# TOTAL MAXIMUM DAILY LOAD (TMDL)

## for

## Pathogens

## in the

## Kentucky Lake Watershed (HUC 06040005)

## Benton, Carroll, Decatur, Henderson, Henry, Houston,

## Humphreys, and Stewart Counties, Tennessee


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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 |
| EPA | Environmental Protection Agency |
| FCLES | Fecal Coliform Load Estimation Spreadsheet |
| GIS | Geographic Information System |
| HSPF | Hydrological Simulation Program - Fortran |
| HUC | Hydrologic Unit Code |
| LA | Load Allocation |
| LSPC | Loading Simulation Program in $C^{++}$ |
| MGD | Million Gallons per Day |
| MOS | Margin of Safety |
| MRLC | Multi-Resolution Land Characteristic |
| MS4 | Municipal Separate Storm Sewer System |
| NMP | Nutrient Management Plan |
| NPS | Nonpoint Source |
| NPDES | National Pollutant Discharge Elimination System |
| NRCS | Natural Resources Conservation Service |
| PDFE | Percent of Days Flow Exceeded |
| Rf3 | Reach File v.3 |
| RILR | Required In-stream Load Reduction |
| RM | River Mile |
| SSO | Sanitary Sewer Overflow |
| STP | Sewage Treatment Plant |
| 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 Kentucky Lake Watershed (HUC 06040005)

**Impaired Waterbody Information**

State: Tennessee
Counties: Carroll, Henderson, and Henry
Watershed: Kentucky Lake (HUC 06040005)
Constituents of Concern: Pathogens

Impaired Waterbodies Addressed in This Document:

| Waterbody ID | Waterbody | RM not Fully Supporting |
|---|---|---|
| TN06040005024 – 1000 | HOLLY FORK CREEK | 13.8 |
| TN06040005032 – 0710 | LITTLE BEAVER CREEK | 5.9 |
| TN06040005032 – 0900 | MUD CREEK | 24.9 |
| TN06040005032 – 1000 | BIG SANDY RIVER | 7.3 |
| TN06040005032 – 2000 | BIG SANDY RIVER | 12.5 |

Designated Uses:

The designated use classifications for Holly Fork Creek, Little Beaver Creek, Mud Creek, and Big Sandy River include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. Big Sandy River is also classified for industrial water supply.

Water Quality Goal:

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

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

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

TMDL Scope:

Waterbodies identified on the EPA-approved 2002 303(d) list as impaired due to pathogens. TMDLs are generally developed for impaired waterbodies on a HUC-12 basis.

Analysis/Methodology:

TMDLs were developed using two different methodologies (below) to assure compliance with the E. Coli 941 counts/100 mL maximum standard and the fecal coliform 200 counts/100 mL geometric mean and 1,000 counts/100 mL maximum standards. The TMDL for Big Sandy River (TN06040005032 – 1000) was developed using only the dynamic loading model methodology (for fecal coliform) because no water quality data were collected at or near the downstream extent of the waterbody for development of load duration curves.

<u>Dynamic Loading Model Method</u>
In order to demonstrate compliance with the 200 counts/100 mL geometric mean standard, the Loading Simulation Program C++ (LSPC) was used to simulate the buildup and washoff of fecal coliform bacteria from land surfaces, loading from point sources, and compute the resulting water quality response. From model output, instream 30-day geometric mean concentrations were computed, critical conditions identified, existing loads determined, and reductions required to meet the target concentrations (standard - MOS) calculated for impaired subwatersheds.

<u>Load Duration Curve Method</u>
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 fecal coliform and E. coli (standard - MOS).

The required load reductions that were determined using each method were compared and the largest load reduction specified as the TMDL for impaired subwatersheds.

Critical Conditions:

An LSPC model simulation period of 10 years and water quality data collected quarterly 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):

Implicit – Conservative modeling assumptions.
Explicit – 10% of the water quality standard for each impaired subwatershed.

## TMDLs, WLAs, & LAs

**Summary of TMDLs, WLAs, & LAs for Impaired Waterbodies**

| Impaired Waterbody | Impaired Waterbody ID | TMDL | WLAs | | | | | LAs | |
|---|---|---|---|---|---|---|---|---|---|
| | | | WWTFs[a] (Monthly Avg.) | | Leaking Collection Systems[b] | CAFOs | MS4s[c] | Precipitation Induced Nonpoint Sources | Other Direct Sources[d] |
| | | | Fecal Coliform | E. Coli | | | | | |
| | | [% Red.] | [cts./day] | [cts./day] | [cts./day] | [cts./day] | [% Red.] | [% Red.] | [cts./day] |
| HOLLY FORK CREEK | TN06040005024 – 1000 | ***75.1*** | $1.893 \times 10^{10}$ | $1.193 \times 10^{10}$ | 0 | 0 | NA | 75.1 | 0 |
| LITTLE BEAVER CREEK | TN06040005032 – 0710 | ***74.1*** | 0 | 0 | NA | NA | NA | 74.1 | 0 |
| MUD CREEK | TN06040005032 – 0900 | ***52.3*** | 0 | 0 | NA | NA | NA | 52.3 | 0 |
| BIG SANDY RIVER | TN06040005032 – 1000 | ***44.8*** | 0 | 0 | NA | NA | NA | 44.8 | 0 |
| BIG SANDY RIVER | TN06040005032 – 2000 | ***56.9*** | 0 | 0 | NA | NA | NA | 56.9 | 0 |

*Note:* *NA = Not applicable.*

*a.* *WLAs for WWTFs expressed as fecal coliform and 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 pathogens.*

*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 pathogens.*

# PROPOSED PATHOGEN TOTAL MAXIMUM DAILY LOAD (TMDL) KENTUCKY LAKE WATERSHED (HUC 06040005)

## 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 Kentucky Lake Watershed identified on the 2002 303(d) list as not supporting designated uses due to pathogens.

## 3.0 WATERSHED DESCRIPTION

The Kentucky Lake watershed (HUC 06040005) is located in Northwestern Tennessee (Figure 1). The watershed lies within the Level III Southeastern Plains (65), Interior Plateau (71), and Mississippi Valley Loess Plains (74) ecoregions. The Big Sandy River watershed, including the Mud Creek and Little Beaver Creek subwatersheds, lies entirely in the Level IV Southeastern Plains and Hills (65e) ecoregion. The Holly Fork watershed lies almost entirely (approximately 99%) in the Level IV Southeastern Plains and Hills (65e) ecoregion with the remainder in the Level IV Western Highland Rim (71f) ecoregion as shown in Figure 2 (USEPA, 1997):

- The Southeastern Plains and Hills (65e) ecoregion has more rolling topography and more relief than the Loess Plains (74b) to the west. Streams have increased gradient, generally sandy substrates, and distinctive faunal characteristics. Current land cover is mostly deciduous and mixed forest with areas of planted pine and pasture; cropland of soybeans, corn, sorghum, cotton, and hay fields occupy the bottoms and terraces. Annual precipitation is 48-52 inches.

- The Western Highland Rim (71f) is characterized by dissected, rolling terrain of open hills, with elevations of 400-1000 feet. The geologic base of Mississippian-age limestone, chert, and shale is covered by soils that tend to be cherty and acidic with low to moderate fertility. Streams are relatively clear with a moderate gradient. Substrates are coarse chert, gravel and sand with areas of bedrock. The native oak-hickory forests were removed over broad areas in the mid-to late 1800's in conjunction with the iron-ore related mining and smelting of the mineral limonite, however today the region is again heavily forested. Some agriculture occurs on the flatter interfluves and in the stream and river valleys.

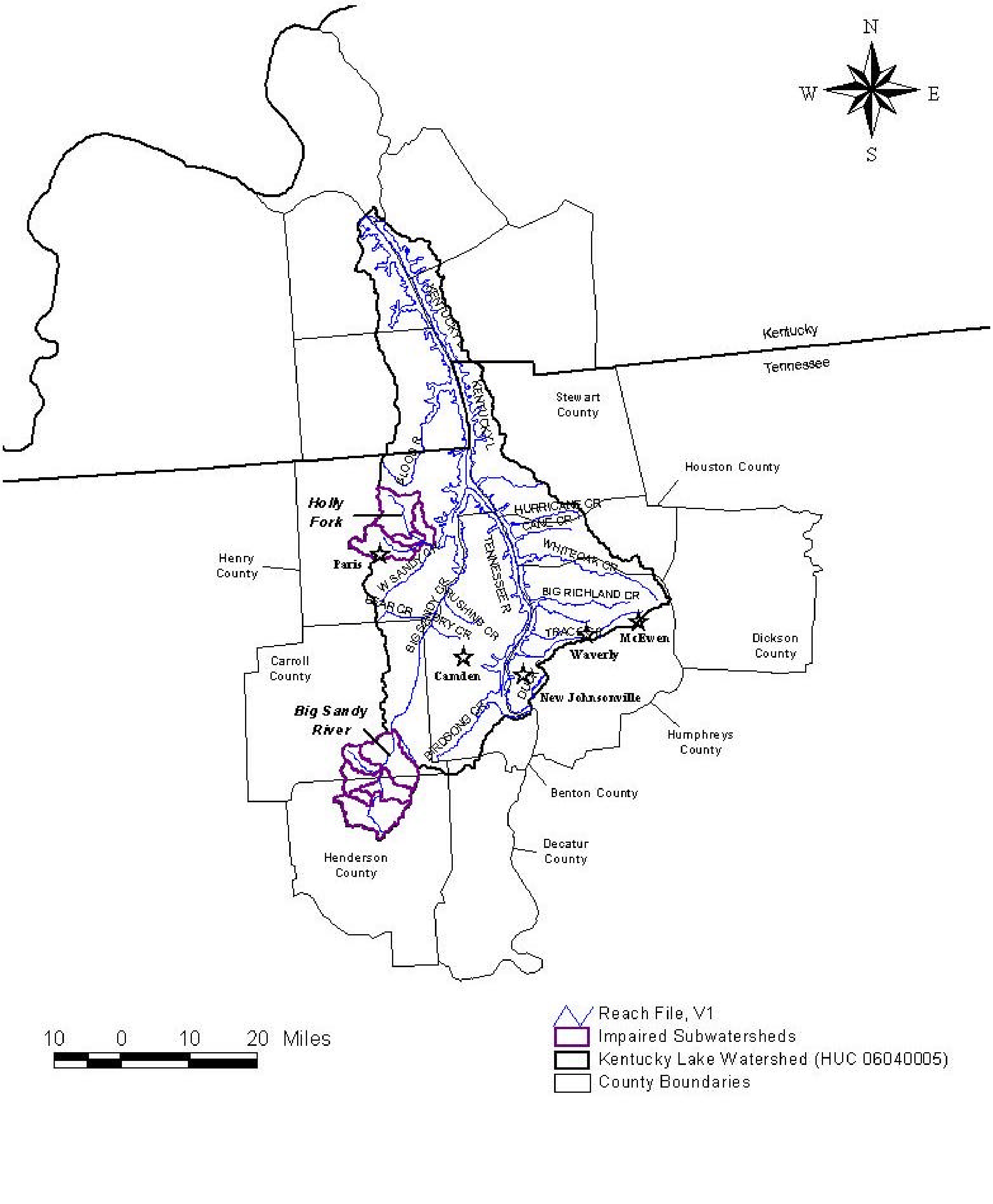


**Figure 1. Location of the Kentucky Lake Watershed and Impaired Subwatersheds.**

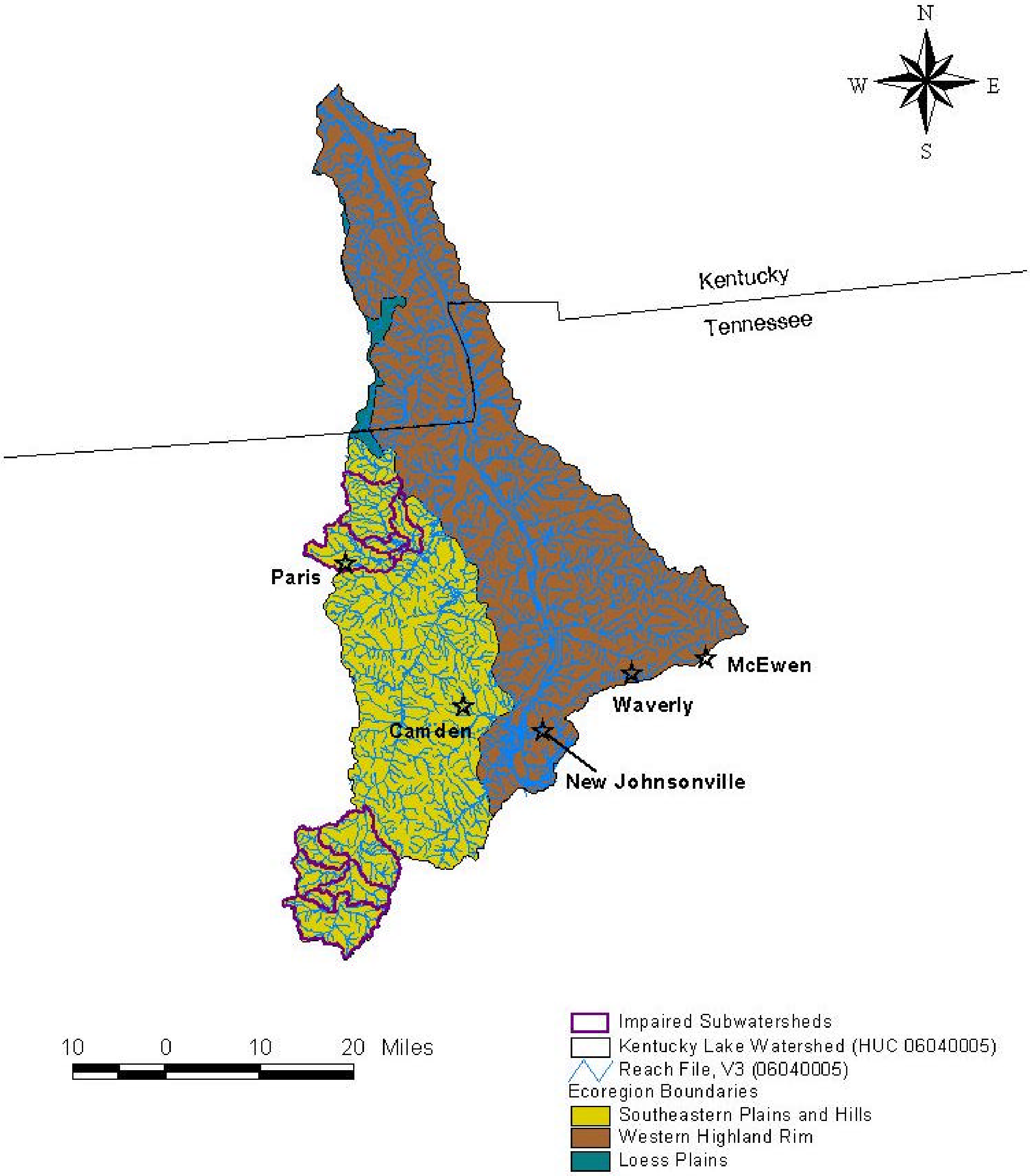


**Figure 2. Level IV Ecoregions in the Kentucky Lake Watershed.**

The predominant land uses are hay, pasture, and cattle with some cultivation of corn and tobacco.

The Kentucky Lake watershed, located in Benton, Carroll, Decatur, Henderson, Henry, Houston, Humphreys, and Stewart Counties, Tennessee, has a drainage area of approximately 1452 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 Kentucky Lake watershed have occurred since 1993 as a result of development, this is the most current land use data available. Land use for the Kentucky Lake watershed is summarized in Table 1 and shown in Figure 3. Predominate land use in the Kentucky Lake watershed is forest (63.7%) followed by agriculture (22.0%). Urban areas represent approximately 1.2% of the total drainage area of the watershed. Details of land use distribution of impaired subwatersheds in the Kentucky Lake watershed are presented in Appendix A.

## 4.0 PROBLEM DEFINITION

The State of Tennessee's final 2002 303(d) list (TDEC, 2004a) was approved by the U.S. Environmental Protection Agency (EPA), Region IV in January of 2004. The list identified Holly Fork Creek, Big Sandy River, Little Beaver Creek, and Mud Creek in the Kentucky Lake watershed as not fully supporting designated use classifications due to pathogens (see Table 2). The designated use classifications for these waterbodies include fish and aquatic life, irrigation, livestock watering & wildlife and recreation. Big Sandy River is also classified for industrial water.

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.

A description of the stream assessment process in Tennessee can be found in *2002 305(b) Report, The Status of Water Quality in Tennessee* (TDEC, 2002a). 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

**Table 1. MRLC Land Use Distribution – Kentucky Lake Watershed**

| Land Use | Area | |
|---|---|---|
| | [acres] | [%] |
| Bare Rock/Sand/Clay | 858 | 0.09 |
| Deciduous Forest | 505,655 | 54.40 |
| Emergent Herbaceous Wetlands | 2,871 | 0.31 |
| Evergreen Forest | 39,535 | 4.25 |
| High Intensity Commercial/Industrial/ Transportation | 4,224 | 0.45 |
| High Intensity Residential | 892 | 0.10 |
| Low Intensity Residential | 6,391 | 0.69 |
| Mixed Forest | 47,073 | 5.06 |
| Open Water | 68,025 | 7.32 |
| Other Grasses (Urban/recreational) | 1,186 | 0.13 |
| Pasture/Hay | 116,417 | 12.52 |
| Quarries/Strip Mines/ Gravel Pits | 828 | 0.09 |
| Row Crops | 87,823 | 9.45 |
| Small Grains | 108 | 0.01 |
| Transitional | 11,168 | 1.20 |
| Woody Wetlands | 36,482 | 3.92 |
| **Total** | **929,536** | **100.00** |

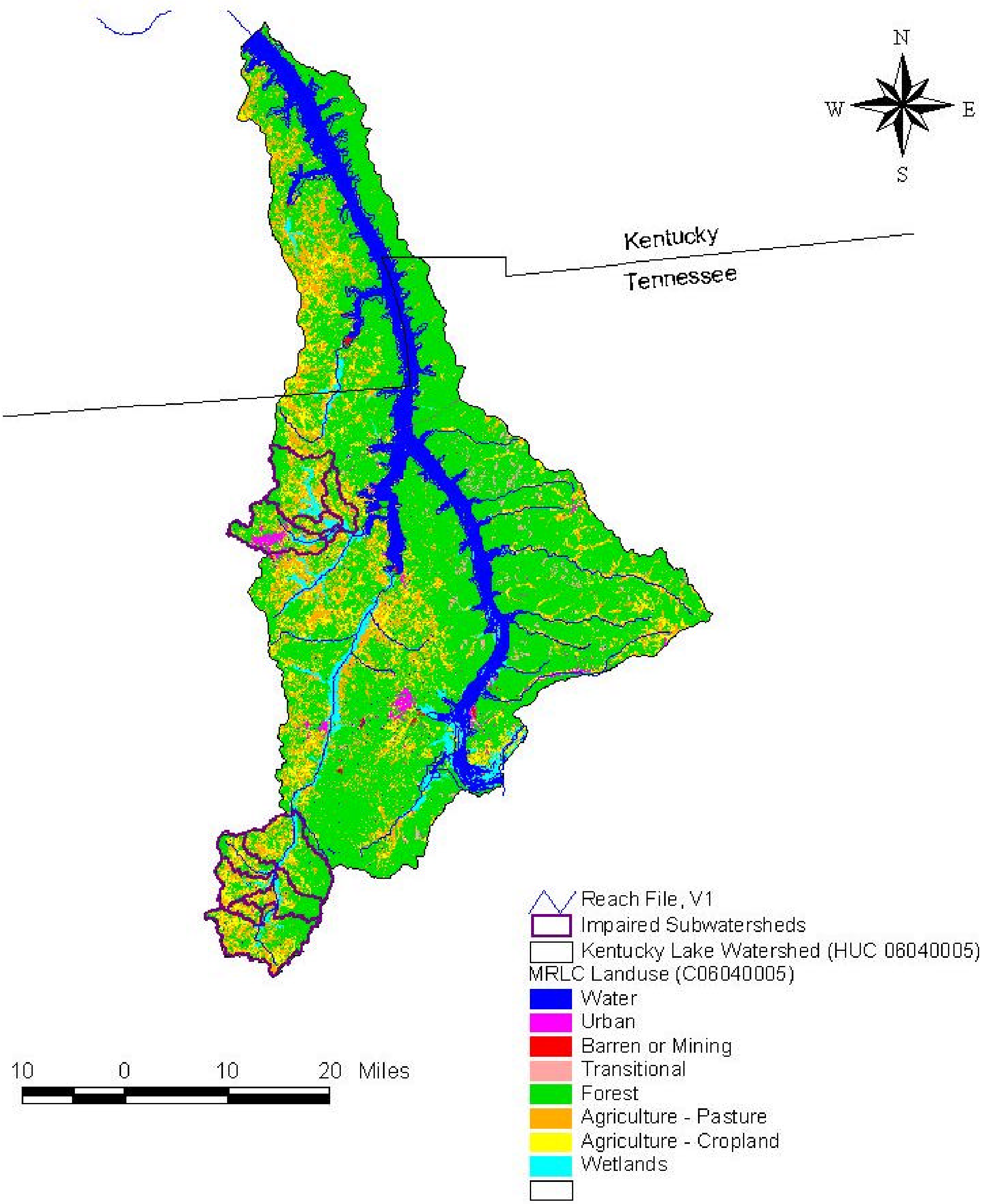


**Figure 3. Land Use Characteristics of the Kentucky Lake Watershed.**

**Table 2. 2002 303(d) List for Pathogens – Kentucky Lake Watershed**

| Waterbody ID | Impacted Waterbody | RM Partially Supporting | RM Not Supporting | CAUSE (Pollutant) | Pollutant Source |
|---|---|---|---|---|---|
| HOLLY FORK CREEK | TN06040005024 – 1000 | 13.8 | | Organic Enrichment/Low DO<br>Pathogens<br>Other Habitat Alterations | Pasture Grazing<br>Channelization |
| LITTLE BEAVER CREEK | TN06040005032 – 0710 | | 5.9 | Nutrients<br>Other Habitat Alterations<br>Pathogens | Pasture Grazing<br>Channelization |
| MUD CREEK | TN06040005032 – 0900 | 24.9 | | Organic Enrichment/Low DO<br>Pathogens | Pasture Grazing |
| BIG SANDY RIVER | TN06040005032 – 1000 | 7.3 | | Organic Enrichment/Low DO<br>Pathogens | Pasture Grazing |
| BIG SANDY RIVER | TN06040005032 – 2000 | 12.5 | | Nutrients<br>Organic Enrichment/Low DO<br>Pathogens | Pasture Grazing |

