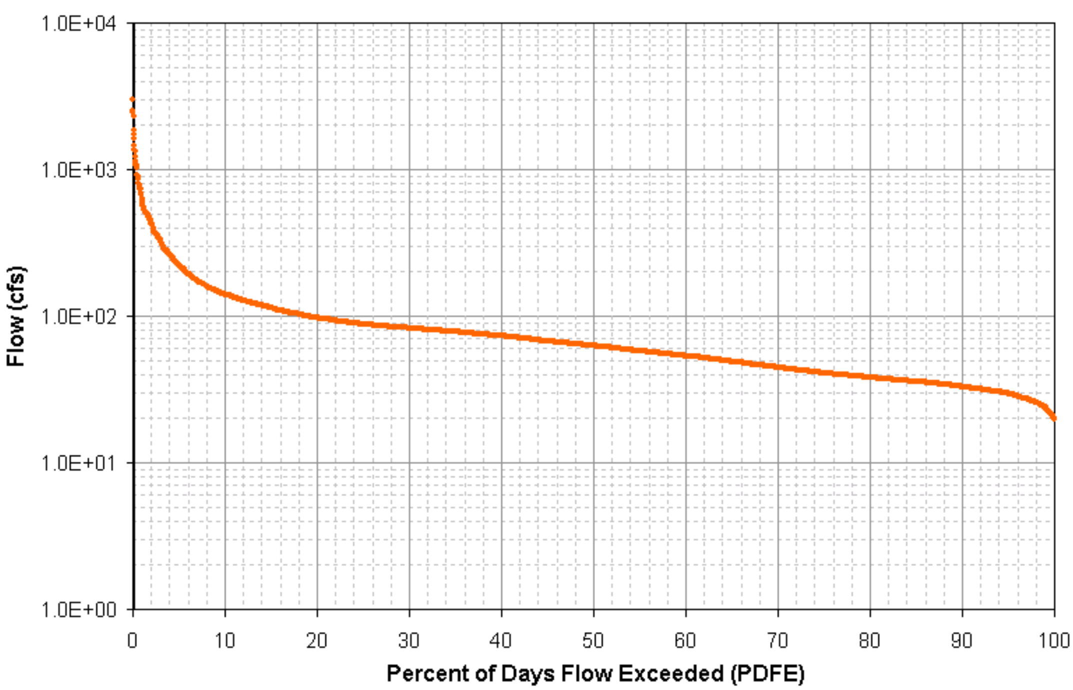

Figure C-6. Flow Duration Curve for West Prong Little Pigeon River at Mile 12.4

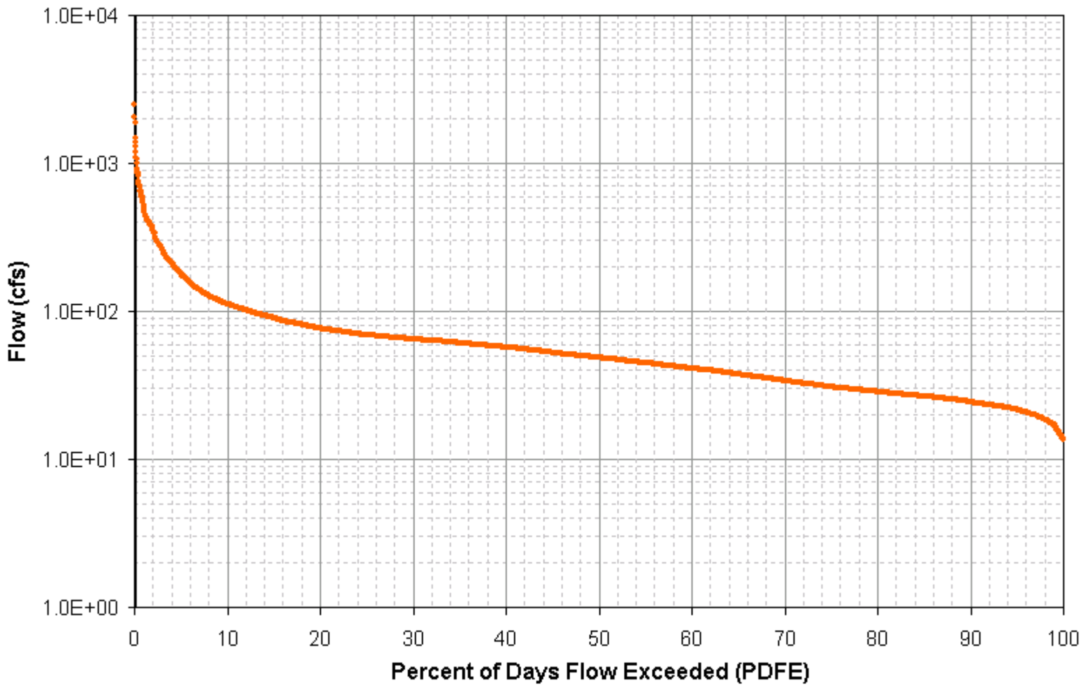

Figure C-7. Flow Duration Curve for West Prong Little Pigeon River at Mile 16.0

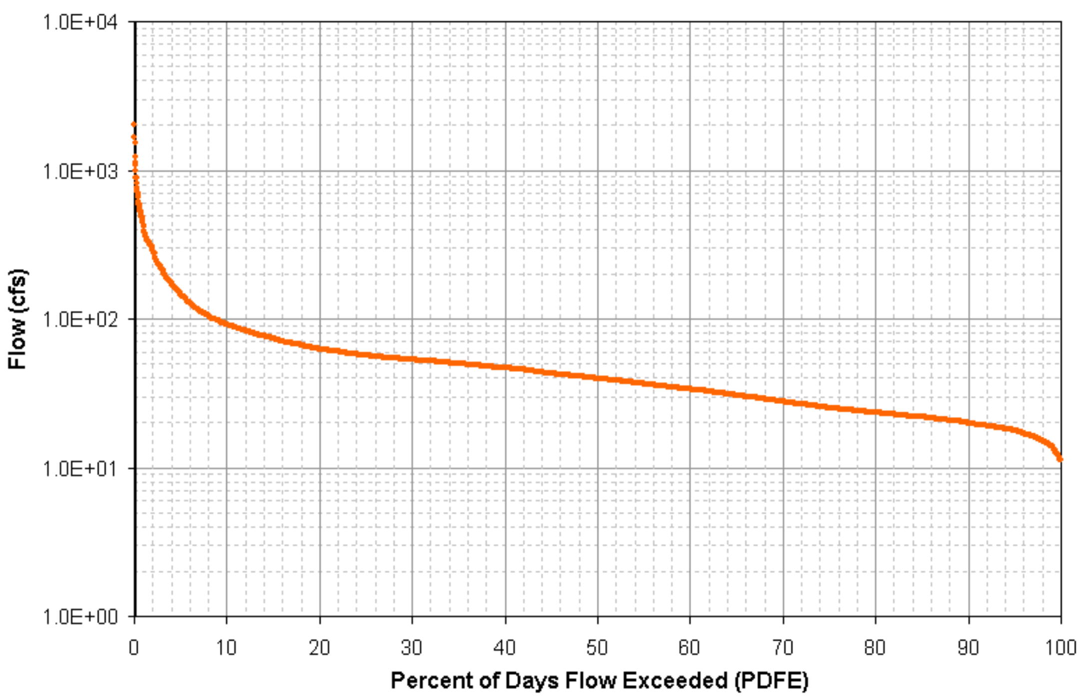

Figure C-8. Flow Duration Curve for West Prong Little Pigeon River at Mile 17.2

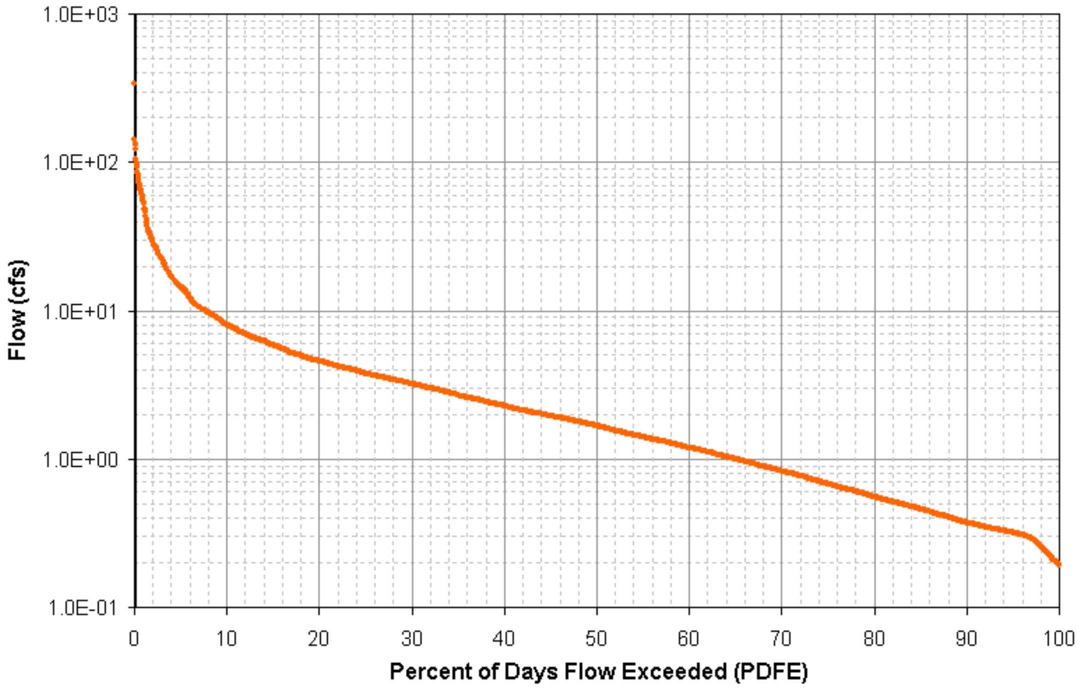

Figure C-9. Flow Duration Curve for Baskins Creek

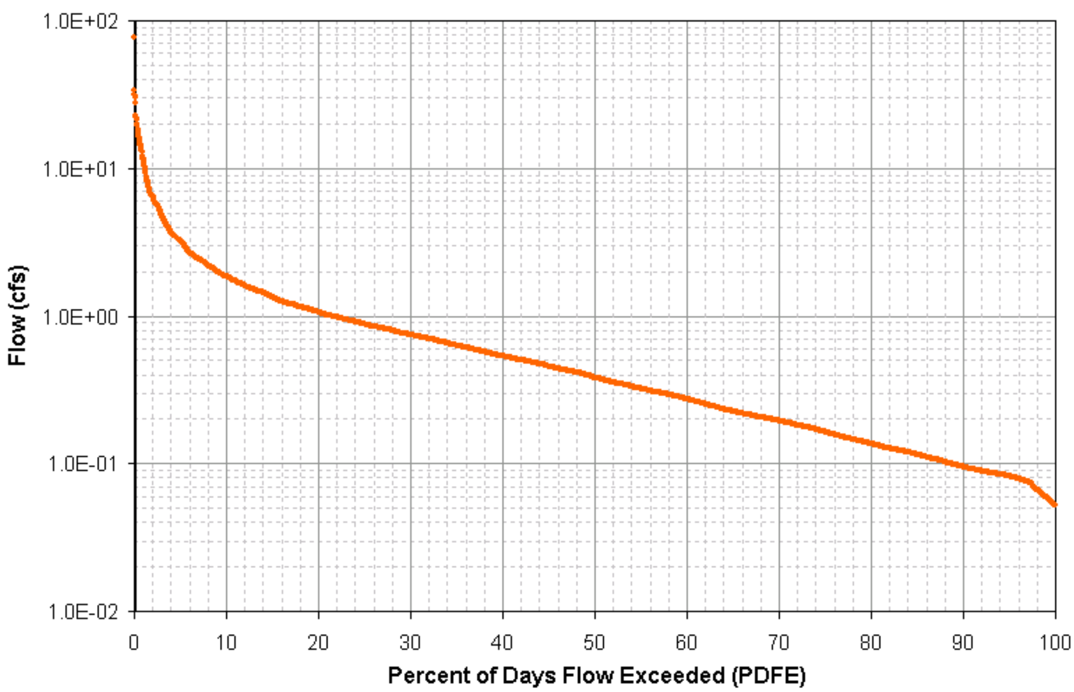

Figure C-10. Flow Duration Curve for Beech Branch

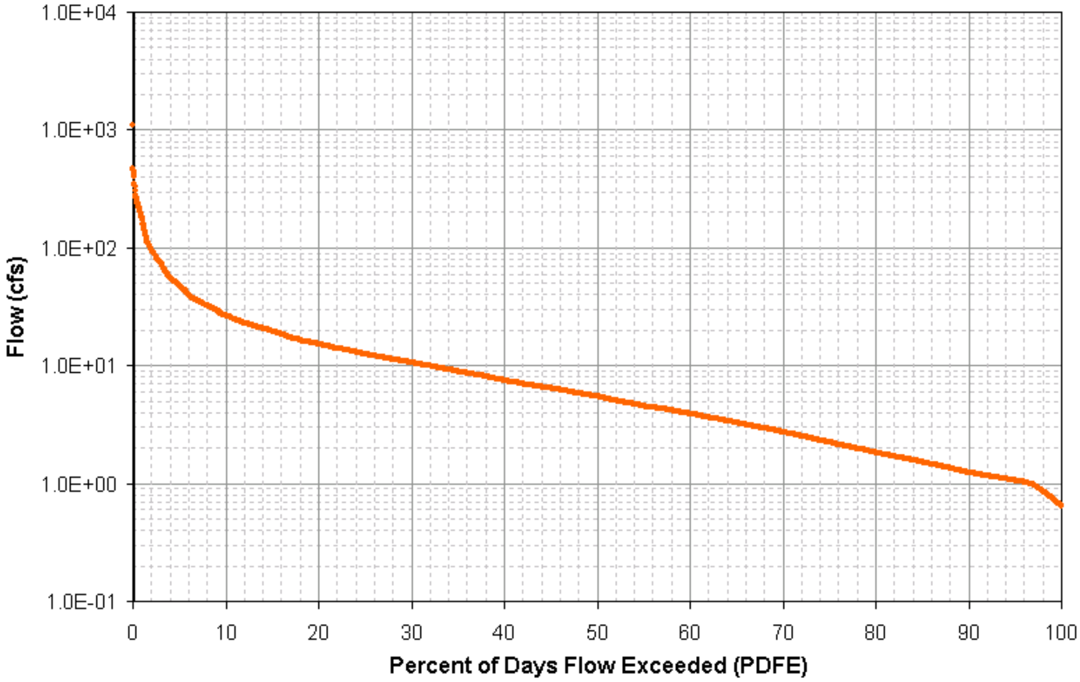

Figure C-11. Flow Duration Curve for Dudley Creek

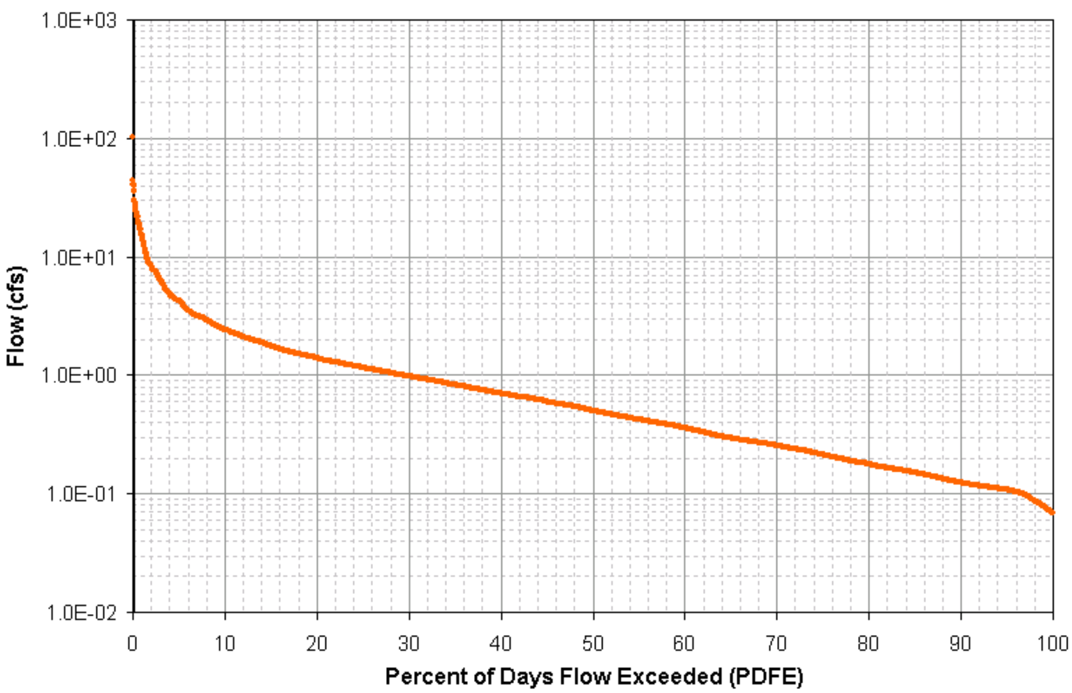

Figure C-12. Flow Duration Curve for Gnatty Branch

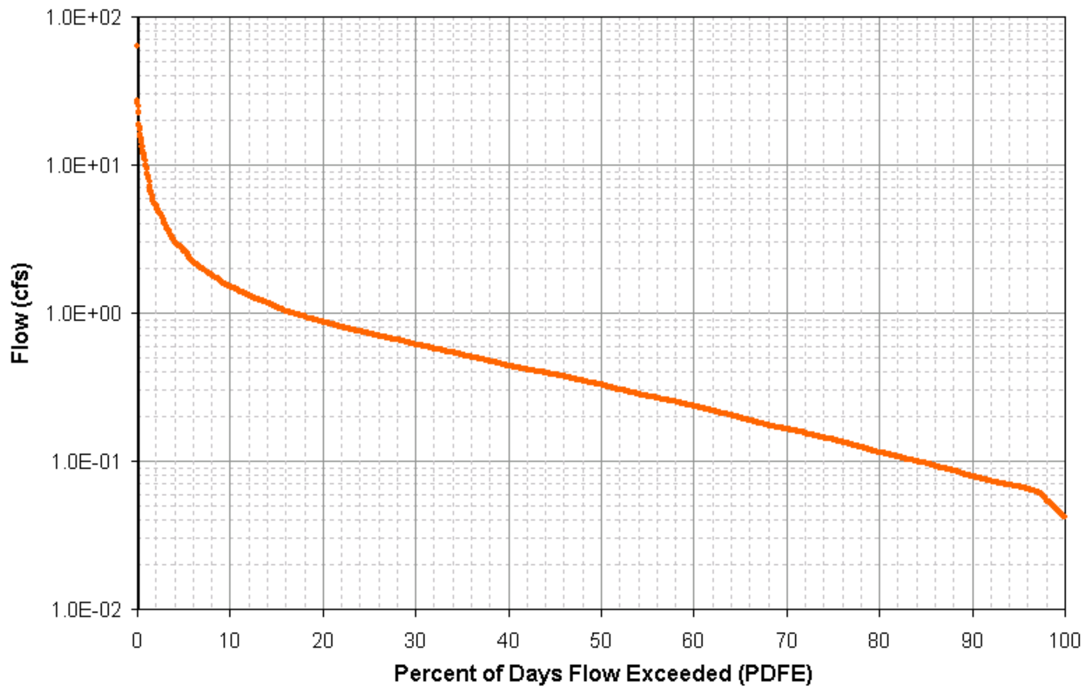

Figure C-13. Flow Duration Curve for Holy Branch

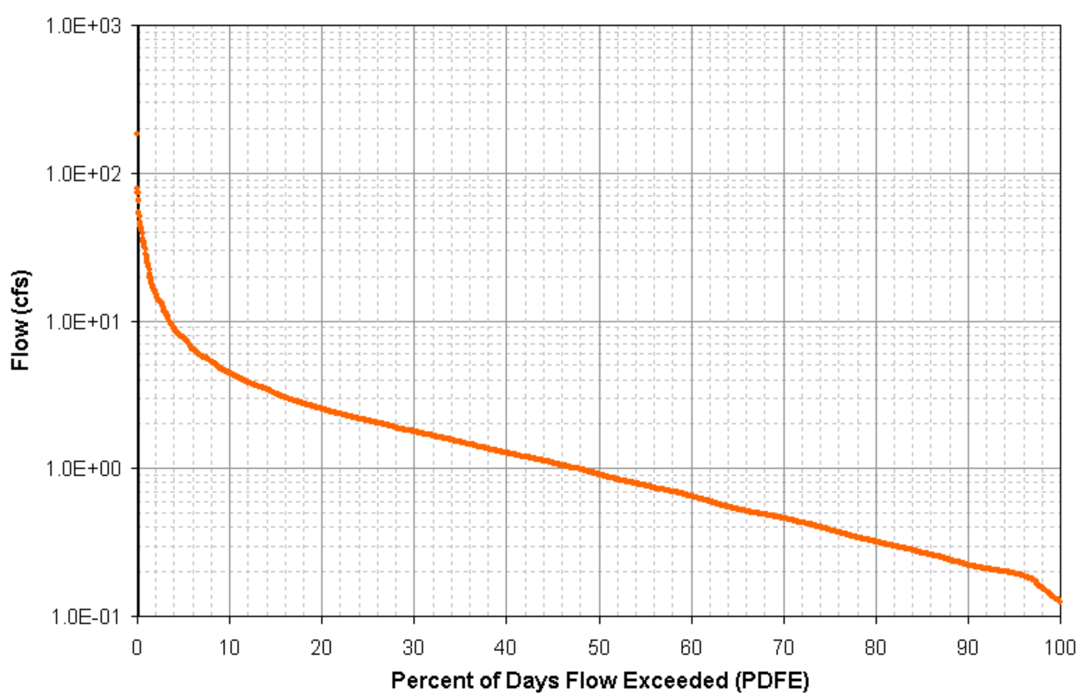

Figure C-14. Flow Duration Curve for Kings Branch

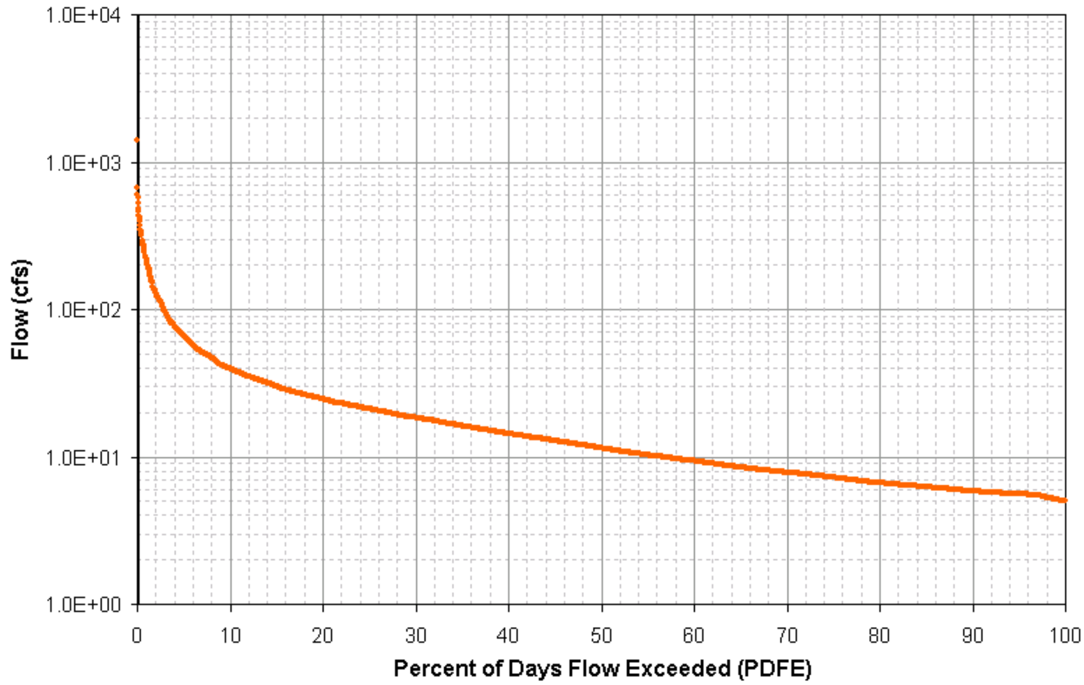

Figure C-15. Flow Duration Curve for Mill Creek

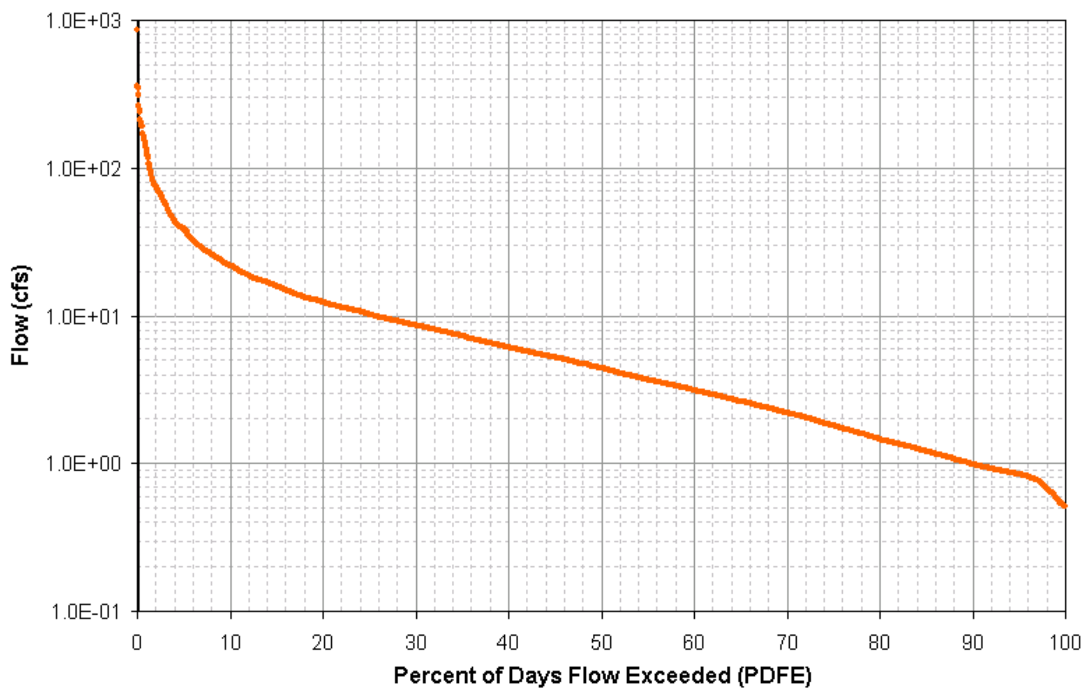

Figure C-16. Flow Duration Curve for Roaring Fork

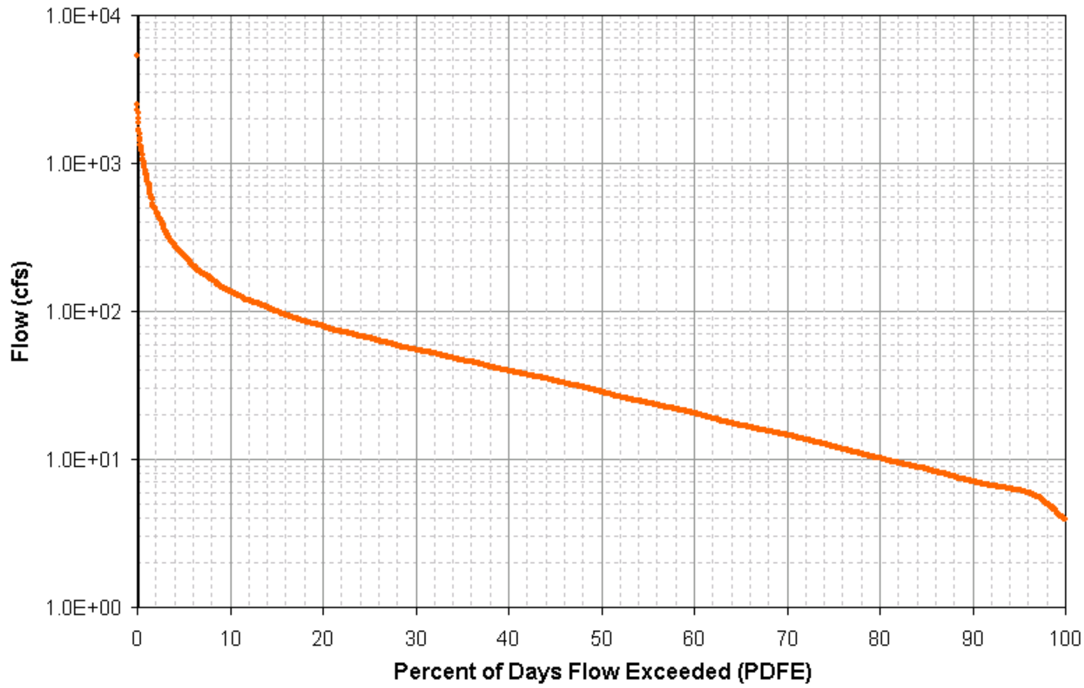

Figure C-17. Flow Duration Curve for Walden Creek

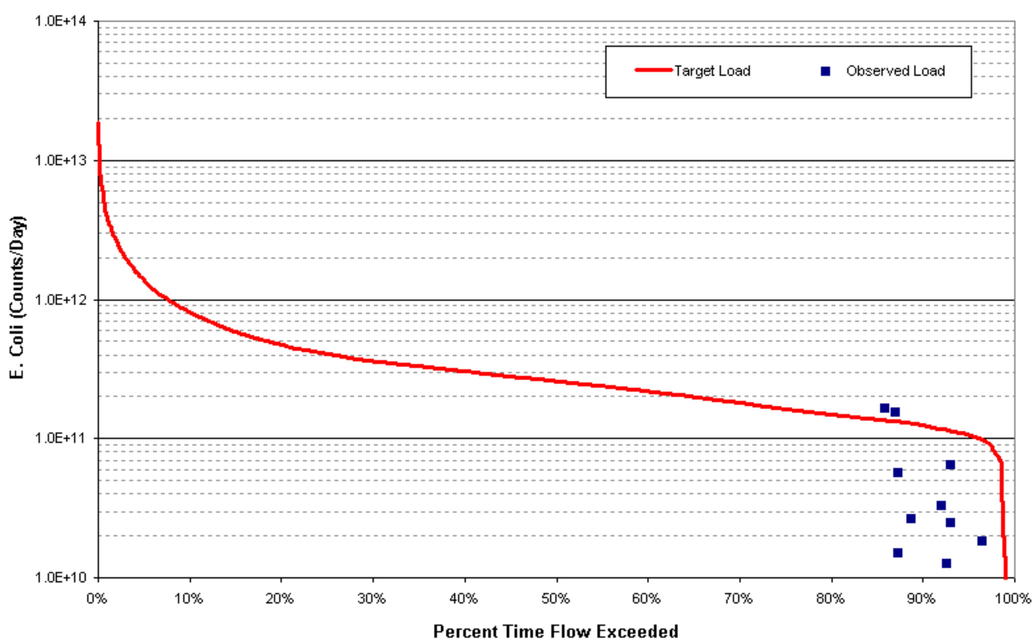

Figure C-18. E. Coli Load Duration Curve for Boyds Creek

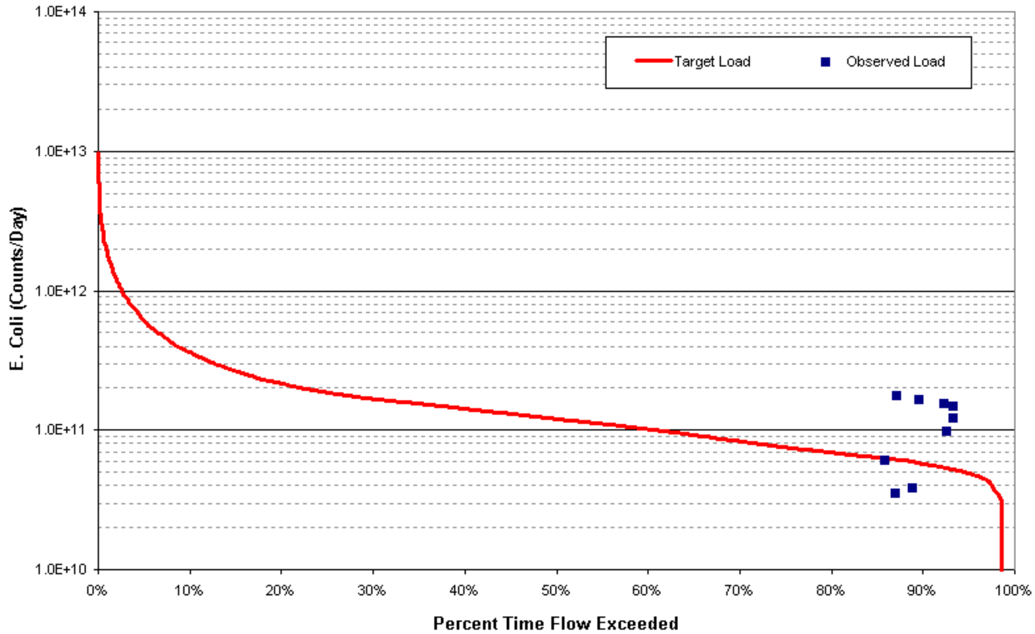

Figure C-19. E. Coli Load Duration Curve for Clear Creek

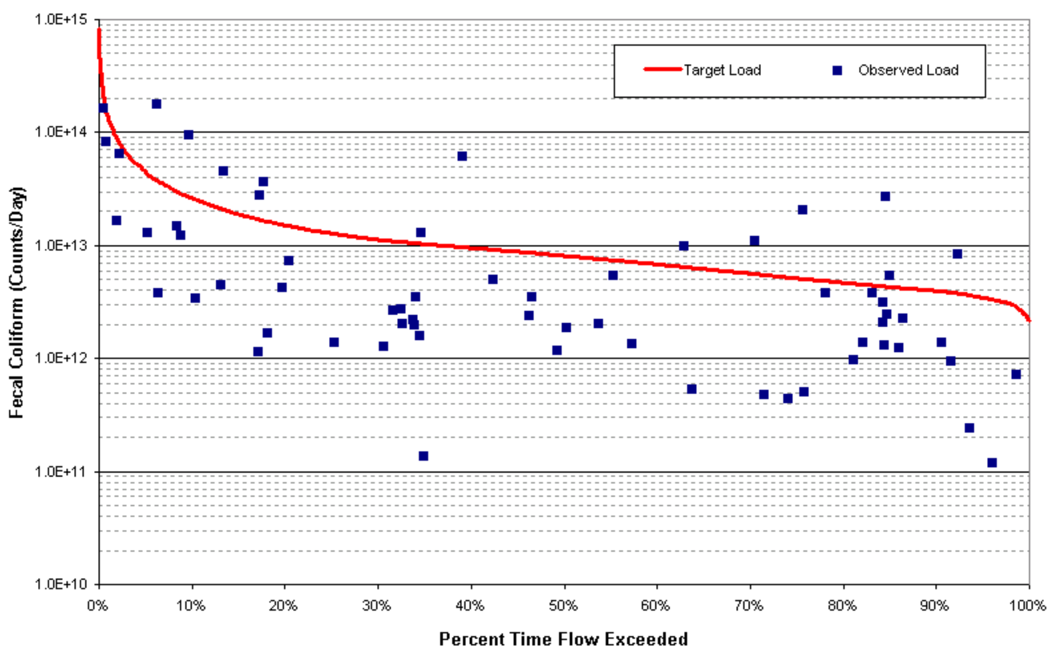