**Table 3. Water Quality Assessment of Waterbodies Impaired Due to Pathogens - Kentucky Lake Watershed**

| Waterbody ID | Segment Name | Cause | Sources | Comments |
|---|---|---|---|---|
| TN06040005024 – 1000 | HOLLY FORK CREEK | Total Fecal Coliform | Grazing in Riparian or Shoreline Zones | TDEC chemical station at Elkhorn Road. Not enough data to change 1998 303(d) assessment. |
| TN06040005032 – 0710 | LITTLE BEAVER CREEK | Escherichia coli | Grazing in Riparian or Shoreline Zones | TDEC chemical station and biological survey at Highway 22. O EPT families, 8 total families. Habitat score = 56. |
| TN06040005032 – 0900 | MUD CREEK | Escherichia coli | Grazing in Riparian or Shoreline Zones | TDEC chemical station and biological survey at Highway 22. 1 EPT families, 14 total families. Habitat score = 154. |
| TN06040005032 – 1000 | BIG SANDY RIVER | Escherichia coli | Grazing in Riparian or Shoreline Zones | TDEC chemical stations at mile 36.3 (Highway 114) and mile 45.2 (Highway 424). |
| TN06040005032 – 2000 | BIG SANDY RIVER | Escherichia coli | Grazing in Riparian or Shoreline Zones | TDEC chemical station at mile 52.9 (Highway 22). |

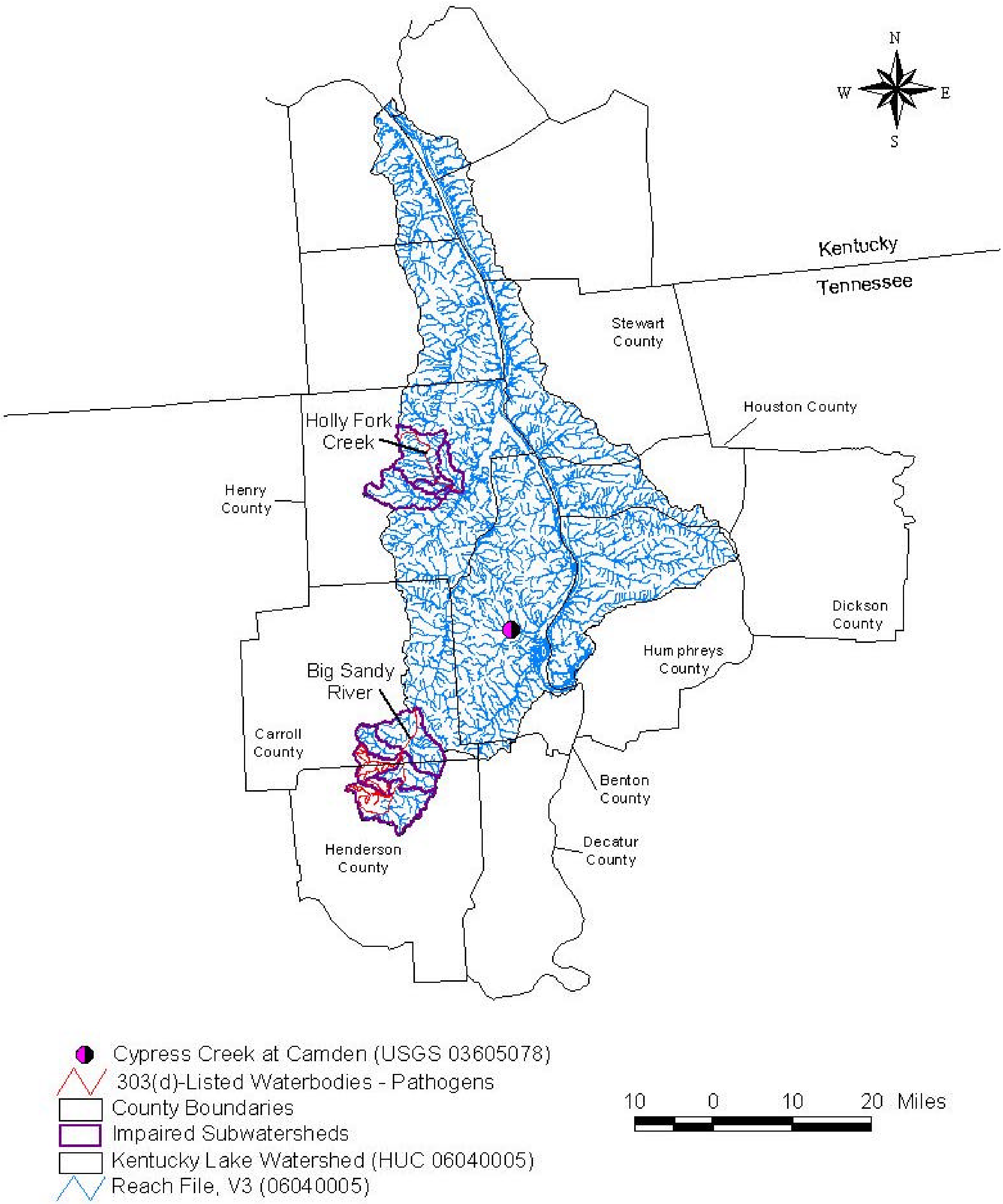


**Figure 4. Waterbodies on the 303(d) List - Pathogens.**

## 5.0 WATER QUALITY GOAL

As previously stated, the designated use classifications for the Kentucky Lake waterbodies include fish & aquatic life, recreation, irrigation, livestock watering & wildlife, and industrial water supply. 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.

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) stated:

> 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 the state of Tennessee, E. coli and fecal coliform are well correlated (R = 0.902) when evaluating all available ecoregion data (623 observations). Furthermore, as described in Section 3.0, the impaired waterbodies of the Kentucky Lake watershed (HUC 06040004) lie almost entirely within level IV ecoregion 65e. The correlation between E. coli and fecal coliform in level III ecoregion 65 is excellent (R = 0.948). In addition, the correlation between E. coli and fecal coliform in level IV ecoregion 65e is good (R = 0.893).

For consistency with current TMDL methodology, since the dynamic loading model method is only applicable to fecal coliform, and to comply with current water quality standards for pathogens, the primary instream goals selected for TMDL development are threefold: 1) the geometric mean standard for fecal coliform of 200 counts/100 mL, 2) the fecal coliform sample maximum of 1,000 counts/100 mL, and 3) the E. coli sample maximum of 941 counts/100 mL. The most protective (or highest percent of load reduction) of the three methodologies will determine the percent reduction(s) required for impaired waterbodies.

*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.*

## 6.0 WATER QUALITY ASSESSMENT AND DEVIATION FROM GOAL

There are four primary water quality monitoring stations that provide data for waterbodies identified as impaired for pathogens in the Kentucky Lake watershed:

- HFORK004.0HN – Holly Fork at Elkhorn Road (˜ RM 4.0).
- LBEAV001.3HE – Little Beaver Creek at Highway 22 (˜ RM 1.3).
- MUD004.7CR – Mud Creek at Highway 22 (˜ RM 4.7).
- BSAND045.2CR – Big Sandy River at Highway 424 (˜ RM 45.2).

The location of these monitoring stations is shown in Figures 5 and 6. Water quality monitoring results for these stations are tabulated in Appendix B and summarized in Table 4. Examination of the data shows violations of the 1,000 counts/100 mL maximum fecal coliform standard and the 941 counts/100 mL maximum E. coli standard at each monitoring station. There were not enough data to determine compliance with the geometric mean standard for fecal coliform or E. coli.

**Table 4. Summary of Water Quality Monitoring Data**

| Monitoring Station | Fecal Coliform | | | | | E. Coli | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Data Pts. | [Counts/100 mL] | | | No. Viol. WQ Std. | Data Pts. | [Counts/100 mL] | | | No. Viol. WQ Std. |
| | | Min. | Avg. | Max. | | | Min. | Avg. | Max. | |
| HFORK004.0HN | 15 | 10 | 1829 | 20,000 | 3 | 6 | 1 | 797 | 1733 | 2 |
| LBEAV001.3HE | 9 | 72 | 1582 | 6400 | 3 | 9 | 83 | 898 | >2419 | 3 |
| MUD004.7CR | 21 | 30 | 2358 | 20,000 | 6 | 11 | 91 | >758 | >2419 | 2 |
| BSAND045.2CR | 21 | 22 | 1543 | 20,000 | 4 | 11 | 50 | 205 | 1120 | 1 |

## 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

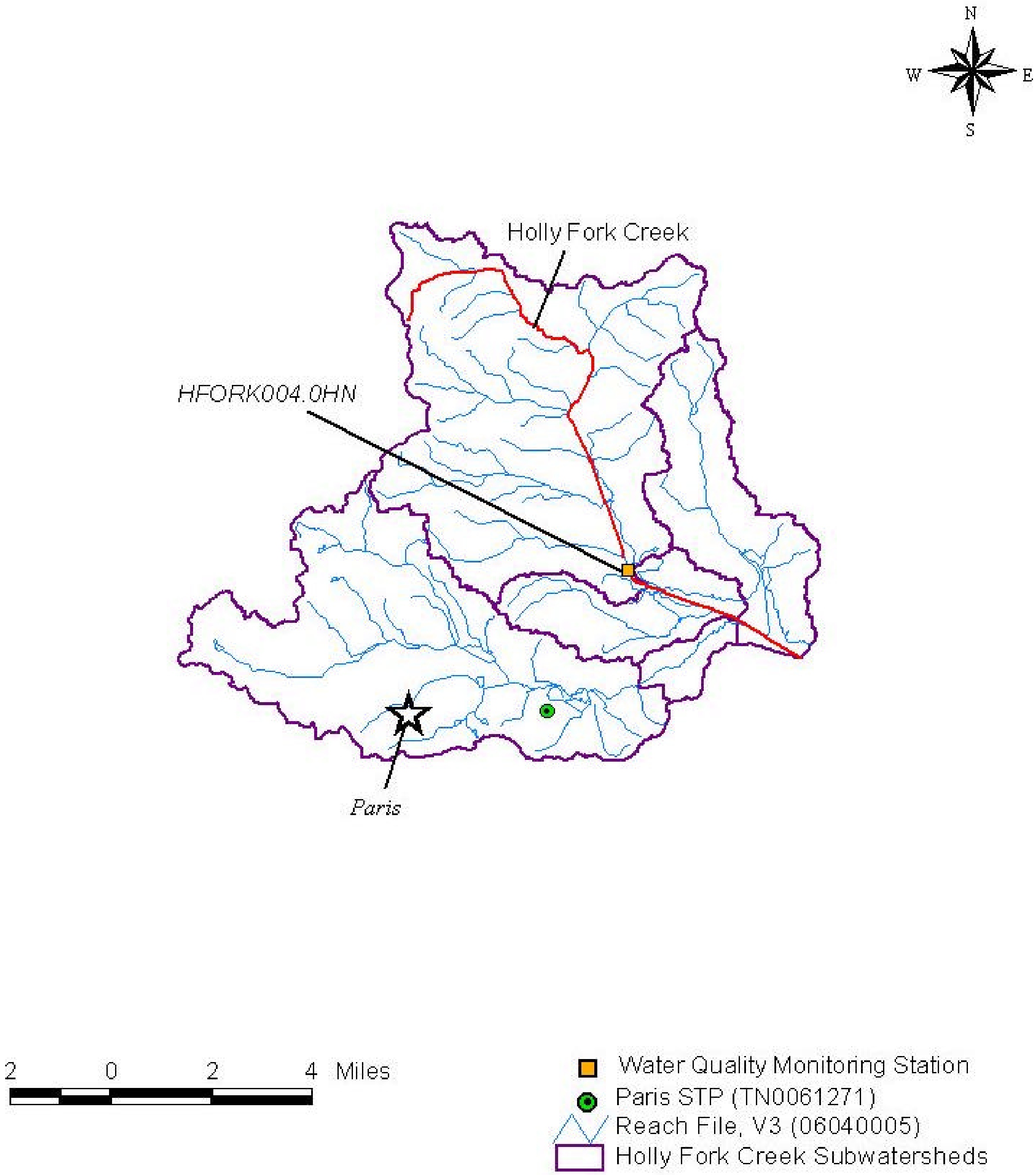


**Figure 5. Selected Water Quality Monitoring Stations and Point Source Dischargers in the Holly Fork Creek Watershed.**

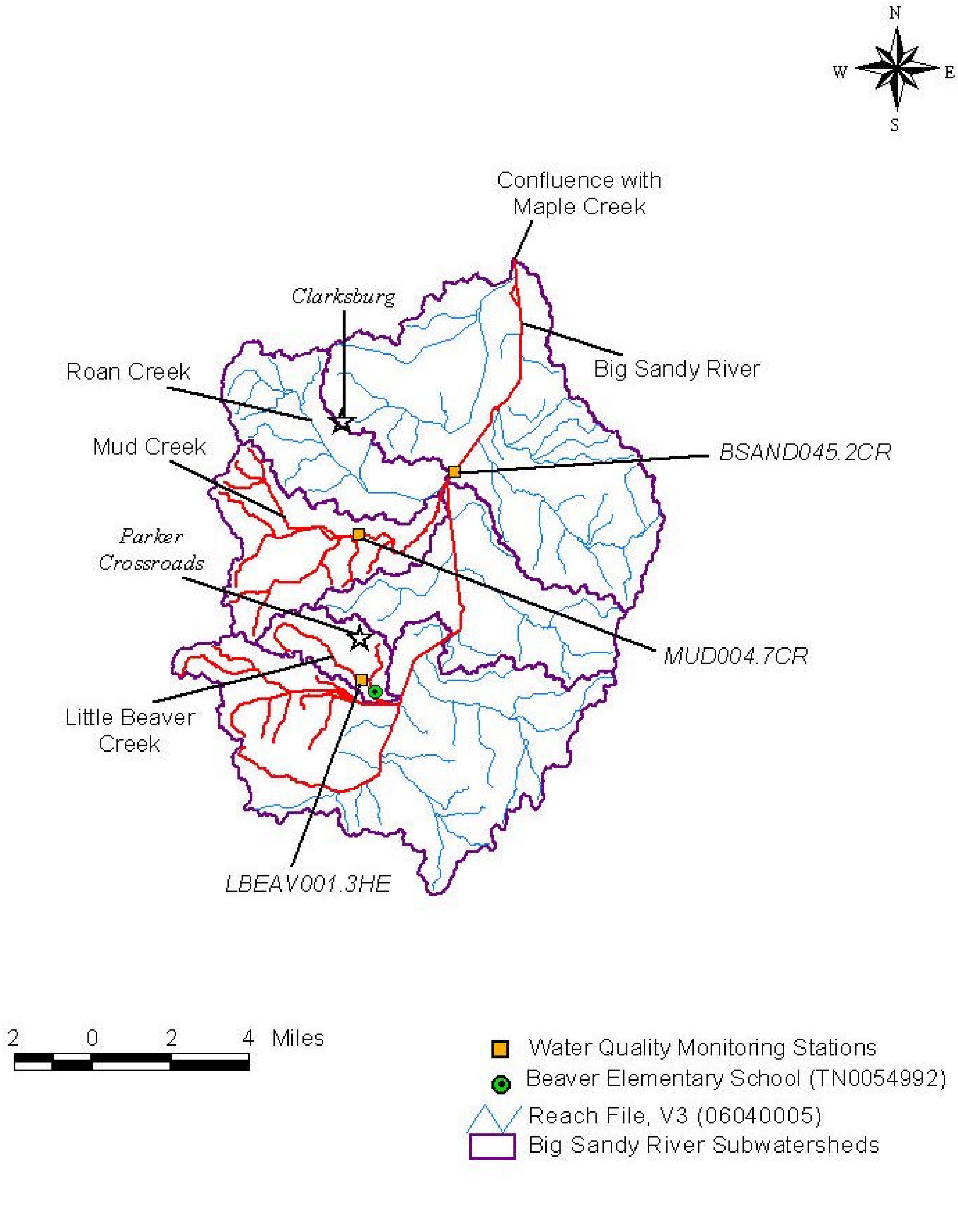


**Figure 6. Selected Water Quality Monitoring Stations and Point Source Dischargers in the Big Sandy River Watershed.**

Allocations (WLAs) for all NPDES regulated point sources. Nonpoint sources are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. For the purposes of this TMDL, all sources of pollutant loading not regulated by NPDES permits are considered nonpoint sources. The TMDL must provide a Load Allocation (LA) for these sources.

### 7.1 Point Sources

#### 7.1.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

Both treated and untreated sanitary wastewater contain coliform bacteria. There were two (2) NPDES permitted WWTFs in the impaired subwatersheds of the Kentucky Lake watershed that were authorized to discharge treated sanitary wastewater during the period of TMDL analysis. These facilities are tabulated in Table 5 and the locations shown in Figures 5 and 6. The fecal coliform and E. coli permit limits for discharges from these two WWTFs are/were 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).

The Paris Sewage Treatment Plant (STP) (TN0061271) serves the Paris municipality and discharges to mile 0.5 of an unnamed tributary to Bailey Fork Creek at mile 6.2. The Beaver Creek Elementary School (TN0054992) formerly discharged to Little Beaver Creek at mile 0.5.

**Table 5. WWTFs Permitted to Discharge Treated Sanitary Wastewater in the Impaired Subwatersheds of the Kentucky Lake Watershed**

| NPDES Permit No. | Facility | Design Flow [MGD] | Receiving Stream |
|---|---|---|---|
| ***TN0061271*** | ***Paris STP*** | ***2.5*** | ***Unnamed Tributary at RM 0.5 to Bailey Fork Creek at RM 6.2*** |
| ***TN0054992*** | ***Beaver Elementary School**** | ***0.0117*** | ***Little Beaver Creek at RM 0.5*** |

* Permit expired on 6/30/03.

#### 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 in the Kentucky Lake 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, 2002b). 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. 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/. For the purposes of Kentucky Lake Pathogen TMDL development, there are no portions of impaired subwatersheds that are covered by an MS4 permit.

### 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, 2002). 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. Requirements of both the general and individual CAFO permits include:

- Development of a Nutrient Management Plan (NMP), and approval of the NMP by the Tennessee Department of Agriculture (TDA).

- Liquid waste handling systems, if utilized, shall be designed, constructed, and operated to contain all process generated waste waters plus the runoff from a 25-year, 24-hour rainfall event. A discharge from a liquid waste handling facility to waters of the state during a chronic or catastrophic rainfall event, or as a result of an unpermitted discharge, upset, or bypass of the system, shall not cause or contribute to an exceedance of Tennessee water quality standards.

- Other Best Management Practices (BMPs).

As of July 2, 2004, there are no Class II CAFOs in the Kentucky Lake watershed with coverage under the general NPDES permit. There is one CAFO with an individual permit located in the watershed. The location of this facility, Nelson Creek Farms (TN0074926), is shown in Figure 7. Nelson Creek Farms is a swine operation located near Nelson Creek in the Holly Fork Creek 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 vast majority of waterbodies identified on the approved 2002 303(d) list as impaired due to pathogens are attributed to nonpoint agricultural or urban sources.

### 7.2.1 Wildlife

Wildlife deposit coliform bacteria, with their feces, onto land surfaces where it can be transported during storm events to nearby streams. The overall deer density for Tennessee was estimated by the Tennessee Wildlife Resources Agency (TWRA) to be 23 animals per square mile. In order to account for higher density areas and loading due to other species, a conservative density of 45 animals per square mile was used for modeling purposes. Fecal coliform loads due to deer are estimated by EPA to be $5.0 \times 10^8$ counts/animal/day.

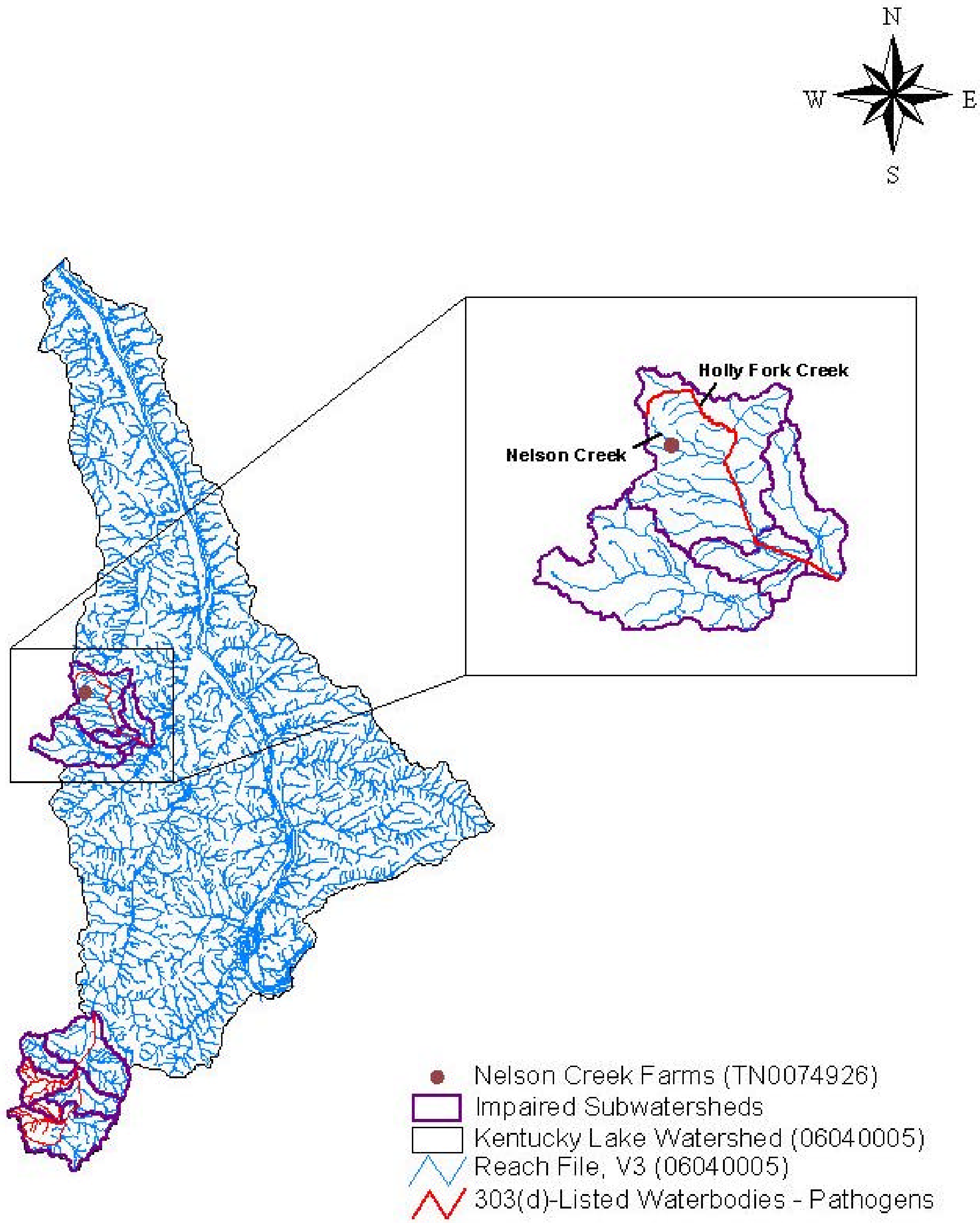


**Figure 7. Location of CAFOs in the Kentucky Lake Watershed.**

### 7.2.2 Agricultural Animals

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

- Agricultural livestock grazing in pastures deposit manure containing coliform bacteria onto land surfaces. This material accumulates during periods of dry weather and is available for washoff and transport to surface waters during storm events. The number of animals in pasture and the time spent grazing are important factors in determining the loading contribution.

- Processed agricultural manure from confined feeding operations is often applied to land surfaces and can provide a significant source of coliform bacteria loading. Guidance for issues relating to manure application is available through the University of Tennessee Agricultural Extension Service and the Natural Resources Conservation Service (NRCS).

- Agricultural livestock and other unconfined animals (i.e., deer and other wildlife) often have direct access to waterbodies and can provide a concentrated source of coliform bacteria loading directly to a stream.

Livestock data for pathogen-impaired subwatersheds were compiled from the 1997 Census of Agriculture utilizing the Watershed Characterization System (WCS) and summarized in Table 6. WCS is an Arcview geographic information system (GIS) based program developed by USEPA Region IV to facilitate watershed characterization and TMDL development.

**Table 6. Livestock Distribution in the Kentucky Lake Watershed**

| Subwatershed | Livestock Population (WCS) | | | | |
|---|---|---|---|---|---|
| | Beef Cow | Milk Cow | Poultry | Hogs | Sheep |
| Holly Fork Creek | 1085 | 218 | 0 | 4404 | 11 |
| Little Beaver Creek[1] | 374 | 2 | 0 | 308 | 5 |
| Mud Creek[1] | 592 | 9 | 0 | 414 | 5 |
| Big Sandy River | 5219 | 59 | 0 | 3869 | 54 |

[1] Little Beaver Creek and Mud Creek are tributaries to Big Sandy River

7.2.3 Failing Septic Systems

Some coliform loading in the Kentucky Lake Watershed can be attributed to failure of septic systems and illicit discharges of raw sewage. Estimates from 1997 county census data of people in subwatersheds of the Kentucky Lake Watershed utilizing septic systems were compiled using the WCS and are summarized in Table 7. In middle 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 7. Population on Septic Systems in the Kentucky Lake Watershed**

| Subwatershed | Population on Septic Systems |
|---|---|
| Holly Fork Creek | 2449 |
| Little Beaver Creek[1] | 246 |
| Mud Creek[1] | 579 |
| Big Sandy River | 5465 |

[1] Little Beaver Creek and Mud Creek are tributaries to Big Sandy River

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. Holly Fork Creek and Little Beaver Creek have the highest percentages of urban land area for impaired waterbodies in the Kentucky Lake Watershed, with 6.1% and 1.6%, respectively. Land use for the Kentucky Lake impaired drainage areas is summarized in Figures 8 and 9 and tabulated in Appendix A. Note that Big Sandy River at Maple Creek and Big Sandy River at Roan Creek correspond to waterbodies TN06040005032-1000 and TN06040005032-2000, respectively (see Figure 6).

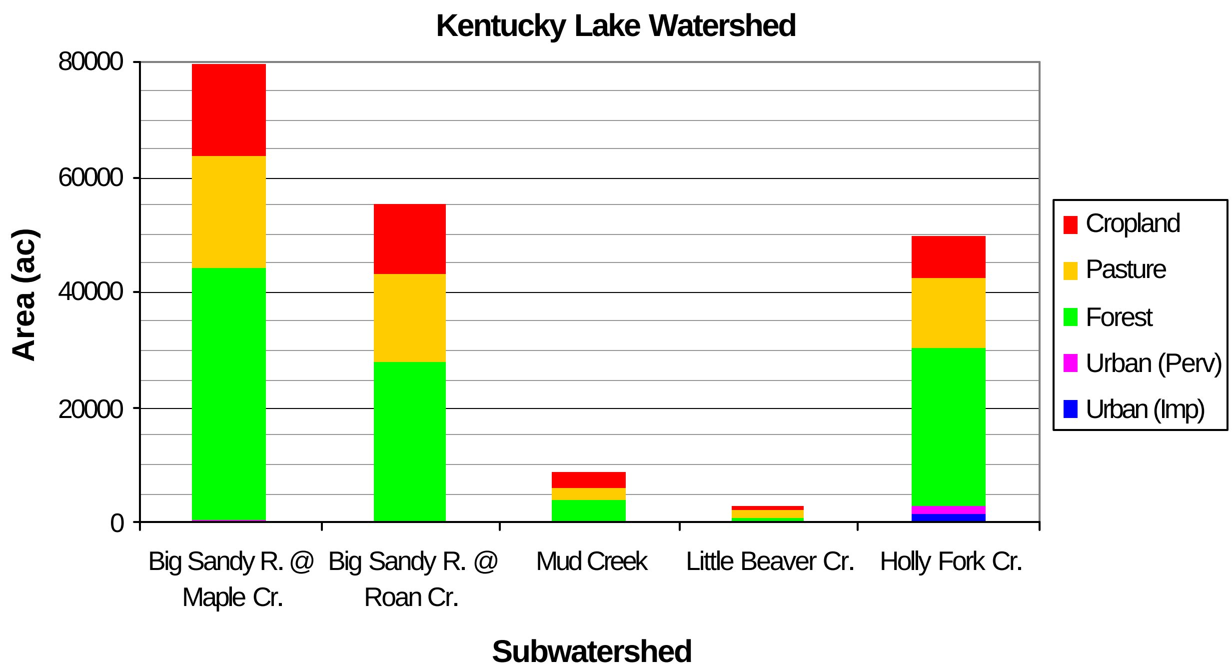


**Figure 8. Land Use Area of Pathogen-Impaired Subwatersheds, Kentucky Lake Watershed.**

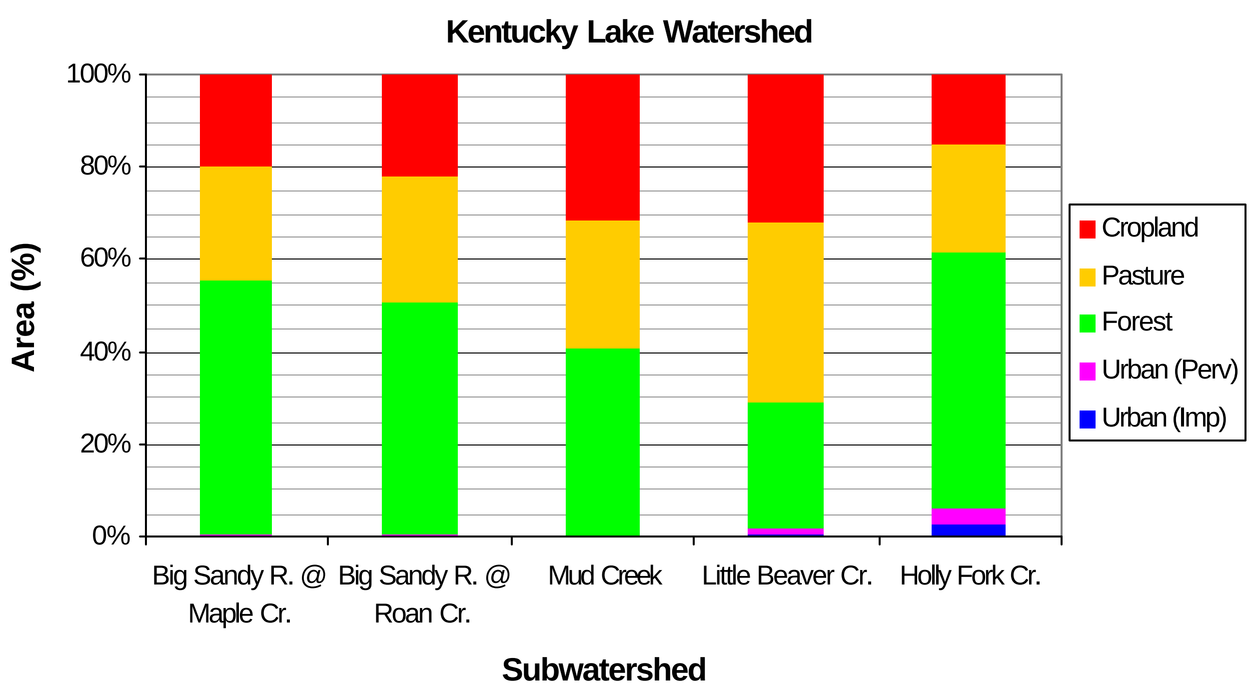


**Figure 9. Land Use Percent of Pathogen-Impaired Subwatersheds, Kentucky Lake Watershed.**

## 8.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOAD

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

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

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

### 8.1 Scope of TMDL Development

This document describes pathogen TMDL, Waste Load Allocation (WLA), and Load Allocation (LA) development for waterbodies identified as impaired due to pathogens on the 2002 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 pathogens on the 2002 303(d) list. In cases where impaired streams are located in the upstream portion of a subwatershed, TMDLs are developed for the impaired drainage area only (as is the case in the Kentucky Lake Watershed). The Kentucky Lake subwatersheds are shown in Figures 1-7.

### 8.2 Critical Conditions

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

#### 8.2.1 Dynamic Loading Model Method

The eleven-year period from January 1, 1990 to December 31, 2000 was used to simulate continuous 30-day geometric mean concentrations to compare to the target. This 11-year period contained a range of hydrologic conditions that included both low and high streamflows from which critical conditions were identified and used to derive the TMDL value. In addition, the 11-year simulation period fully encompassed the available water quality data collected at relevant Kentucky Lake monitoring stations, generally during the periods 1990-1991 and 1999-2000.

The 30-day critical period is the period preceding the highest simulated violation of the geometric mean standard (USEPA, 1991). Meeting water quality standards during the critical period ensures that water quality standards can be achieved throughout the simulation period. For Holly Fork Creek, the highest violation of the 30-day geometric mean occurred during the 30-day period 8/24/90 – 9/22/90. For Little Beaver Creek and Mud Creek, the highest violations of the 30-day geometric means occurred during the 30-day period 11/14/98 – 12/13/98. For Big Sandy River (both locations), the highest violations of the 30-day geometric means occurred during the 30-day period 9/11/99 – 10/10/99.

#### 8.2.2 Load Duration Curve Method

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 Kentucky Lake impaired waterbodies. Water quality data have been collected during all flow ranges. Based on the location of the majority of water quality exceedances on the load duration curves (between the 0% and 40% duration intervals), runoff during wet weather events is the probable dominant delivery mode for pathogens (see Section 9.3 and Appendix D).

### 8.3 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. The TMDLs for the Kentucky Lake Watershed were developed using two different methodologies to assure compliance with both the 200 counts/100 mL geometric mean standard and the dual maximum standards (ref.: Section 5.0) of 1,000 counts/100 mL for fecal coliform and 941 counts/100 mL for E. coli.

#### 8.3.1 Dynamic Loading Model Method

In order to demonstrate compliance with the 200 counts/100 mL geometric mean standard, a dynamic loading model was utilized to: a) continuously simulate fecal coliform bacteria deposition on land surfaces and pollutant transport to receiving waters in response to storm events; b) incorporate seasonal effects on the production and fate of fecal coliform bacteria; and c) simulate continuous fecal coliform concentration in surface waters.

The Loading Simulation Program C++ (LSPC) is a dynamic watershed model based on the Hydrologic Simulation Program - Fortran (HSPF) and was selected for TMDL analysis of pathogen impaired waters in the Kentucky Lake Watershed. LSPC was used to simulate the deposition and transport of fecal coliform bacteria from land surfaces, incorporate point source loading, and compute the resulting water quality response. From model output, instream 30-day geometric mean concentrations were computed, critical conditions identified, existing loads determined, and reductions required to meet the target concentrations (standard - MOS) calculated. Details of model development, calibration and TMDL analysis are presented in Appendix C.

#### 8.3.2 Load Duration Curve Method

A load duration curve 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 and determination of the load reductions required to meet the target maximum concentration (standard - MOS). Details of load duration curve development for Kentucky Lake impaired waterbodies are presented in Appendix D.

### 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 to develop allocations; or b) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations. In these TMDLs, both explicit and implicit MOS were utilized.

Dynamic Loading Model Analysis
An explicit MOS, equal to 10% of the geometric mean fecal coliform standard (200 counts/100 mL), was utilized for TMDL modeling analysis. Application of this explicit MOS of 20 counts/100 mL results in an effective 30-day geometric mean target concentration of 180 counts/100 mL.

Implicit MOS includes the use of conservative modeling assumptions and an 11-year continuous simulation that incorporates a range of meteorological events. Conservative modeling assumptions used include: septic systems discharging directly into the streams; development of the TMDL using loads based on the design flow and fecal coliform permit limits of NPDES facilities; and all land uses connected directly to streams.

Load Duration Curve Analysis
An explicit MOS, equal to 10% of the maximum coliform standard, was utilized for TMDL analysis. Application of the explicit MOS of 100 counts/100 mL to the fecal coliform maximum standard of 1000 counts/100 mL results in an effective maximum target concentration of 900 counts/100 mL. Application of the explicit MOS of 94 counts/100 mL to the E. coli maximum standard of 941 counts/100 mL results in an effective maximum target concentration of 847 counts/100 mL.

### 8.5 Expression of TMDLs, WLAs, & LAs

In this document, the pathogen TMDL is expressed as the percent reduction in instream loading required to decrease: a) the existing 30-day geometric mean concentration of fecal coliform to the target of 180 counts/100 mL, b) the existing maximum concentration of fecal coliform to the target of 900 counts/100 mL, and c) the existing maximum concentration of E. coli to the target of 847 counts/100 mL. 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, WLAs for CAFOs, and LAs for “other direct sources”) are expressed as counts per day.

#### 8.5.1 Determination of TMDLs

Load reductions for impaired waterbodies were developed using the Dynamic Loading Model to achieve compliance with the 30-day geometric mean target concentration (Appendix C). Load reductions were also developed for these waterbodies using Load Duration Curves to achieve compliance with the maximum target concentrations (Appendix D). The instream load reductions determined by these two methodologies (dynamic loading model and load duration curves) were compared and the largest required load reduction was selected as the TMDL. The Dynamic Loading Model methodology, only, was used to determine load reduction for Big Sandy River at Maple Creek due to the lack of available in-stream water quality data for this waterbody. The largest required load reduction (to achieve compliance with the dual maximum target concentrations) was selected as the TMDL. TMDL load reductions for Kentucky Lake are shown in Table 8.

**Table 8. Determination of TMDLs for Impaired Waterbodies, Kentucky Lake Watershed**

| Impaired Waterbody Name | Impaired Waterbody ID | Required Load Reduction | | | |
|---|---|---|---|---|---|
| | | Dynamic Loading Model [%] (Fecal Coliform) | Load Duration Curve [%] | | TMDL [%] |
| | | | Fecal Coliform | E. Coli | |
| HOLLY FORK CREEK | TN06040005024 – 1000 | **75.1** | **40.7** | **NA**[1] | **75.1** |
| LITTLE BEAVER CREEK | TN06040005032 – 0710 | **74.1** | **73.1** | **38.0** | **74.1** |
| MUD CREEK | TN06040005032 – 0900 | **52.3** | **40.6** | **NA**[1] | **52.3** |
| BIG SANDY RIVER | TN06040005032 – 1000 | **44.8** | **NA**[2] | **NA**[2] | **44.8** |
| BIG SANDY RIVER | TN06040005032 – 2000 | **56.9** | **51.0** | **NA**[1] | **56.9** |

[1] **Not Applicable:** Percent reductions for load duration do not meet minimum sample water quality exceedances (see Appendix D for methodology description and results).
[2] **Not Applicable:** Sample data not available for load duration analyses.

### 8.5.2 Determination of WLAs & LAs

WLAs & LAs are developed in Appendix E for point sources and nonpoint sources, respectively. TMDLs, WLAs, & LAs for the Kentucky Lake impaired waterbodies are summarized in Table 9.

## 8.6 Seasonal Variation

Seasonal variation was incorporated in the continuous simulation water quality model by using varying monthly loading rates and daily meteorological data over an 11-year period. Seasonal variation was incorporated in the load duration curves by using the entire simulation period and all water quality data collected at the monitoring stations. The water quality data were collected during all seasons.

**Table 9. WLAs & LAs for the Kentucky Lake Watershed**

| Impaired Waterbody Name | Impaired Waterbody ID | WLAs: WWTFs[a] (Monthly Avg.) Fecal Coliform | WLAs: WWTFs[a] (Monthly Avg.) E. Coli | WLAs: Leaking Collection Systems[b] | WLAs: CAFOs | WLAs: MS4s[c] | LAs: Precipitation Induced Nonpoint Sources | LAs: Other Direct Sources[d] |
|---|---|---|---|---|---|---|---|---|
| | | [cts./day] | [cts./day] | [cts./day] | [cts./day] | [% Red.] | [% Red.] | [cts./day] |
| HOLLY FORK CREEK | TN06040005024 – 1000 | **$1.893 \times 10^{10}$** | **$1.193 \times 10^{10}$** | **0** | **0** | **NA** | **75.1** | **0** |
| LITTLE BEAVER CREEK | TN06040005032 – 0710 | **0** | **0** | **NA** | **NA** | **NA** | **74.1** | **0** |
| MUD CREEK | TN06040005032 – 0900 | **0** | **0** | **NA** | **NA** | **NA** | **52.3** | **0** |
| BIG SANDY RIVER | TN06040005032 – 1000 | **0** | **0** | **NA** | **NA** | **NA** | **44.8** | **0** |
| BIG SANDY RIVER | TN06040005032 – 2000 | **0** | **0** | **NA** | **NA** | **NA** | **56.9** | **0** |

Note: NA = Not Applicable.

a. WLAs for WWTFs expressed as fecal coliform and 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 pathogens.

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 pathogens.

## 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 Kentucky Lake 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 fecal coliform and E. coli limits.

#### 9.1.2 NPDES Regulated Concentrated Animal Feeding Operations (CAFOs)

Existing or future CAFOs that are located in impaired subwatersheds will be required to comply with WLAs consistent with their permits. These WLAs will be implemented through the Nutrient Management Plan (NMP), liquid waste handling system, and Best Management Practices (BMP) provisions of NPDES Permit No. TNA000000, *Class II Concentrated Animal Feeding Operation General Permit* or the individual NPDES permit for Class I CAFOs. All discharges, except during a catastrophic or chronic rainfall event, are not authorized by this permit. Any discharge shall not cause an exceedance of Tennessee water quality standards.

### 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 Kentucky Lake Watershed to reduce the amount of coliform bacteria transported to surface waters from agricultural sources. These BMPs (e.g., pasture management, heavy use area treatment, grade stabilization, alternative water supplies, etc.) may have contributed to reductions in in-stream concentrations of coliform bacteria in the Holly Fork Creek and Big Sandy River subwatersheds during the TMDL evaluation period. The TDA keeps a database of BMPs implemented in Tennessee. Those listed in the Kentucky Lake Watershed are shown in Figure 10. 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. Coliform bacteria 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.

### 9.3 Example Application of Load Duration Curves for Implementation Planning

The Load Duration Curve methodology (Appendix D) 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 fecal coliform load duration analysis was utilized for implementation planning because the data are more abundant than E. coli and cover a longer period of record. The fecal coliform load duration curve for Mud Creek at mile 4.7 (Figure 11) was analyzed to determine the frequency with which water quality monitoring data exceed the fecal coliform target maximum concentration of 900 counts/100 mL (standard – MOS) under five flow conditions (low, dry, mid-range, moist, and high). Observation of the plot suggests the Mud Creek watershed is impacted primarily by non-point sources.

Table 10 presents Load Duration analysis statistics for fecal coliform in Mud Creek 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 Mud Creek 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 Kentucky Lake Watershed for reduction of pathogen loading and mitigation of water quality impairment.