Figure C-20. Fecal Coliform Load Duration Curve for Little Pigeon River at Mile 0.8

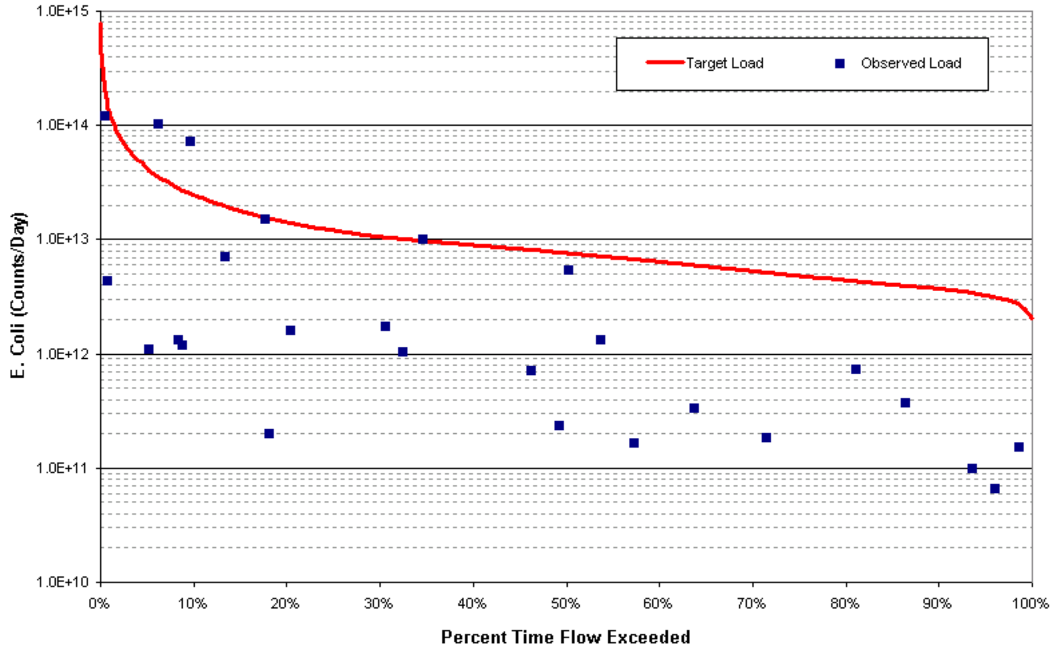

Figure C-21. E. Coli Load Duration Curve for Little Pigeon River at Mile 0.8

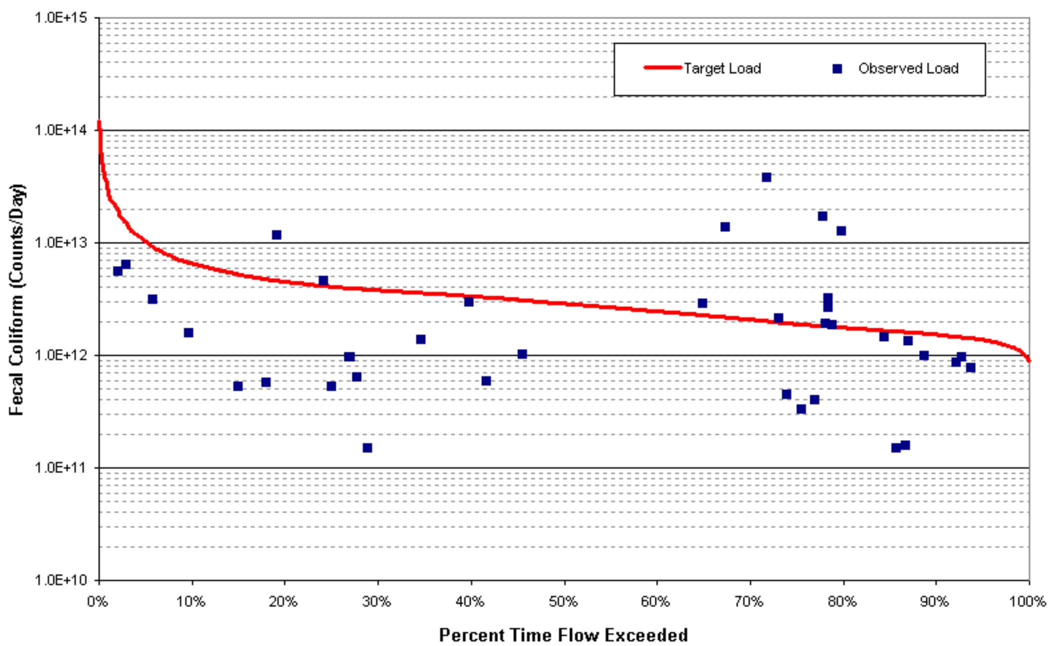

Figure C-22. Fecal Coliform Load Duration Curve for West Prong Little Pigeon River at Mile 1.2

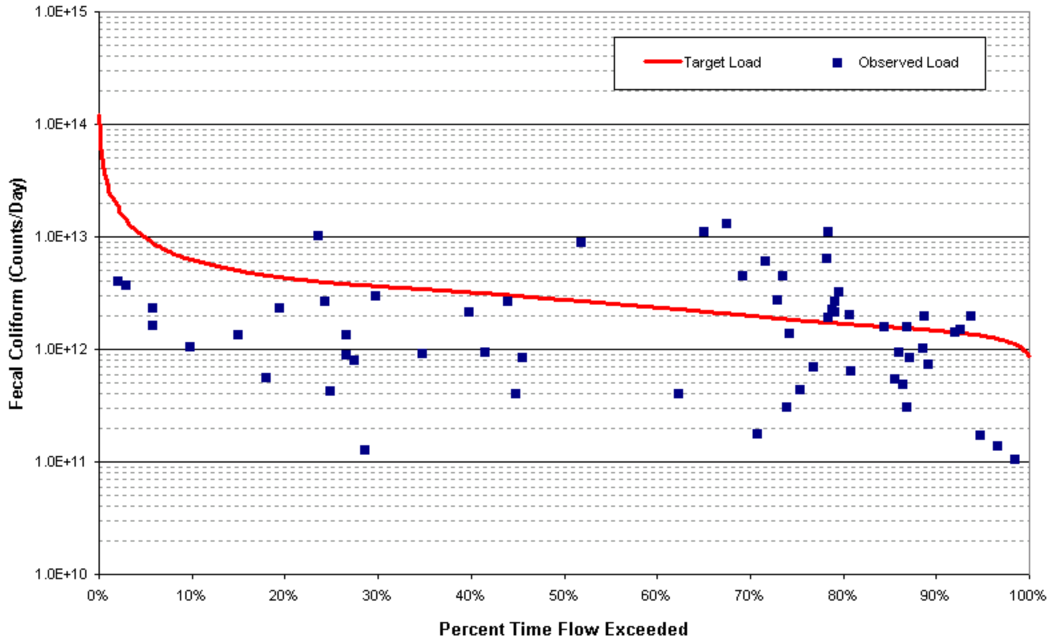

Figure C-23. Fecal Coliform Load Duration Curve for West Prong Little Pigeon River at Mile 4.6

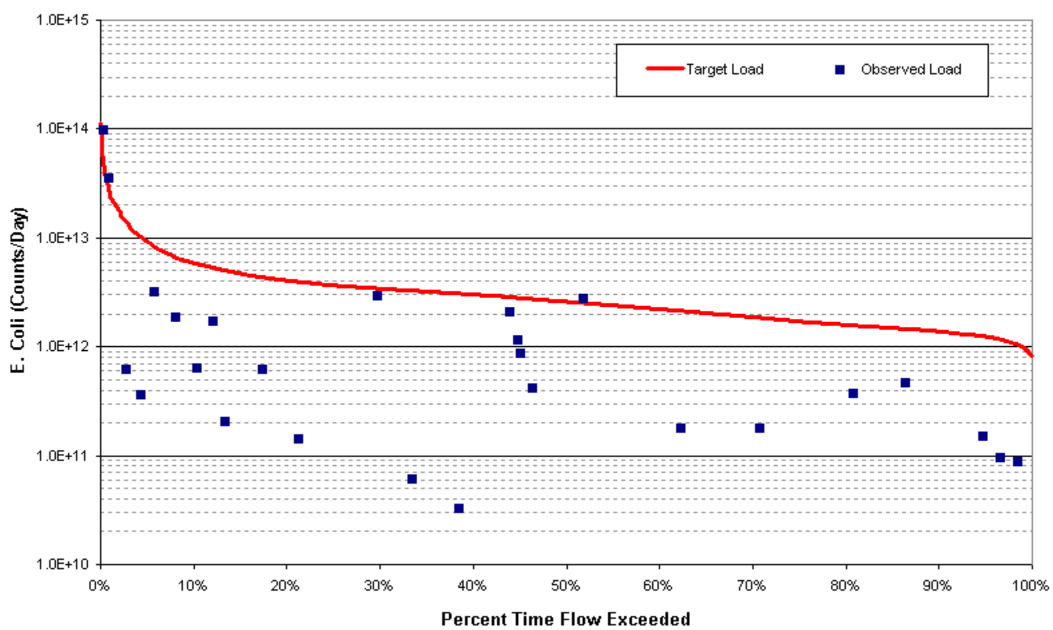

Figure C-24. E. Coli Load Duration Curve for West Prong Little Pigeon River at Mile 4.6

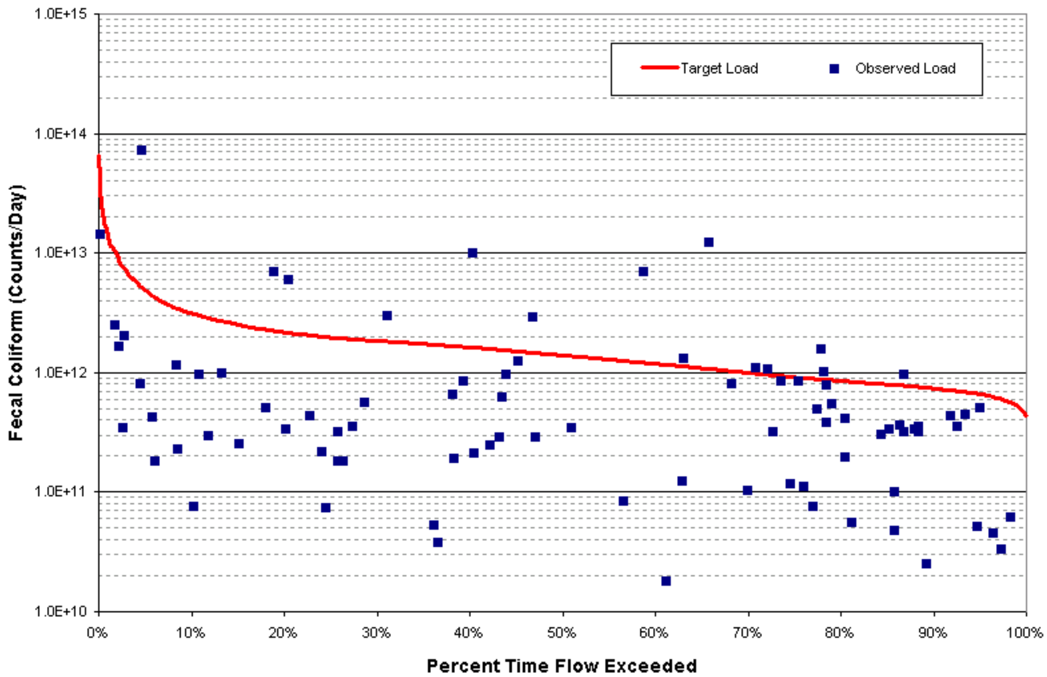

Figure C-25. Fecal Coliform Load Duration Curve for West Prong Little Pigeon River at Mile 12.4

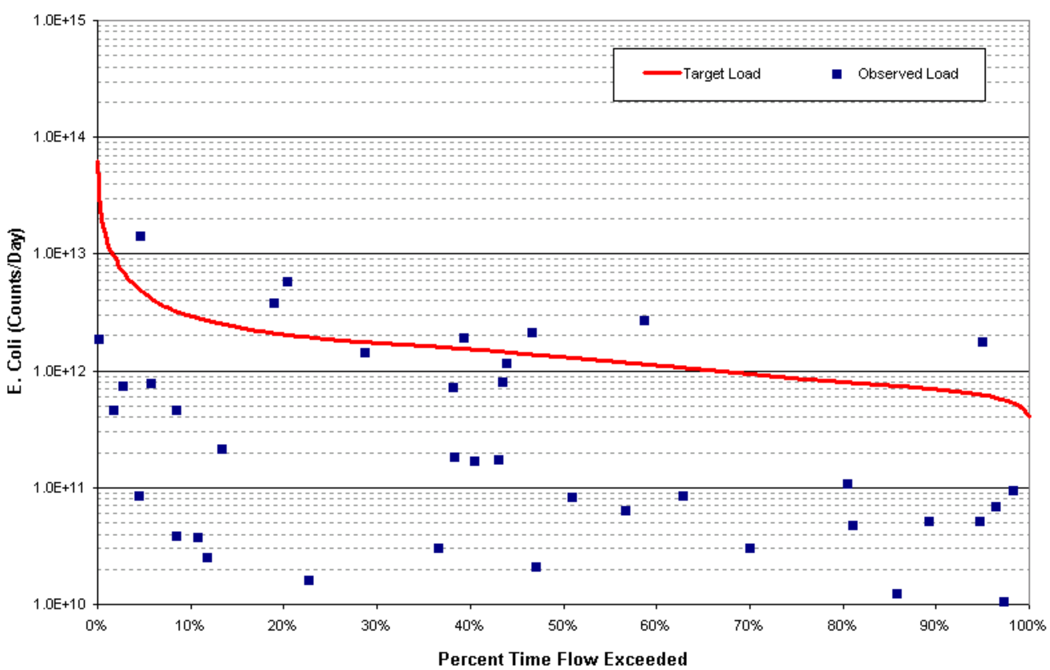

Figure C-26. E. Coli Load Duration Curve for West Prong Little Pigeon River at Mile 12.4

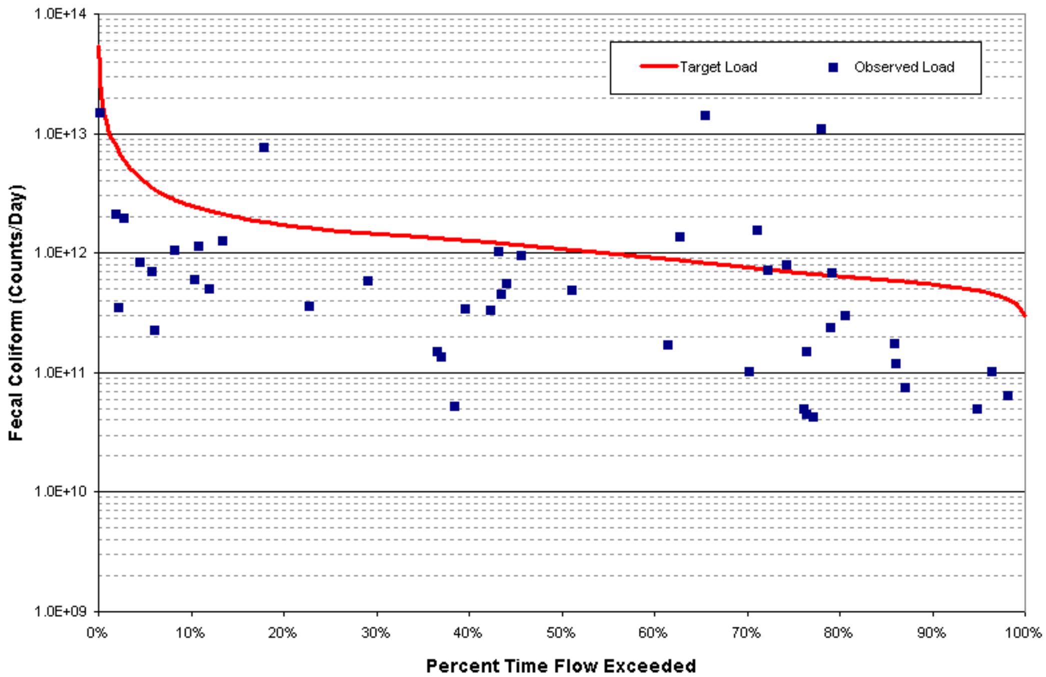

Figure C-27. Fecal Coliform Load Duration Curve for West Prong Little Pigeon River at Mile 16.0

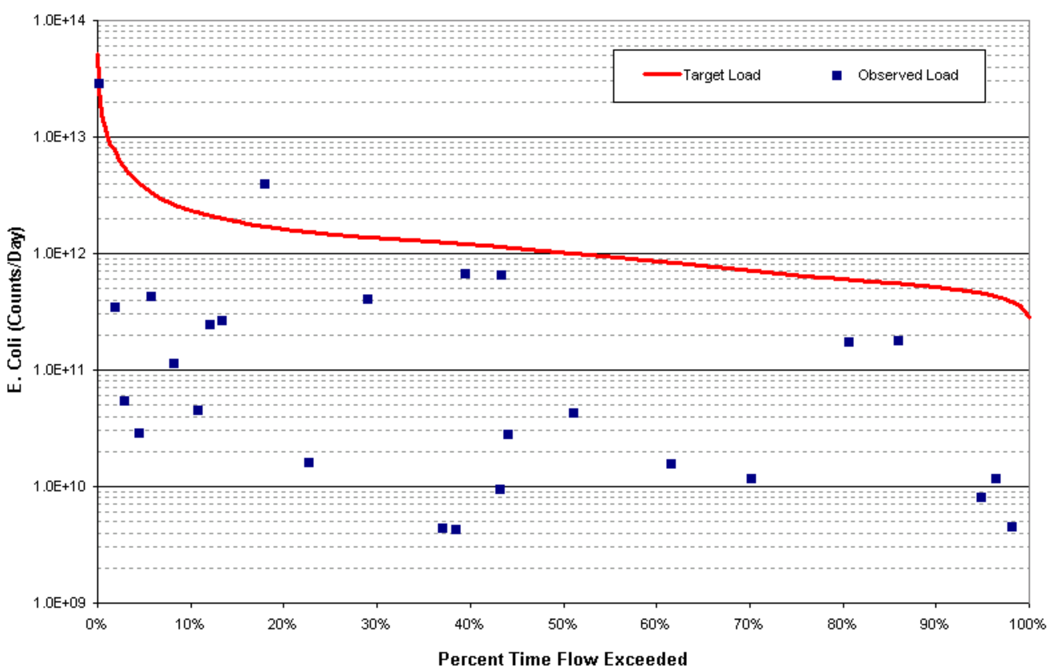

Figure C-28. E. Coli Load Duration Curve for West Prong Little Pigeon River at Mile 16.0

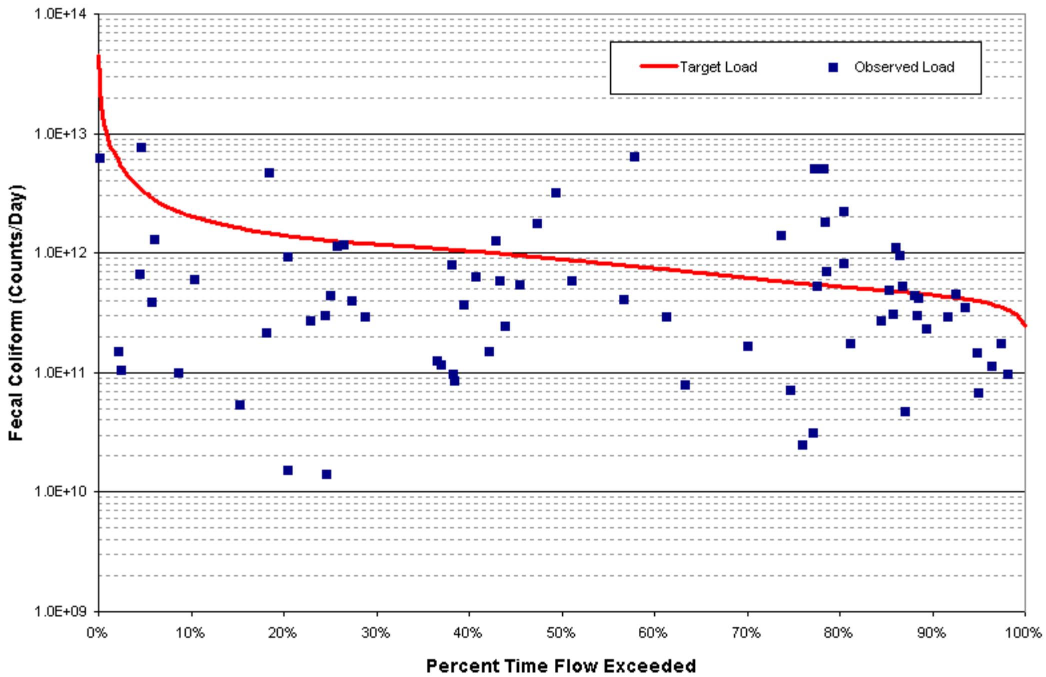

Figure C-29. Fecal Coliform Load Duration Curve for West Prong Little Pigeon River at Mile 17.2

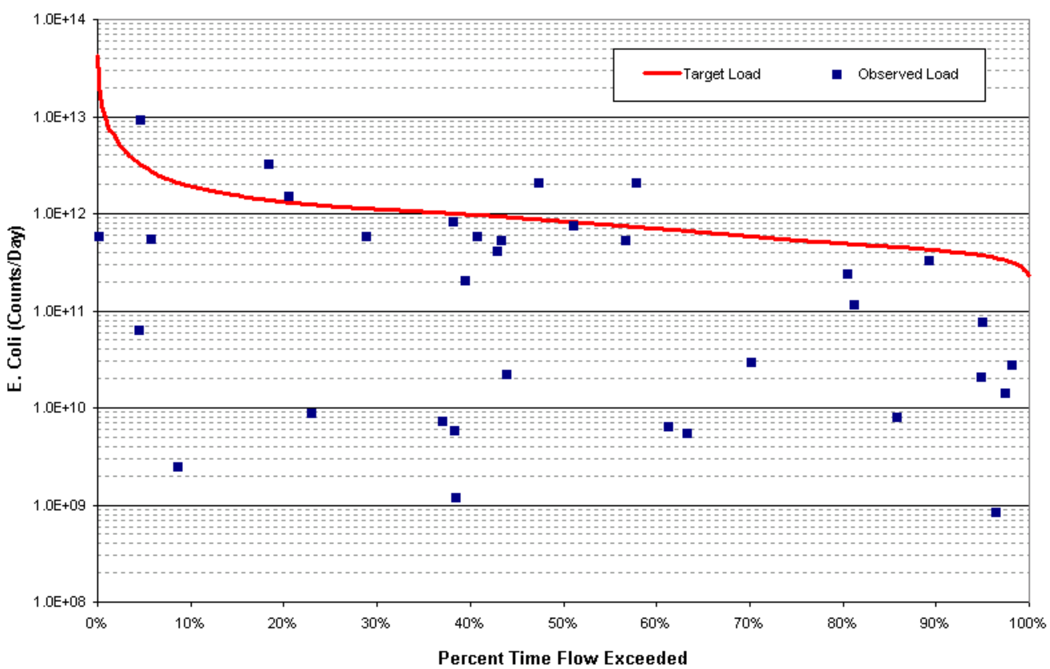

Figure C-30. E. Coli Load Duration Curve for West Prong Little Pigeon River at Mile 17.2