See Appendix D for a detailed discussion of the Load Duration Curve Methodology applied to the Kentucky Lake Watershed.

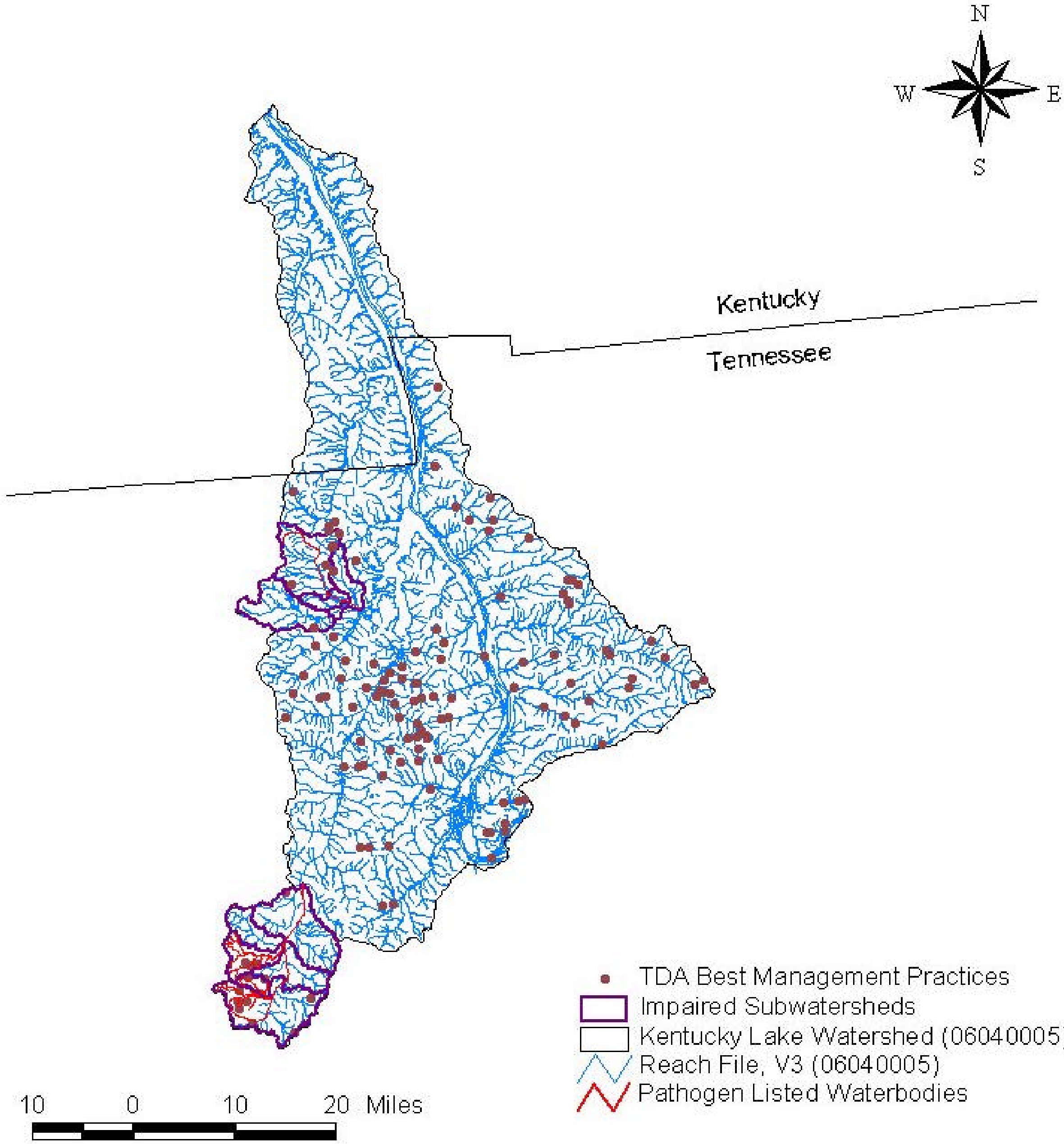


**Figure 10. Tennessee Department of Agriculture Best Management Prcatices located in the Kentucky Lake Watershed.**

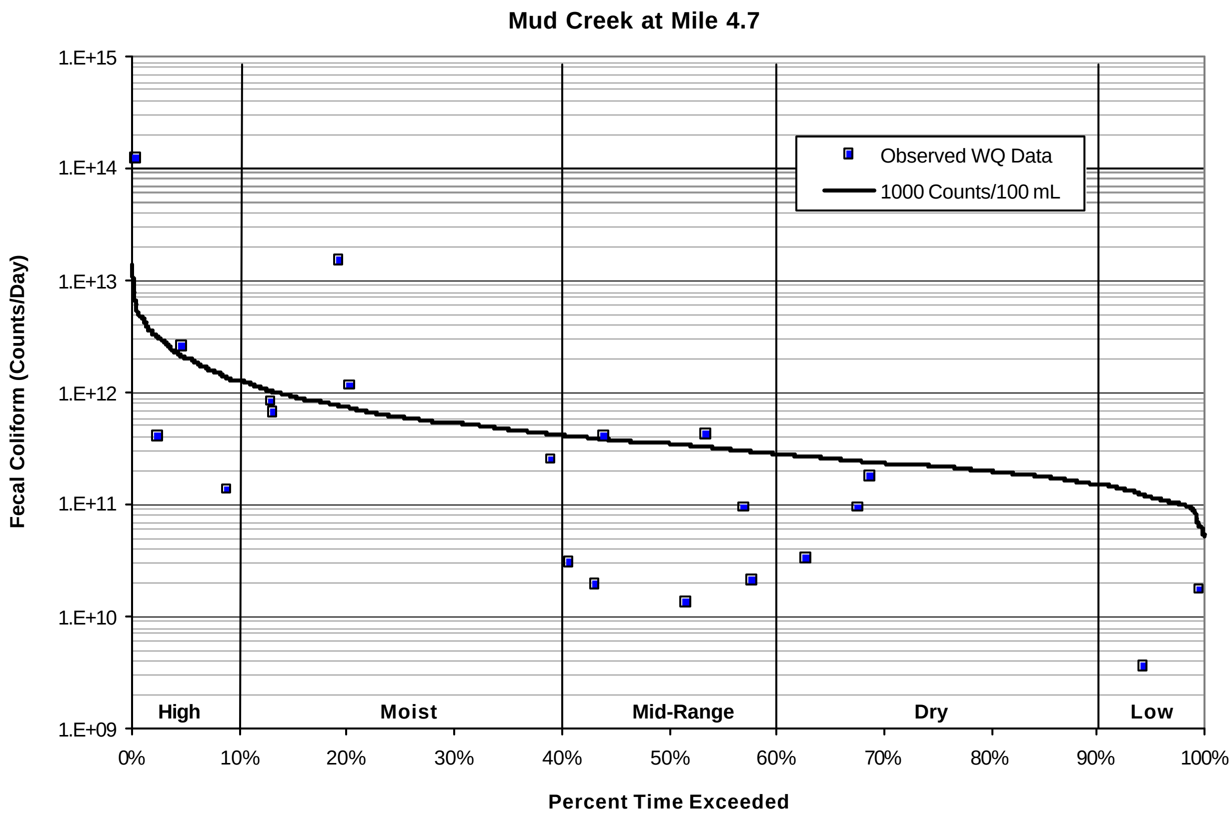


**Figure 11**. Load Duration Curve for Mud Creek Implementation.

**Table 10. Load Duration Curve Summary for Implementation Strategies**

| Flow Condition | | High | Moist | Mid-range | Dry | Low |
|---|---|---|---|---|---|---|
| % Time Flow Exceeded | | 0-10 | 10-40 | 40-60 | 60-90 | 90-100 |
| Mud Creek at Mile 4.7 | % Samples > 900 Counts/100 mL[1] | 50 | 40 | 28.6 | 0.0 | 0.0 |
| | Reduction[2] | 48.9% | 64.6% | 21.3% | 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[3] | | | | M | H | H |
| Pasture Management/Land Application of Manure[3] | | H | H | M | L | |
| Riparian Buffers[3] | | | 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 fecal coliform (1000 Counts/100 mL) minus 10% MOS (100 Counts/100 mL).
[2] Reductions based on analyses of observed values in each range (see Appendix E).
[3] Example Best Management Practices (BMPs) for Agricultural Source reduction. Actual BMPs applied to Kentucky Lake watershed may vary.

## 9.4 Additional Monitoring

Documenting progress in reducing the quantity of pathogens entering the Kentucky Lake 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 standards for pathogens.

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 monitoring and assessment activities are recommended for the Holly Fork Creek and Big Sandy River watersheds to verify the assessment status of the stream reaches identified on the 2002 303(d) list as impaired due to pathogens. If it is determined that these stream reaches are still not fully supporting designated uses, then sufficient data to enable development of a TMDL must be acquired. In addition, collection of pathogen data at sufficient frequency to support calculation of the geometric mean, as described in Tennessee's General Water Quality Criteria (TDEC, 2004b), is encouraged.

## 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, utilization of Bacteria Source Tracking (BST) technologies are recommended.

## 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 Kentucky Lake watershed were 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 TMDL 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 TMDL (similar to the website announcement) was included in one of the NPDES permit Public Notice mailings which was sent to approximately 90 interested persons or groups who have requested this information.

3) A letter was sent to the active WWTF located in pathogen-impaired subwatersheds in the Kentucky Lake watershed, permitted to discharge treated effluent containing pathogens, advising them of the proposed TMDLs and their availability on the TDEC website. The letter also stated that a copy of the draft TMDL document would be provided on request. A letter was sent to the following facility:

   Paris STP (TN0061271)

No written comments were received during the proposed TMDL public comment period. No requests to hold public meetings were received regarding the proposed TMDLs as of close of business on December 13, 2004.

## 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 Kentucky Lake Watershed

**Table A-1. MRLC Land Use Distribution of Kentucky Lake Subwatersheds**

| Land Use | Kentucky Lake Subwatersheds | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Holly Fork Creek | | Little Beaver Creek[1] | | Mud Creek[1] | | Big Sandy River at Roan Creek[1] | | Big Sandy River at Maple Creek | |
| | [acres] | [%] | [acres] | [%] | [acres] | [%] | [acres] | [%] | [acres] | [%] |
| Bare Rock/Sand/Clay | 1 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| Deciduous Forest | 17890 | 35.9 | 517 | 17.6 | 2318 | 26.4 | 15846 | 28.7 | 25894 | 32.6 |
| Evergreen Forest | 819 | 1.6 | 46 | 1.6 | 218 | 2.5 | 5335 | 9.7 | 7733 | 9.7 |
| High Intensity Commercial/Industrial/Transp. | 806 | 1.6 | 10 | 0.4 | 2 | 0.0 | 57 | 0.1 | 74 | 0.1 |
| High Intensity Residential | 344 | 0.7 | 0 | 0.0 | 0 | 0.0 | 1 | 0.0 | 2 | 0.0 |
| Low Intensity Residential | 1900 | 3.8 | 36 | 1.2 | 0 | 0.0 | 115 | 0.2 | 192 | 0.2 |
| Mixed Forest | 2965 | 5.9 | 153 | 5.2 | 413 | 4.7 | 3624 | 6.6 | 5635 | 7.1 |
| Open Water | 78 | 0.2 | 3 | 0.1 | 77 | 0.9 | 188 | 0.3 | 225 | 0.3 |
| Other Grasses (Urban/recreation; e.g. parks) | 49 | 0.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| Pasture/Hay | 11986 | 24.0 | 1138 | 38.7 | 2413 | 27.5 | 15075 | 27.3 | 19464 | 24.5 |
| Quarries/Strip Mines/Gravel Pits | 1 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| Row Crops | 7406 | 14.9 | 920 | 31.3 | 2764 | 31.5 | 12076 | 21.9 | 15773 | 19.9 |
| Small Grains | 0 | 0.0 | 27 | 0.9 | 0 | 0.0 | 108 | 0.2 | 108 | 0.1 |
| Transitional | 69 | 0.1 | 2 | 0.1 | 11 | 0.1 | 49 | 0.1 | 69 | 0.1 |
| Woody Wetlands | 5534 | 11.1 | 87 | 3.0 | 571 | 6.5 | 2741 | 5.0 | 4262 | 5.4 |
| Total | 49846 | 100.0 | 2939 | 100.0 | 8786 | 100.0 | 55214 | 100.0 | 79431 | 100.0 |

[1] Little Beaver Creek, Mud Creek, and Big Sandy River at Roan Creek are subsets of Big Sandy River at Maple Creek.

# 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 Kentucky Lake Watershed. The location of these monitoring stations is shown in Figures 5 and 6. Monitoring data recorded at these stations for Fecal Coliform and Escherichia Coli (E. Coli) are tabulated in Table B-1.

**Table B-1. Water Quality Monitoring Data – Kentucky Lake Watershed**

| Monitoring Station | Date | Fecal Coliform [cts./100 mL] | E. Coli [cts./100 mL] |
|---|---|---|---|
| HFORK004.0HN | 5/10/90 | 755 | **NA** |
| | 7/16/90 | 10 | **NA** |
| | 9/12/90 | 310 | **NA** |
| | 11/28/90 | **20000** | **NA** |
| | 12/11/90 | 190 | **NA** |
| | 12/17/90 | 827 | **NA** |
| | 3/13/91 | 340 | **NA** |
| | 3/20/91 | 170 | **NA** |
| | 3/27/91 | 410 | **NA** |
| | 4/10/91 | **1255** | **NA** |
| | 12/20/91 | 280 | **NA** |
| | 4/11/00 | 210 | 190 |
| | 5/17/00 | 900 | 816 |
| | 5/23/00 | **NA** | **1733** |
| | 6/21/00 | 580 | **1120** |
| | 7/12/00 | **1200** | 921 |
| LBEAV001.3HE | 10/13/99 | **2500** | 479 |
| | 11/9/99 | 250 | 201 |
| | 12/15/99 | 510 | **1046** |
| | 1/13/00 | 72J | 83 |
| | 2/15/00 | **3100J** | **>2419** |
| | 3/16/00 | **6400** | **>2419** |
| | 4/13/00 | 760 | 613 |
| | 5/18/00 | 300 | 344 |
| | 6/22/00 | 350 | 727 |
| MUD004.7CR | 5/9/90 | 73 | **NA** |
| | 9/13/90 | 30 | **NA** |
| | 11/29/90 | **20000** | **NA** |
| | 12/12/90 | 736 | **NA** |
| | 12/18/90 | **20000** | **NA** |
| | 2/21/91 | 136 | **NA** |
| | 3/14/91 | 50 | **NA** |

**Table B-1. Water Quality Monitoring Data – Kentucky Lake Watershed (Cont.)**

| Monitoring Station | Date | Fecal Coliform [cts./100 mL] | E. Coli [cts./100 mL] |
|---|---|---|---|
| **MUD004.7CR** | 3/21/91 | 40 | **NA** |
| | 3/28/91 | 100 | **NA** |
| | 4/11/91 | **1055** | **NA** |
| | 9/14/99 | 270 | 261 |
| | 10/12/99 | 660 | 387 |
| | 11/8/99 | 310 | 238 |
| | 12/14/99 | **1200** | **>2419** |
| | 1/11/00 | 120J | 84 |
| | 2/16/00 | **1600** | 687 |
| | 3/14/00 | 70J | 285 |
| | 4/13/00 | 810 | 648 |
| | 5/18/00 | **1300** | **2419** |
| | 6/22/00 | 580 | 816 |
| | 7/13/00 | 380 | 91 |
| **BSAND045.2CR** | 5/9/90 | 145 | **NA** |
| | 7/18/90 | 136 | **NA** |
| | 9/13/90 | 170 | **NA** |
| | 11/29/90 | **6300** | **NA** |
| | 12/12/90 | 127 | **NA** |
| | 12/18/90 | **20000** | **NA** |
| | 2/21/91 | 230 | **NA** |
| | 3/14/91 | 936 | **NA** |
| | 3/21/91 | 40 | **NA** |
| | 3/28/91 | **1654** | **NA** |
| | 4/11/91 | 510 | **NA** |
| | 8/18/99 | 76 | 13 |
| | 9/15/99 | 68 | 51 |
| | 10/13/99 | 300 | 261 |
| | 11/8/99 | 58 | 50 |
| | 12/15/99 | 130 | 128 |
| | 1/11/00 | **1100J** | **1120** |
| | 3/15/00 | 22 | 17 |
| | 4/11/00 | **NA** | 272 |
| | 5/17/00 | 110 | 135 |
| | 6/21/00 | 230 | 145 |
| | 7/12/00 | 70 | 57 |

[1] NA = Not Applicable (no data collected).
[2] J = estimated.

# APPENDIX C

## Dynamic Loading Model Methodology

## DYNAMIC LOADING MODEL METHOD

### C.1 Model Selection

The Loading Simulation Program C++ (LSPC) was selected for TMDL analysis of pathogen-impaired waters in the Holly Fork Creek and Big Sandy River subwatersheds of the Kentucky Lake Watershed. LSPC is a dynamic watershed model based on the Hydrologic Simulation Program - Fortran (HSPF) and is well suited to demonstrate compliance with the 200 counts/100 mL geometric mean standard. LSPC was used to simulate the buildup and washoff of fecal coliform bacteria from land surfaces in response to storm events, loading from point sources, and compute the resulting water quality response. From model output, instream 30-day geometric mean concentrations were computed, critical conditions identified, existing loads determined, and reductions required to meet target concentrations (standard - MOS) were calculated.

### C.2 Model Set Up

The Holly Fork Creek and Big Sandy River watersheds were delineated into subwatersheds in order to facilitate model hydrologic and water quality calibration; and to characterize relative fecal coliform contributions from significant contributing drainage areas. Boundaries were constructed so that subwatershed "pour points" coincided with HUC-12 delineations and water quality monitoring stations. Watershed delineation was based on the Rf3 stream coverage and Digital Elevation Model (DEM) data. This discretization allows management and load reduction alternatives to be varied by subwatershed.

Several computer-based tools were utilized to generate input data for the LSPC model. The Watershed Characterization System (WCS), a geographic information system (GIS) tool, was used to display, analyze, and compile available information to support water quality model simulations for selected subwatersheds. This information includes land use categories, point source dischargers, soil types and characteristics, population data (human and livestock), and stream characteristics. Results of the WCS characterization was input into the Fecal Coliform Loading Estimation Spreadsheet (FCLES), developed by Tetra Tech, Inc., to estimate LSPC input parameters associated with fecal coliform buildup (loading rates) and subsequent washoff from land surfaces. In addition, FCLES was used to estimate direct sources of fecal coliform loading to water bodies from leaking septic systems and animals having access to streams. Information from the WCS and FCLES utilities were used as initial input for variables in the LSPC model.

An important factor influencing model results is the precipitation data contained in the meteorological data files used in these simulations. The pattern and intensity of rainfall affects the buildup and washoff of fecal coliform bacteria from the land into the streams, as well as the dilution potential of the stream. Weather data from multiple meteorological stations were available for the time period from January 1970 through December 2001. 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.

## C.3 Model Calibration

The calibration of the LSPC watershed model involves both hydrology and water quality components. The model must first be calibrated to appropriately represent hydrologic response to meteorological conditions before water quality calibration and subsequent simulations can be performed. Due to the lack of continuous flow data at the mouths of the listed waterbodies, data collected at the nearest appropriate location was used to calibrate the subwatershed models.

### C.3.1 Hydrologic Calibration

Hydrologic calibration of the watershed model involves comparison of simulated streamflow to historic streamflow data from U. S. Geological Survey (USGS) stream gaging stations for the same period of time. A USGS continuous record station located in the Kentucky Lake watershed with a sufficiently long and recent historical record was selected as the basis of the hydrology calibration. Cypress Creek at Camden, USGS Station 03605078 (see Figure 4), was 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 Cypress Creek at Camden, USGS Station 03605078, are shown in Table C-1 and Figures C-1 and C-2.

### C.3.2 Water Quality Calibration

After hydrologic calibration, the watershed model was calibrated for water quality through comparison of simulated fecal coliform concentrations to instream monitoring data at a specified location. Watershed data, produced with WCS, were processed through the FCLES spreadsheet to generate fecal coliform loading data for use as initial input to the LSPC model. In the model, in-stream decay of fecal coliform bacteria was estimated using the values reported in Lombardo (1972). For freshwater streams, decay ranges from 0.008 $hr^{-1}$ to 0.13 $hr^{-1}$, with a median value of 0.048 $hr^{-1}$. The value of 0.083 $hr^{-1}$ was used as initial input to model simulations.

#### C.3.2.1 Point Sources

For existing conditions, NPDES facilities located in modeled watersheds are represented as point sources of average (constant) flow and concentration based on the facility's flow and effluent fecal coliform concentration as reported on Discharge Monitoring Reports (DMRs).

#### C.3.2.2 Nonpoint Sources

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

C.3.2.2.1 Wildlife

Wildlife deposit fecal coliform bacteria, with their feces, onto land surfaces where it can be transported during storm events to nearby streams. The overall deer density for Tennessee was estimated by the Tennessee Wildlife Resources Agency (TWRA) to be 23 animals per square mile. In order to account for higher density areas and loading due to other species, a conservative density of 45 animals per square mile was used for modeling purposes. Fecal coliform loads due to deer are estimated by EPA to be $5.0 \times 10^8$ counts/animal/day. The resulting fecal coliform loading on a unit area basis is $3.52 \times 10^7$ counts/acre/day and is considered background.

C.3.2.2.2 Land Application of Agricultural Manure

In the water quality model, livestock populations are distributed to subwatersheds based on information derived from WCS. Fecal coliform loading rates were calculated from livestock populations based on manure application rates, literature values for bacteria concentrations in livestock manure, and the following assumptions:

- Fecal content in manure was adjusted to account for die-off due to known treatment/storage methods.
- Manure application rates from the various animal sources are applied according to application practices throughout the year.
- The fraction of manure available for runoff is dependent on the method of manure application. In the water quality model, the fraction available is estimated based on incorporation into the soil.

Fecal coliform production rates used in the model for beef cattle, dairy cattle, hogs, and chicken are $1.06 \times 10^{11}$ counts/day/beef cow, $1.04 \times 10^{11}$ counts/day/dairy cow, $1.24 \times 10^{10}$ counts/day/hog, and $1.38 \times 10^8$ counts/day/chicken (NCSU, 1994).

C.3.2.2.3 Grazing Animals

Cattle spend time grazing on pastureland and deposit feces onto the land. During storm events, a portion of this material containing fecal coliform bacteria is transported to streams. Beef cattle are assumed to spend all their time in pasture. The percentage of feces deposited during grazing time is used to estimate fecal coliform loading rates from pastureland. Because there is no assumed monthly variation in animal access to pastures in east Tennessee, the fecal loading rate does not vary significantly throughout the year. Therefore, the loading rate to pastureland is assumed to be relatively constant within each subwatershed. However, this rate varies across subwatersheds depending on livestock population. The approximate loads from grazing cattle vary from $5.70 \times 10^{10}$ to $1.512 \times 10^{11}$ counts/acre-day. Contributions of fecal coliform from wildlife (as noted in Section C.3.2.2.1) are also included in these rates.

C.3.2.2.4 Urban Development

Urban land use represented in the MRLC database includes areas classified as: high intensity commercial, industrial, transportation; high intensity residential; and low density residential. Associated with each of these classifications is a percent of the land area that is impervious. A single, area-weighted loading rate from urban areas is used for each subwatershed in the model and is based on the percentage of each urban land use type in the watershed and buildup and accumulation rates referenced in Horner (Horner, 1992). In the water quality calibrated models, this rates vary is $1.0 \times 10^9$ counts/acre-day and is assumed constant within each subwatershed throughout the year.

C.3.2.2.5 Other Direct Sources

As previously stated, there are a number of nonpoint sources of fecal coliform bacteria that are not associated with land loading and washoff processes. These include animal access to streams, failing septic systems, illicit discharges, and other undefined sources. In each subwatershed, these miscellaneous sources have been modeled as point sources of constant flow and fecal coliform concentration and are referred to as "other direct sources" in this document. The <u>initial</u> baseline values of flow and concentration were estimated using the FCLES spreadsheets and the following assumptions:

- The load attributed to animals having access to streams is initially based on the beef cow population in the watershed. The percentage of animals having access to streams is derived from assumptions on animals in operations that are adjacent to streams and seasonal and behavioral assumptions. Literature values were used to estimate the fecal coliform bacteria concentration in beef cow manure.

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

Flow and concentration variables were adjusted during water quality calibration to best-fit simulated in-stream fecal coliform concentrations during dry weather conditions.

C.3.2.3 Water Quality Calibration Results

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

- Rate of fecal coliform bacteria accumulation
- Maximum storage of fecal coliform bacteria
- Rate of surface runoff that will remove 90% of stored fecal coliform bacteria
- Concentration of fecal coliform bacteria in interflow
- Concentration of fecal coliform bacteria in groundwater
- Concentration of fecal coliform bacteria and rate of flow of "other direct sources".
- In-stream fecal coliform decay (die-off) rate

At times, a high observed value may not have been simulated in the model due to the absence of rainfall at the meteorological station as compared to localized rainfall occurring in the watershed, or as the result of an unknown source that is not included in the model.

Water quality calibration for the Holly Fork Creek subwatersheds was performed at mile 4.0 on Holly Creek. Water quality calibration for the Big Sandy River subwatersheds was performed at mile 1.3 on Little Beaver Creek, mile 4.7 on Mud Creek, and mile 45.2 on Big Sandy River. Little Beaver Creek and Mud Creek are tributaries to Big Sandy River; therefore, Little Beaver Creek and Mud Creek were water quality calibrated prior to completion of Big Sandy River calibration. The results of the Holly Fork Creek and Big Sandy River water quality calibrations are shown in Figures C-3 - C-6. Results show that the models adequately simulate peaks in fecal coliform bacteria in response to rainfall events and pollutant loading dynamics.

## C.4 Margin of Safety

There are two methods for incorporating an MOS in the analysis: a) implicitly incorporate the MOS using conservative model assumptions to develop allocations; or b) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations. For TMDL analyses using LSPC, both an explicit and implicit MOS were used. The explicit MOS is 20 counts/100 mL, equal to 10% of the 200 counts/100 mL geometric standard. This results in a target fecal coliform concentration of 180 counts/100 mL. The implicit MOS includes the use of conservative modeling assumptions and a 10-year continuous simulation that incorporates a wide range of meteorological events. Conservative modeling assumptions used include: septic systems discharging directly into the streams; development of the TMDL using loads based on the design flow and fecal coliform permit limits of NPDES facilities; and all land uses connected directly to streams.

*Note: In this document, the water quality standard is the instream goal. The term "target concentration" reflects the application of an explicit Margin of Safety (MOS) to the water quality standard. See Section 5.0.*

## C.5 Determination of Existing Loading

The critical condition for nonpoint source fecal coliform loading is typically an extended dry period followed by a rainfall runoff event. During the dry weather period, 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 simulated in the water quality model.

For each modeled subwatershed, the 10-year simulation period was used to generate daily mean instream concentrations. These were used to calculate continuous 30-day geometric mean concentrations that were then compared to the target concentration. The 10-year simulation period contained a range of hydrologic conditions that included both low and high streamflows. The 30-day critical period for each subwatershed is the period preceding the highest simulated violation of the geometric mean standard. The magnitude of the highest peak, together with the corresponding simulated flow, represents the existing fecal coliform loading to the waterbody.

The drainage areas of the waterbody segments (Holly Fork Creek and Big Sandy River) coincided with HUC-12 subwatersheds, water quality monitoring stations, and the outlets (endpoints) of 303(d)-Listed segments. The waterbody segments were at the "pour points" of these subwatersheds. In addition, the pour points coinciding with water quality monitoring stations had sufficient fecal coliform data for water quality calibration. Existing loads and required load reductions were determined on a subwatershed basis for the Holly Fork Creek, Little Beaver Creek, Mud Creek, and Big Sandy River waterbodies.

The results of the 11-year simulation used to determine existing conditions for Holly Fork Creek, Little Beaver Creek, Mud Creek, and Big Sandy River (each waterbody) are shown in Figures C-7 - C-11.

## C.6 Determination of TMDL

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:

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

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>.

For the purposes of these analyses, fecal coliform TMDLs are expressed as the percent reduction in instream loading required to decrease the existing instream 30-day geometric mean concentration (as defined in Section C.5) to the target of 180 counts/100 mL. The required reduction can be determined directly using the following equation:

$$\text{TMDL} = \text{RILR} = \frac{[(C)\ (Q)\ (\text{Const})]_{\text{Existing}} - [(C)\ (Q)\ (\text{Const})]_{\text{Target}}}{[(C)\ (Q)\ (\text{Const})]_{\text{Existing}}} \times 100$$

where: RILR = Required Instream Load Reduction [%]
C = Instream Concentration [counts/100 mL]
Q = Daily Mean Flow [cfs]
Const = Unit Conversion Constant

Since the streamflow for the existing condition is equal to the streamflow for the target condition:

$$\text{TMDL} = \text{RILR} = \cancel{\frac{(Q)\ (\text{Const})}{(Q)\ (\text{Const})}} \times \frac{[C]_{\text{Existing}} - [C]_{\text{Target}}}{[C]_{\text{Existing}}} \times 100$$

therefore:

$$\text{TMDL} = \text{RILR} = \frac{[C]_{\text{Existing}} - [C]_{\text{Target}}}{[C]_{\text{Existing}}} \times 100$$

As an example, for the subwatershed at the pour point of the 303(d)-Listed segment of Mud Creek, the simulated 30-day geometric mean concentration for the existing loading condition (ref.: Section C.5) is 377 counts/100 mL. The required instream load reduction is calculated by:

$$\text{TMDL} = \text{RILR} = \frac{(377 \text{ cts/100 mL}) - (180 \text{ cts/100 mL})}{(377 \text{ cts/100 mL})} \times 100$$

TMDL = RILR = 52.3%

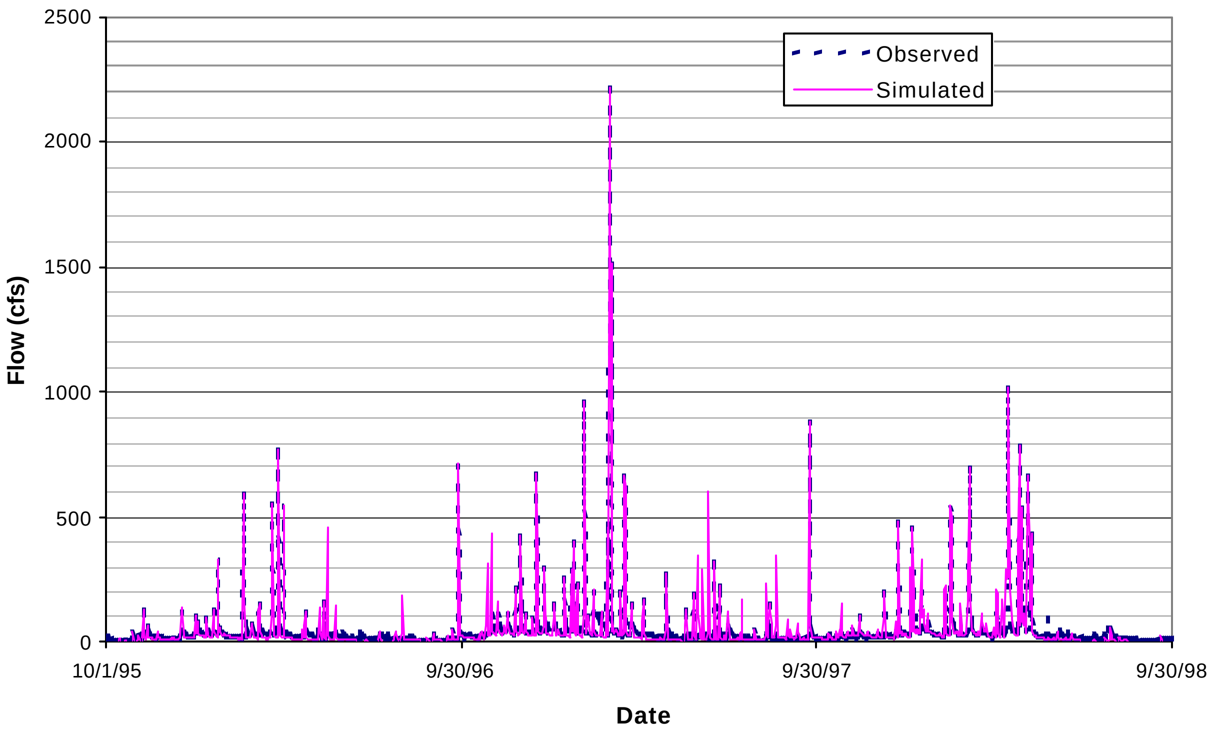
Required load reductions are summarized in Table C-2.

**Table C-1. Hydrologic Calibration Summary: Cypress Creek at Camden (USGS 03605078)**

| | | | |
|---|---|---|---|
| **Simulation Name:** | Cypress Creek | **Simulation Period:** | |
| | USGS 03605078 | **Watershed Area (ac):** | 17472 |
| ***Period for Flow Analysis*** | | | |
| ***Begin Date:*** | **10/01/95** | | |
| ***End Date:*** | **09/30/01** | | |
| Total Simulated In-stream Flow: | **112.74** | Total Observed In-stream Flow: | **106.78** |
| Total of highest 10% flows: | **77.53** | Total of Observed highest 10% flows: | **67.84** |
| Total of lowest 50% flows: | **6.98** | Total of Observed Lowest 50% flows: | **7.58** |
| Simulated Summer Flow Volume ( months 7-9): | **9.30** | Observed Summer Flow Volume (7-9): | **7.70** |
| Simulated Fall Flow Volume (months 10-12): | **18.66** | Observed Fall Flow Volume (10-12): | **17.77** |
| Simulated Winter Flow Volume (months 1-3): | **55.47** | Observed Winter Flow Volume (1-3): | **55.32** |
| Simulated Spring Flow Volume (months 4-6): | **29.32** | Observed Spring Flow Volume (4-6): | **25.98** |
| Total Simulated Storm Volume: | **110.31** | Total Observed Storm Volume: | **104.16** |
| Simulated Summer Storm Volume (7-9): | **8.69** | Observed Summer Storm Volume (7-9): | **7.06** |
| *Errors (Simulated-Observed)* | | *Recommended Criteria* | Last run |
| Error in total volume: | **5.59** | 10 | |
| Error in 50% lowest flows: | **-7.90** | 10 | |
| Error in 10% highest flows: | **14.29** | 15 | |
| Seasonal volume error - Summer: | **20.69** | 30 | |
| Seasonal volume error - Fall: | **4.98** | 30 | |
| Seasonal volume error - Winter: | **0.26** | 30 | |
| Seasonal volume error - Spring: | **12.88** | 30 | |
| Error in storm volumes: | **5.90** | 20 | |
| Error in summer storm volumes: | **23.05** | 50 | |

**Table C-2. TMDLs for Kentucky Lake Waterbodies – 30-Day Geometric Mean Target**

| Impaired Waterbody Name | Waterbody ID | Existing Conditions: Date(s) of Max. 30-Day Geom. Mean Concen. | Existing Conditions: Max. 30-Day Geom. Mean Concentration [cts./100 mL] | TMDL - Required Load Reduction [%] |
|---|---|---|---|---|
| HOLLY FORK CREEK | TN06040005024 – 1000 | **9/22/90** | **723** | **75.1** |
| LITTLE BEAVER CREEK | TN06040005032 – 0710 | **12/13/98** | **694** | **74.1** |
| MUD CREEK | TN06040005032 – 0900 | **12/13/98** | **377** | **52.3** |
| BIG SANDY RIVER | TN06040005032 – 1000 | **10/10/99** | **326** | **44.8** |
| BIG SANDY RIVER | TN06040005032 – 2000 | **10/10/99** | **418** | **56.9** |



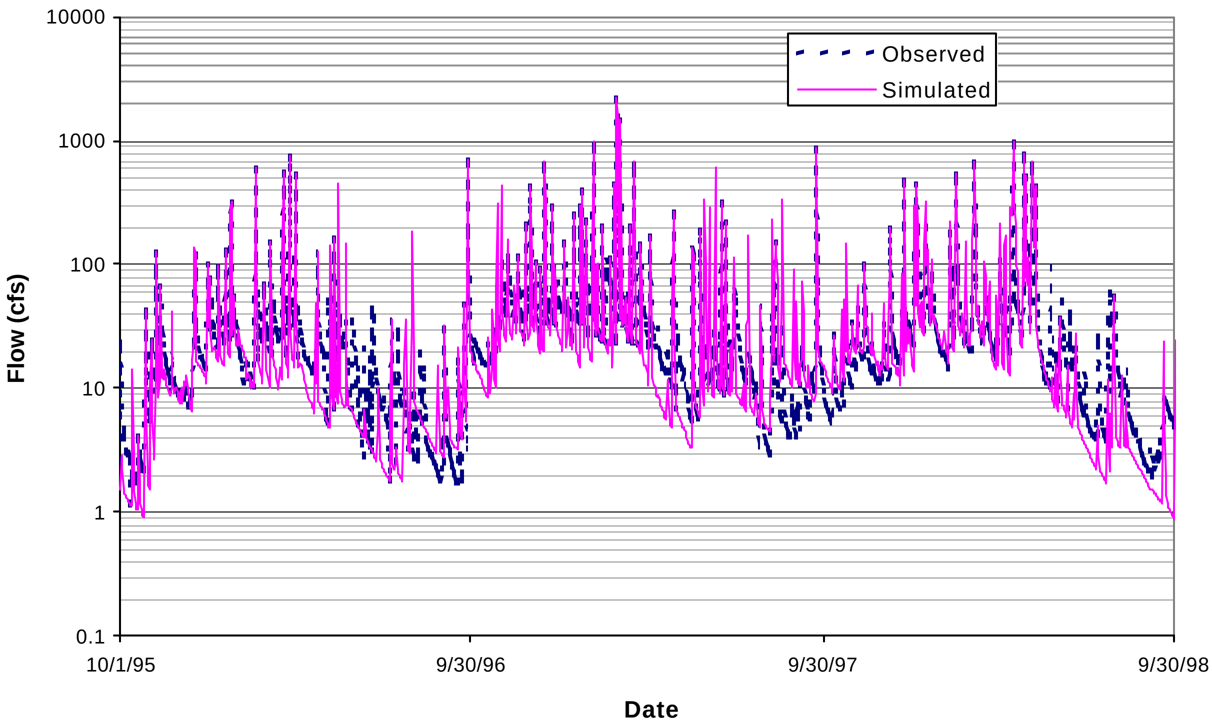
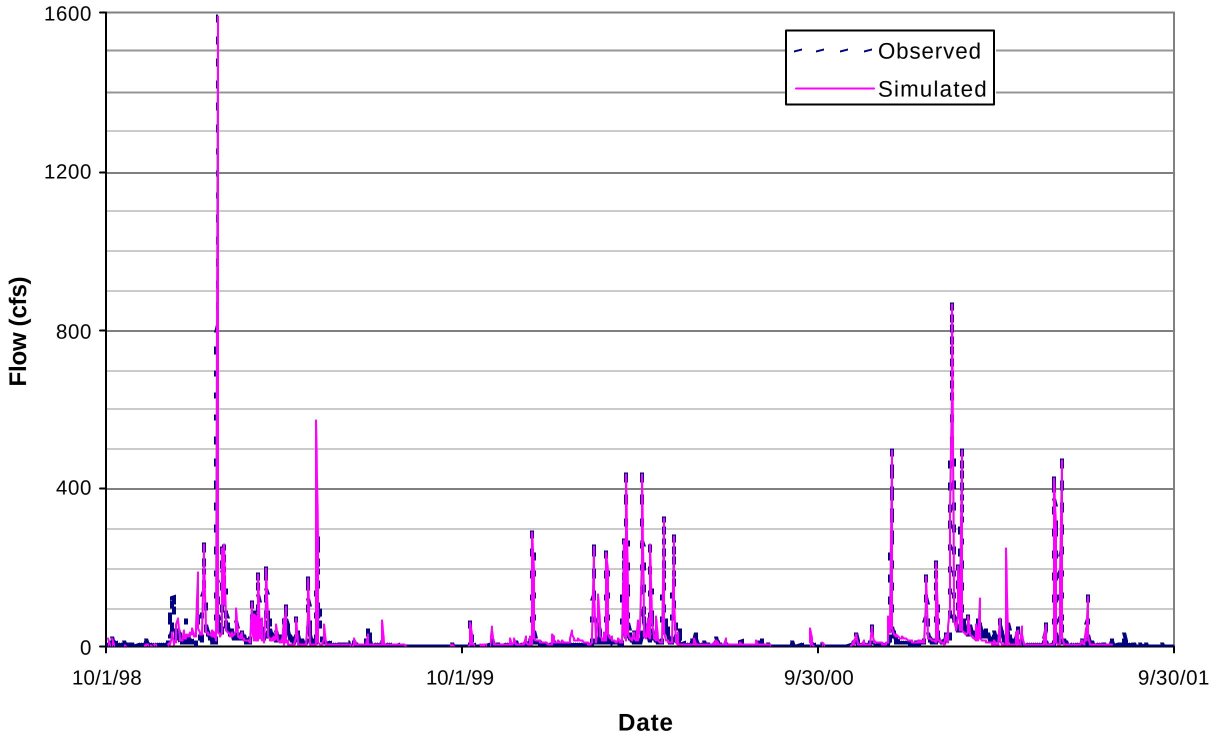