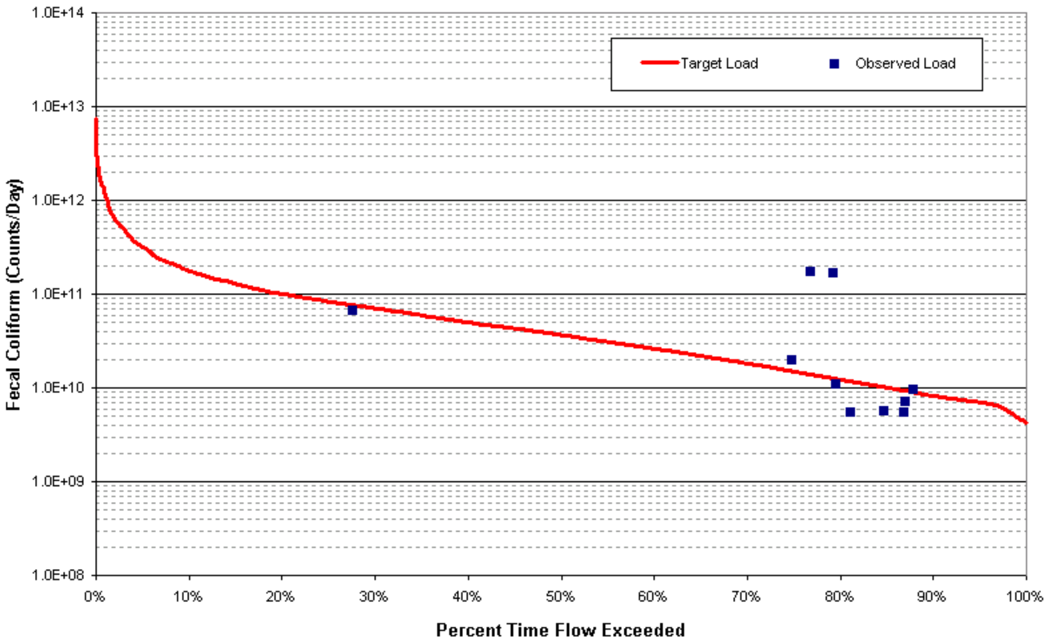

Figure C-31. Fecal Coliform Load Duration Curve for Baskins Creek

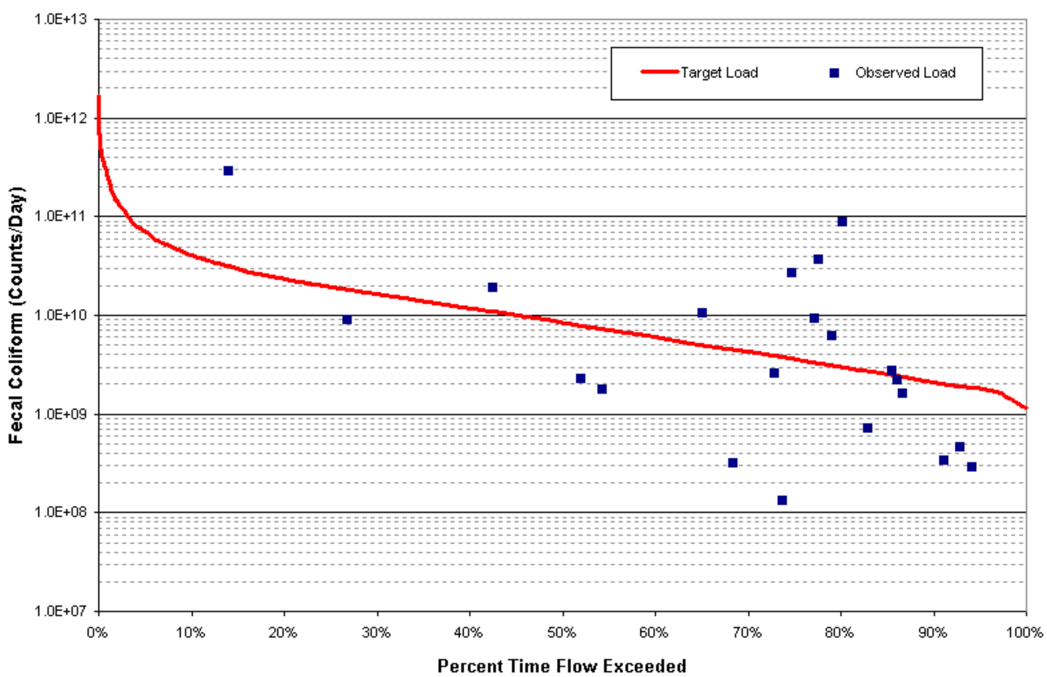

Figure C-32. Fecal Coliform Load Duration Curve for Beech Branch

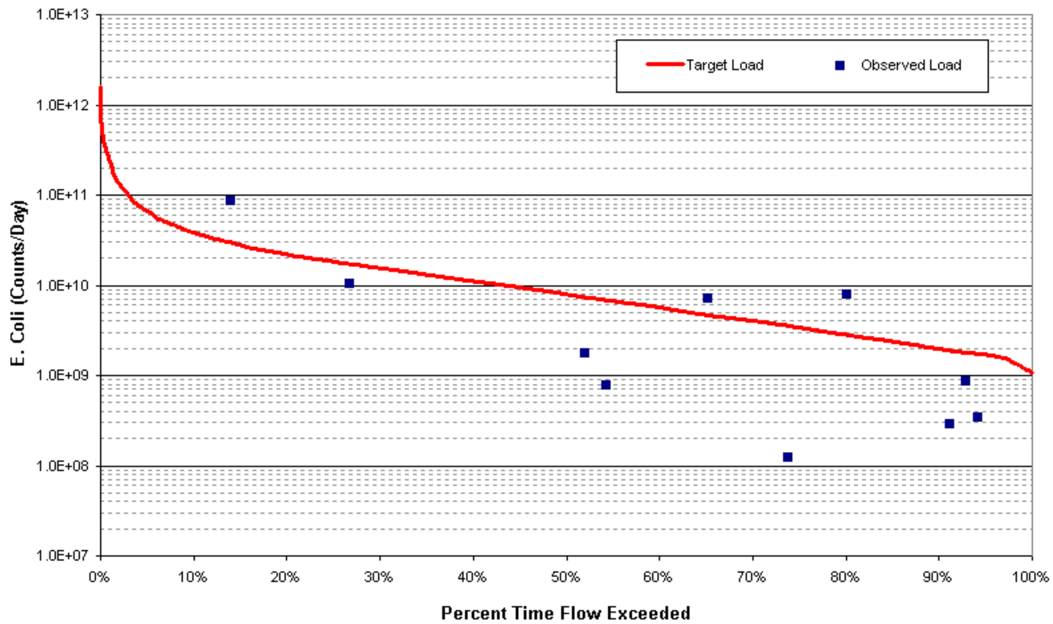

Figure C33. E. Coli Load Duration Curve for Beech Branch

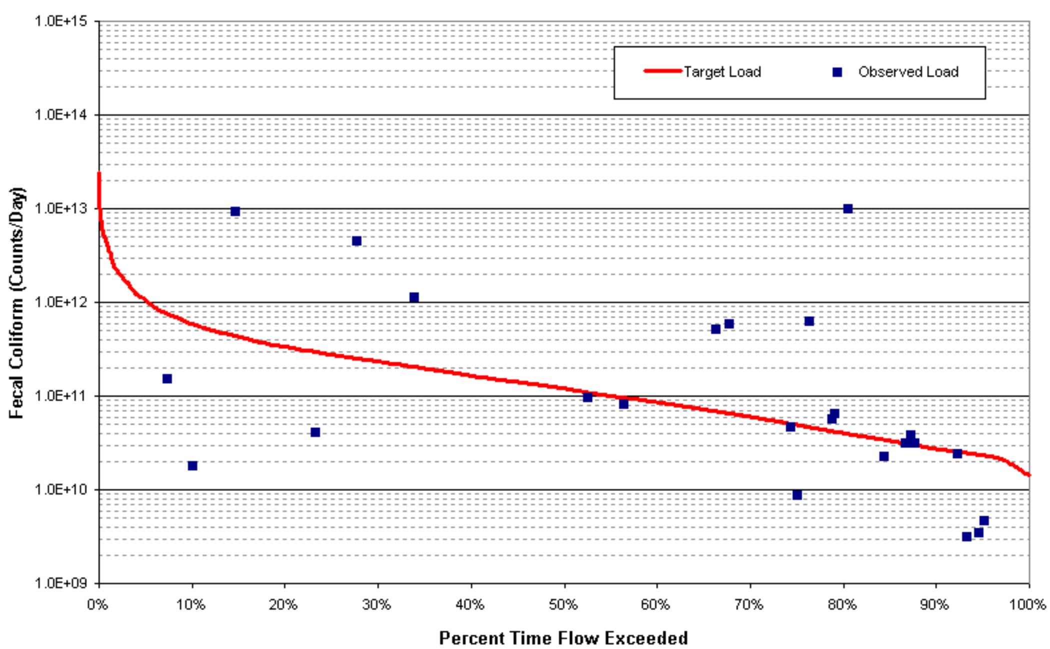

Figure C34. Fecal Coliform Load Duration Curve for Dudley Creek

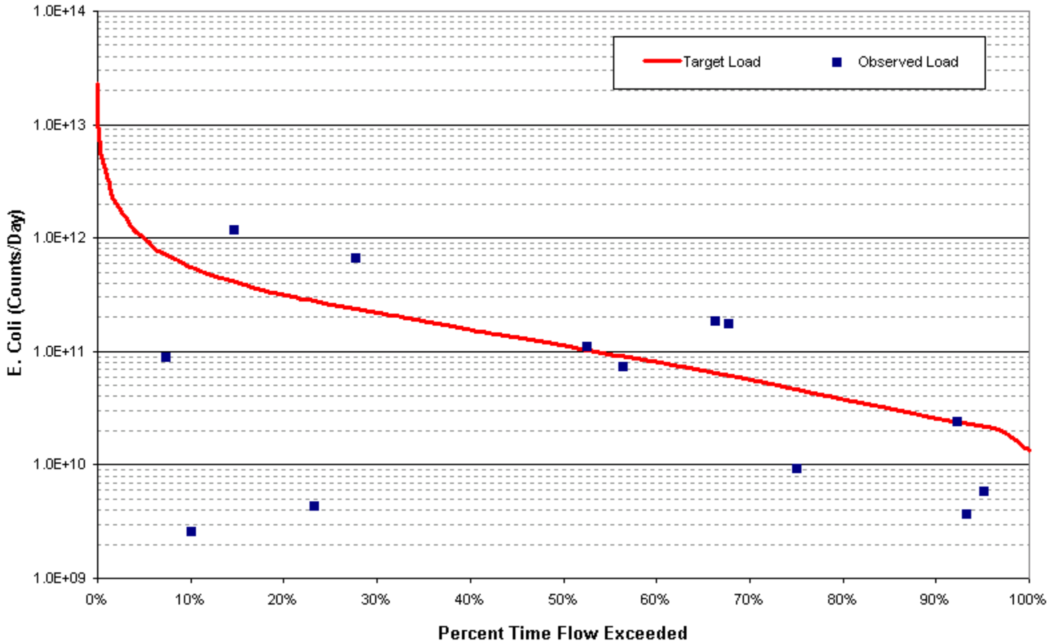

Figure C-35. E. Coli Load Duration Curve for Dudley Creek

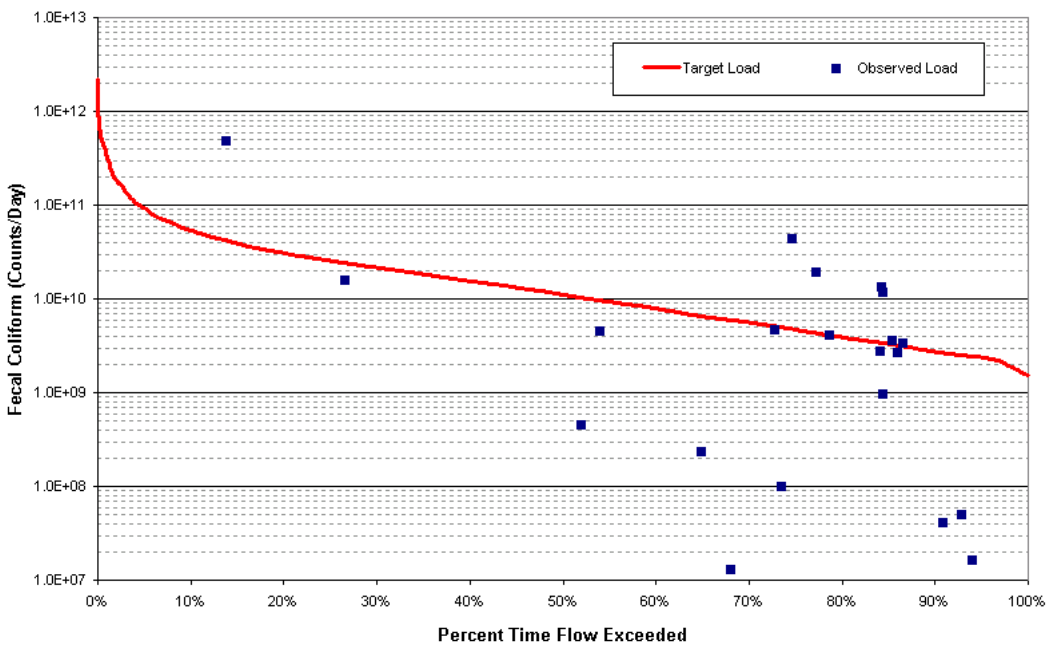

Figure C-36. Fecal Coliform Load Duration Curve for Gnatty Branch

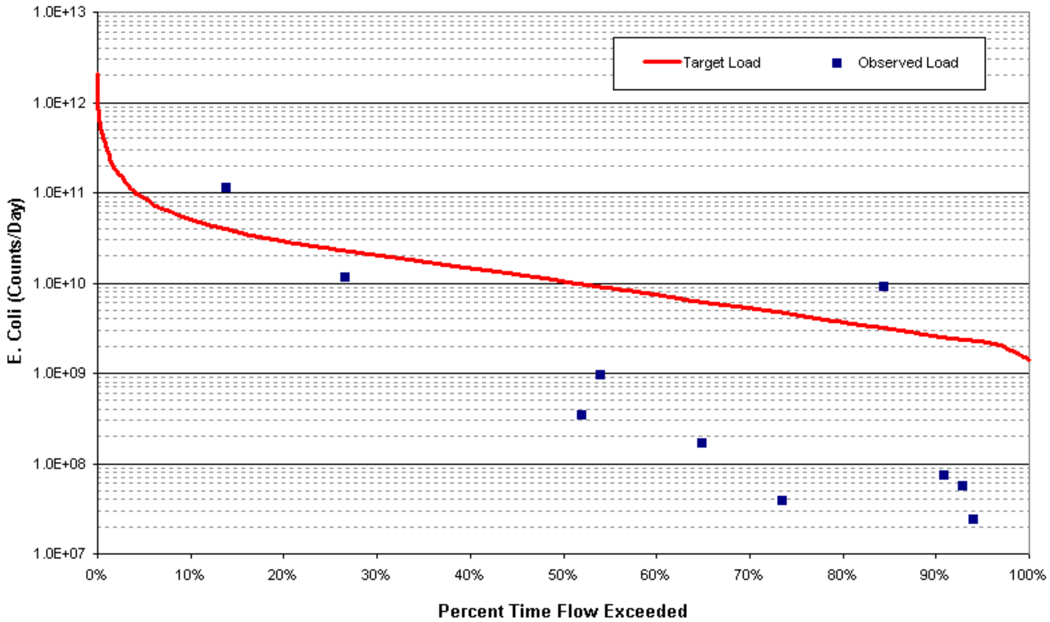

Figure C-37. E. Coli Load Duration Curve for Gnatty Branch

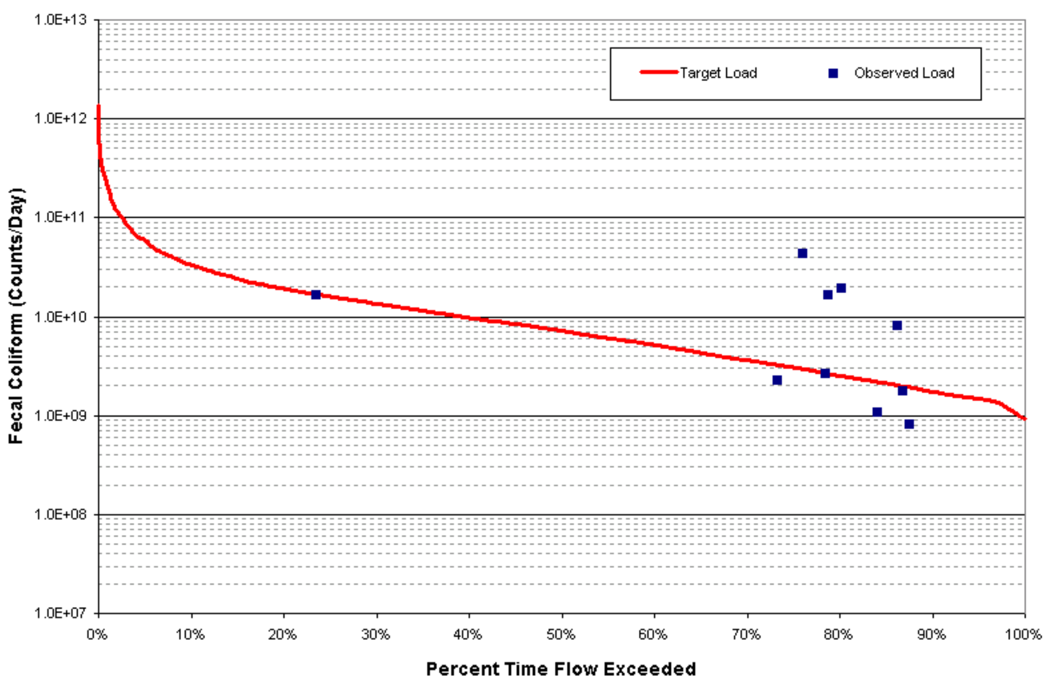

Figure C-38. Fecal Coliform Load Duration Curve for Holy Branch

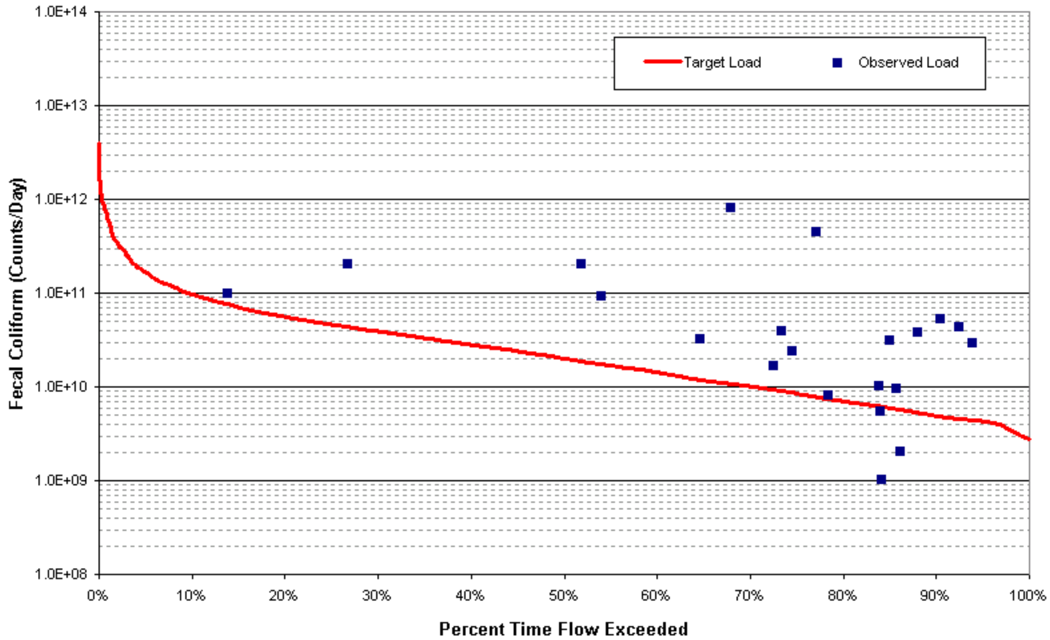

Figure C-39. Fecal Coliform Load Duration Curve for Kings Branch

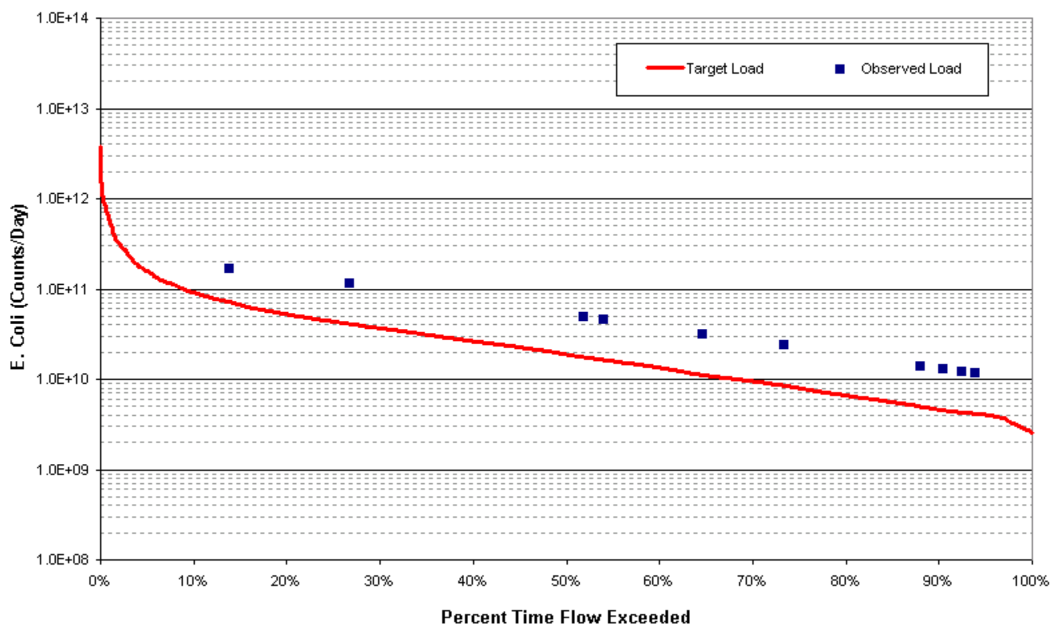

Figure C-40. E. Coli Load Duration Curve for Kings Branch

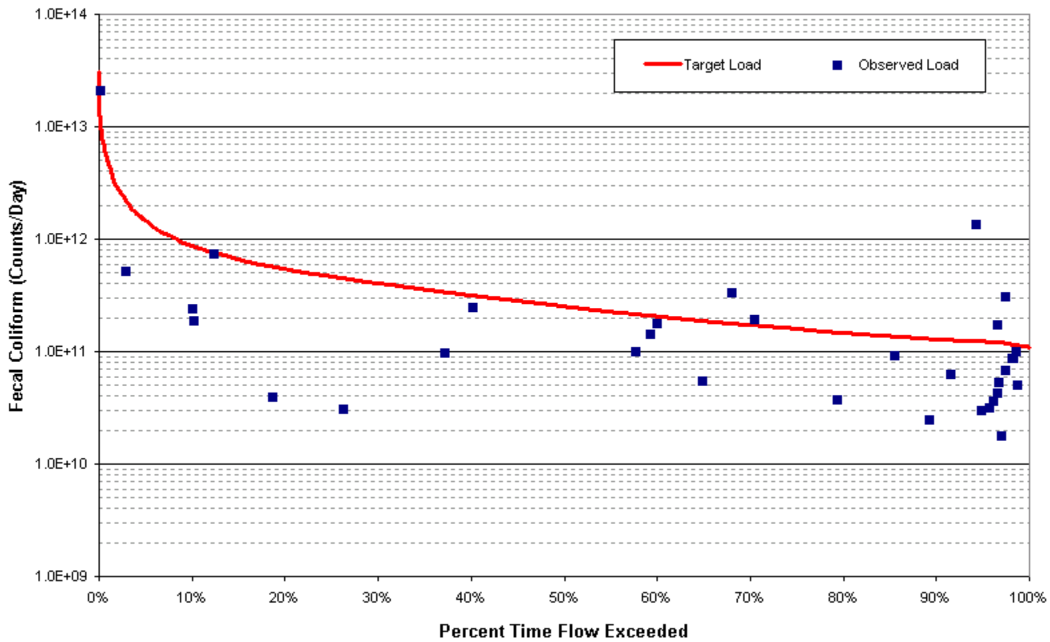

Figure C-41. Fecal Coliform Load Duration Curve for Mill Creek

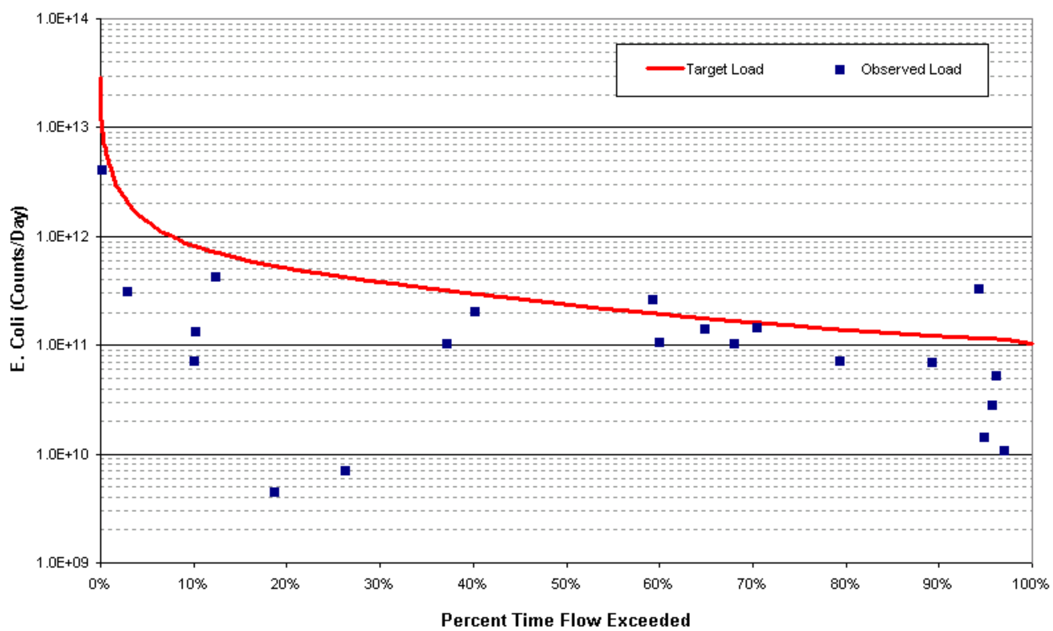

Figure C-42. E. Coli Load Duration Curve for Mill Creek

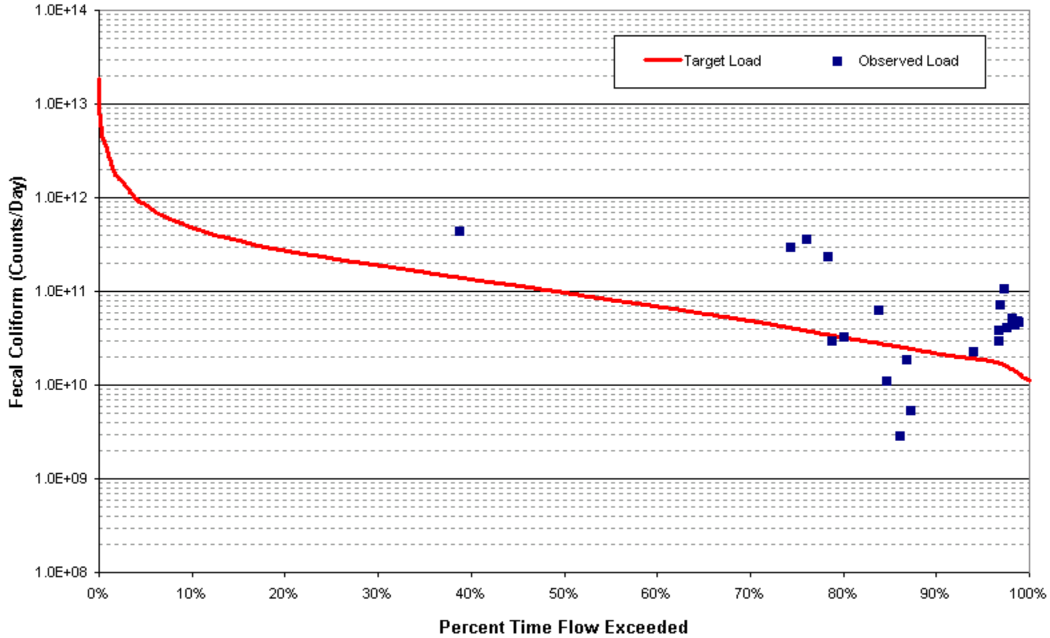

Figure C-43. Fecal Coliform Load Duration Curve for Roaring Fork

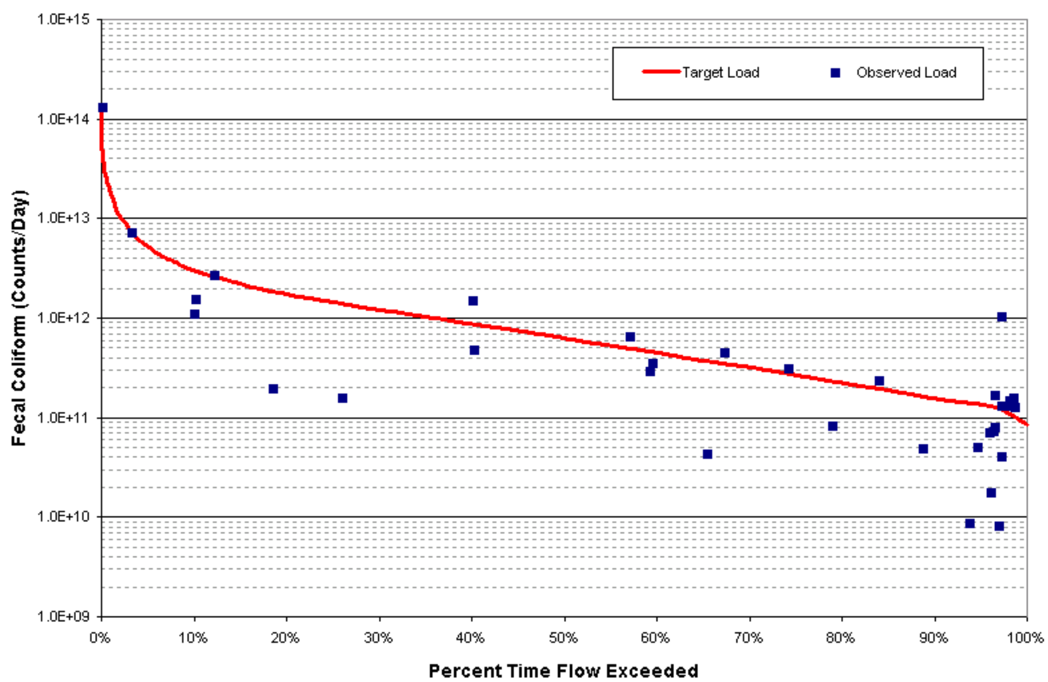

Figure C-44. Fecal Coliform Load Duration Curve for Walden Creek

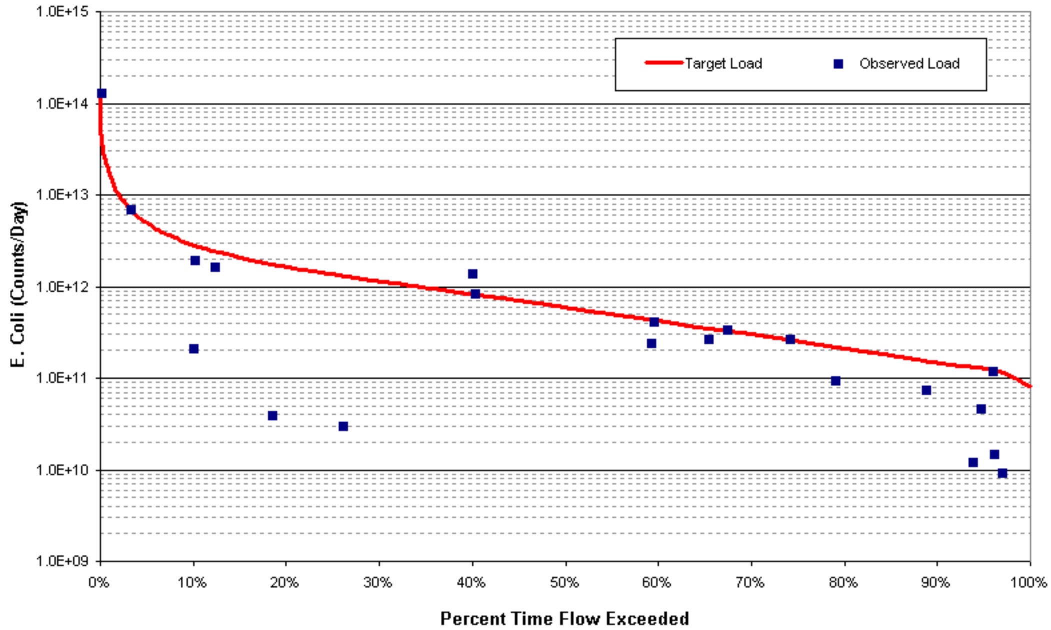

Figure C-45. E. Coli Load Duration Curve for Walden Creek

Table C-1. Required Reduction for Boyds Creek – E. Coli Analysis

Sample Date	Flow	PDFE	E. Coli Sample Concentration	E. Coli Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]
8/16/01	6.44	86.9%	**980**	13.6
8/29/01	5.49	93.0%	488	**NR**
9/10/01	6.54	85.8%	**1046**	19.0
9/12/01	6.39	87.3%	365	**NR**
9/17/01	6.23	88.7%	173	**NR**
10/16/01	6.40	87.2%	96	**NR**
10/23/01	5.66	92.0%	238	**NR**
10/31/01	5.59	92.6%	93	**NR**
11/1/01	5.48	93.0%	186	**NR**
11/15/01	4.79	96.4%	157	**NR**
		90th Percentile	**987**	**14.2**

Note: NR = Not Required
* 30-day Geometric Mean could not be calculated due to insufficient data

Table C-2. Required Reduction for Clear Creek – E. Coli Analysis

Sample Date	Flow	PDFE	E. Coli Sample Concentration	E. Coli Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]
8/16/01	2.98	86.9%	488	**NR**
8/29/01	2.53	93.3%	**>2419**	>65.0
9/10/01	3.04	85.8%	816	**NR**
9/17/01	2.88	88.8%	548	**NR**
10/12/01	2.80	89.5%	**>2419**	>65.0
10/16/01	2.98	87.1%	**>2419**	>65.0
10/16/01	2.98	87.1%	**>2419**	>65.0
10/23/01	2.60	92.3%	**>2419**	>65.0
10/31/01	2.58	92.6%	**1553**	45.5
11/1/01	2.52	93.3%	**1986**	57.4
		90th Percentile	**>2419**	**>65.0**

Note: NR = Not Required
* 30-day Geometric Mean could not be calculated due to insufficient data

Table C-3. Required Load Reduction for Little Pigeon River at Mile 0.8 – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
8/11/92	292.82	62.9%	**1400**	35.7		
8/13/92	253.84	70.5%	**1800**	50.0		
8/17/92	230.19	75.6%	**3700**	75.7		
8/19/92	221.45	78.0%	700	**NR**		
8/25/92	202.35	83.0%	770	**NR**	**1381.14**	87.0
8/26/92	197.83	84.2%	660	**NR**	**1221.21**	85.3
8/27/92	196.91	84.5%	**5700**	84.2	**1521.85**	**88.2**
9/2/92	197.78	84.2%	430	**NR**	**1299.45**	86.1
9/3/92	196.00	84.7%	520	**NR**	**1173.72**	84.7
9/4/92	194.89	85.0%	**1150**	21.7	**1171.33**	84.6
3/29/93	974.37	13.0%	190	**NR**		
3/30/93	777.06	17.1%	60	**NR**		
3/31/93	4174.82	1.9%	165	**NR**		
4/19/93	478.31	33.8%	170	**NR**		
4/20/93	471.83	34.4%	140	**NR**	134.96	
4/21/93	495.72	31.6%	220	**NR**	146.41	
4/22/93	478.89	33.7%	190	**NR**	151.96	
4/23/93	467.32	34.9%	12	**NR**	110.64	
4/26/93	775.32	17.2%	**1470**	38.8	147.48	
4/27/93	691.50	19.7%	250	**NR**	155.47	
8/23/93	204.68	82.1%	280	**NR**		
8/24/93	197.43	84.3%	270	**NR**		
8/25/93	191.54	86.0%	270	**NR**		
8/30/93	177.99	90.6%	320	**NR**		
8/31/93	175.21	91.5%	220	**NR**	**270.08**	33.4
9/1/93	171.78	92.2%	**2000**	55.0	**377.06**	52.3
11/22/93	236.55	74.0%	76	**NR**		
11/23/93	229.68	75.8%	90	**NR**		
11/29/93	476.33	34.0%	300	**NR**		
11/30/93	392.04	46.5%	370	**NR**		
12/1/93	337.12	55.3%	660	**NR**	**218.77**	17.7
12/6/93	3968.97	2.1%	680	**NR**	**264.28**	31.9
12/8/93	1681.79	6.3%	94	**NR**	**228.00**	21.1
12/9/93	1158.12	10.4%	120	**NR**	**210.42**	14.5
12/13/93	577.59	25.3%	98	**NR**	193.29	6.9

Table C-3 (cont). Required Load Reduction for Little Pigeon River at Mile 0.8 – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
12/14/93	488.97	32.6%	170	**NR**	190.83	5.7
12/16/93	439.92	39.0%	**5800**	84.5	**260.28**	30.8
8/26/94	418.32	42.3%	490	**NR**		
6/8/98	1226.74	9.6%	**3200**	71.9		
6/24/98	470.84	34.6%	**1120**	19.6		
7/13/98	394.04	46.2%	250	**NR**		
7/27/98	366.08	50.2%	210	**NR**		
8/10/98	345.71	53.6%	244	**NR**		
8/31/98	288.75	63.7%	76	**NR**		
9/14/98	247.47	71.5%	80	**NR**		
10/5/98	208.69	81.1%	190	**NR**		
10/19/98	190.92	86.3%	490	**NR**		
11/9/98	164.38	93.6%	60	**NR**		
11/23/98	151.48	96.0%	32	**NR**		
12/7/98	133.34	98.5%	220	**NR**		
1/11/99	738.44	18.1%	94	**NR**		
2/1/99	757.08	17.7%	**2000**	55.0		
2/22/99	504.87	30.6%	104	**NR**		
6/2/99	372.79	49.2%	130	**NR**		
6/24/99	325.89	57.3%	170	**NR**		
7/1/99	1379.75	8.3%	440	**NR**		
7/6/99	490.09	32.4%	230	**NR**		
7/7/99	11292.90	0.4%	600	**NR**		
7/8/99	7741.98	0.7%	440	**NR**	**339.97**	47.1
7/15/99	1952.44	5.2%	270	**NR**	**327.16**	45.0
7/19/99	677.63	20.4%	440	**NR**	**341.31**	47.3
7/20/99	1724.97	6.2%	**4200**	78.6	**467.10**	61.5
7/21/99	1300.69	8.8%	390	**NR**	**457.83**	60.7
7/22/99	948.23	13.4%	**2000**	55.0	**530.57**	66.1
	90th Percentile (all)		**2000**	**55.0**		
	90th Percentile (1998-99)		**2000**	**55.0**		
	90th Percentile (1992-94)		**1840**	**51.1**		

Note: NR = Not Required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table C-4. Required Load Reduction for Little Pigeon River at Mile 0.8 – E. Coli Analysis

Sample Date	Flow	PDFE	E. Coli			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
6/8/98	1226.74	9.6%	**2419**	65.0		
6/24/98	470.84	34.6%	866	**NR**		
7/13/98	394.04	46.2%	74	**NR**		
7/27/98	366.08	50.2%	613	**NR**		
8/10/98	345.71	53.6%	157	**NR**		
8/31/98	288.75	63.7%	47	**NR**		
9/14/98	247.47	71.5%	31	**NR**		
10/5/98	208.69	81.1%	144	**NR**		
10/19/98	190.92	86.3%	80	**NR**		
11/9/98	164.38	93.6%	25	**NR**		
11/23/98	151.48	96.0%	18	**NR**		
12/7/98	133.34	98.5%	47	**NR**		
1/11/99	738.44	18.1%	11	**NR**		
2/1/99	757.08	17.7%	816	**NR**		
2/22/99	504.87	30.6%	142	**NR**		
6/2/99	372.79	49.2%	26	**NR**		
6/24/99	325.89	57.3%	21	**NR**		
7/1/99	1379.75	8.3%	39	**NR**		
7/6/99	490.09	32.4%	88	**NR**		
7/7/99	11292.90	0.4%	435	**NR**		
7/8/99	7741.98	0.7%	23	**NR**	59.10	
7/15/99	1952.44	5.2%	23	**NR**	50.50	
7/19/99	677.63	20.4%	96	**NR**	55.35	
7/20/99	1724.97	6.2%	**2419**	65.0	88.76	
7/21/99	1300.69	8.8%	38	**NR**	80.77	
7/22/99	948.23	13.4%	308	**NR**	92.34	
	90th Percentile		841	**NR**		

Note: NR = Not Required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table C-5. Required Load Reduction for West Prong Little Pigeon River at Mile 1.2 – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
8/11/92	103.56	64.8%	**1160**	22.4		
8/13/92	99.20	67.3%	**5800**	84.5		
8/17/92	91.68	71.8%	**17000**	94.7		
8/19/92	89.16	73.0%	1000	**NR**		
8/25/92	82.05	78.3%	**1600**	43.8	**2834.59**	93.6
8/26/92	80.54	79.7%	**6500**	86.2	**3255.08**	94.5
8/27/92	82.63	77.7%	**8500**	89.4	**3733.47**	**95.2**
9/2/92	81.97	78.4%	**1350**	33.3	**3287.68**	94.5
9/3/92	81.74	78.7%	940	**NR**	**2860.70**	93.7
9/4/92	82.27	78.1%	960	**NR**	**2564.79**	93.0
3/29/93	239.50	14.9%	90	**NR**		
3/30/93	215.73	18.0%	110	**NR**		
3/31/93	687.60	2.9%	380	**NR**		
4/19/93	178.15	27.7%	150	**NR**		
4/20/93	179.71	26.9%	220	**NR**	165.50	
4/21/93	188.41	24.1%	1000	**NR**	**223.35**	19.4
4/22/93	179.62	27.0%	220	**NR**	**222.87**	19.2
4/23/93	175.47	28.9%	35	**NR**	176.83	
4/26/93	209.32	19.1%	**2300**	60.9	**235.15**	23.5
4/27/93	185.37	24.9%	117	**NR**	**219.30**	17.9
8/23/93	75.36	84.4%	790	**NR**		
8/24/93	73.18	86.9%	760	**NR**		
8/25/93	71.21	88.7%	570	**NR**		
8/30/93	66.63	92.1%	530	**NR**		
8/31/93	65.73	92.7%	600	**NR**	**641.72**	72.0
9/1/93	64.49	93.7%	500	**NR**	**615.58**	70.8
11/22/93	74.33	85.6%	84	**NR**		
11/23/93	73.34	86.6%	90	**NR**		
11/29/93	87.84	73.9%	210	**NR**		
11/30/93	85.49	75.5%	160	**NR**		
12/1/93	83.75	76.9%	200	**NR**	138.41	
12/6/93	931.56	2.0%	250	**NR**	152.75	
12/8/93	421.17	5.8%	310	**NR**	169.00	
12/9/93	303.72	9.6%	212	**NR**	173.86	

Table C-5 (cont). Required Load Reduction for West Prong Little Pigeon River at Mile 1.2 – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
12/13/93	163.26	34.6%	350	**NR**	**187.91**	4.2
12/14/93	149.30	41.6%	162	**NR**	**185.14**	2.8
12/16/93	140.67	45.5%	300	**NR**	**193.45**	7.0
8/30/94	152.37	39.8%	810	**NR**		
	90th Percentile (all)		**3700**	**75.7**		

Note: NR = Not Required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table C-6. Required Load Reduction for West Prong Little Pigeon River at Mile 4.6 – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
7/29/92	91.78	69.2%	**2000**			
8/5/92	84.86	73.5%	**2200**			
8/6/92	181.76	23.6%	**2300**			
8/11/92	98.48	65.0%	**4600**			
8/13/92	94.55	67.5%	**5700**		**3053.25**	**94.1**
8/17/92	87.99	71.6%	**2800**		**3009.51**	94.0
8/19/92	85.66	72.9%	**1300**		**2669.42**	93.3
8/25/92	78.79	78.3%	1000	**NR**	**2361.10**	92.4
8/26/92	77.39	79.5%	**1700**		**2276.47**	92.1
8/27/92	78.64	78.4%	**5800**	**NR**	**2499.65**	92.8
3/29/93	228.68	14.9%	240	**NR**		
3/30/93	206.35	18.0%	110	**NR**		
3/31/93	670.70	2.9%	230	**NR**		
4/19/93	170.90	27.4%	190	**NR**		
4/20/93	172.47	26.6%	210	**NR**	**189.17**	4.8
4/21/93	179.61	24.2%	610	**NR**	**229.94**	21.7
4/22/93	172.33	26.6%	320	**NR**	**241.05**	25.3
4/23/93	168.34	28.5%	31	**NR**	**186.54**	3.5
4/26/93	198.96	19.3%	480	**NR**	**207.19**	13.1
4/27/93	177.63	24.8%	98	**NR**	**192.25**	6.4
7/8/93	83.73	74.2%	670	**NR**		
7/14/93	78.84	78.2%	**3300**			
7/19/93	78.32	78.8%	**1200**			
7/20/93	77.93	79.1%	**1140**			
7/21/93	77.85	79.1%	**1400**		**1334.63**	86.5
7/22/93	75.99	80.7%	**1100**		**1292.31**	86.1
7/26/93	70.98	85.9%	540	**NR**	**1140.85**	84.2
7/27/93	70.06	87.1%	500	**NR**	**1029.07**	82.5
7/28/93	68.58	88.5%	610	**NR**	**970.98**	81.5
7/29/93	67.75	89.1%	450	**NR**	**899.10**	80.0
8/23/93	72.33	84.3%	890	**NR**		
8/24/93	70.28	86.8%	920	**NR**		
8/25/93	68.39	88.7%	**1190**			
8/30/93	64.03	91.9%	910	**NR**		

Table C-6 (cont). Required Load Reduction for West Prong Little Pigeon River at Mile 4.6 – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
8/31/93	63.19	92.6%	970	**NR**	**970.30**	81.4
9/1/93	61.98	93.7%	1300	30.8	**1018.78**	82.3
11/22/93	71.38	85.5%	310	**NR**		
11/23/93	70.43	86.8%	180	**NR**		
11/29/93	84.22	73.9%	150	**NR**		
11/30/93	82.02	75.3%	220	**NR**		
12/1/93	80.38	76.8%	360	**NR**	**231.36**	22.2
12/6/93	881.37	2.0%	190	**NR**	**223.89**	19.6
12/8/93	398.78	5.8%	170	**NR**	**215.25**	16.4
12/9/93	287.96	9.7%	152	**NR**	**206.09**	12.7
12/13/93	155.84	34.7%	240	**NR**	**209.61**	14.1
12/14/93	142.83	41.5%	270	**NR**	**214.98**	16.3
12/16/93	134.69	45.5%	260	**NR**	**218.73**	17.7
8/30/94	146.19	39.8%	610	**NR**		
6/8/98	401.95	5.8%	240	**NR**		
6/24/98	165.73	29.7%	740	**NR**		
7/13/98	138.16	43.9%	800	**NR**		
7/27/98	136.17	44.8%	120	**NR**		
8/10/98	122.13	51.8%	3000	70.0		
8/31/98	103.61	62.2%	160	**NR**		
9/14/98	89.23	70.8%	82	**NR**		
10/5/98	75.92	80.8%	350	**NR**		
10/19/98	70.65	86.4%	280	**NR**		
11/9/98	60.59	94.7%	118	**NR**		
11/23/98	56.49	96.6%	100	**NR**		
12/7/98	50.98	98.4%	84	**NR**		
1/11/99	158.23	33.5%	120	**NR**		
2/1/99	190.71	21.3%	200	**NR**		
2/22/99	148.80	38.4%	84	**NR**		
6/2/99	135.68	45.0%	250	**NR**		
6/24/99	132.69	46.4%	630	**NR**		
7/1/99	499.38	4.3%	460	**NR**		
7/6/99	210.10	17.4%	260	**NR**		
7/7/99	2343.82	0.3%	2100	57.1		

Table C-6 (cont). Required Load Reduction for West Prong Little Pigeon River at Mile 4.6 – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
7/8/99	1468.83	0.9%	700	**NR**	**643.99**	**72.0**
7/15/99	695.17	2.7%	290	**NR**	**563.81**	68.1
7/19/99	256.12	12.1%	280	**NR**	**510.16**	64.7
7/20/99	319.04	8.1%	**1200**	25.0	**567.73**	68.3
7/21/99	277.89	10.4%	500	**NR**	**559.77**	67.8
7/22/99	243.17	13.4%	320	**NR**	**529.33**	66.0
	90th Percentile (all)		**2170**	**58.5**		
	90th Percentile (1998-99)		1000	**NR**		
	90th Percentile (1992-94)		**2450**	**63.3**		

Note: NR = Not Required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table C-7. Required Load Reduction for West Prong Little Pigeon River at Mile 4.6 – E. Coli Analysis

Sample Date	Flow	PDFE	E. Coli			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
6/8/98	401.95	5.8%	328	**NR**		
6/24/98	165.73	29.7%	727	**NR**		
7/13/98	138.16	43.9%	613	**NR**		
7/27/98	136.17	44.8%	344	**NR**		
8/10/98	122.13	51.8%	921	**NR**		
8/31/98	103.61	62.2%	70	**NR**		
9/14/98	89.23	70.8%	81	**NR**		
10/5/98	75.92	80.8%	200	**NR**		
10/19/98	70.65	86.4%	270	**NR**		
11/9/98	60.59	94.7%	101	**NR**		
11/23/98	56.49	96.6%	70	**NR**		
12/7/98	50.98	98.4%	71	**NR**		
1/11/99	158.23	33.5%	16	**NR**		
2/1/99	190.71	21.3%	31	**NR**		
2/22/99	148.80	38.4%	9	**NR**		
6/2/99	135.68	45.0%	261	**NR**		
6/24/99	132.69	46.4%	130	**NR**		
7/1/99	499.38	4.3%	30	**NR**		
7/6/99	210.10	17.4%	121	**NR**		
7/7/99	2343.82	0.3%	**1733**	51.1		
7/8/99	1468.83	0.9%	**980**	13.6	**240.31**	**53.0**
7/15/99	695.17	2.7%	37	**NR**	175.93	35.8
7/19/99	256.12	12.1%	276	**NR**	187.62	39.8
7/20/99	319.04	8.1%	238	**NR**	193.28	41.5
7/21/99	277.89	10.4%	93	**NR**	178.19	36.6
7/22/99	243.17	13.4%	35	**NR**	151.43	25.4
		90th Percentile	805	**NR**		

Note: NR = Not Required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table C-8. Required Load Reduction for West Prong Little Pigeon River at Mile 12.4 – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
7/29/92	46.76	68.2%	700	**NR**		
8/5/92	43.21	72.6%	300	**NR**		
8/6/92	82.72	31.1%	**1500**	40.0		
8/11/92	51.26	63.0%	**1050**	14.3		
8/13/92	48.84	65.7%	**10300**	91.3	**1277.81**	**85.9**
8/17/92	44.71	70.8%	1000	**NR**	**1226.66**	85.3
8/19/92	43.64	72.1%	1000	**NR**	**1191.37**	84.9
8/25/92	39.97	77.9%	**1600**	43.8	**1236.11**	85.4
8/26/92	39.31	79.0%	570	**NR**	**1134.24**	84.1
8/27/92	41.27	75.4%	850	**NR**	**1101.98**	83.7
3/29/93	114.62	15.1%	90	**NR**		
3/30/93	104.23	18.0%	200	**NR**		
3/31/93	355.14	2.6%	40	**NR**		
4/19/93	87.71	26.4%	84	**NR**		
4/20/93	88.49	25.8%	150	**NR**	98.07	
4/21/93	91.09	24.0%	98	**NR**	98.06	
4/22/93	88.51	25.7%	85	**NR**	96.08	
4/23/93	86.41	27.3%	170	**NR**	103.18	
4/26/93	98.47	20.2%	140	**NR**	106.74	
4/27/93	90.33	24.5%	34	**NR**	95.20	
7/8/93	42.65	73.5%	820	**NR**		
7/14/93	40.18	77.4%	510	**NR**		
7/19/93	39.68	78.4%	810	**NR**		
7/20/93	39.73	78.2%	**1060**	15.1		
7/21/93	39.69	78.4%	400	**NR**	**678.34**	73.5
7/22/93	38.53	80.4%	440	**NR**	**631.12**	71.5
7/26/93	36.05	85.2%	380	**NR**	**587.00**	69.3
7/27/93	35.58	86.4%	420	**NR**	**562.94**	68.0
7/28/93	34.74	87.9%	400	**NR**	**541.97**	66.8
7/29/93	34.40	88.4%	420	**NR**	**528.33**	65.9
8/23/93	36.47	84.3%	340	**NR**		
8/24/93	35.47	86.7%	**1120**	19.6		
8/25/93	34.50	88.3%	380	**NR**		
8/30/93	32.32	91.8%	560	**NR**		

Table C-8 (cont). Required Load Reduction for West Prong Little Pigeon River at Mile 12.4 – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
8/31/93	31.91	92.5%	460	**NR**	**517.95**	65.2
9/1/93	31.24	93.4%	590	**NR**	**529.31**	66.0
11/22/93	35.90	85.8%	114	**NR**		
11/23/93	35.42	86.8%	370	**NR**		
11/29/93	41.89	74.6%	114	**NR**		
11/30/93	41.01	75.9%	112	**NR**		
12/1/93	40.31	77.0%	78	**NR**	133.25	
12/6/93	427.44	2.1%	160	**NR**	137.37	
12/8/93	193.75	6.0%	38	**NR**	114.33	
12/9/93	140.60	10.2%	22	**NR**	93.05	
12/13/93	77.99	36.1%	28	**NR**	81.42	
12/14/93	71.88	42.2%	140	**NR**	85.96	
12/16/93	68.09	45.2%	760	**NR**	104.80	
9/1/94	73.73	40.3%	**5600**	83.9		
6/2/98	239.59	4.6%	**12300**	92.7		
6/8/98	200.99	5.8%	86	**NR**		
6/15/98	97.67	20.4%	**2500**	64.0		
6/24/98	84.94	28.7%	270	**NR**		
7/6/98	74.58	39.3%	472	**NR**		
7/13/98	70.71	43.1%	168	**NR**		
7/20/98	66.47	46.7%	**1800**	50.0		
7/27/98	70.25	43.5%	360	**NR**		
8/3/98	73.37	40.5%	120	**NR**		
8/10/98	62.37	51.0%	230	**NR**		
8/24/98	56.87	56.6%	60	**NR**		
8/31/98	52.89	61.1%	14	**NR**		
9/14/98	45.39	70.0%	94	**NR**		
9/21/98	55.08	58.7%	**5200**	82.7		
10/5/98	38.48	80.5%	210	**NR**		
10/13/98	38.09	81.1%	60	**NR**		
10/19/98	35.90	85.8%	54	**NR**		
10/26/98	34.06	89.2%	30	**NR**		
11/9/98	30.37	94.7%	70	**NR**		
11/16/98	30.05	95.0%	690	**NR**		

Table C-8 (cont). Required Load Reduction for West Prong Little Pigeon River at Mile 12.4 – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
11/23/98	28.52	96.4%	66	**NR**		
11/30/98	27.28	97.3%	50	**NR**		
12/7/98	25.55	98.3%	100	**NR**		
12/14/98	51.34	62.9%	100	**NR**		
1/11/99	77.45	36.6%	20	**NR**		
1/25/99	155.11	8.5%	60	**NR**		
2/1/99	93.65	22.7%	190	**NR**		
2/8/99	75.76	38.1%	360	**NR**		
2/22/99	75.64	38.3%	104	**NR**		
6/2/99	69.75	43.9%	570	**NR**		
6/24/99	66.14	47.1%	178	**NR**		
7/1/99	248.15	4.4%	134	**NR**		
7/6/99	101.22	18.9%	**2800**	67.9		
7/7/99	1447.34	0.2%	410	**NR**		
7/8/99	486.69	1.7%	210	**NR**	**356.40**	**49.5**
7/15/99	346.65	2.7%	240	**NR**	**333.67**	46.1
7/19/99	129.89	11.8%	94	**NR**	**278.43**	35.4
7/20/99	156.41	8.4%	300	**NR**	**281.04**	36.0
7/21/99	137.79	10.8%	290	**NR**	**282.02**	36.2
7/22/99	122.17	13.3%	330	**NR**	**286.49**	37.2
	90th Percentile (all)		**1234**	**27.1**		
	90th Percentile (1998-99)		**1870**	**51.9**		
	90th Percentile (1992-94)		**1078**	**16.5**		

Note: NR = Not Required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table C-9. Required Load Reduction for West Prong Little Pigeon River at Mile 12.4 – E. Coli Analysis

Sample Date	Flow	PDFE	E. Coli			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
6/2/98	239.59	4.6%	**>2419**	>65.0		
6/8/98	200.99	5.8%	157	**NR**		
6/15/98	97.67	20.4%	**>2419**	>65.0		
6/24/98	84.94	28.7%	687	**NR**		
7/6/98	74.58	39.3%	**1046**	19.0		
7/13/98	70.71	43.1%	99	**NR**		
7/20/98	66.47	46.7%	**1300**	34.9		
7/27/98	70.25	43.5%	461	**NR**		
8/3/98	73.37	40.5%	93	**NR**		
8/10/98	62.37	51.0%	54	**NR**		
8/24/98	56.87	56.6%	46	**NR**		
8/31/98	52.89	61.1%	1	**NR**		
9/14/98	45.39	70.0%	27	**NR**		
9/21/98	55.08	58.7%	**1986**	57.6		
10/5/98	38.48	80.5%	114	**NR**		
10/13/98	38.09	81.1%	51	**NR**		
10/19/98	35.90	85.8%	14	**NR**		
10/26/98	34.06	89.2%	62	**NR**		
11/9/98	30.37	94.7%	70	**NR**		
11/16/98	30.05	95.0%	**2419**	65.0		
11/23/98	28.52	96.4%	99	**NR**		
11/30/98	27.28	97.3%	16	**NR**		
12/7/98	25.55	98.3%	150	**NR**		
12/14/98	51.34	62.9%	67	**NR**		
1/11/99	77.45	36.6%	16	**NR**		
1/25/99	155.11	8.5%	10	**NR**		
2/1/99	93.65	22.7%	7	**NR**		
2/8/99	75.76	38.1%	387	**NR**		
2/22/99	75.64	38.3%	99	**NR**		
6/2/99	69.75	43.9%	687	**NR**		
6/24/99	66.14	47.1%	13	**NR**		
7/1/99	248.15	4.4%	14	**NR**		
7/6/99	101.22	18.9%	**1553**	45.5		
7/7/99	1447.34	0.2%	52	**NR**		