**Figure C-1. Hydrologic Calibration: Cypress Creek at Camden, USGS 03605078 (WYs 1996-1998)**



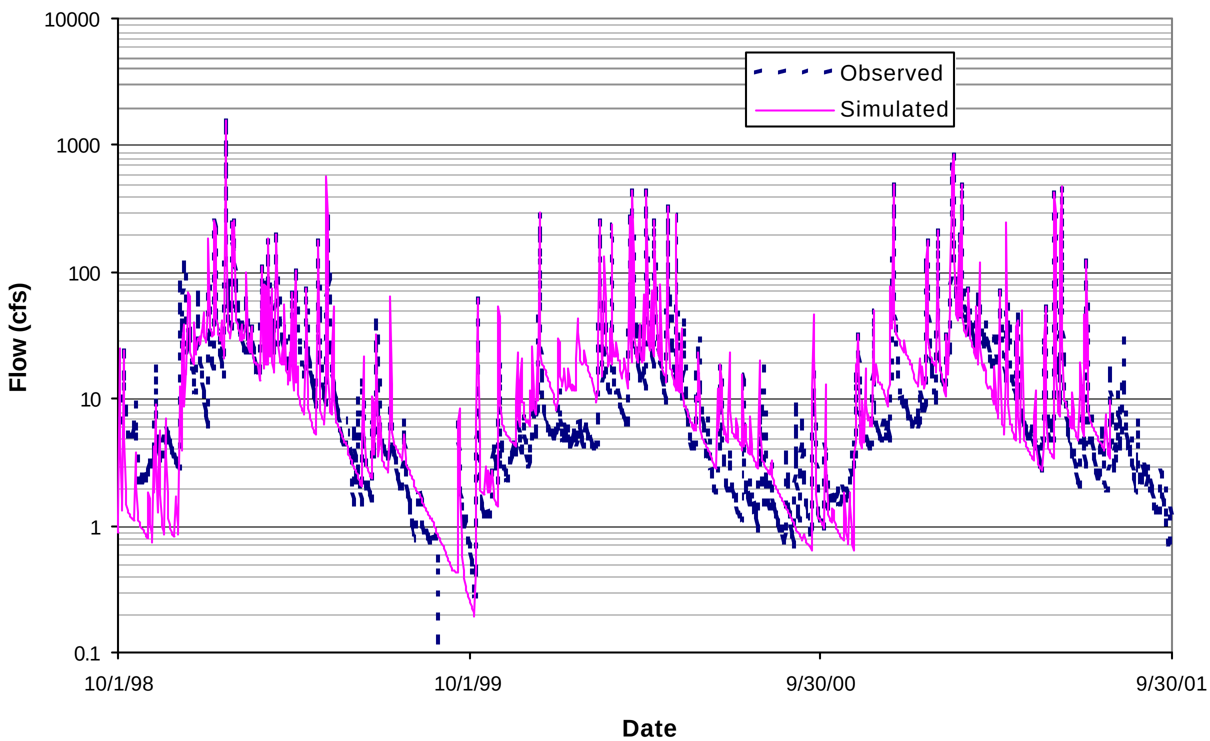
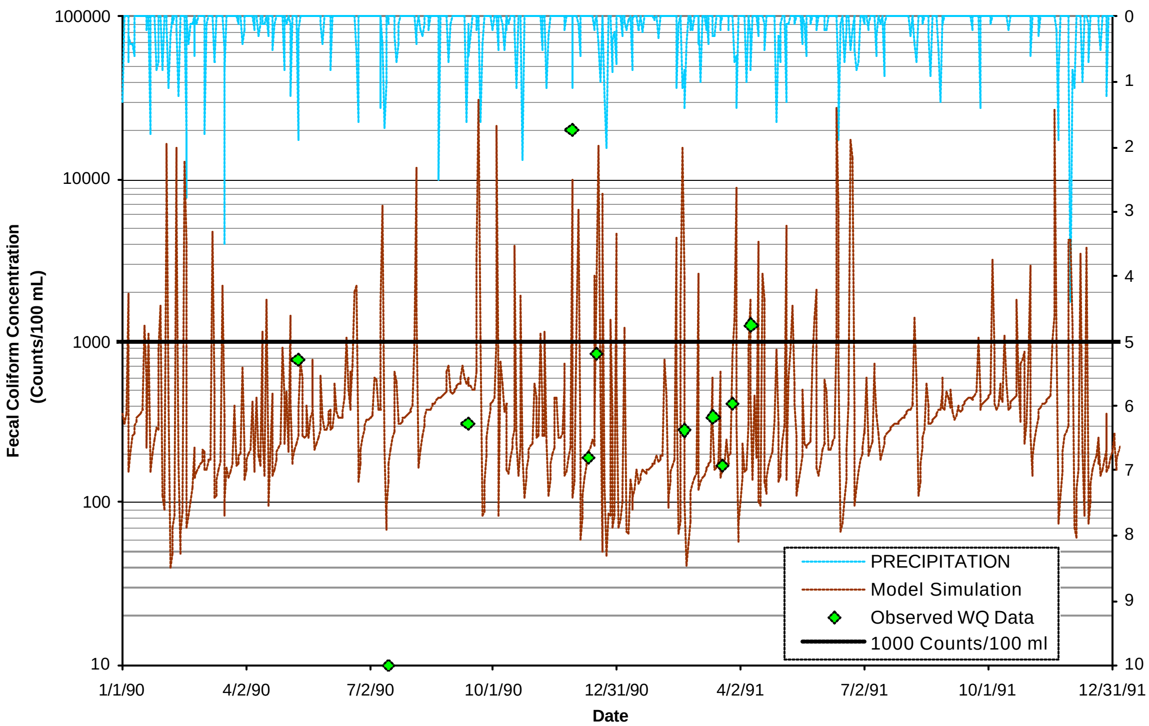




**Figure C-2. Hydrologic Calibration: Cypress Creek at Camden, USGS 03605078 (WYs 1999-2001)**



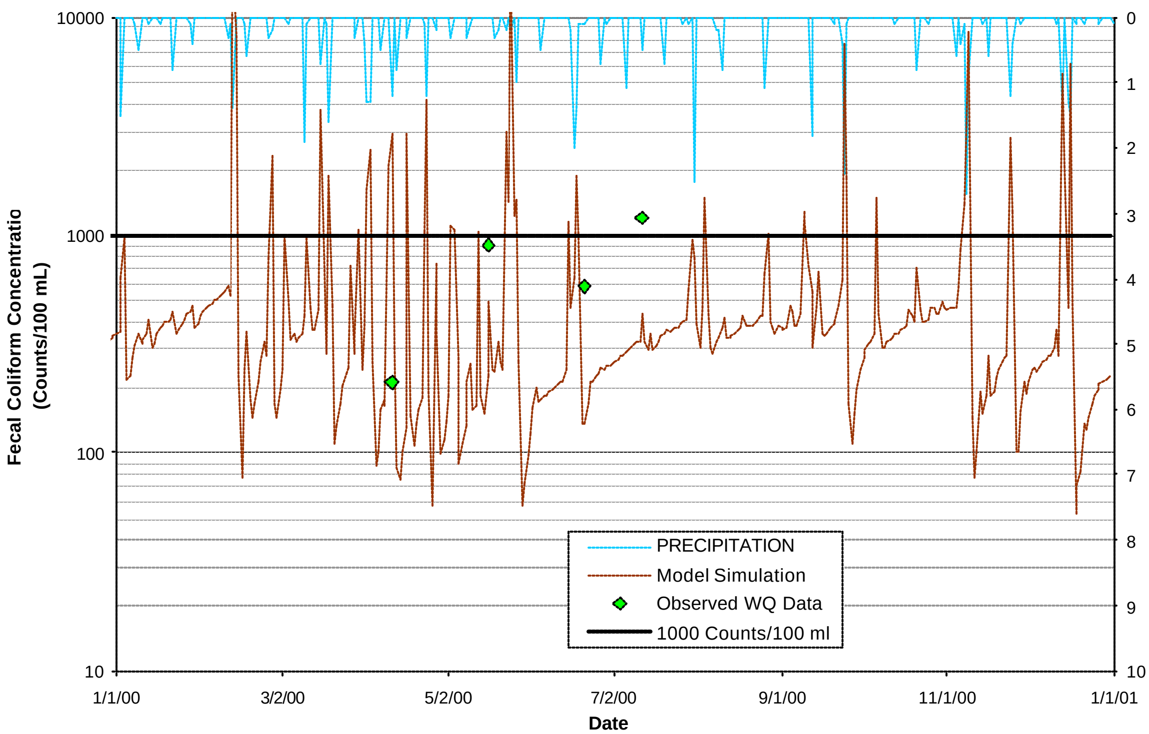




**Figure C-3. Water Quality Calibration of Holly Fork Creek at Mile 4.0 (HFORK004.0HN)**

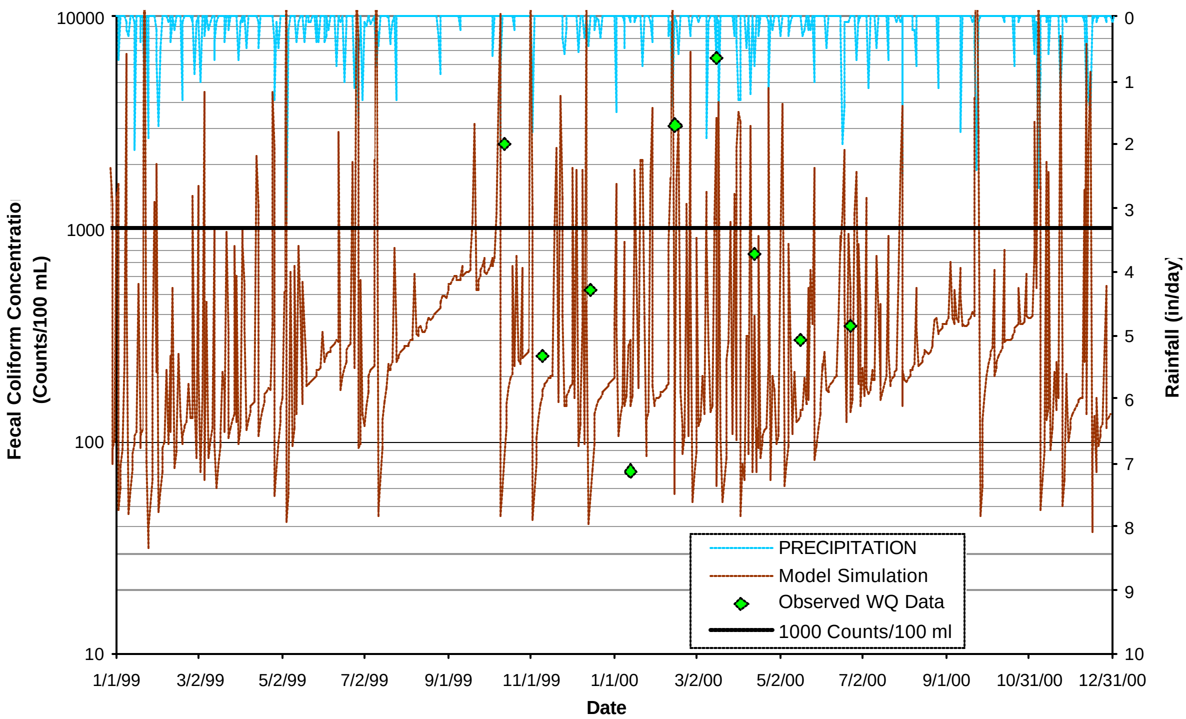
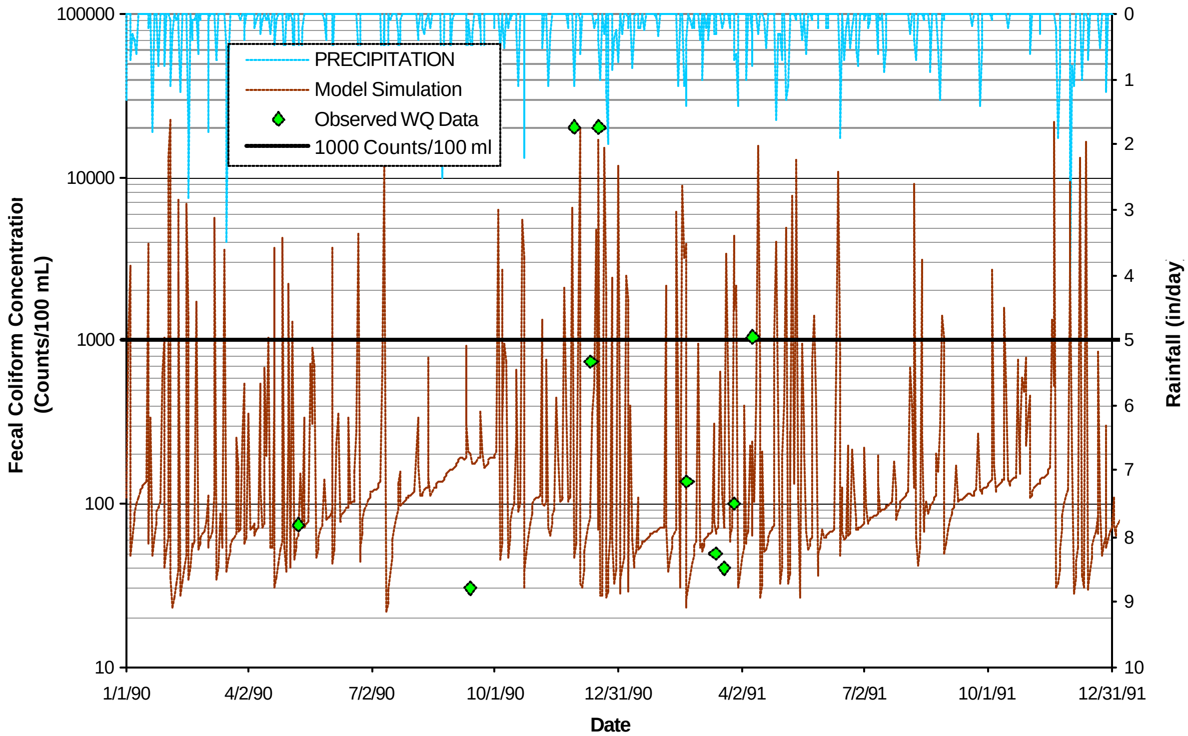



**Figure C-4. Water Quality Calibration of Little Beaver Creek at Mile 1.3 (LBEAV001.3HE)**



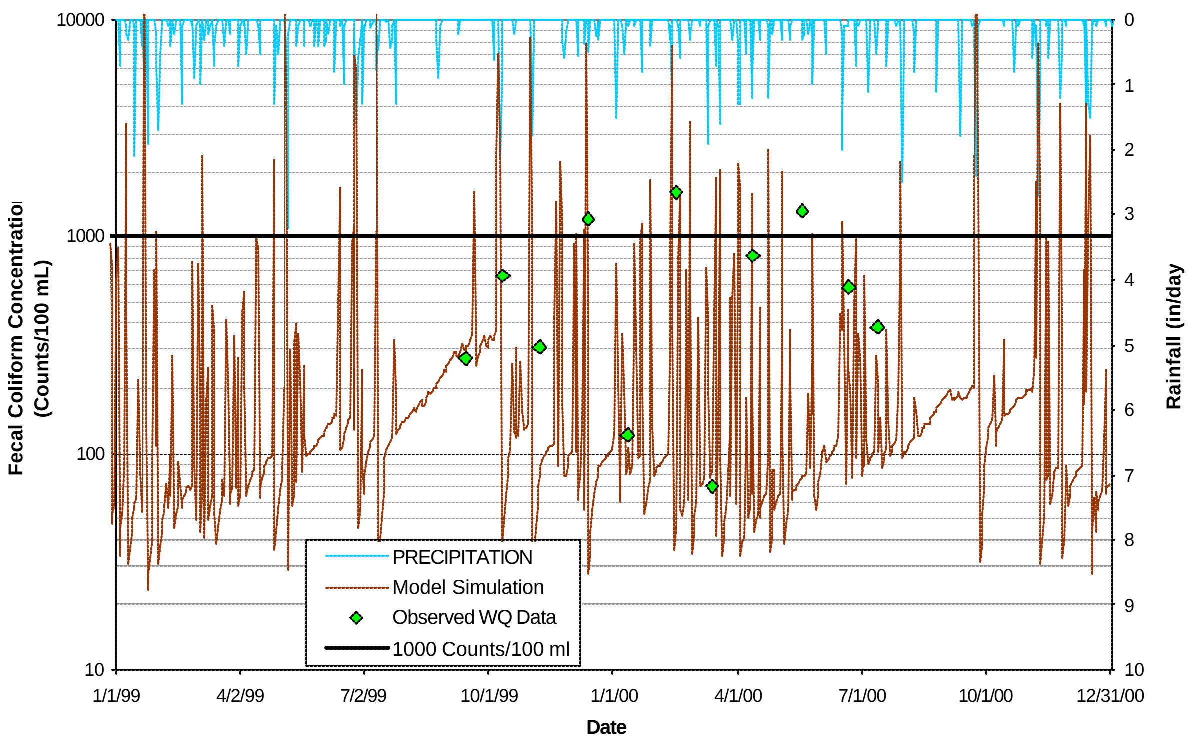
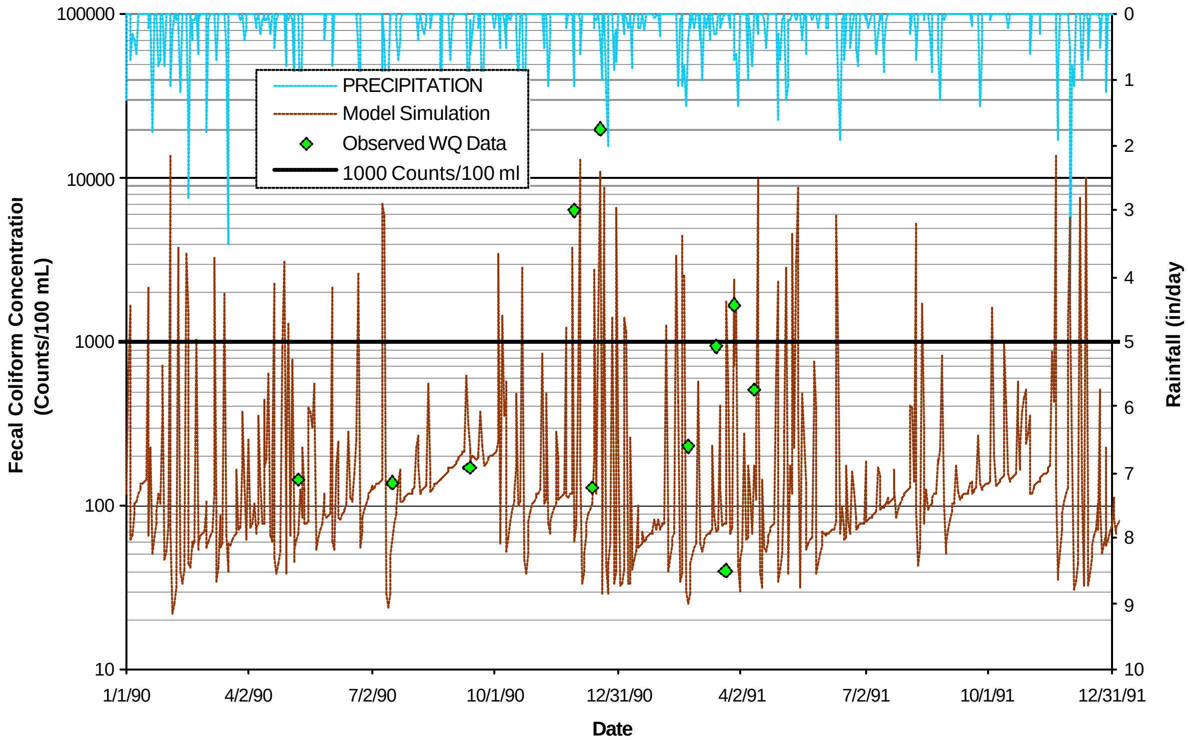




**Figure C-5. Water Quality Calibration of Mud Creek at Mile 4.7 (MUD004.7CR)**



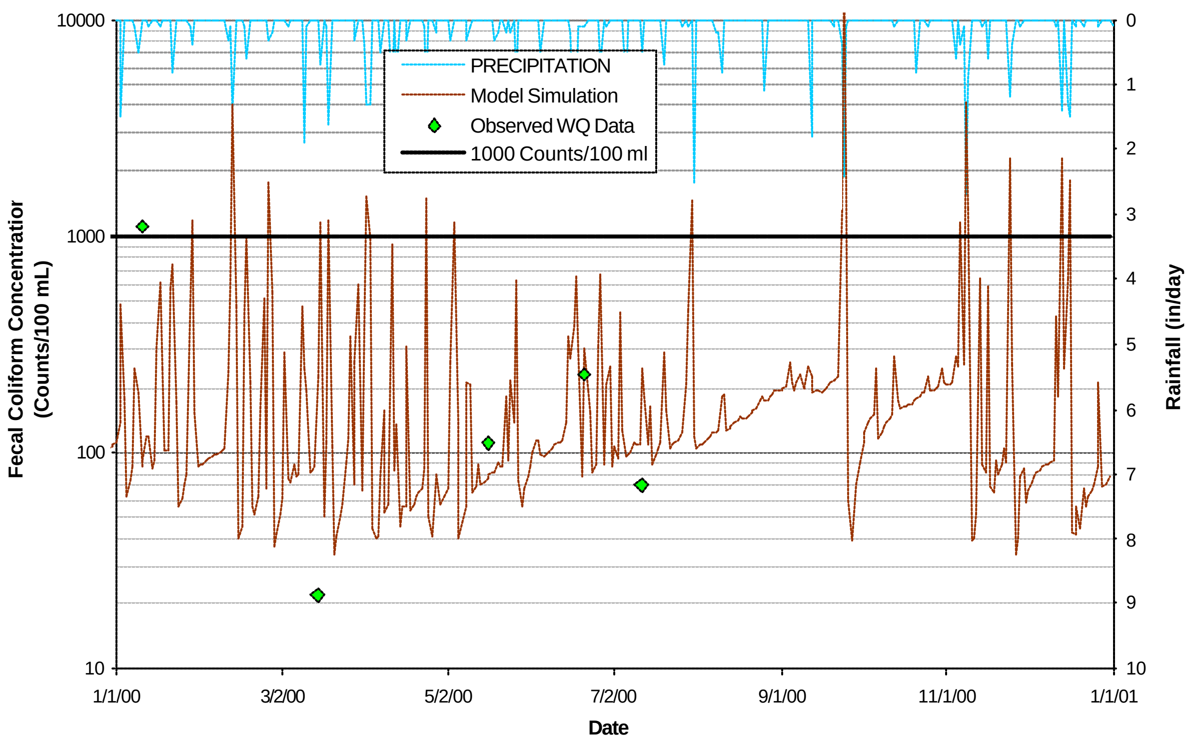




**Figure C-6. Water Quality Calibration of Big Sandy River at Mile 45.2 (BSAND045.2CR)**

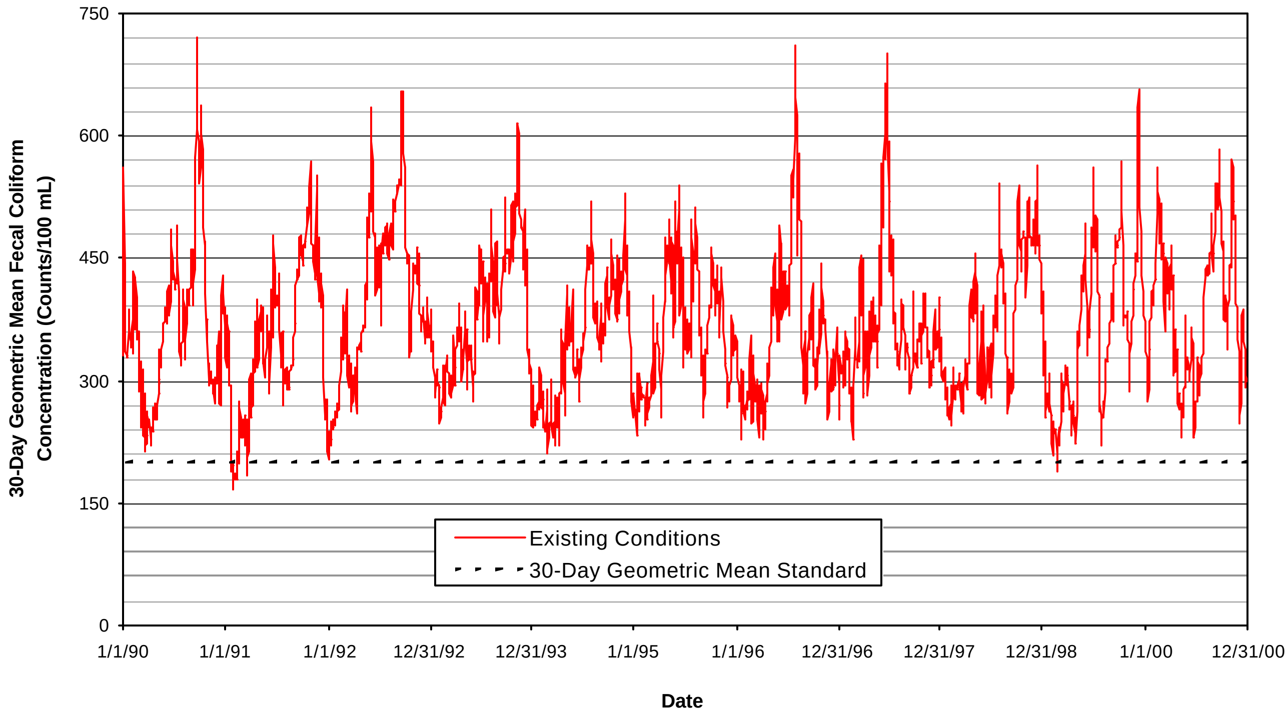



**Figure C-7. Simulated 30-Day Geometric Mean Fecal Coliform Concentrations for Holly Fork Creek at the Mouth for Existing Conditions.**