Table C-9 (cont). Required Load Reduction for West Prong Little Pigeon River at Mile 12.4 – E. Coli Analysis

Sample Date	Flow	PDFE	E. Coli			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
7/8/99	486.69	1.7%	39	**NR**	56.45	
7/15/99	346.65	2.7%	88	**NR**	60.79	
7/19/99	129.89	11.8%	8	**NR**	45.50	
7/20/99	156.41	8.4%	120	**NR**	51.36	
7/21/99	137.79	10.8%	11	**NR**	43.28	
7/22/99	122.17	13.3%	71	**NR**	45.47	
		90th Percentile	**>1596**	**>46.9**		

Note: NR = Not Required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table C-10. Required Load Reduction for West Prong Little Pigeon River at Mile 16.0 – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
8/11/92	39.73	62.7%	**1400**	35.7		
8/13/92	37.55	65.5%	**15400**	94.2		
8/17/92	33.87	71.1%	**1900**	52.6		
8/19/92	33.01	72.3%	900	**NR**		
8/25/92	30.02	78.0%	**15000**	94.0		
8/26/92	29.49	79.2%	940	**NR**		
8/27/92	31.82	74.3%	**1020**	11.8		
9/2/92	30.68	76.4%	200	**NR**		
9/3/92	29.58	79.0%	330	**NR**		
9/4/92	30.69	76.4%	60	**NR**		
11/22/93	26.72	86.0%	180	**NR**		
11/23/93	26.34	87.0%	116	**NR**		
11/30/93	30.87	76.1%	66	**NR**		
12/1/93	30.30	77.1%	58	**NR**		
12/6/93	342.84	2.1%	42	**NR**		
12/8/93	154.08	6.1%	60	**NR**		
12/9/93	111.20	10.3%	220	**NR**		
12/13/93	60.79	36.5%	100	**NR**		
12/14/93	56.03	42.3%	240	**NR**		
12/16/93	52.84	45.6%	740	**NR**		
6/8/98	160.18	5.8%	180	**NR**		
6/24/98	66.55	29.0%	360	**NR**		
7/13/98	55.00	43.4%	340	**NR**		
7/27/98	58.11	39.5%	240	**NR**		
8/10/98	48.22	51.1%	410	**NR**		
8/31/98	40.53	61.5%	170	**NR**		
9/14/98	34.43	70.2%	120	**NR**		
10/5/98	28.83	80.6%	430	**NR**		
10/19/98	26.74	85.9%	270	**NR**		
11/9/98	22.21	94.8%	92	**NR**		
11/23/98	20.73	96.4%	200	**NR**		
12/7/98	18.57	98.2%	140	**NR**		
1/11/99	60.26	37.0%	92	**NR**		
2/1/99	73.88	22.7%	200	**NR**		

Table C-10 (cont). Required Load Reduction for West Prong Little Pigeon River at Mile 16.0 – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
2/22/99	58.99	38.4%	36	**NR**		
6/2/99	54.39	44.0%	420	**NR**		
6/24/99	55.18	43.2%	770	**NR**		
7/1/99	198.06	4.4%	174	**NR**		
7/6/99	82.51	17.9%	3800	76.3		
7/7/99	1197.52	0.2%	510	**NR**		
7/8/99	375.44	1.9%	230	**NR**	**569.15**	**68.4**
7/15/99	277.75	2.8%	290	**NR**	**508.65**	64.6
7/19/99	102.83	12.0%	200	**NR**	**445.15**	59.6
7/20/99	126.76	8.2%	340	**NR**	**430.41**	58.2
7/21/99	109.23	10.8%	430	**NR**	**430.36**	58.2
7/22/99	96.71	13.4%	540	**NR**	**440.24**	59.1
	90th Percentile (all)		**1210**	**25.6**		
	90th Percentile (1998-99)		525	**NR**		
	90th Percentile (1992-94)		**3210**	**72.0**		

Note: NR = Not Required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table C-11. Required Load Reduction for West Prong Little Pigeon River at Mile 16.0 – E. Coli Analysis

Sample Date	Flow	PDFE	E. Coli			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
6/8/98	160.18	5.8%	108	**NR**		
6/24/98	66.55	29.0%	248	**NR**		
7/13/98	55.00	43.4%	488	**NR**		
7/27/98	58.11	39.5%	479	**NR**		
8/10/98	48.22	51.1%	36	**NR**		
8/31/98	40.53	61.5%	16	**NR**		
9/14/98	34.43	70.2%	14	**NR**		
10/5/98	28.83	80.6%	248	**NR**		
10/19/98	26.74	85.9%	272	**NR**		
11/9/98	22.21	94.8%	15	**NR**		
11/23/98	20.73	96.4%	23	**NR**		
12/7/98	18.57	98.2%	10	**NR**		
1/11/99	60.26	37.0%	3	**NR**		
2/1/99	73.88	22.7%	9	**NR**		
2/22/99	58.99	38.4%	3	**NR**		
6/2/99	54.39	44.0%	21	**NR**		
6/24/99	55.18	43.2%	7	**NR**		
7/1/99	198.06	4.4%	6	**NR**		
7/6/99	82.51	17.9%	**1986**	57.4		
7/7/99	1197.52	0.2%	**980**	13.6		
7/8/99	375.44	1.9%	38	**NR**	79.15	
7/15/99	277.75	2.8%	8	**NR**	54.02	
7/19/99	102.83	12.0%	99	**NR**	58.90	
7/20/99	126.76	8.2%	37	**NR**	55.58	
7/21/99	109.23	10.8%	17	**NR**	48.72	
7/22/99	96.71	13.4%	112	**NR**	52.95	
		90th Percentile	484	**NR**		

Note: NR = Not Required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table C-12. Required Load Reduction for West Prong Little Pigeon River at Mile 17.2 – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
3/29/93	74.09	15.3%	30	**NR**		
3/30/93	67.27	18.1%	130	**NR**		
3/31/93	239.22	2.5%	18	**NR**		
4/19/93	56.38	26.5%	860	**NR**		
4/20/93	57.55	25.1%	310	**NR**	113.35	
4/21/93	58.23	24.4%	210	**NR**	125.62	
4/22/93	56.91	25.7%	820	**NR**	164.23	
4/23/93	55.52	27.4%	290	**NR**	176.33	
4/26/93	63.08	20.5%	10	**NR**	128.19	
4/27/93	58.09	24.6%	10	**NR**	99.33	
7/8/93	26.39	73.6%	**2200**	59.1		
7/12/93	24.78	77.2%	**8400**	89.3		
7/14/93	24.72	77.5%	880	**NR**		
7/19/93	24.41	78.5%	**1160**	22.4		
7/20/93	24.45	78.3%	**8400**	89.3	**2754.13**	93.5
7/21/93	24.42	78.4%	**3000**	70.0	**2793.66**	93.6
7/22/93	23.64	80.4%	**3900**	76.9	**2930.03**	**93.9**
7/26/93	22.00	85.3%	920	**NR**	**2535.05**	92.9
7/27/93	21.68	86.5%	**1800**	50.0	**2440.41**	92.6
7/28/93	21.12	88.0%	850	**NR**	**2196.13**	91.8
7/29/93	20.90	88.5%	810	**NR**	**2005.76**	91.0
8/23/93	22.26	84.4%	500	**NR**		
8/24/93	21.60	86.8%	990	**NR**		
8/25/93	20.96	88.4%	580	**NR**		
8/30/93	19.51	91.7%	610	**NR**		
8/31/93	19.24	92.5%	960	**NR**	**700.05**	74.3
9/1/93	18.79	93.5%	770	**NR**	**711.25**	74.7
11/22/93	21.89	86.0%	**2100**	57.1		
11/23/93	21.58	87.0%	90	**NR**		
11/29/93	25.87	74.7%	112	**NR**		
11/30/93	25.29	76.0%	40	**NR**		
12/1/93	24.83	77.1%	52	**NR**	134.51	
12/6/93	280.12	2.1%	22	**NR**	99.47	
12/8/93	125.90	6.1%	420	**NR**	122.20	

Table C-12 (cont). Required Load Reduction for West Prong Little Pigeon River at Mile 17.2 – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
12/9/93	90.89	10.3%	270	**NR**	134.93	
12/13/93	49.76	36.5%	102	**NR**	130.80	
12/14/93	45.88	42.2%	134	**NR**	131.11	
12/16/93	43.28	45.5%	510	**NR**	148.35	
9/15/94	40.59	49.4%	**3200**	71.9		
6/2/98	156.48	4.6%	**2000**	55.0		
6/8/98	131.01	5.8%	122	**NR**		
6/15/98	62.97	20.5%	600	**NR**		
6/24/98	54.54	28.8%	220	**NR**		
7/6/98	47.65	39.4%	320	**NR**		
7/13/98	45.08	43.3%	530	**NR**		
7/20/98	42.06	47.3%	**1700**	47.1		
7/27/98	48.41	38.2%	670	**NR**		
8/3/98	46.79	40.7%	550	**NR**		
8/10/98	39.52	51.1%	610	**NR**		
8/24/98	35.85	56.7%	470	**NR**		
8/31/98	33.22	61.3%	360	**NR**		
9/14/98	28.21	70.1%	240	**NR**		
9/21/98	35.20	57.8%	**7500**	88.0		
10/5/98	23.62	80.5%	**1420**	36.6		
10/13/98	23.36	81.2%	310	**NR**		
10/19/98	21.90	85.8%	580	**NR**		
10/26/98	20.67	89.3%	460	**NR**		
11/9/98	18.18	94.8%	330	**NR**		
11/16/98	18.01	95.0%	154	**NR**		
11/23/98	16.98	96.4%	270	**NR**		
11/30/98	16.16	97.4%	444	**NR**		
12/7/98	15.24	98.2%	260	**NR**		
12/14/98	32.03	63.3%	100	**NR**		
1/11/99	49.30	37.0%	96	**NR**		
1/25/99	100.56	8.6%	40	**NR**		
2/1/99	60.22	22.9%	186	**NR**		
2/8/99	48.40	38.3%	82	**NR**		
2/22/99	48.33	38.4%	72	**NR**		

Table C-12 (cont). Required Load Reduction for West Prong Little Pigeon River at Mile 17.2 – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
6/2/99	44.60	43.9%	226	**NR**		
6/24/99	45.43	42.9%	**1150**	21.7		
7/1/99	161.85	4.4%	170	**NR**		
7/6/99	66.89	18.4%	**2900**	69.0		
7/7/99	986.03	0.2%	260	**NR**		
7/8/99	301.96	1.9%	280	**NR**	**528.61**	**65.9**
7/15/99	227.09	2.8%	340	**NR**	**491.13**	63.3
7/19/99	84.19	12.0%	146	**NR**	**412.98**	56.4
7/20/99	103.19	8.3%	**1200**	25.0	**471.88**	61.9
7/21/99	89.38	10.8%	250	**NR**	**439.72**	59.1
7/22/99	79.14	13.4%	410	**NR**	**411.28**	56.2
	90th Percentile (all)		**2120**	**57.6**		
	90th Percentile (1998-99)		**1448**	**37.9**		
	90th Percentile (1992-94)		**3040**	**70.4**		

Note: NR = Not Required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table C-13. Required Load Reduction for West Prong Little Pigeon River at Mile 17.2 – E. Coli Analysis

Sample Date	Flow	PDFE	E. Coli			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
6/2/98	156.48	4.6%	**>2419**	>65.0		
6/8/98	131.01	5.8%	173	**NR**		
6/15/98	62.97	20.5%	**980**	13.6		
6/24/98	54.54	28.8%	435	**NR**		
7/6/98	47.65	39.4%	178	**NR**		
7/13/98	45.08	43.3%	479	**NR**		
7/20/98	42.06	47.3%	**1986**	57.4		
7/27/98	48.41	38.2%	689	**NR**		
8/3/98	46.79	40.7%	517	**NR**		
8/10/98	39.52	51.1%	770	**NR**		
8/24/98	35.85	56.7%	613	**NR**		
8/31/98	33.22	61.3%	8	**NR**		
9/14/98	28.21	70.1%	42	**NR**		
9/21/98	35.20	57.8%	**>2419**	>65.0		
10/5/98	23.62	80.5%	410	**NR**		
10/13/98	23.36	81.2%	201	**NR**		
10/19/98	21.90	85.8%	15	**NR**		
10/26/98	20.67	89.3%	649	**NR**		
11/9/98	18.18	94.8%	46	**NR**		
11/16/98	18.01	95.0%	172	**NR**		
11/23/98	16.98	96.4%	2	**NR**		
11/30/98	16.16	97.4%	36	**NR**		
12/7/98	15.24	98.2%	74	**NR**		
12/14/98	32.03	63.3%	7	**NR**		
1/11/99	49.30	37.0%	6	**NR**		
1/25/99	100.56	8.6%	<1	**NR**		
2/1/99	60.22	22.9%	6	**NR**		
2/8/99	48.40	38.3%	5	**NR**		
2/22/99	48.33	38.4%	<1	**NR**		
6/2/99	44.60	43.9%	20	**NR**		
6/24/99	45.43	42.9%	365	**NR**		
7/1/99	161.85	4.4%	16	**NR**		
7/6/99	66.89	18.4%	**1986**	57.4		
7/7/99	986.03	0.2%	24	**NR**		

Table C-13 (cont). Required Load Reduction for West Prong Little Pigeon River at Mile 17.2 – E. Coli Analysis

Sample Date	Flow	PDFE	E. Coli			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
7/8/99	301.96	1.9%	461	**NR**	**166.59**	32.2%
7/15/99	227.09	2.8%	249	**NR**	**178.14**	**36.6%**
7/19/99	84.19	12.0%	6	**NR**	109.74	
7/20/99	103.19	8.3%	192	**NR**	117.69	
7/21/99	89.38	10.8%	11	**NR**	90.44	
7/22/99	79.14	13.4%	111	**NR**	80.33	
		90th Percentile	**>1081**	**>21.6**		

Note: NR = Not Required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table C-14. Required Load Reduction for Baskins Creek – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform Sample Concentration	Fecal Coliform Required Reduction	Fecal Coliform Geometric Mean[a]	Fecal Coliform Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
7/29/92	0.58	79.2%	**12000**	92.5		
8/5/92	0.47	84.7%	500	**NR**		
8/6/92	3.49	27.5%	800	**NR**		
8/11/92	0.69	74.7%	**1200**	25.0		
8/13/92	0.63	76.8%	**11400**	92.1	**2309.22**	**92.2**
8/17/92	0.57	79.5%	790	**NR**	**1931.19**	90.7
8/19/92	0.53	81.0%	420	**NR**	**1553.00**	88.4
8/25/92	0.43	86.8%	530	**NR**	**1357.72**	86.7
8/26/92	0.41	87.8%	960	**NR**	**1306.42**	86.2
8/27/92	0.42	87.0%	700	**NR**	**1227.40**	85.3
9/1/93	0.58	79.2%	560	**NR**		
9/13/94	0.47	84.7%	130	**NR**		
	90th Percentile (all)		**11460**	**92.2**		

Note: NR = Not Required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table C-15. Required Load Reduction for Beech Branch – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
7/29/92	0.15	77.1%	**2500**	64.0		
8/5/92	0.12	82.9%	240	**NR**		
8/6/92	0.50	42.5%	**1600**	43.8		
8/11/92	0.18	72.8%	590	**NR**		
8/13/92	0.17	74.7%	**6800**	86.8	**1309.56**	86.3
8/17/92	0.15	77.5%	**10200**	91.2	**1843.76**	**90.2**
8/19/92	0.14	79.0%	**1800**	50.0	**1837.45**	**90.2**
8/25/92	0.11	85.5%	1000	**NR**	**1702.90**	89.4
8/26/92	0.11	86.6%	610	**NR**	**1519.32**	88.2
8/27/92	0.11	86.1%	810	**NR**	**1426.70**	87.4
9/13/94	0.21	68.3%	64	**NR**		
6/2/98	1.45	13.9%	**8300**	89.2		
6/15/98	0.83	26.7%	450	**NR**		
7/6/98	0.33	54.2%	220	**NR**		
7/20/98	0.23	65.1%	**1900**	52.6		
8/3/98	0.36	51.9%	260	**NR**		
8/24/98	0.17	73.7%	32	**NR**		
9/21/98	0.14	80.1%	**26500**	96.6		
10/13/98	0.09	91.1%	150	**NR**		
10/26/98	0.08	94.1%	140	**NR**		
11/16/98	0.09	92.8%	220	**NR**		
11/30/98	0.08	94.8%	6	**NR**		
12/14/98	1.88	9.9%	840	**NR**		
1/25/99	1.90	9.7%	70	**NR**		
2/8/99	0.96	22.6%	580	**NR**		
	90th Percentile (all)		**7700**	**88.3**		
	90th Percentile (1998-99)		**6380**	**85.9**		
	90th Percentile (1992-94)		**6800**	**86.8**		

Note: NR = Not Required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table C-16. Required Load Reduction for Beech Branch – E. Coli Analysis

Sample Date	Flow	PDFE	E. Coli	
			Sample Concentration	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]
6/2/98	1.45	13.9%	**>2419**	>65.0
6/15/98	0.83	26.7%	517	**NR**
7/6/98	0.33	54.2%	96	**NR**
7/20/98	0.23	65.1%	**1300**	34.9
8/3/98	0.36	51.9%	205	**NR**
8/24/98	0.17	73.7%	29	**NR**
9/21/98	0.14	80.1%	**>2419**	>65.0
10/13/98	0.09	91.1%	129	**NR**
10/26/98	0.08	94.1%	166	**NR**
11/16/98	0.09	92.8%	411	**NR**
11/30/98	0.08	94.8%	9	**NR**
12/14/98	1.88	9.9%	866	**NR**
1/25/99	1.90	9.7%	56	**NR**
2/8/99	0.96	22.6%	770	**NR**
		90th Percentile	**>2083**	**>59.3**

Note: NR = Not Required
* 30-day Geometric Mean could not be calculated due to insufficient data

Table C-17. Required Load Reduction for Dudley Creek – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
7/29/92	1.93	78.8%	1200	25.0		
8/5/92	1.56	84.3%	600	**NR**		
8/6/92	9.32	33.9%	5000	82.0		
8/11/92	2.31	74.3%	820	**NR**		
8/13/92	2.12	76.3%	12000	92.5	**2041.08**	91.2
8/17/92	1.90	79.0%	1400	35.7	**1916.77**	90.6
8/19/92	1.79	80.5%	225000	99.6	**3786.43**	**95.2**
8/25/92	1.43	86.6%	900	**NR**	**3163.96**	94.3
8/26/92	1.37	87.7%	930	**NR**	**2761.52**	93.5
8/27/92	1.39	87.3%	1140	**NR**	**2527.69**	92.9
9/15/94	2.52	72.1%	12	**NR**	**2041.08**	91.2
6/2/98	20.18	14.6%	18700	95.2		
6/15/98	11.41	27.7%	16000	94.4		
7/6/98	4.38	56.4%	770	**NR**		
7/20/98	2.97	67.7%	8000	88.8		
8/3/98	4.96	52.5%	800	**NR**		
8/24/98	2.24	75.1%	160	**NR**		
9/21/98	3.13	66.3%	6700	86.6		
10/13/98	1.15	92.3%	870	**NR**		
10/26/98	1.06	95.1%	180	**NR**		
11/16/98	1.12	93.3%	114	**NR**		
11/30/98	1.08	94.5%	134	**NR**		
12/14/98	34.63	7.3%	180	**NR**		
1/25/99	26.67	10.0%	28	**NR**		
2/8/99	13.49	23.2%	126	**NR**		
	90th Percentile (all)		**14400**	**93.8**		
	90th Percentile (1998-99)		**13600**	**93.4**		
	90th Percentile (1992-94)		**12000**	**92.5**		

Note: NR = Not Required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table C-18. Required Load Reduction for Dudley Creek – E. Coli Analysis

Sample Date	Flow	PDFE	E. Coli	
			Sample Concentration	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]
6/2/98	20.18	14.6%	**>2419**	>65.0
6/15/98	11.41	27.7%	**>2419**	>65.0
7/6/98	4.38	56.4%	687	**NR**
7/20/98	2.97	67.7%	**>2419**	>65.0
8/3/98	4.96	52.5%	921	**NR**
8/24/98	2.24	75.1%	172	**NR**
9/21/98	3.13	66.3%	**>2419**	>65.0
10/13/98	1.15	92.3%	866	**NR**
10/26/98	1.06	95.1%	228	**NR**
11/16/98	1.12	93.3%	135	**NR**
11/30/98	1.08	94.5%	22	**NR**
12/14/98	34.63	7.3%	104	**NR**
1/25/99	26.67	10.0%	4	**NR**
2/8/99	13.49	23.2%	13	**NR**
		90th Percentile	**>2419**	**>65.0**

Note: NR = Not Required
* 30-day Geometric Mean could not be calculated due to insufficient data

Table C-19. Required Load Reduction for Gnatty Branch – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
8/11/92	0.23	72.7%	820	25.0		
8/13/92	0.22	74.6%	**8300**	89.2		
8/17/92	0.20	77.2%	**4000**	77.5		
8/19/92	0.19	78.6%	900	**NR**		
8/25/92	0.15	85.3%	1000	**NR**	**1896.00**	**90.5**
8/26/92	0.14	86.5%	970	**NR**	**1695.62**	89.4
8/27/92	0.15	86.0%	750	**NR**	**1509.10**	88.1
9/2/92	0.16	84.1%	730	**NR**	**1378.14**	86.9
9/3/92	0.16	84.2%	**3500**	74.3	**1528.51**	88.2
9/4/92	0.15	84.4%	260	**NR**	**1280.38**	85.9
9/13/94	0.27	68.0%	2	**NR**		
6/2/98	1.92	13.8%	**10200**	91.2		
6/15/98	1.10	26.6%	600	**NR**		
7/6/98	0.44	54.0%	420	**NR**		
7/20/98	0.30	64.9%	32	**NR**		
8/3/98	0.47	51.9%	40	**NR**		
8/24/98	0.23	73.5%	18	**NR**		
9/21/98	0.15	84.3%	**3100**	71.0		
10/13/98	0.12	90.8%	14	**NR**		
10/26/98	0.11	94.0%	6	**NR**		
11/16/98	0.11	92.8%	18	**NR**		
11/30/98	0.11	94.8%	<2	**NR**		
12/14/98	2.47	9.8%	140	**NR**		
1/25/99	2.51	9.6%	490	**NR**		
2/8/99	1.27	22.5%	54	**NR**		
	90th Percentile (all)		**3800**	**76.3**		
	90th Percentile (1998-99)		**2350**	**61.7**		
	90th Percentile (1992-94)		**4000**	**77.5**		

Note: NR = Not Required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table C-20. Required Load Reduction for Gnatty Branch – E. Coli Analysis

Sample Date	Flow	PDFE	E. Coli	
			Sample Concentration	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]
6/2/98	1.92	13.8%	**>2419**	>65.0
6/15/98	1.10	26.6%	435	**NR**
7/6/98	0.44	54.0%	91	**NR**
7/20/98	0.30	64.9%	23	**NR**
8/3/98	0.47	51.9%	30	**NR**
8/24/98	0.23	73.5%	7	**NR**
9/21/98	0.15	84.3%	**>2419**	>65.0
10/13/98	0.12	90.8%	25	**NR**
10/26/98	0.11	94.0%	9	**NR**
11/16/98	0.11	92.8%	20	**NR**
11/30/98	0.11	94.8%	1	**NR**
12/14/98	2.47	9.8%	121	**NR**
1/25/99	2.51	9.6%	613	**NR**
2/8/99	1.27	22.5%	22	**NR**
		90th Percentile	**>1877**	**>54.9**

Note: NR = Not Required
* 30-day Geometric Mean could not be calculated due to insufficient data

Table C-21. Required Load Reduction for Holy Branch – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
7/29/92	0.12	78.4%	900	**NR**		
8/5/92	0.10	84.0%	450	**NR**		
8/6/92	0.76	23.5%	900	**NR**		
8/11/92	0.15	73.3%	630	**NR**		
8/13/92	0.14	75.9%	**13400**	93.3	**1252.07**	85.6
8/17/92	0.12	78.7%	**5700**	84.2	**1611.89**	88.8
8/19/92	0.11	80.2%	**7000**	87.1	**1988.13**	90.9
8/25/92	0.09	86.2%	**3600**	75.0	**2141.30**	**91.6**
8/26/92	0.09	87.5%	380	**NR**	**1767.03**	89.8
8/27/92	0.09	86.8%	800	**NR**	**1632.41**	89.0
	90th Percentile (all)		**7640**	**88.2**		

Note: NR = Not Required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table C-22. Required Load Reduction for Kings Branch – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
8/11/92	0.43	72.4%	**1600**	43.8		
8/13/92	0.40	74.4%	**2500**	64.0		
8/17/92	0.36	77.0%	**52000**	98.3		
8/19/92	0.34	78.4%	990	**NR**		
8/25/92	0.27	84.9%	**4800**	81.3	**3971.81**	**95.5**
8/26/92	0.26	86.1%	320	**NR**	**2610.25**	93.1
8/27/92	0.26	85.6%	**1500**	40.0	**2411.63**	92.5
9/2/92	0.28	83.8%	**1500**	40.0	**2272.66**	92.1
9/3/92	0.28	84.0%	800	**NR**	**2023.72**	91.1
9/4/92	0.28	84.1%	150	**NR**	**1560.07**	88.5
9/13/94	0.49	67.9%	**69000**	98.7		
6/2/98	3.49	13.8%	**1160**	22.4		
6/15/98	1.99	26.7%	**4200**	78.6		
7/6/98	0.79	53.9%	**4900**	81.6		
7/20/98	0.54	64.5%	**2500**	64.0		
8/3/98	0.85	51.8%	**10000**	91.0		
8/24/98	0.41	73.3%	**3900**	76.9		
9/21/98	0.24	87.9%	**6500**	86.2		
10/13/98	0.22	90.4%	**10000**	91.0		
10/26/98	0.20	93.8%	**6000**	85.0		
11/16/98	0.21	92.4%	**8500**	89.4		
11/30/98	0.20	94.7%	**4100**	78.1		
12/14/98	4.51	9.7%	460	**NR**		
1/25/99	4.57	9.5%	700	**NR**		
2/8/99	2.30	22.5%	**8900**	89.9		
	90th Percentile (all)		**10000**	**91.0**		
	90th Percentile (1998-99)		**9670**	**90.7**		
	90th Percentile (1992-94)		**5200**	**98.3**		

Note: NR = Not Required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table C-23. Required Load Reduction for Kings Branch – E. Coli Analysis

Sample Date	Flow	PDFE	E. Coli Sample Concentration	E. Coli Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]
6/2/98	3.49	13.8%	**1986**	57.4
6/15/98	1.99	26.7%	**>2419**	>65.0
7/6/98	0.79	53.9%	**>2419**	>65.0
7/20/98	0.54	64.5%	**>2419**	>65.0
8/3/98	0.85	51.8%	**>2419**	>65.0
8/24/98	0.41	73.3%	**>2419**	>65.0
9/21/98	0.24	87.9%	**>2419**	>65.0
10/13/98	0.22	90.4%	**>2419**	>65.0
10/26/98	0.20	93.8%	**>2419**	>65.0
11/16/98	0.21	92.4%	**>2419**	>65.0
11/30/98	0.20	94.7%	**>2419**	>65.0
12/14/98	4.51	9.7%	**2419**	65.0
1/25/99	4.57	9.5%	**1553**	45.5
2/8/99	2.30	22.5%	**>2419**	>65.0
		90th Percentile	**>2419**	**>65.0**

Note: NR = Not Required
* 30-day Geometric Mean could not be calculated due to insufficient data

Table C-24. Required Load Reduction for Mill Creek – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
7/14/93	5.43	97.4%	510	**NR**		
7/19/93	5.50	96.5%	1270	29.1		
7/20/93	5.49	96.6%	320	**NR**		
7/21/93	5.48	96.7%	400	**NR**		
7/22/93	5.42	97.4%	2300	60.9	**717.90**	**74.9**
7/26/93	5.28	98.1%	670	**NR**	**709.68**	74.6
7/27/93	5.25	98.3%	670	**NR**	**703.87**	74.4
7/28/93	5.21	98.6%	780	**NR**	**712.97**	74.8
7/29/93	5.19	98.7%	400	**NR**	**668.62**	73.1
8/4/93	5.76	91.5%	440	**NR**	**641.22**	71.9
8/24/93	6.21	85.5%	600	**NR**	**577.19**	68.8
8/30/94	9.78	57.7%	420	**NR**		
6/8/98	39.33	10.2%	194	**NR**		
6/24/98	14.28	40.2%	700	**NR**		
7/13/98	9.39	59.9%	780	**NR**		
7/27/98	8.51	64.9%	260	**NR**		
8/10/98	8.08	68.0%	1700	47.1		
8/31/98	6.70	79.4%	230	**NR**		
9/14/98	5.89	89.3%	170	**NR**		
10/5/98	5.54	96.1%	270	**NR**		
10/19/98	5.60	94.9%	220	**NR**		
11/9/98	5.56	95.7%	230	**NR**		
11/23/98	5.63	94.3%	9900	90.9		
12/7/98	5.46	97.0%	134	**NR**		
1/11/99	25.88	18.7%	62	**NR**		
2/1/99	39.64	10.0%	250	**NR**		
2/22/99	20.38	26.2%	62	**NR**		
6/2/99	9.48	59.3%	620	**NR**		
6/24/99	7.80	70.4%	1000	**NR**		
7/1/99	34.33	12.3%	880	**NR**		
7/6/99	15.35	37.2%	260	**NR**		
7/7/99	568.05	0.1%	1500	40.0		
7/8/99	100.30	2.9%	210	**NR**	590.95	69.5%
7/15/99	56.28	6.2%	460	**NR**	566.79	68.2%

Table C-24 (cont). Required Load Reduction for Mill Creek – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
7/19/99	23.40	21.4%	220	**NR**	**495.12**	63.6
7/20/99	40.77	9.6%	**2500**	64.0	**606.19**	70.3
7/21/99	29.40	15.4%	**2600**	65.4	**712.65**	**74.7**
7/22/99	24.83	19.9%	250	**NR**	**641.77**	72.0
	90th Percentile (all)		**1880**	**52.1**		
	90th Percentile (1998-99)		**2100**	**57.1**		
	90th Percentile (1992-94)		**1221**	**26.3**		

Note: NR = Not Required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table C-25. Required Load Reduction for Mill Creek – E. Coli Analysis

Sample Date	Flow	PDFE	E. Coli			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
6/8/98	39.33	10.2%	140	**NR**		
6/24/98	14.28	40.2%	579	**NR**		
7/13/98	9.39	59.9%	461	**NR**		
7/27/98	8.51	64.9%	687	**NR**		
8/10/98	8.08	68.0%	517	**NR**		
8/31/98	6.70	79.4%	436	**NR**		
9/14/98	5.89	89.3%	488	**NR**		
10/5/98	5.54	96.1%	387	**NR**		
10/19/98	5.60	94.9%	104	**NR**		
11/9/98	5.56	95.7%	206	**NR**		
11/23/98	5.63	94.3%	**>2419**	>65.0		
12/7/98	5.46	97.0%	80	**NR**		
1/11/99	25.88	18.7%	7	**NR**		
2/1/99	39.64	10.0%	73	**NR**		
2/22/99	20.38	26.2%	14	**NR**		
6/2/99	9.48	59.3%	**1120**	24.4		
6/24/99	7.80	70.4%	770	**NR**		
7/1/99	34.33	12.3%	501	**NR**		
7/6/99	15.35	37.2%	276	**NR**		
7/7/99	568.05	0.1%	291	**NR**		
7/8/99	100.30	2.9%	127	**NR**	**330.36**	65.8
7/15/99	56.28	6.2%	326	**NR**	**329.63**	65.7
7/19/99	23.40	21.4%	124	**NR**	**286.66**	60.6
7/20/99	40.77	9.6%	649	**NR**	**317.49**	64.4
7/21/99	29.40	15.4%	**2419**	65.0	**397.85**	**71.6**
7/22/99	24.83	19.9%	189	**NR**	**369.31**	69.4
	90th Percentile (all)		**>945**	**>10.4**		

Note: NR = Not Required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table C-26. Required Load Reduction for Roaring Fork – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
7/29/92	1.58	78.4%	6000	85.0		
8/5/92	1.27	83.8%	2000	55.0		
8/6/92	6.39	38.8%	2800	67.9		
8/11/92	1.85	74.3%	6500	86.2		
8/13/92	1.72	76.1%	8700	89.7	**4526.42**	**96.0**
8/17/92	1.55	78.7%	770	**NR**	**3369.33**	94.7
8/19/92	1.46	80.0%	920	**NR**	**2799.03**	93.6
8/25/92	1.16	86.1%	100	**NR**	**1845.57**	90.2
8/26/92	1.11	87.2%	200	**NR**	**1441.78**	87.5
8/27/92	1.13	86.8%	670	**NR**	**1335.41**	86.5
7/8/93	0.87	94.0%	1060	15.1		
7/14/93	0.75	97.3%	5900	84.8		
7/19/93	0.79	96.7%	2000	55.0		
7/20/93	0.78	96.7%	1560	42.3		
7/21/93	0.78	96.9%	3800	76.3	**2366.02**	92.4
7/22/93	0.74	97.5%	2300	60.9	**2354.89**	92.4
7/26/93	0.67	98.2%	3200	71.9	**2460.35**	92.7
7/27/93	0.65	98.4%	2800	67.9	**2500.44**	92.8
7/28/93	0.63	98.7%	3200	71.9	**2569.92**	93.0
7/29/93	0.62	98.8%	3100	71.0	**2618.57**	93.1
8/25/93	1.23	84.6%	370	**NR**	**2010.96**	91.0
9/13/94	2.21	69.7%	460	**NR**		
	90th Percentile (all)		**5990**	**85.0**		

Note: NR = Not Required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table C-27. Required Load Reduction for Walden Creek – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
7/14/93	5.56	97.2%	960	**NR**		
7/19/93	5.84	96.4%	510	**NR**		
7/20/93	5.78	96.5%	570	**NR**		
7/21/93	5.74	96.6%	1200	25.0		
7/22/93	5.54	97.2%	300	**NR**	**631.54**	71.5
7/26/93	4.97	98.2%	1200	25.0	**702.86**	74.4
7/27/93	4.87	98.3%	1090	17.4	**748.32**	75.9
7/28/93	4.74	98.6%	1340	32.8	**804.85**	77.6
7/29/93	4.65	98.7%	1100	18.2	**833.28**	78.4
8/4/93	5.53	97.3%	7700	88.3	**1040.79**	82.7
8/23/93	8.85	84.1%	1100	18.2	**1592.81**	**88.7**
9/6/94	22.45	57.1%	1200	25.0		
6/8/98	135.48	10.2%	470	**NR**		
6/24/98	39.54	40.1%	1520	**NR**		
7/13/98	20.74	59.6%	700	**NR**		
7/27/98	16.80	65.4%	104	**NR**		
8/10/98	15.74	67.4%	1150	21.7		
8/31/98	10.50	79.0%	320	**NR**		
9/14/98	7.38	88.8%	270	**NR**		
10/5/98	5.95	96.0%	490	**NR**		
10/19/98	6.24	94.7%	330	**NR**		
11/9/98	5.92	96.1%	120	**NR**		
11/23/98	6.38	93.8%	56	**NR**		
12/7/98	5.61	97.0%	60	**NR**		
1/11/99	84.53	18.5%	94	**NR**		
2/1/99	137.16	10.0%	330	**NR**		
2/22/99	63.09	26.1%	102	**NR**		
6/2/99	21.05	59.3%	570	**NR**		
6/24/99	12.62	74.2%	1010	10.9		
7/1/99	116.26	12.3%	950	**NR**		
7/6/99	39.21	40.3%	490	**NR**		
7/7/99	2196.85	0.1%	2400	62.5		
7/8/99	330.23	3.3%	900	**NR**	**1003.09**	**82.1**
7/15/99	200.21	6.2%	330	**NR**	**833.43**	78.4

Table C-27 (cont). Required Load Reduction for Walden Creek – Fecal Coliform Analysis

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
7/19/99	74.45	21.3%	390	**NR**	747.74	75.9
7/20/99	141.79	9.4%	900	**NR**	765.27	76.5
7/21/99	98.30	15.4%	540	**NR**	736.19	75.5
7/22/99	80.57	19.7%	410	**NR**	694.34	74.1
	90th Percentile (all)		**1242**	**27.5**		
	90th Percentile (1998-99)		**1080**	**16.7**		
	90th Percentile (1992-94)		**1326**	**32.1**		

Note: NR = Not Required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

Table C-28. Required Load Reduction for Walden Creek – E. Coli Analysis

Sample Date	Flow	PDFE	E. Coli			
			Sample Concentration	Required Reduction	Geometric Mean[a]	Required Reduction
	[cfs]	[%]	[cts/100 ml]	[%]	[cts/100 ml]	[%]
6/8/98	135.48	10.2%	579	**NR**		
6/24/98	39.54	40.1%	**1414**	40.1		
7/13/98	20.74	59.6%	816	**NR**		
7/27/98	16.80	65.4%	649	**NR**		
8/10/98	15.74	67.4%	866	**NR**		
8/31/98	10.50	79.0%	365	**NR**		
9/14/98	7.38	88.8%	411	**NR**		
10/5/98	5.95	96.0%	816	**NR**		
10/19/98	6.24	94.7%	299	**NR**		
11/9/98	5.92	96.1%	101	**NR**		
11/23/98	6.38	93.8%	77	**NR**		
12/7/98	5.61	97.0%	66	**NR**		
1/11/99	84.53	18.5%	19	**NR**		
2/1/99	137.16	10.0%	62	**NR**		
2/22/99	63.09	26.1%	19	**NR**		
6/2/99	21.05	59.3%	461	**NR**		
6/24/99	12.62	74.2%	866	**NR**		
7/1/99	116.26	12.3%	575	**NR**		
7/6/99	39.21	40.3%	866	**NR**		
7/7/99	2196.85	0.1%	**2419**	65.0		
7/8/99	330.23	3.3%	866	**NR**	**979.88**	**88.5**
7/15/99	200.21	6.2%	308	**NR**	**807.98**	86.0
7/19/99	74.45	21.3%	272	**NR**	**691.60**	83.7
7/20/99	141.79	9.4%	579	**NR**	**676.41**	83.3
7/21/99	98.30	15.4%	548	**NR**	**660.77**	82.9
7/22/99	80.57	19.7%	219	**NR**	**591.68**	80.9
	90th Percentile (all)		866	**NR**		

Note: NR = Not Required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.

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 Lower French Broad 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 Lower French Broad 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 August 2004. 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 (10/1/91 – 9/30/01) 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. Two USGS continuous record stations located near the Lower French Broad watershed with a sufficiently long and recent historical record were 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 Bullrun Creek near Halls Crossroads, USGS Station 03535000, drainage area 68 square miles, are shown in Table D-1 and Figures D-1 and D-2. The results of the hydrologic calibration for Little Pigeon River above Sevierville, USGS Station 03469175, drainage area 183 square miles, are shown in Table D-2 and Figures D-3 and D-4.

Table D-1. Hydrologic Calibration Summary: Bullrun Creek (USGS 03535000)

Simulation Name:	USGS03535000	**Simulation Period:**	
		Watershed Area (ac):	43607.17
Period for Flow Analysis			
Begin Date:	**10/01/80**	**Baseflow PERCENTILE:**	2.5
End Date:	**09/30/86**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**82.36**	Total Observed In-stream Flow:	**91.27**
Total of highest 10% flows:	**42.83**	Total of Observed highest 10% flows:	**47.36**
Total of lowest 50% flows:	**9.68**	Total of Observed Lowest 50% flows:	**10.06**
Simulated Summer Flow Volume (months 7-9):	**9.30**	Observed Summer Flow Volume (7-9):	**7.91**
Simulated Fall Flow Volume (months 10-12):	**14.00**	Observed Fall Flow Volume (10-12):	**15.95**
Simulated Winter Flow Volume (months 1-3):	**31.45**	Observed Winter Flow Volume (1-3):	**35.49**
Simulated Spring Flow Volume (months 4-6):	**27.61**	Observed Spring Flow Volume (4-6):	**31.92**
Total Simulated Storm Volume:	**76.18**	Total Observed Storm Volume:	**83.16**
Simulated Summer Storm Volume (7-9):	**7.76**	Observed Summer Storm Volume (7-9):	**5.88**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**-9.76**	10	
Error in 50% lowest flows:	**-3.75**	10	
Error in 10% highest flows:	**-9.57**	15	
Seasonal volume error - Summer:	**17.59**	30	
Seasonal volume error - Fall:	**-12.22**	30	
Seasonal volume error - Winter:	**-11.39**	30	
Seasonal volume error - Spring:	**-13.50**	30	
Error in storm volumes:	**-8.39**	20	
Error in summer storm volumes:	**31.99**	50	

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

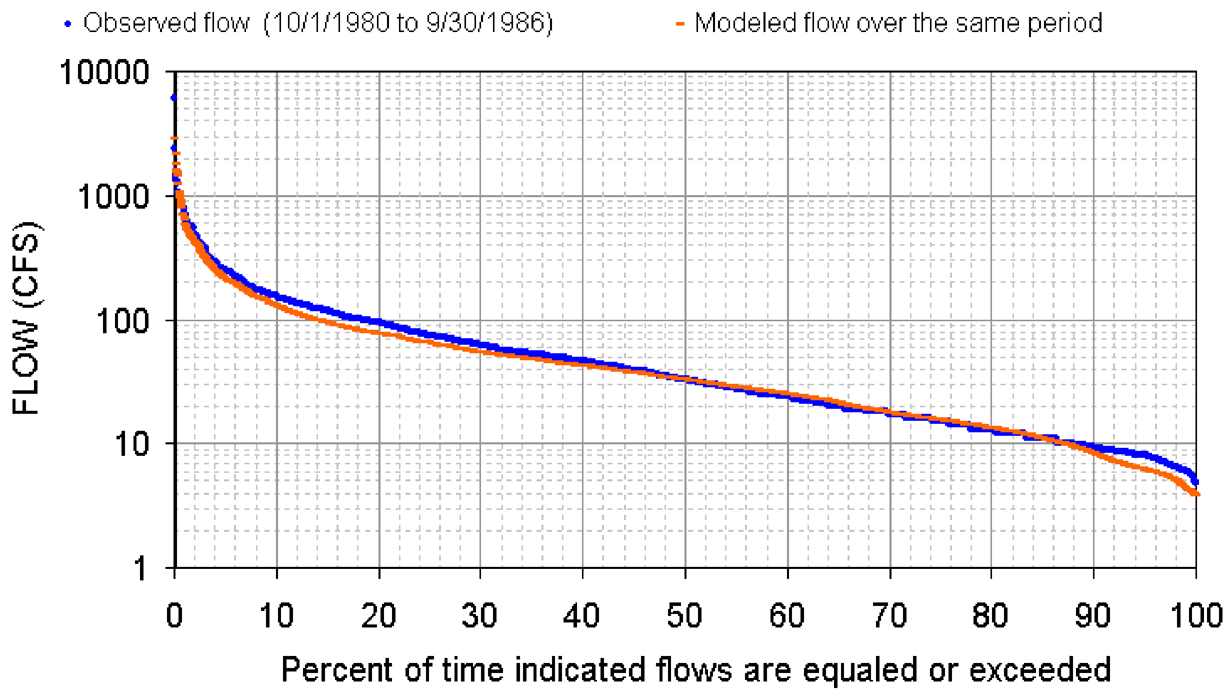

Figure D-1. Hydrologic Calibration: Bullrun Creek, USGS 03535000 (WYs1981-86)

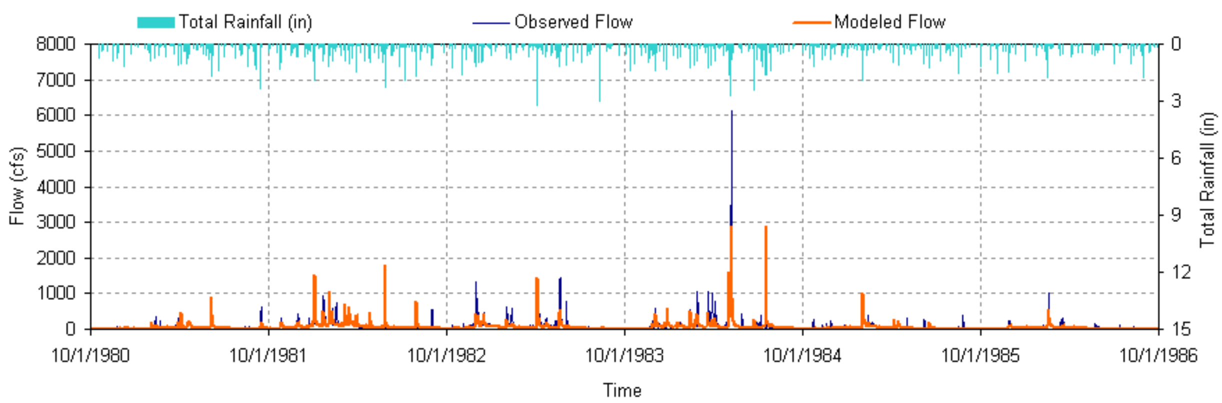

Figure D-2. 6-Year Hydrologic Comparison: Bullrun Creek, USGS 03535000

Table D-2. Hydrologic Calibration Summary: Little Pigeon River (USGS 03469175)

Simulation Name:	USGS03469175	**Simulation Period:**	
		Watershed Area (ac):	117378.26
Period for Flow Analysis		**Watershed Area (sq mi):**	183.34
Begin Date:	**10/01/88**	**Baseflow PERCENTILE:**	2.5
End Date:	**09/30/98**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**259.40**	Total Observed In-stream Flow:	**281.28**
Total of highest 10% flows:	**118.19**	Total of Observed highest 10% flows:	**115.21**
Total of lowest 50% flows:	**46.90**	Total of Observed Lowest 50% flows:	**44.67**
Simulated Summer Flow Volume (months 7-9):	**31.14**	Observed Summer Flow Volume (7-9):	**36.47**
Simulated Fall Flow Volume (months 10-12):	**44.16**	Observed Fall Flow Volume (10-12):	**48.25**
Simulated Winter Flow Volume (months 1-3):	**108.93**	Observed Winter Flow Volume (1-3):	**120.92**
Simulated Spring Flow Volume (months 4-6):	**75.17**	Observed Spring Flow Volume (4-6):	**75.65**
Total Simulated Storm Volume:	**217.13**	Total Observed Storm Volume:	**250.32**
Simulated Summer Storm Volume (7-9):	**20.42**	Observed Summer Storm Volume (7-9):	**28.76**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**-7.78**	10	
Error in 50% lowest flows:	**4.99**	10	
Error in 10% highest flows:	**2.59**	15	
Seasonal volume error - Summer:	**-14.62**	30	
Seasonal volume error - Fall:	**-8.49**	30	
Seasonal volume error - Winter:	**-9.91**	30	
Seasonal volume error - Spring:	**-0.63**	30	
Error in storm volumes:	**-13.26**	20	
Error in summer storm volumes:	**-29.01**	50	

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

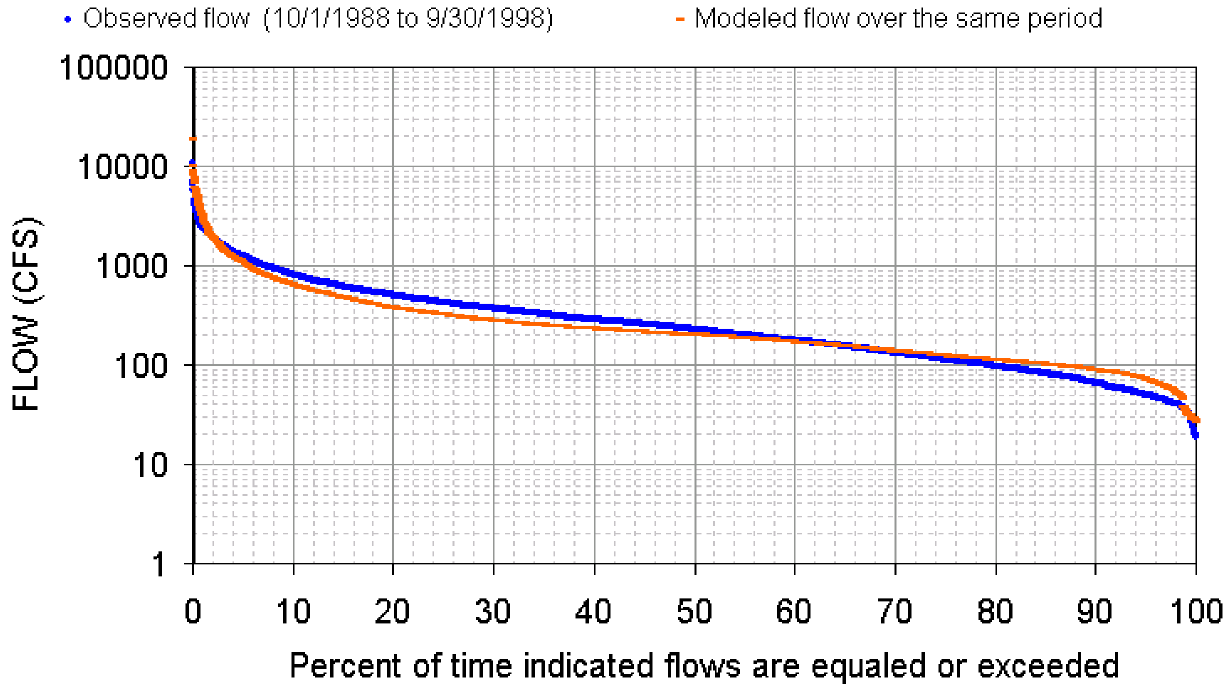

Figure D-3. Hydrologic Calibration: Little Pigeon River, USGS 03469175 (WYs1988-98)

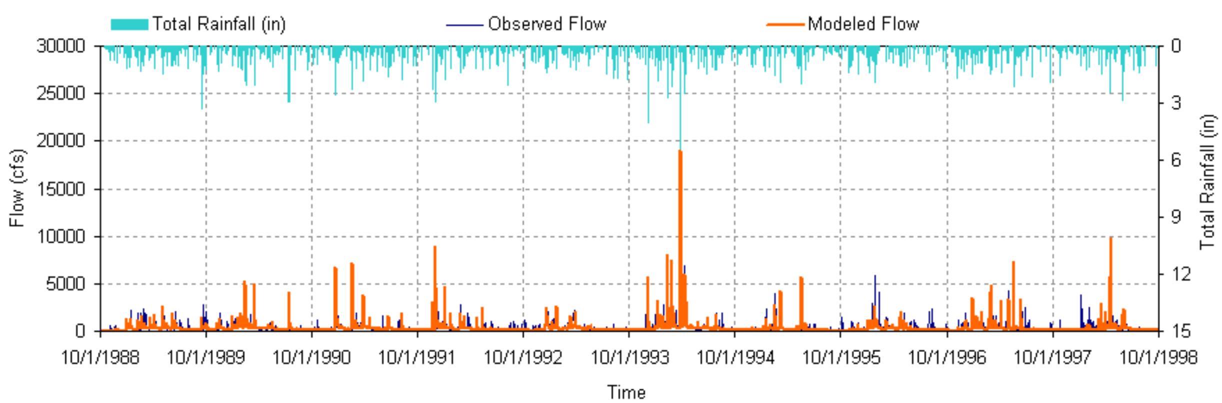

Figure D-4. 10-Year Hydrologic Comparison: Little Pigeon River, USGS 03469175

APPENDIX E

Comparison of Monitoring Data for Two Date Ranges

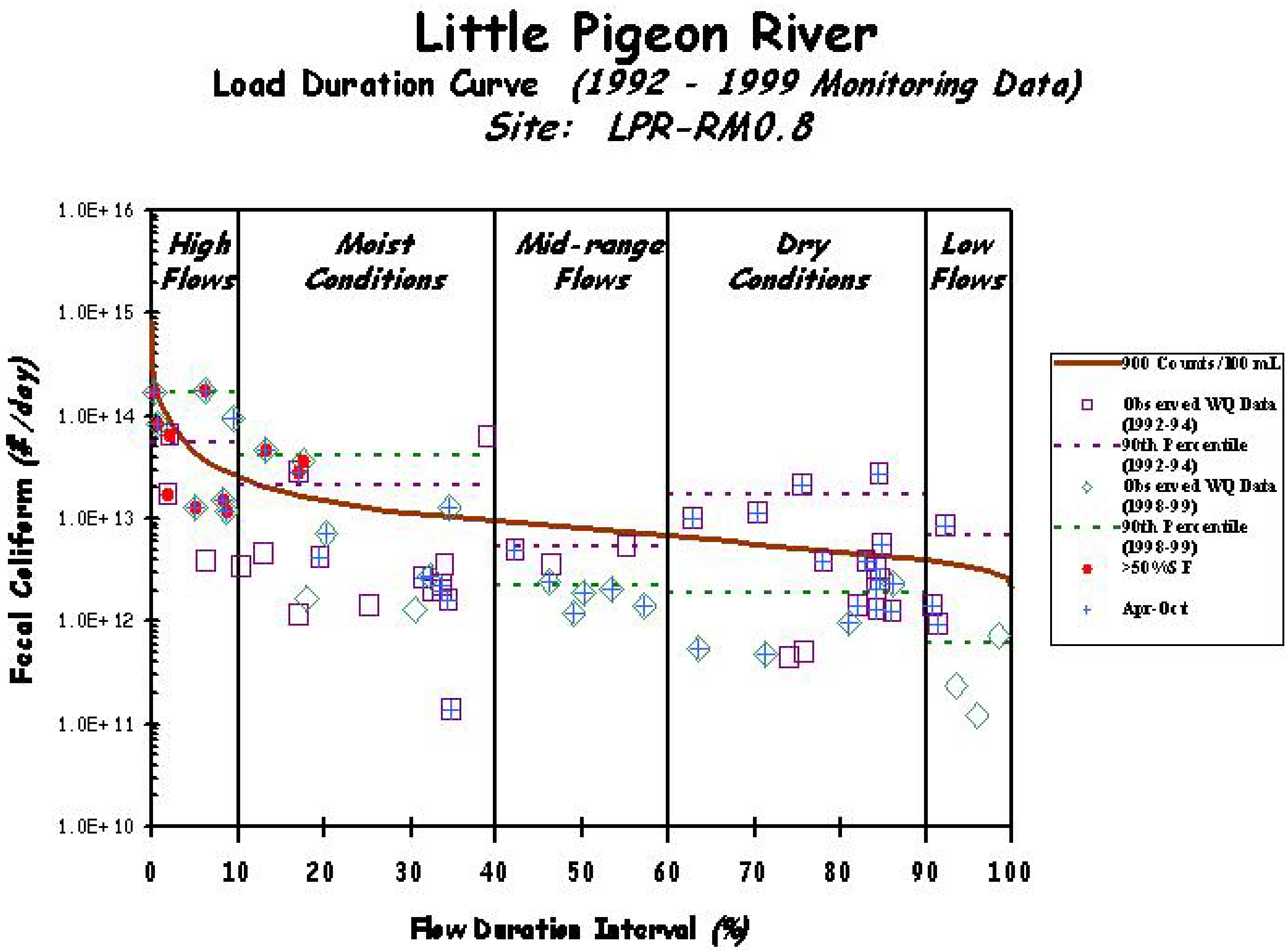

Figure E-1. Fecal Coliorm Load Duration Curve for Little Pigeon River

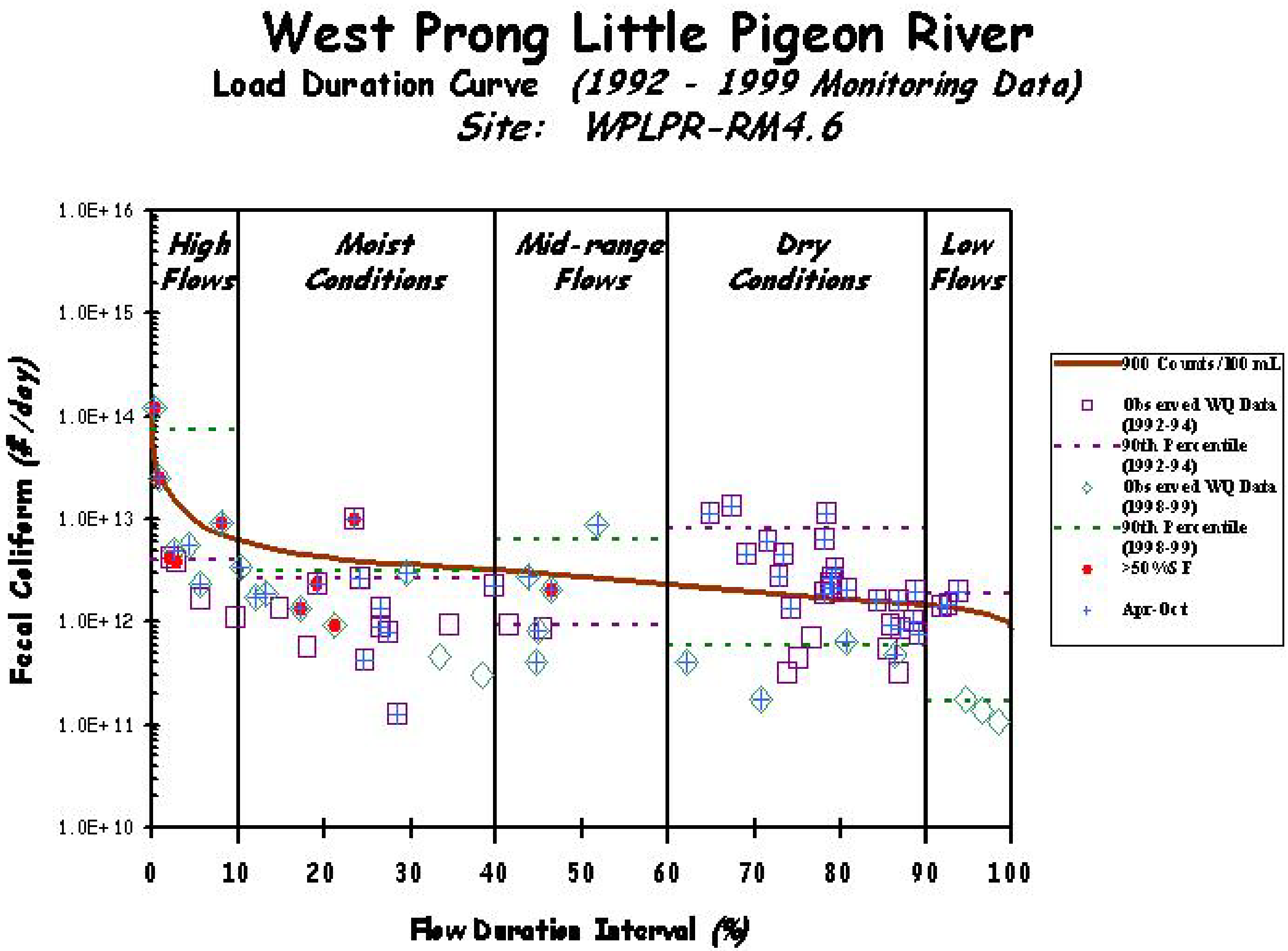

Figure E-2. Fecal Coliorm Load Duration Curve for West Prong Little Pigeon River – RM4.6