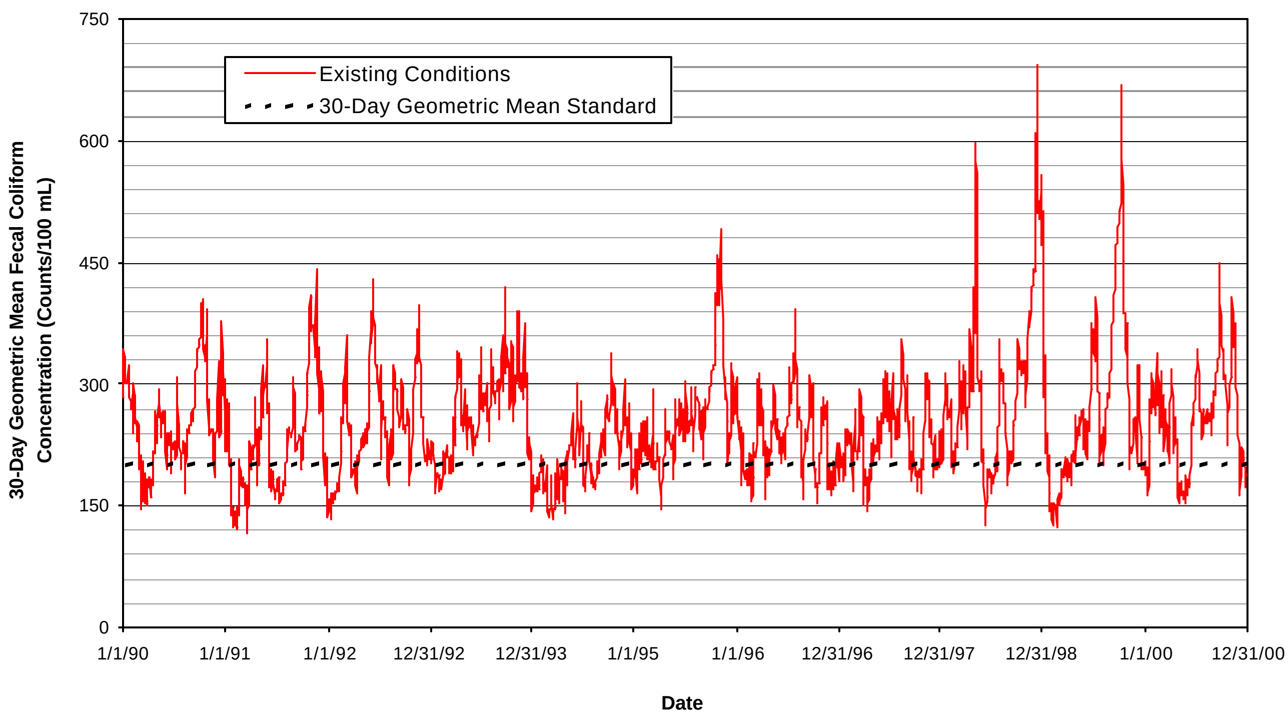



**Figure C-8. Simulated 30-Day Geometric Mean Fecal Coliform Concentrations for Little Beaver Creek at the Mouth for Existing Conditions.**

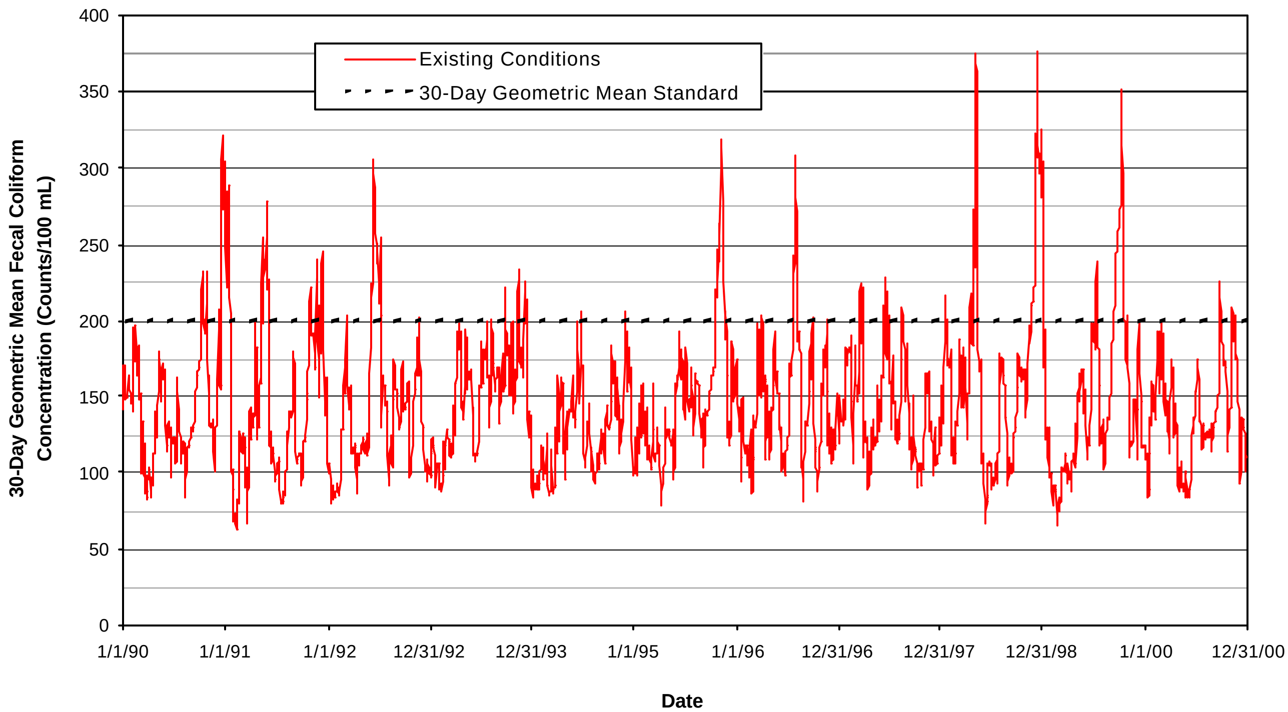



**Figure C-9. Simulated 30-Day Geometric Mean Fecal Coliform Concentrations for Mud Creek at the Mouth for Existing Conditions.**

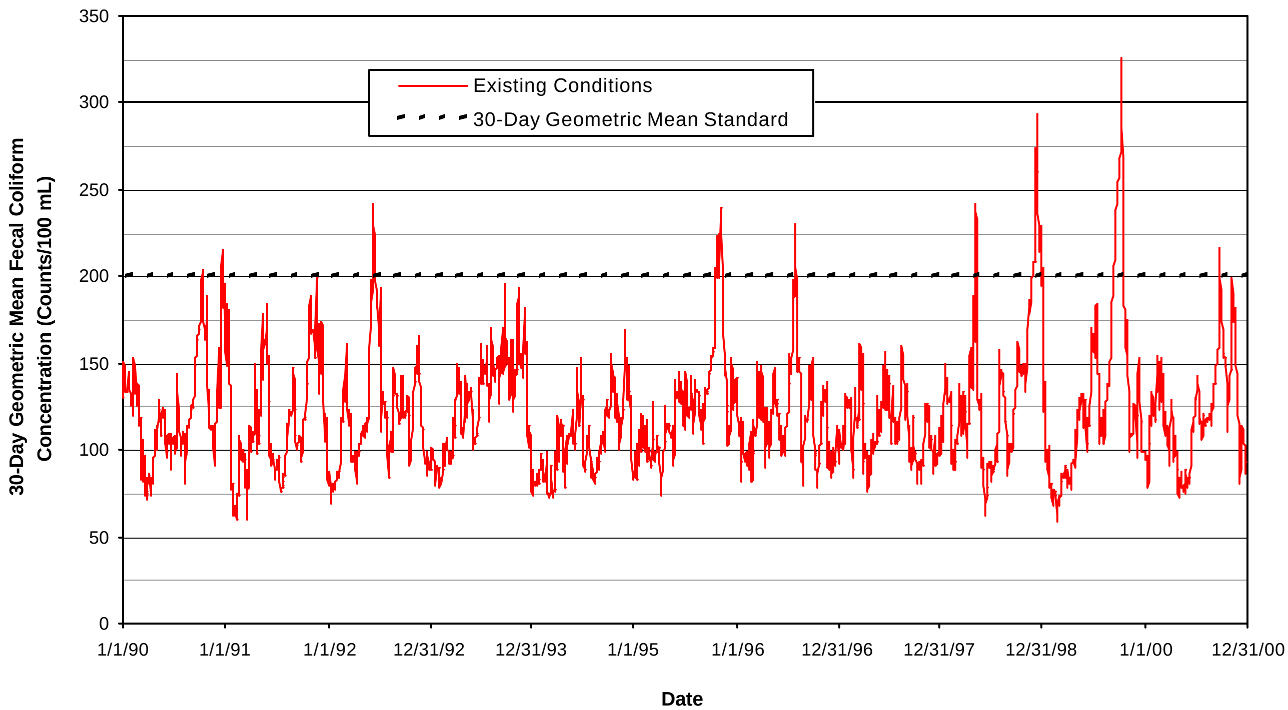



**Figure C-10. Simulated 30-Day Geometric Mean Fecal Coliform Concentrations for Big Sandy River at the confluence with Maple Creek for Existing Conditions.**

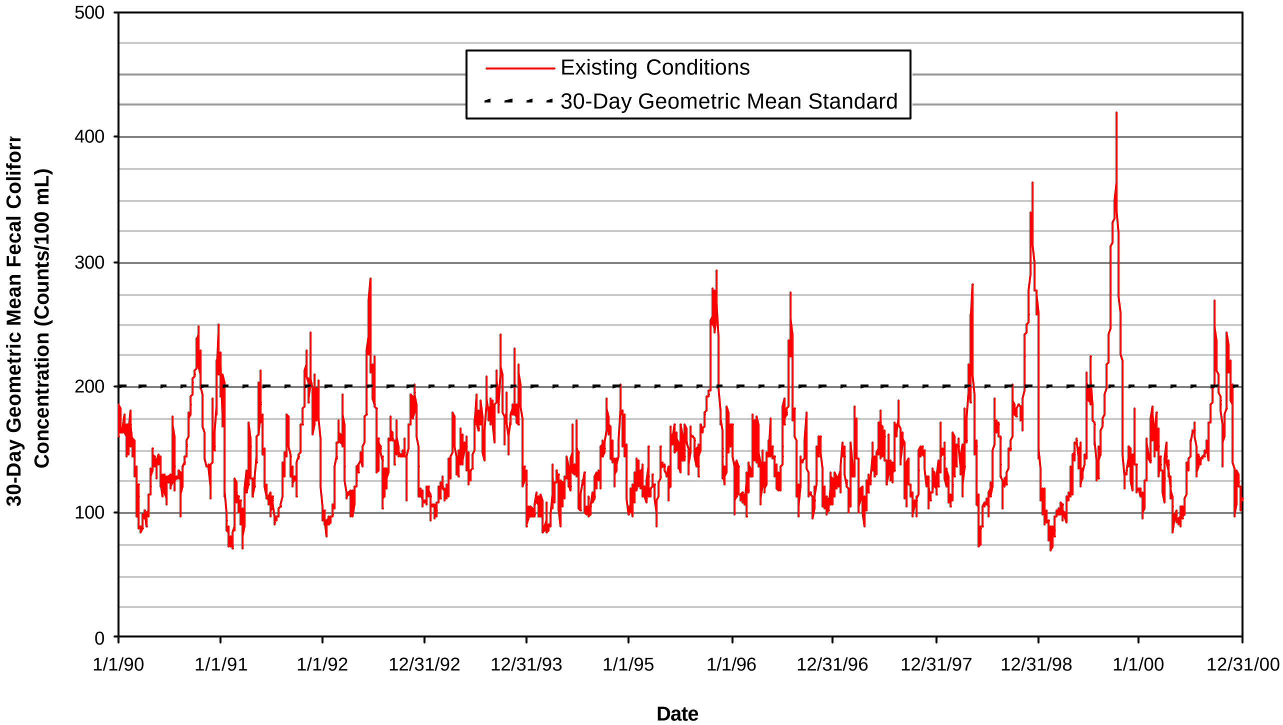



**Figure C-11. Simulated 30-Day Geometric Mean Fecal Coliform Concentrations for Big Sandy River at the confluence with Roan Creek for Existing Conditions.**

# APPENDIX D

## Load Duration Curve Methodology

## LOAD DURATION CURVE METHOD

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 are useful for TMDL analysis:

> *Note: The following was based on information from Nevada Division of Environmental Protection, Bureau of Water Quality Planning website (Nevada, 2003):*

- Load duration curves can serve as TMDL targets, thereby establishing allowable loading to waterbodies over the entire range of flow.

- Pollutant monitoring data, plotted on a load duration curve, provide a visual depiction of stream water quality with respect to allowable loads. The frequency and magnitude of exceedances are also illustrated.

- Load duration curves can be used to characterize the flow conditions under which exceedances occur. For example, exceedances that occur in the 0% to 10% area of the curve may be considered to represent extreme high flow problems that may be beyond feasible management solutions. Exceedances in the 99% to 100% area reflect extreme drought conditions.

- Different loading mechanisms can dominate at different flow regimes. Exceedances of the load duration curve during high flow conditions may indicate excessive nonpoint source loading associated with rain events, while exceedances at the lower flows can indicate point source problems.

### D.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) drainage area extrapolation of data from a nearby continuous-record station of similar size and topography; and 2) calculation of daily mean flow using a dynamic computer model, such as LSPC.

Flow duration curves for Holly Fork Creek, Little Beaver Creek, Mud Creek, and Big Sandy River were derived from hydrologic simulations based on parameters derived from calibration at USGS Station No. 03605078, located on Cypress Creek at Camden, in the Kentucky Lake watershed. The data used, in each case, included the period of record from 1/1/90 – 12/31/00. The flow duration curves for Holly Fork Creek at mile 4.0, Little Beaver Creek at mile 1.3, Mud Creek at mile 4.7, and Big Sandy River at mile 45.2 are shown in Figures D-1 through D-4.

## D.2 Development of Load Duration Curves

Fecal coliform and E. coli load duration curves for Holly Fork Creek, Little Beaver Creek, Mud Creek, and Big Sandy River were developed from the flow duration curves developed in Section D.1 and available water quality monitoring data. Load duration curves were developed using the following procedure:

1. A load-duration curve was generated for Holly Fork Creek at mile 4.0 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 load corresponding to each ranked daily mean flow is:

   $(\text{Target Load})_{\text{Holly Fork Creek}}$ = (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 the monitoring station (ref.: Table B-1) by multiplying the sample concentration by the derived daily mean flow for the sampling date and the required unit conversion factor.

   *Note: 1) 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 Step 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 2 according to the PDFE. The resulting fecal coliform and E. coli load duration curves for Holly Fork Creek at mile 4.0, Little Beaver Creek at mile 1.3, Mud Creek at mile 4.7, and Big Sandy River at mile 45.2 are shown in Figures D-5 through D-12.

4. For cases where the existing load exceeded the water quality standard, the reduction corresponding to each sample load was determined through comparison with the target load corresponding to the PDFE. The geometric means of the calculated reductions of existing fecal coliform load and E. coli load, respectively, required to meet the TMDL targets were considered to be the required load reductions for the Holly Fork Creek, Little Beaver Creek, Mud Creek, and Big Sandy River subwatersheds (see Tables D-1 through D-8).

   *Note: A minimum of three (3) water quality samples, corresponding to exceedances of the water quality standard, are required in order to consider the calculated required load reduction for designation as the TMDL reduction. Required load reductions calculated for sampling sites with less than three exceedances will be used for information purposes only.*