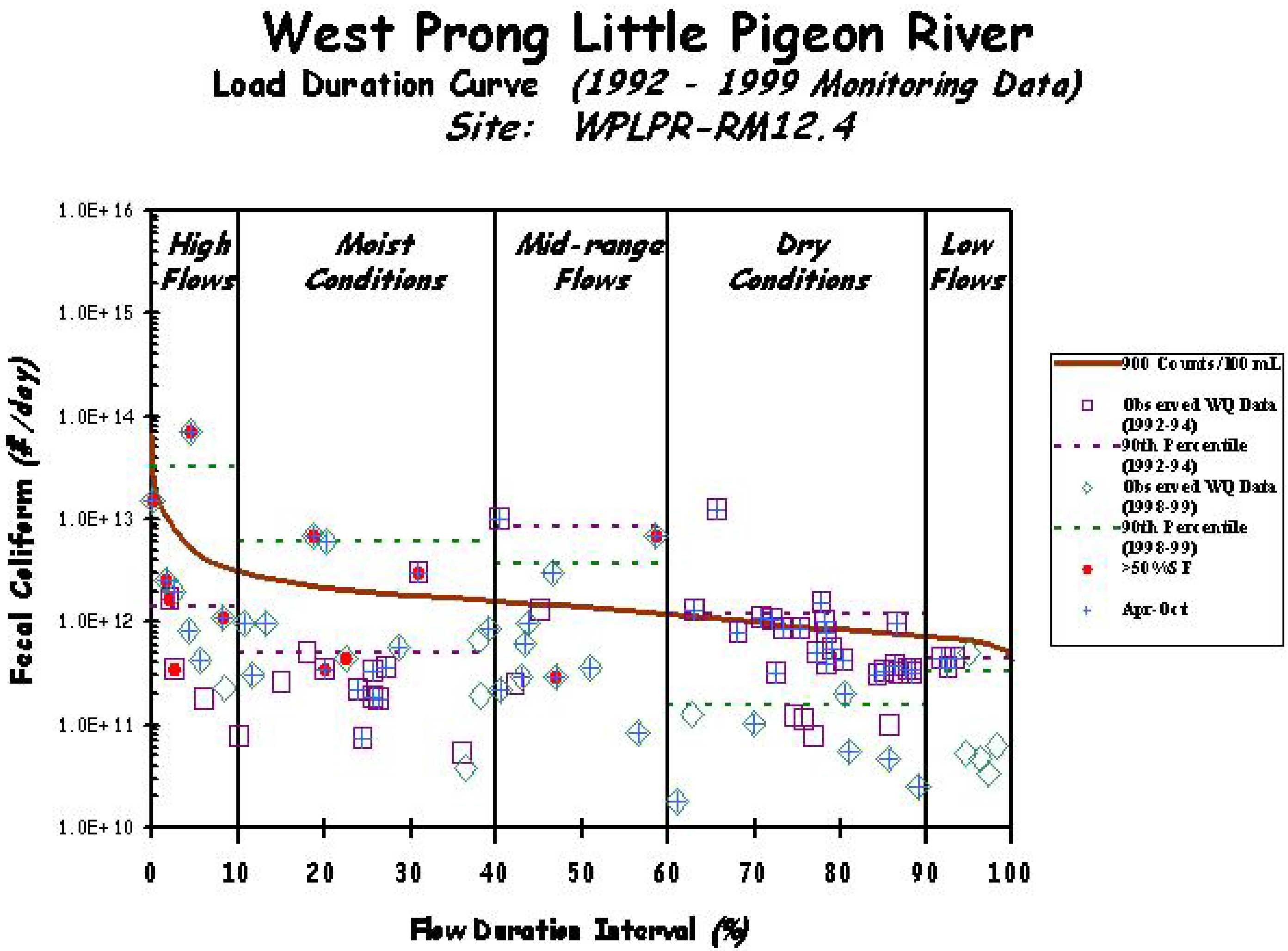

Figure E-3. Fecal Coliorm Load Duration Curve for West Prong Little Pigeon River – RM12.4

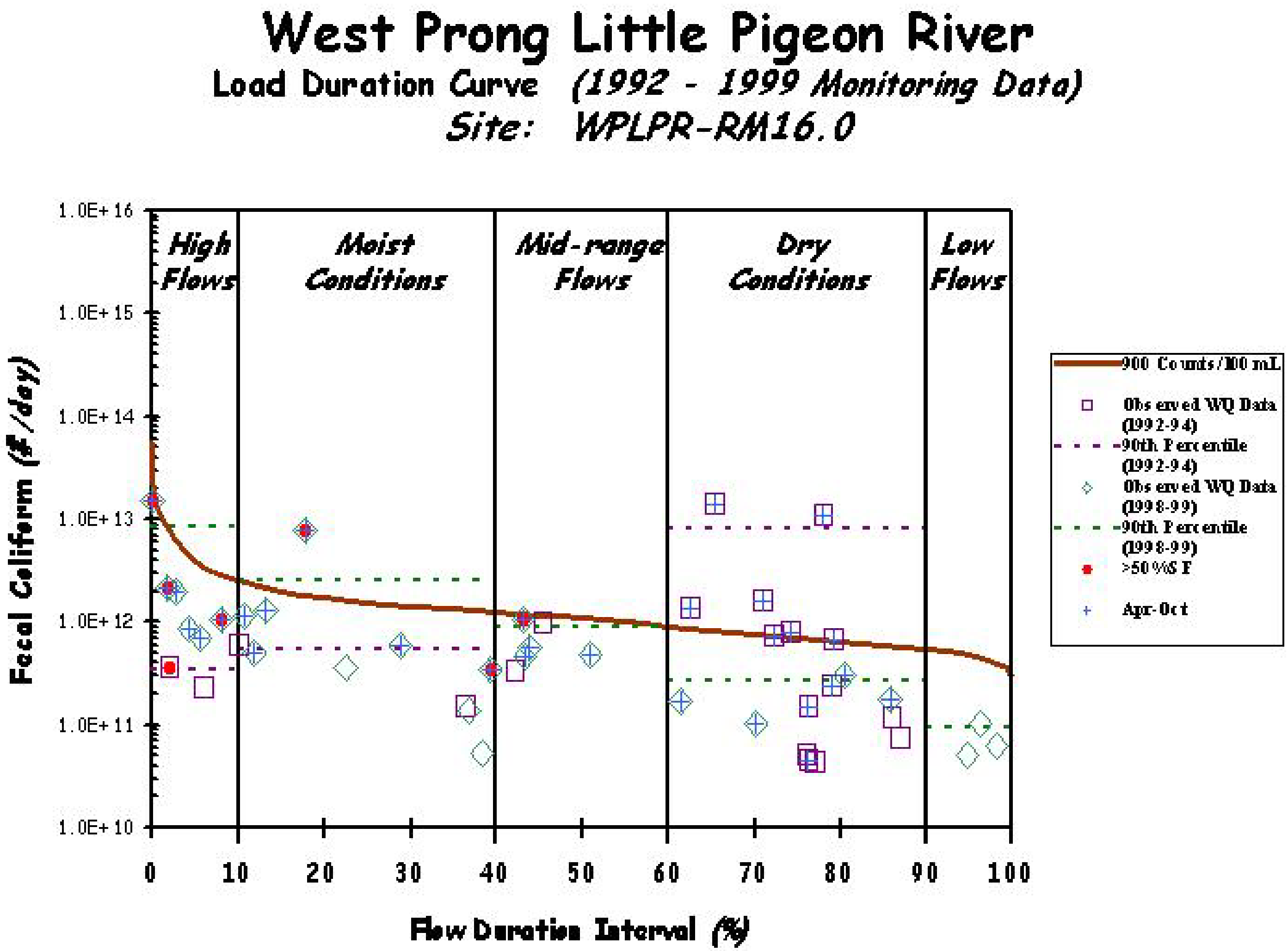

Figure E-4. Fecal Coliorm Load Duration Curve for West Prong Little Pigeon River – RM16.0

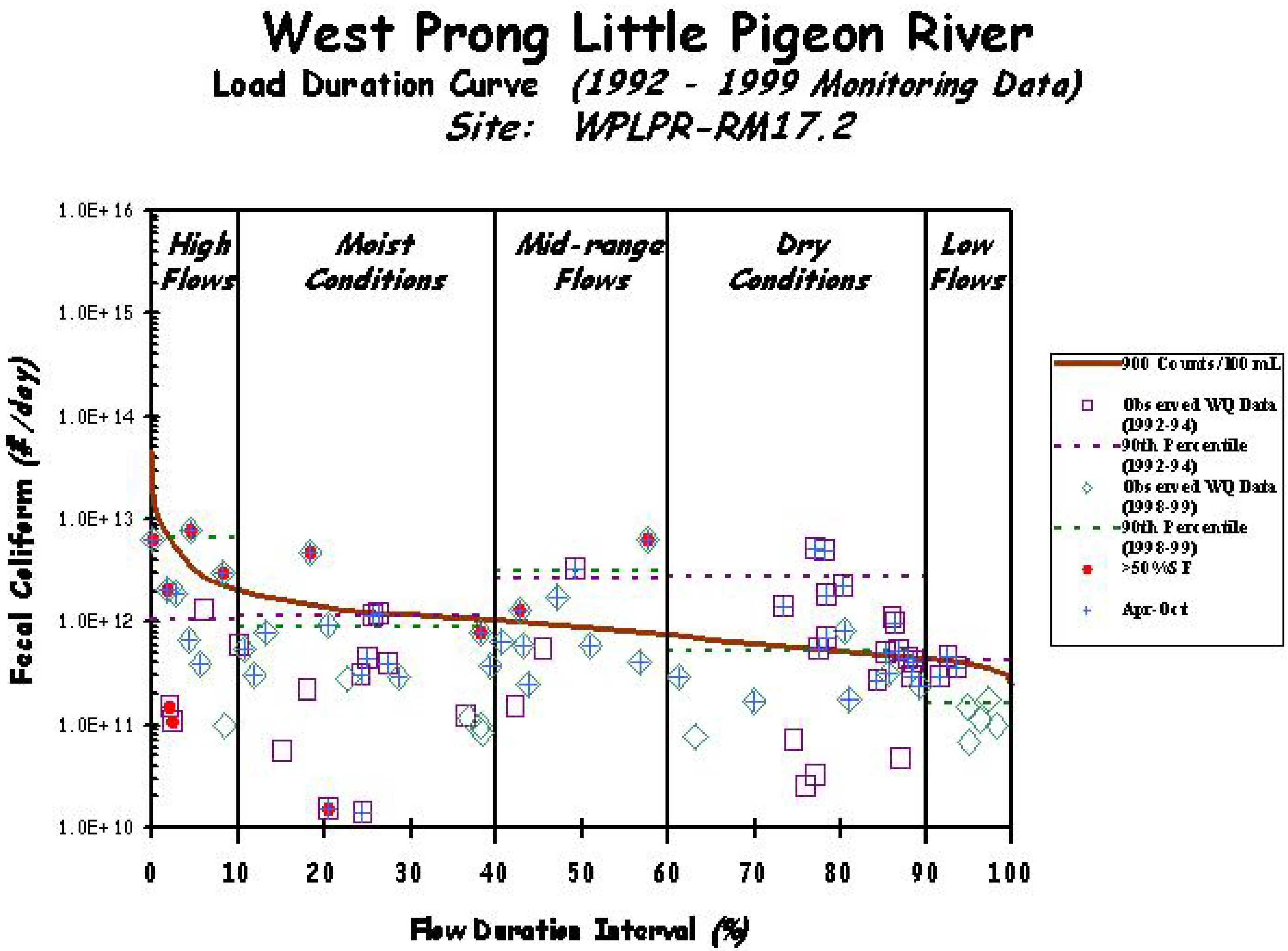

Figure E-5. Fecal Coliorm Load Duration Curve for West Prong Little Pigeon River – RM17.2

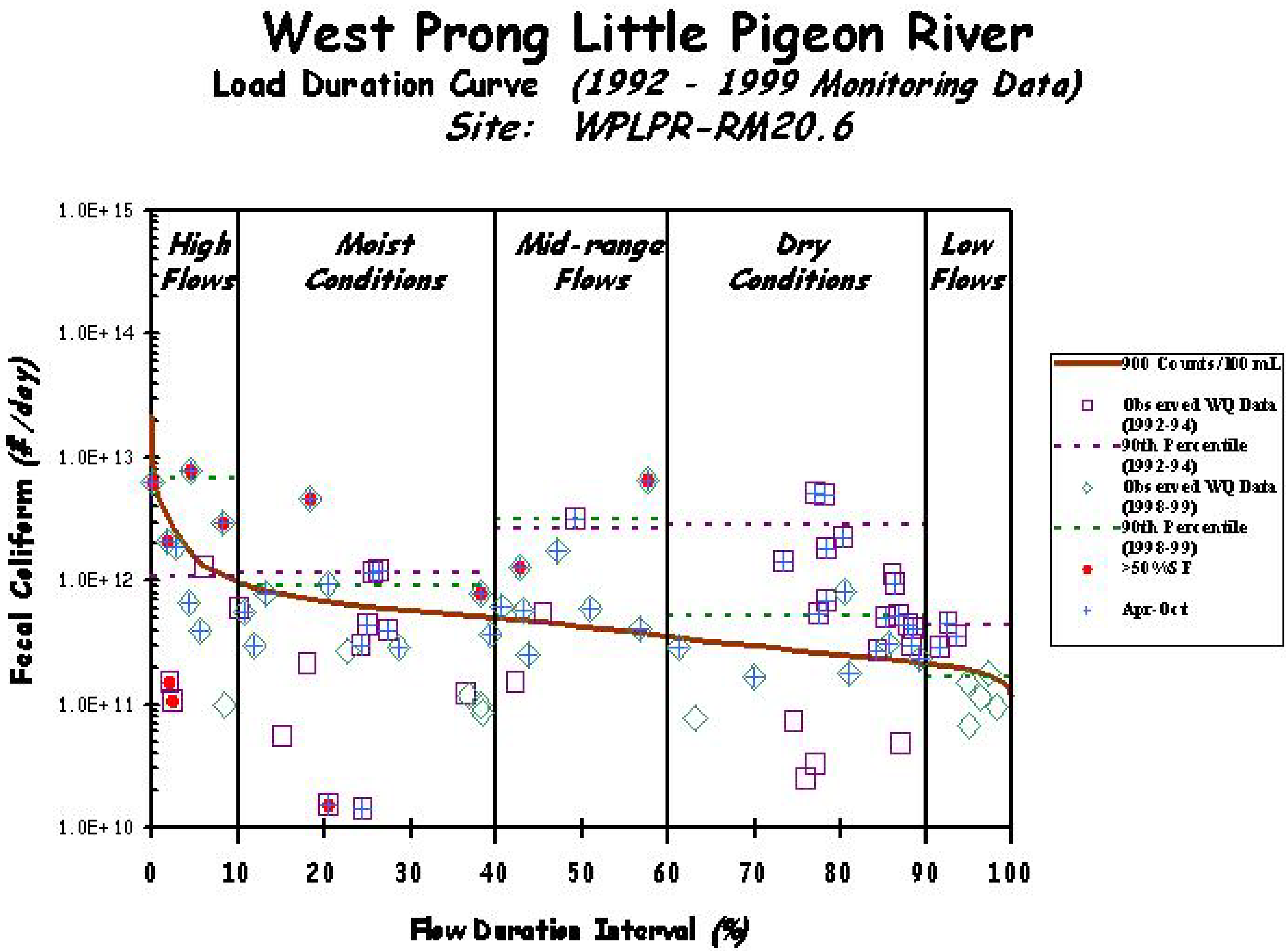

Figure E-6. Fecal Coliorm Load Duration Curve for West Prong Little Pigeon River – RM20.9

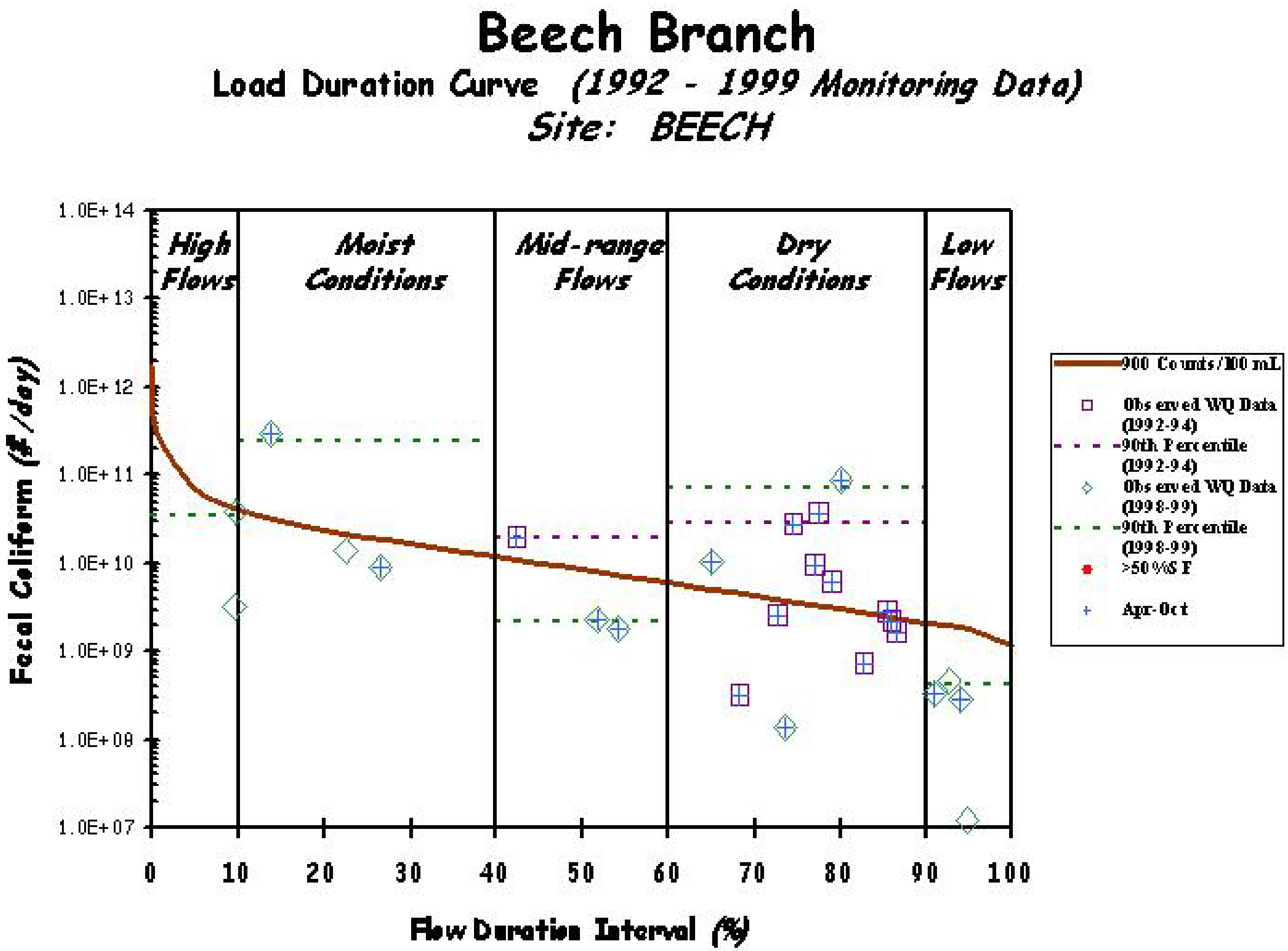

Figure E-7. Fecal Coliorm Load Duration Curve for Beech Branch

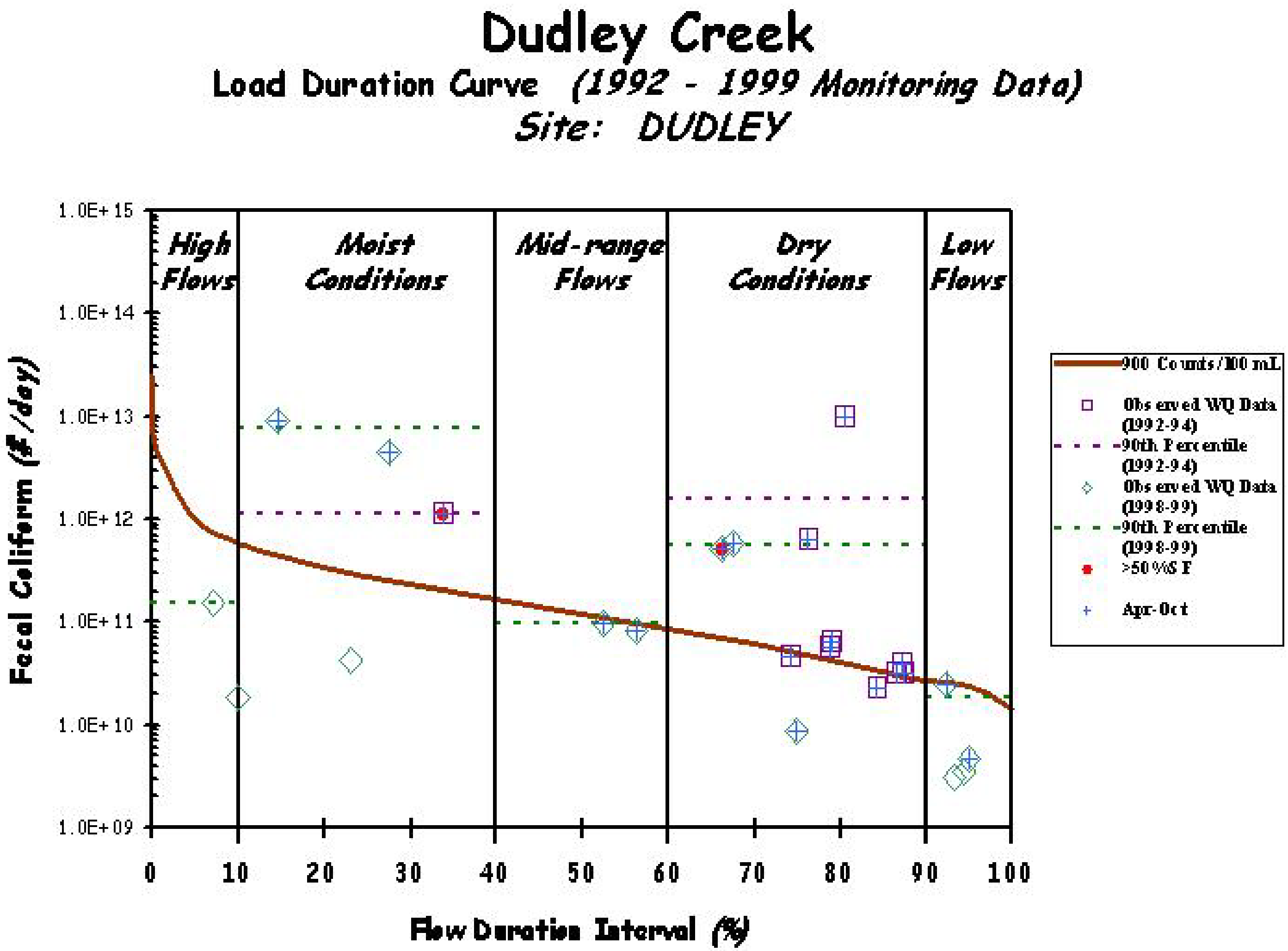

Figure E-8. Fecal Coliorm Load Duration Curve for Dudley Creek

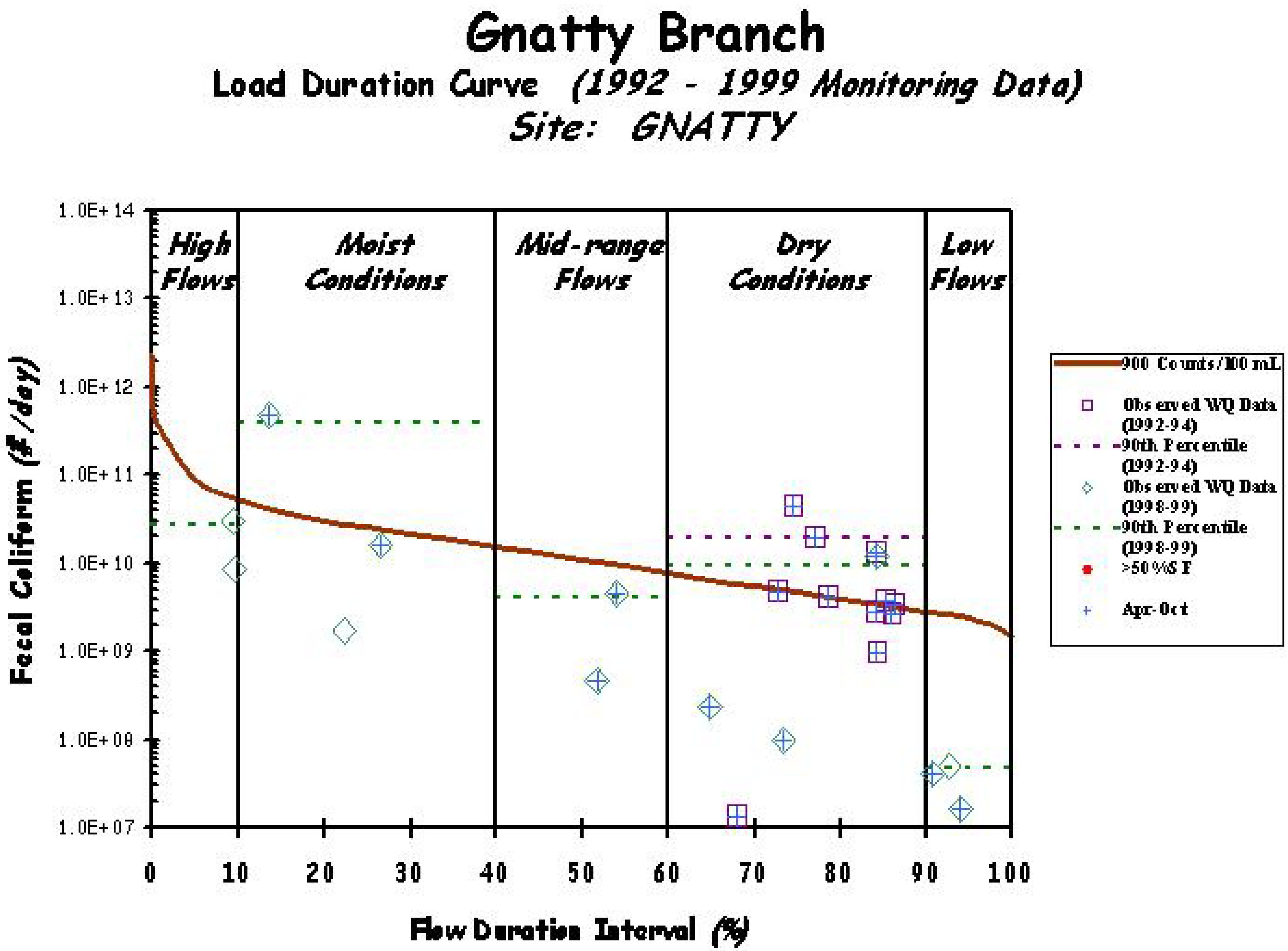

Figure E-9. Fecal Coliorm Load Duration Curve for Gnatty Branch

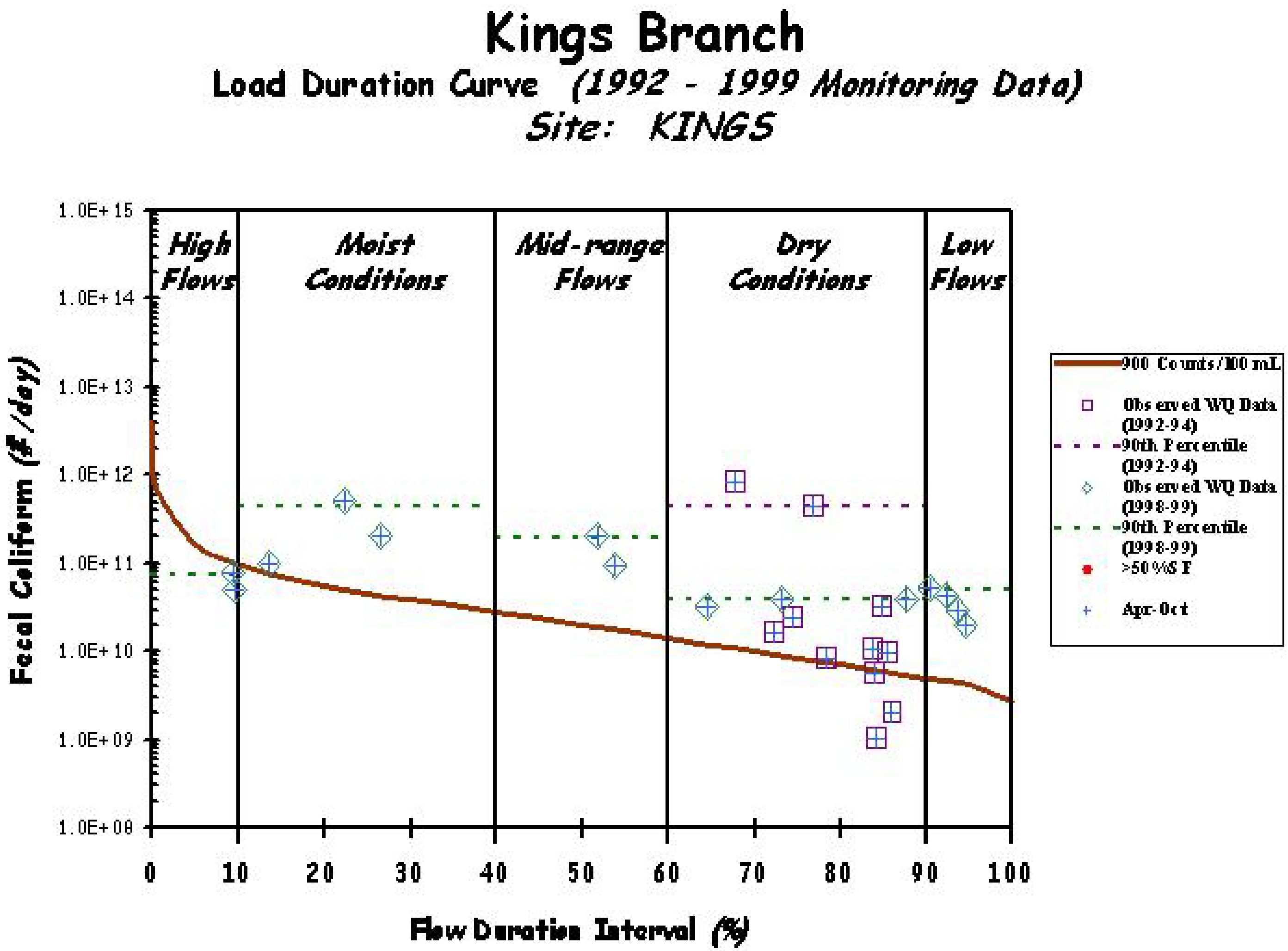

Figure E-10. Fecal Coliorm Load Duration Curve for Kings Branch

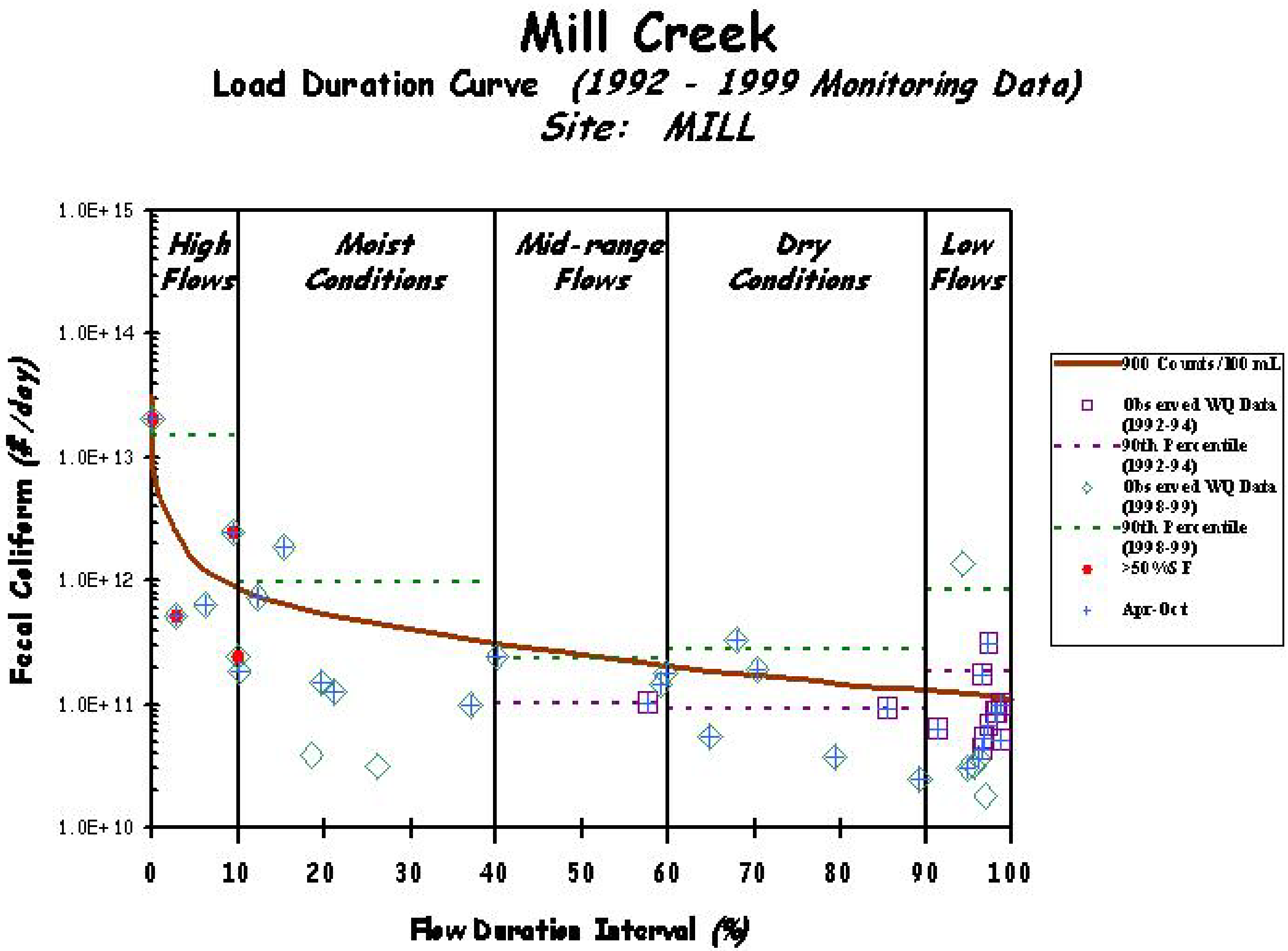

Figure E-11. Fecal Coliorm Load Duration Curve for Mill Creek

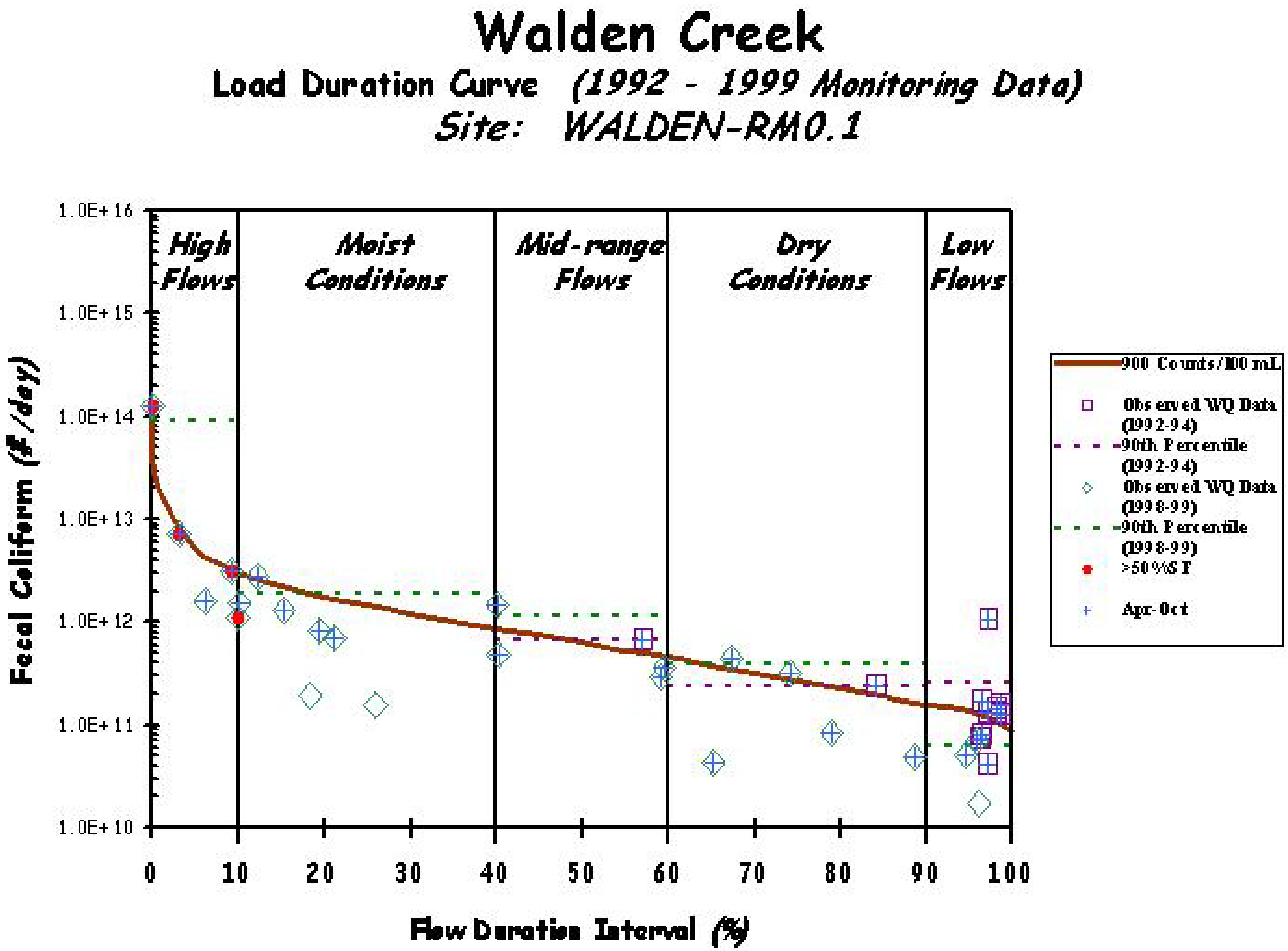

Figure E-12. Fecal Coliorm Load Duration Curve for Walden Creek

APPENDIX F

Determination of WLAs & LAs

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

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

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

For pathogen TMDLs in each impaired subwatershed, WLA terms include:

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

- $[\sum WLAs]_{CAFO}$ is the allowable load for all CAFOs in an impaired subwatershed. 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.

- $[\sum WLAs]_{MS4}$ is the required load reduction for discharges from MS4s. Fecal coliform and/or E. coli loading from MS4s is the result of buildup/wash-off processes associated with storm events. The percent load reductions for MS4s are considered to be equal to the load reductions developed for TMDLs.

LA terms include:

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

- $[\sum LAs]_{SW}$ represents the required reduction in fecal coliform and/or 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. The percent load reductions for precipitation-induced nonpoint sources are considered to be equal to the load reductions developed for TMDLs (and specified for MS4s).

Explicit MOS has already been incorporated into TMDL development as stated in Appendix C. TMDLs, WLAs, & LAs are applied to the entire subwatershed. WLAs & LAs for Lower French Broad waterbodies are summarized in Table F-1.

Table F-1. WLAs & LAs for Lower French Broad, Tennessee

HUC-12 Subwatershed (06010107__) or Drainage Area	Impaired Waterbody Name	Impaired Waterbody ID	WLAs				LAs	
			WWTFs[a] (Monthly Avg.) E. Coli	Leaking Collection Systems[b]	CAFOs	MS4s[c]	Precipitation Induced Nonpoint Sources	Other Direct Sources[d]
			[cts./day]	[cts./day]	[cts./day]	[% Red.]	[% Red.]	[cts./day]
0202	Boyds Creek	TN06010107003 – 1000	**8.584×10^{7}**	**0**	**NA**	**14.2**	**14.2**	**0**
0315	Little Pigeon River	TN06010107007 – 1000 & – 2000	**3.374×10^{10}**	**0**	**NA**	**88.2**	**88.2**	**0**
Gnatty (0307)	Gnatty Branch	TN06010107010 – 0100	**NA***	**NA**	**NA**	**61.7**	**61.7**	**0**
Kings (0307)	Kings Branch	TN06010107010 – 0200	**NA***	**NA**	**NA**	**90.7**	**90.7**	**0**
Beech (0307)	Beech Branch	TN06010107010 – 0300	**NA***	**NA**	**NA**	**85.9**	**85.9**	**0**
0311	Dudley Creek	TN06010107010 – 0400	**NA***	**NA**	**NA**	**93.4**	**93.4**	**0**
0310	Roaring Fork	TN06010107010 – 0500	**NA***	**NA**	**NA**	**96.0**	**96.0**	**0**
0309	Baskins Creek	TN06010107010 – 0600	**NA***	**NA**	**NA**	**92.2**	**92.2**	**0**
0313	West Prong Little Pigeon River	TN06010107010 – 1000	**3.374×10^{10}**	**0**	**NA**	**72.0**	**72.0**	**0**
Holy (0307)	Holy Branch	TN06010107010 – 1300	**NA***	**NA**	**NA**	**91.6**	**91.6**	**0**
0312	Mill Creek	TN06010107010 – 1800	**NA***	**NA**	**NA**	**74.7**	**74.7**	**0**
0312	Walden Creek	TN06010107010 – 1900	**3.577×10^{8}**	**0**	**NA**	**88.5**	**88.5**	**0**
WPLPR (0307)	West Prong Little Pigeon River	TN06010107010 – 2000	**1.431×10^{10}**	**0**	**NA**	**51.9**	**51.9**	**0**
WPLPR (0307)	West Prong Little Pigeon River	TN06010107010 – 3000	**1.431×10^{10}**	**0**	**NA**	**68.4**	**68.4**	**0**
0103	Clear Creek	TN06010107029T – 1100 & – 1150	**NA***	**NA**	**NA**	**NA**	**>65.0**	**0**

Note: NA = Not Applicable.

* *Future WWTFs must meet instream water quality standards at the point of discharge as specified in their NPDES permit.*

a. *WLAs for WWTFs expressed as E. coli loads (counts/day).*

b. *The objective for leaking collection systems is a waste load allocation of zero. It is recognized, however, that a WLA of 0 counts/day may not be practical. For these sources, the WLA is interpreted to mean a reduction in coliform loading to the maximum extent practicable, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.*

c. *Applies to any MS4 discharge loading in the subwatershed.*

d. *The objective for all "other direct sources" is a load allocation of zero. It is recognized, however, that for leaking septic systems a LA of 0 counts/day may not be practical. For these sources, the LA is interpreted to mean a reduction in coliform loading by the application of best management practices, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.*

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 PATHOGENS IN LOWER FRENCH BROAD WATERSHED (HUC 06010107), TENNESSEE

Announcement is hereby given of the availability of Tennessee's proposed Total Maximum Daily Load (TMDL) for pathogens in the Lower French Broad watershed, located in eastern 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.

West Prong Little Pigeon River and its tributaries are listed on Tennessee's final 2002 303(d) list as not supporting designated use classifications due, in part, to discharge of pathogens from pasture land, collection system failure, and septic tanks. 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 up to 96% for the West Prong Little Pigeon River subwatershed and its tributaries.

The proposed Lower French Broad pathogen 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 July 25, 2005 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 Notice Comments Received

RECEIVED
JUL 15 2005
OPERATIONS & ENGINEERING
JERRY LEDBETTER, P.E.
SENIOR DIRECTOR

BILL HASLAM, MAYOR

City of Knoxville

July 12, 2005

Mr. Paul E. Davis, P.E., Director
Division of Water Pollution Control
Watershed Management Section
7th Floor, L&C Annex
401 Church Street
Nashville, TN 37243-1534

Re: Comments for the proposed Lower French Broad pathogen TMDL.

Mr. Paul Davis:

After reviewing the proposed Lower French Broad pathogen TMDL, the City respectfully requests to be excluded from this particular TMDL since we have no meaningful jurisdiction or control over any significant land in this watershed. The current Urban Growth Boundary restricts the City from any further annexation of any land in this watershed.

Of the estimated 800 square miles of watershed, approximately 0.47 square miles are in the City limits. This area is within the last few river miles so no meaningful contribution could be managed before the French Broad combines with the Holston River. The 0.47 square miles of land in the City is made up of 0.43 square miles of land owned by the State of Tennessee, 0.03 square miles of land owned by KUB and approximately 0.01 square miles of land as City right of way. The State's land is a wildlife reserve and not necessarily under the jurisdiction or authority of the City. KUB's land includes a closed water plant and an inactive wastewater plant with no discharge. The City's land is a single mile stretch of road with a bridge over the river.

Since only 5 one-thousandths of one percent of the watershed are in the control of the City or KUB and additional annexation is prohibited, there is no reasonable purpose to include the City in the TMDL. Any runoff from this miniscule amount of land within the city that is not owned by the State will enter the river just before the confluence with the Holston River. The remaining land, which is owned and controlled by the State of Tennessee, serves as a buffer.

The City is willing and active in helping the State reduce pathogens in the remaining waterways throughout the City but we simply do not have any opportunities to help the French Broad River. Please consider this request and remove the City of Knoxville from this TMDL.

Sincerely,

David W. Hagerman, P.E.

Cc: Brent J. Johnson, P.E., Engineering Planning Chief
Steve J. King, P.E., Engineering Director

City County Building 400 Main Street P.O. Box 1631, Suite 480 Knoxville, TN 37902 www.cityofknoxville.org/engineering
Office: (865) 215-2148 Fax: (865) 215-2631 Please report water pollution to the Water Quality Hotline (865) 215-4147

McGill
ASSOCIATES

July 22,2005

Ms. Sherry H. Wang, Ph.D., Manager
Watershed Management Section
Tennessee Department of Environment and Conservation
Division of Water Pollution Control
401 Church Street
L&C Annex, Seventh Floor
Nashville, Tennessee 37243-1534

RE: Draft Proposed Total Maximum Daily Load (TMDL) for Pathogens in the Lower French Broad Watershed (HUC 06010107) - Cocke, Jefferson and Sevier Counties, Tennessee

Dear Dr. Wang:

I want to thank you for your June 20,2005 letter to the City of Gatlinburg concerning TDEC's draft TMDL for pathogens in the Lower French Broad Watershed. We certainly appreciate the opportunity to relay to you our comments on the TMDL process as it applies to pathogen impairment within this watershed.

As you know, McGill Associates and the City of Gatlinburg are working very closely with your office and the Division of Water Pollution Control to address water quality issues within the West Prong of the Little Pigeon River watershed. We have appreciated the opportunity to meet with you and your colleagues, both in the Nashville Central Office and the Knoxville Field Office to define the purpose and objectives of the Water Quality Management Plan for the West Prong. We have recently met several times with John West and Jonathon Burr to discuss in detail our planning and monitoring work scope for the West Prong. This important watershed planning process has begun with the initial Bacterial Source Tracking sampling and analyses in conjunction with Dr. Alice Layton at the University of Tennessee Center for Environmental Biotechnology.

TDEC's evaluation of the waters in and around Gatlinburg as impaired due to pathogens has resulted in the waters being listed on Tennessee's 303(d) list. Improving the pathogen levels in the West Prong, with the overall objective of bringing these important waters into compliance with Tennessee's water quality standards for bacteria is certainly

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a critical and shared goal of the water quality management effort we are working to accomplish. The relationship between the TMDLs being proposed for this portion of the Lower French Broad Watershed and our cooperative efforts to develop a comprehensive water quality management plan for the West Prong and the Little Pigeon is extremely important.

With this relationship in mind, we would like to provide some specific comments concerning the referenced draft TMDL. We would note that while our observations will be particularly directed to the West Prong and the Little Pigeon Watershed, our more general comments about the TMDL process for pathogens have applicability to the overall document.

First, we applaud TDEC's efforts to perform a TMDL process for bacteria within these aquatic systems. Throughout the United States, EPA and the States have continued to struggle with the TMDL process in general and specifically pollutant impacts from bacteria and sediment have proved very challenging from both a technical basis and in their real world application within a complex regulatory framework. As a result, the TMDLs and waste load allocations (WLAs) developed for pathogens within a specific watershed or stream basin must only be considered "general" guidelines or goals for reduction. The behavior of pathogens within natural systems and the effects of physical and chemical conditions within those waters vary greatly over time and season. The clear implication of the specific TMDL goals and WLAs proposed for the streams around and just downstream of Gatlinburg is that a lot of work has to be accomplished to come close to the targeted reduction levels. The specific "numbers" cannot be considered "set in concrete" or "allocated" to specific sources because the numbers themselves are only "general" in nature and the sources are too varied and dispersed to effectively allocate loading. The TMDL process is a Federal statutory requirement and as such is a "necessity" for State compliance with the Federal Clean Water Act. The basic usefulness of the TMDL process is in identifying the "magnitude" of the problem and helping to properly direct resources toward the sources of the contamination. As a means of identifying reduction objectives, the draft TMDL for the Lower French Broad Watershed certainly has established some important pathogen management goals.

Second, the West Prong area has a wide variety of land uses and local jurisdictional authorities. Expanding the view to the Little Pigeon River watershed as a whole and the pathogen issues associated with the entire watershed only complicates this equation. Many of the tributary watersheds "feeding" the West Prong have a combination of land use, jurisdiction and ownership challenges. Since the overall objective is to reduce pathogen inputs to the watershed to "restore" stream use designations, the TMDL process aimed at this objective must acknowledge and note these "source reduction" issues. Those Gatlinburg tributaries listed in the TMDL document (Beech Branch, Dudley Creek, Roaring Fork, Baskins Creek, Holy Creek, and the upper West Prong itself) as being "impaired" for pathogens lists prospective reductions of pathogen loading ranging from 85.9 % to 96 % (tributary numbers). Even if every source or "type" of source was specifically identified within each stream basin and the loading "attributed" accurately to each, the management authority and the regulatory or public policy mechanisms available today cannot come close to achieving these kinds of reductions. Again, the TMDL process helps to quantify the magnitude of the problem, but it also needs to fully describe and realistically address the water quality management actions that must be taken to achieve maximum reduction. The report describes "sources" of this contamination overall within the upper West Prong as "on-site treatment systems (septic systems and similar decentralized systems) [and] sanitary sewer overflows." However, the information available about the watershed indicates a complex mix of potential sources of pathogen impacts with an equally complex mix of reduction measures. We recommend that the report more fully discuss and describe this complexity.

The land use variation within the upper West Prong includes the Great Smoky Mountains National Park, rural private property in the County, residential private property within the City's Urban Growth area, commercial property within the Urban Growth area, and high-density commercial and residential property within the City limits. Even the National Park property contains "some" pathogen loading, and that loading, while hopefully relatively low, can still increase dramatically in response to rain events and time of year. This pathogen impact must be considered essentially "uncontrollable" since there would appear to be no acceptable BMP (best management practice) that could effectively be counted on to reduce this loading.

The nature of the upper West Prong in land value and development patterns has limited the impact of livestock operations on pathogen levels within the watershed. However, because reduction targets are so demanding, it will be essential to apply effective BMPs wherever these sources are identified. The water quality management efforts we are undertaking within the West Prong watershed should greatly help to better categorize the different sources within each stream basin and identify any potential livestock contribution areas. There are two horse riding stable areas within the National Park upstream from Gatlinburg operated by vendors on Park land. These will need to be specifically evaluated to determine if existing BMPs are adequate or if additional efforts should be undertaken to effect better pathogen control. Even small livestock areas can contribute large loadings of pathogens if effective controls are not in place. The TMDL process must be closely tied to "on the ground" realities within the watershed.

The "failing" or "improper" on-site, septic tank pathogen releases affecting these waters within unsewered areas are variable depending on the density of these sources and the weather and seasonal soil conditions. The regulatory mechanism that could help address these sources falls at least from an enforcement stance to the Sevier County Health Department. Since site limitations and poor soil conditions exist in this area, the ability to repair or replace the inadequate systems is very limited. Wastewater sewer service will be essential in effectively eliminating these sources. This requires public sewer infrastructure, which must be available (treatment capacity) and effectively "managed" and funded by the local authorities to reach these sites. Property owners also must be compelled to "connect" to public sewer when it becomes available. For those rural "county" tributaries "outside" of the Gatlinburg urban area and upstream of Pigeon Forge, (King and Gnatty Branches as well as the other tributary components outside of the City limits) just getting sewer infrastructure to these areas will be quite a public policy challenge, but will be the only effective way to address residential on-site system inadequacies to the extent that they exist. The "effectiveness" of efforts to eliminate or minimize septic tank system impacts will be limited by the time needed to "build" the needed infrastructure and the participation of the property owners. Reductions in pathogens in these areas can only be documented effectively by long-term, on-going monitoring.

Urban or high density developed areas within the watershed also contribute a variety of pollutants, including pathogens. These occur mainly through domestic animals and occasional sanitary sewer releases from the collection system. The sewer overflows in the Gatlinburg system are rare and occur almost entirely during dry weather. Wet weather overflows are very rare due to superior operation and management of the collection system. Gatlinburg has worked diligently to effectively manage and keep its collection system in good repair and will continue these efforts at a sufficient level to minimize overflows to the extent that is possible. However, this infrastructure improvement process requires the diligent application of local resources and is costly and time consuming. The TMDL document "allocates" zero loading "allowed" from this source and notes that this "may not be practical." We believe this is an appropriate nod toward the reality of collection systems since the table that presents this WLA also notes that this allocation is directed at "a reduction in coliform loading to the maximum extent practicable." Gatlinburg has certainly taken strong efforts to improve the management and operation of its collection system and will do more. The issue of stormwater pathogen contribution first needs to be defined in this watershed (which can only be done through more monitoring and evaluation) and then it may be possible to develop BMP actions that can work to reduce this "precipitation induced non-point source" of bacteria. The City's MS4 requirements also directly support the reduction efforts from this bacteria source.

The pathogen WLAs for the wastewater treatment discharges in the watershed are the most direct and measurable TMDL component of this process. The disinfection technologies and the extensive monitoring information available for these releases should make documentation of these pathogen sources very effective.

Lastly, the TMDL report addresses the implementation of the WLAs and LAs by discussing general categories of sources within the watersheds. The report notes that the TMDL development process is a "first phase of a long term effort to restore the water quality of impaired water bodies in the Lower French Broad Watershed through reduction of excessive pathogen loading." We believe this is a good overall assessment of the TMDL process, but since much of the report is aimed at providing the allocation numbers, we believe too much emphasis may be placed on those numbers and the high levels of reduction that they require to achieve compliance. While the Implementation Plan generally addresses the concept of reducing pathogen inputs to the maximum degree possible from stormwater, sanitary sewer releases, NPDES concentrated animal feeding operations (CAFOs), and non-point sources, the reduction TMDLs listed in the report places an unrealistic level of performance on these actions. The best model for addressing the elevated bacteria levels in this watershed is the development of a data supported, water quality management plan for reducing pathogen inputs sub-watershed by sub-watershed and an on-going monitoring program that will track actual improvements in the bacteria levels in the watershed. We believe that the monitoring and evaluation work planned for the Gatlinburg area and discussed with TDEC is a good beginning to being able to do this in the upper West Prong watershed. The Bacterial Source Tracking (BST) methodology being provided by the University of Tennessee Center for Environmental Biotechnology for our watershed evaluation should provide excellent supplemental information concerning source determination.

As an overall consideration of the State's TMDL efforts in the West Prong, we believe it is essential that the Water Quality Management Plan development process the City is undertaking with the other local jurisdictions over the next year must properly reference and acknowledge the pathogen reduction objectives identified in TDEC's "final" TMDL document for the area. It is also equally important that the final TMDL document acknowledge the complexity and difficulty of the "on the ground" reduction efforts needed to meet the goals of removing this impairment. We would also respectfully request that the TMDL document note the efforts being undertaken by the local government organizations within the West Prong and Little Pigeon River watershed to address the water quality impairment in this basin.

Thank you again for the opportunity to comment on this document. If you or any of the Water Pollution Control Division staff have any questions about these comments, please let me know.

Sincerely,

McGILL ASSOCIATES, P.A.

Gary R. McGill, P.E.

Cc: Cindy Ogle, City Manager
Ron Greene, Assistant City Manager/ Public Works Director
Dale Phelps, Utilities Manager
Paul Davis, Director – TDEC Division of Water Pollution Control
Ed Polk, Permit Section Manager – TDEC Nashville Central Office
John West, TDEC – Knoxville Environmental Field Office
Jonathon Burr, TDEC – Knoxville Environmental Field Office

APPENDIX I

Response to Public Comments

Response to comments provided by the City of Knoxville (see Appendix H):

Based on review of the documentation supplied by the City of Knoxville, TDEC concurs with their assessment that they have no meaningful jurisdiction or control over any significant land in this watershed. Therefore, the City of Knoxville has been removed from the list of MS4s (Section 7.1.2 and Section 10).

Response to comments provided by the McGill Associates on behalf of the City of Gatlinburg (see Appendix H):

As requested, several minor revisions have been made to the TMDL document. Additional information, when available, has been provided relating to ongoing projects to address the water quality impairments in this watershed.

As noted in the comments, TMDL development is a "first phase of a long term effort to restore the water quality of impaired water bodies in the Lower French Broad Watershed through reduction of excessive pathogen loading". The purpose of the TMDL is to assess the entire watershed and provide an overview of possible reduction methods. The development of a water quality management plan such as the work planned for the Gatlinburg area is an excellent example of implementing monitoring and evaluation strategies to reduce excessive pathogen loading.

As noted in the comments, the "basic usefulness of the TMDL process is in identifying the 'magnitude' of the problem and helping to properly direct resources toward the sources of contaminations". The specific TMDL goals and WLAs proposed for impaired waterbodies in the Lower French Broad watershed indicate that a lot of work remains to be done to reduce the magnitude of the impairment. Regardless of the percent reduction specified in the TMDL for impaired waterbodies, the ultimate goal is to achieve compliance with water quality standards, enabling removal of specific waterbodies from the State's 303(d) list.