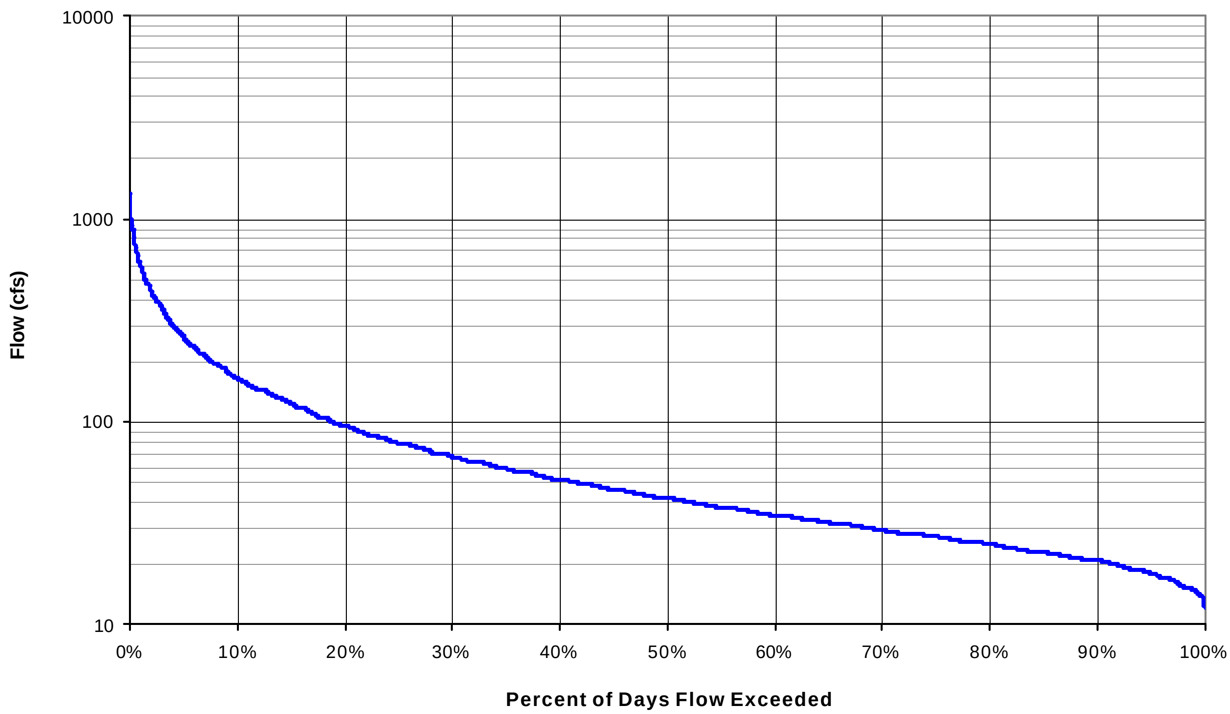



**Figure D-1. Flow Duration Curve for Holly Fork Creek at Mile 4.0**

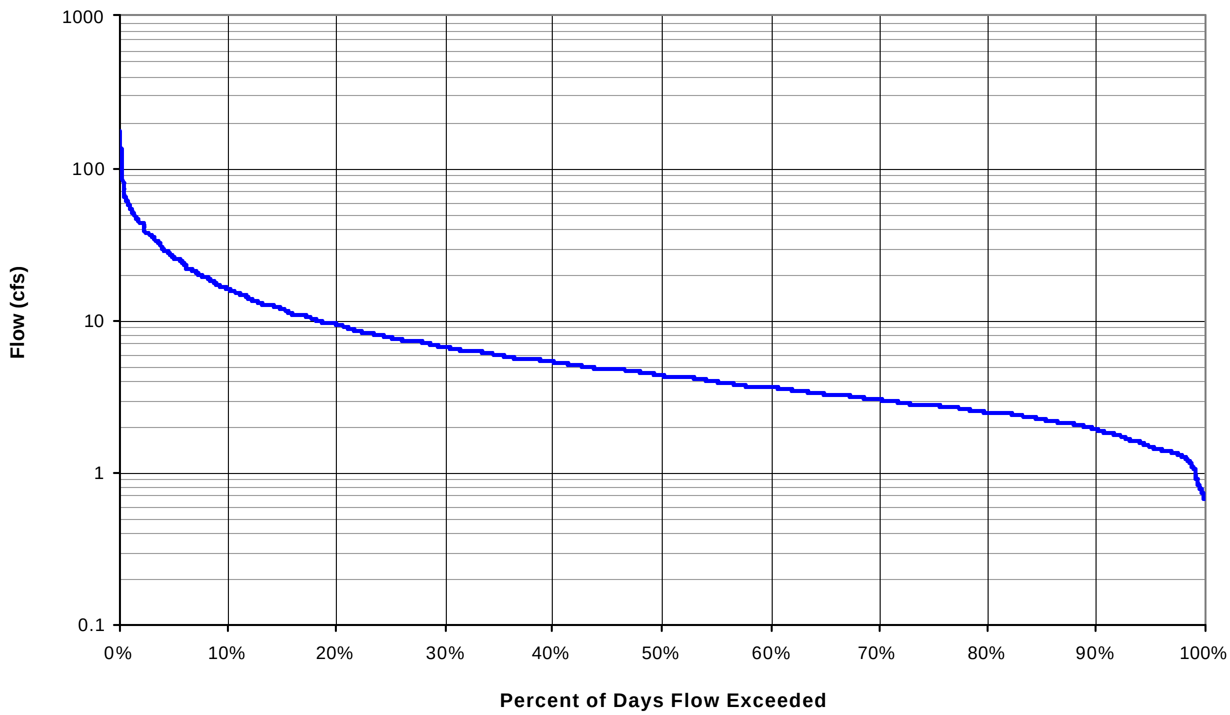



**Figure D-2. Flow Duration Curve for Little Beaver Creek at Mile 1.3**

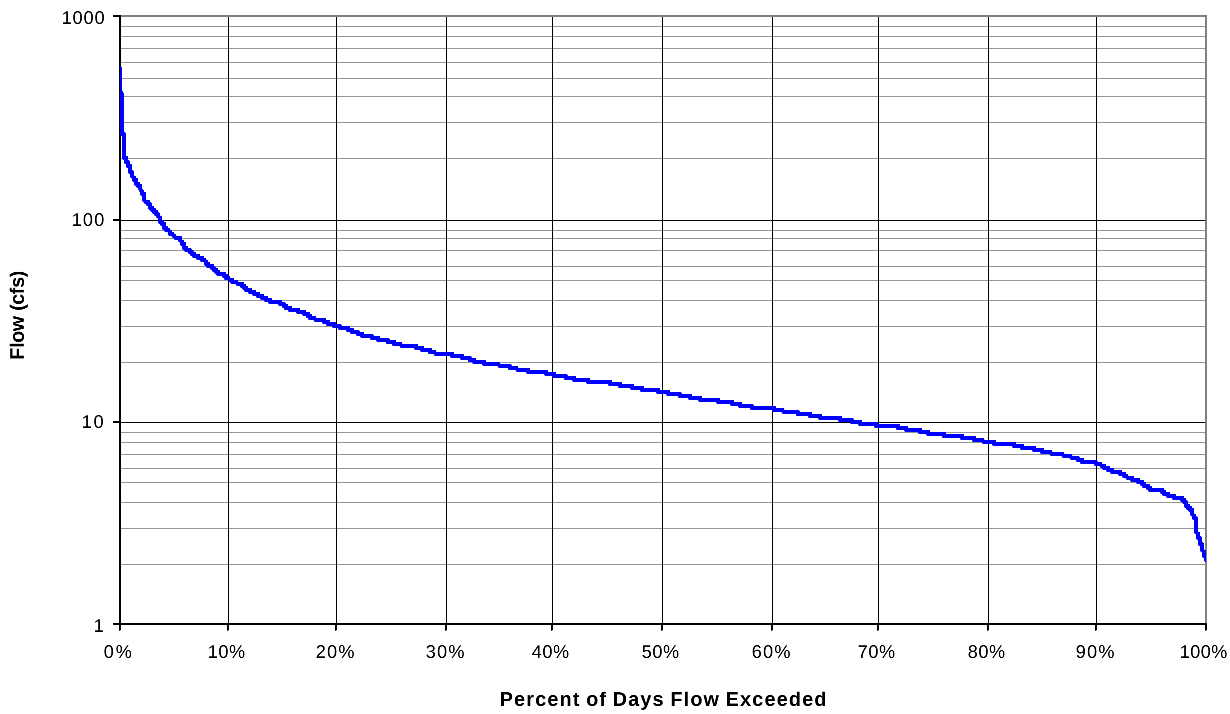



**Figure D-3. Flow Duration Curve for Mud Creek at Mile 4.7**

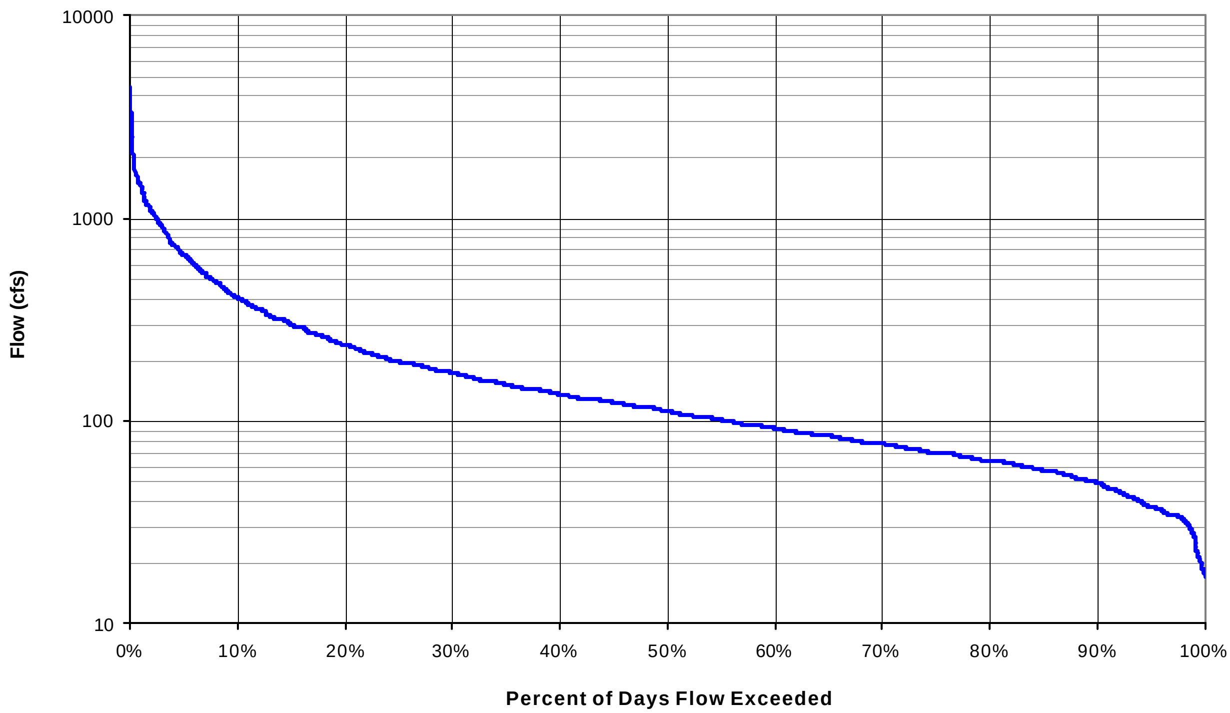



**Figure D-4. Flow Duration Curve for Big Sandy River at Mile 45.2**

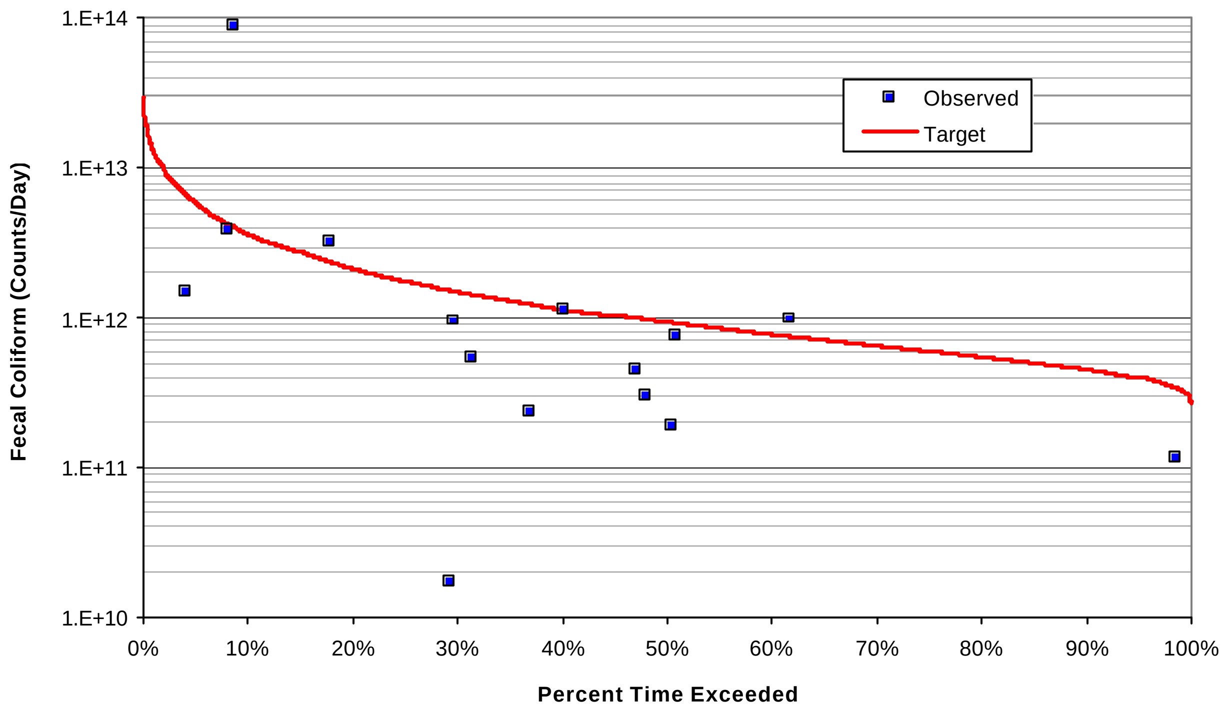



**Figure D-5. Fecal Coliform Load Duration Curve for Holly Fork Creek at Mile 4.0**

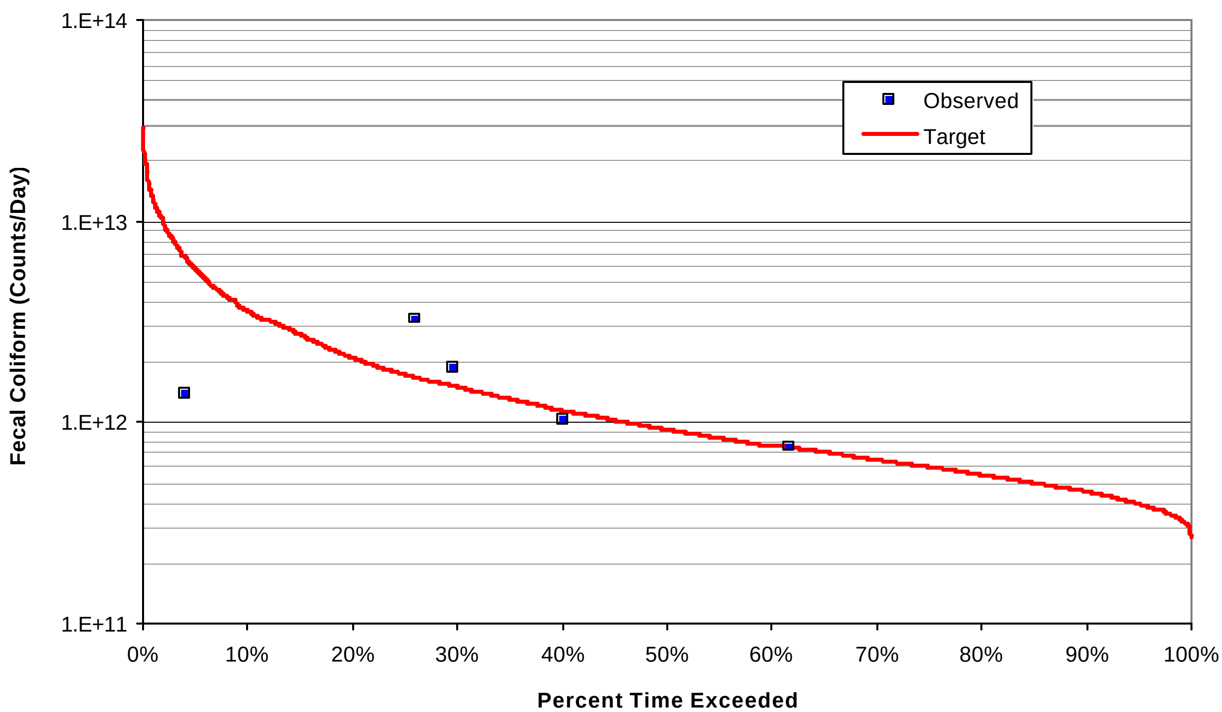



**Figure D-6. E. Coli Load Duration Curve for Holly Fork Creek at Mile 4.0**

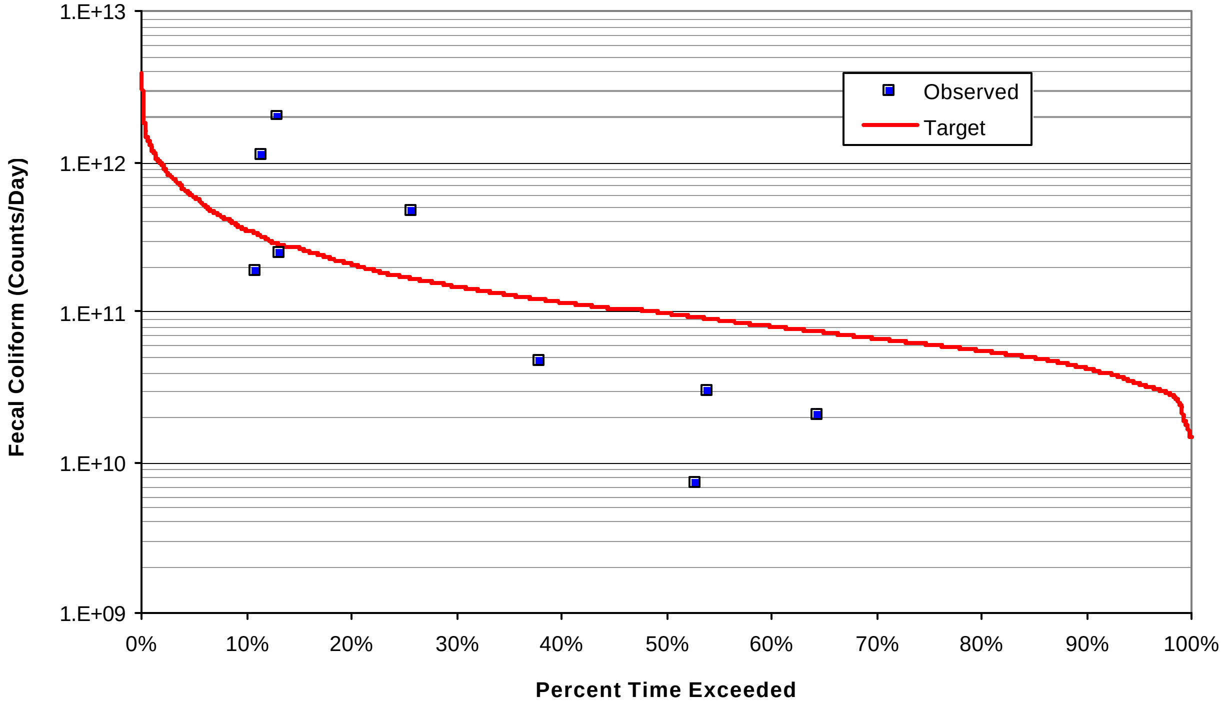



**Figure D-7. Fecal Coliform Load Duration Curve for Little Beaver Creek at Mile 1.3**

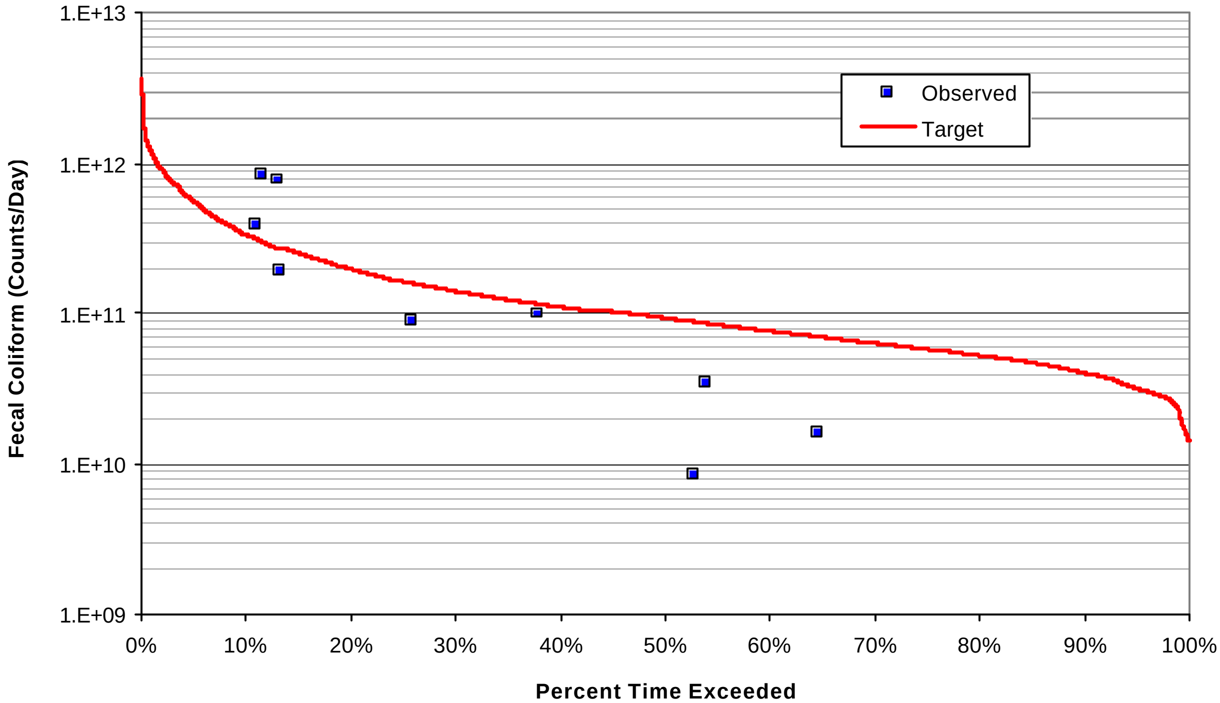



**Figure D-8. E. Coli Load Duration Curve for Little Beaver Creek at Mile 1.3**

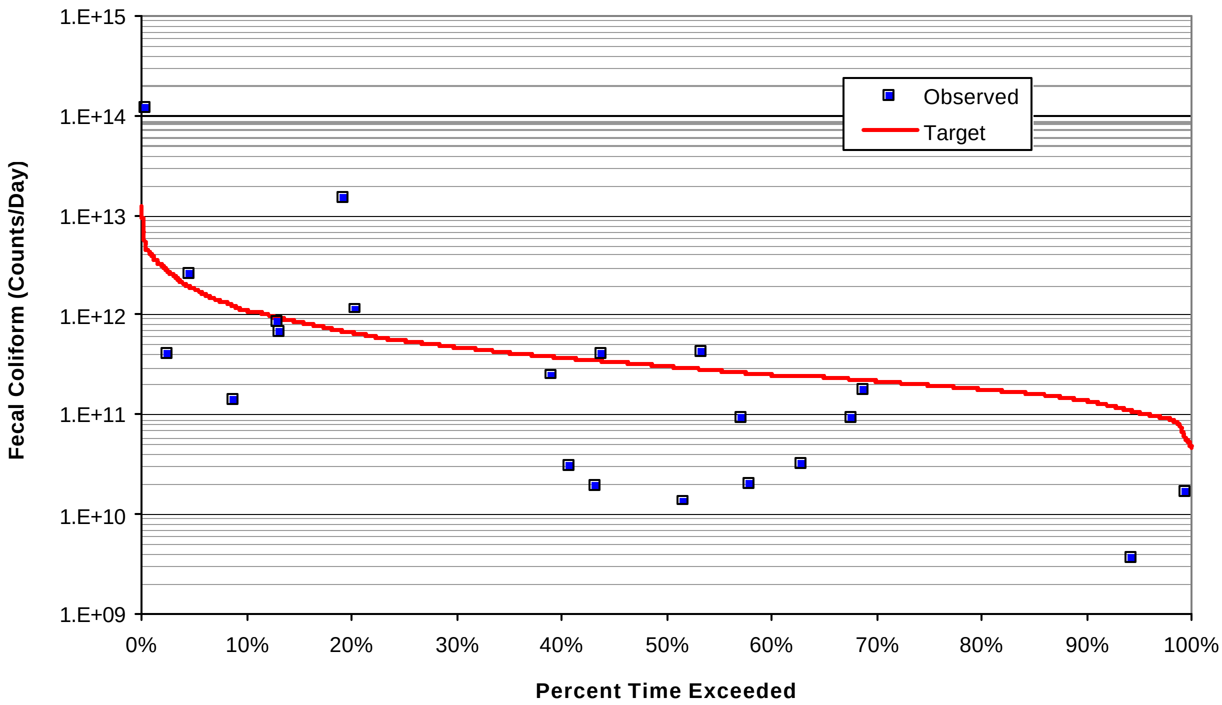



**Figure D-9. Fecal Coliform Load Duration Curve for Mud Creek at Mile 4.7**

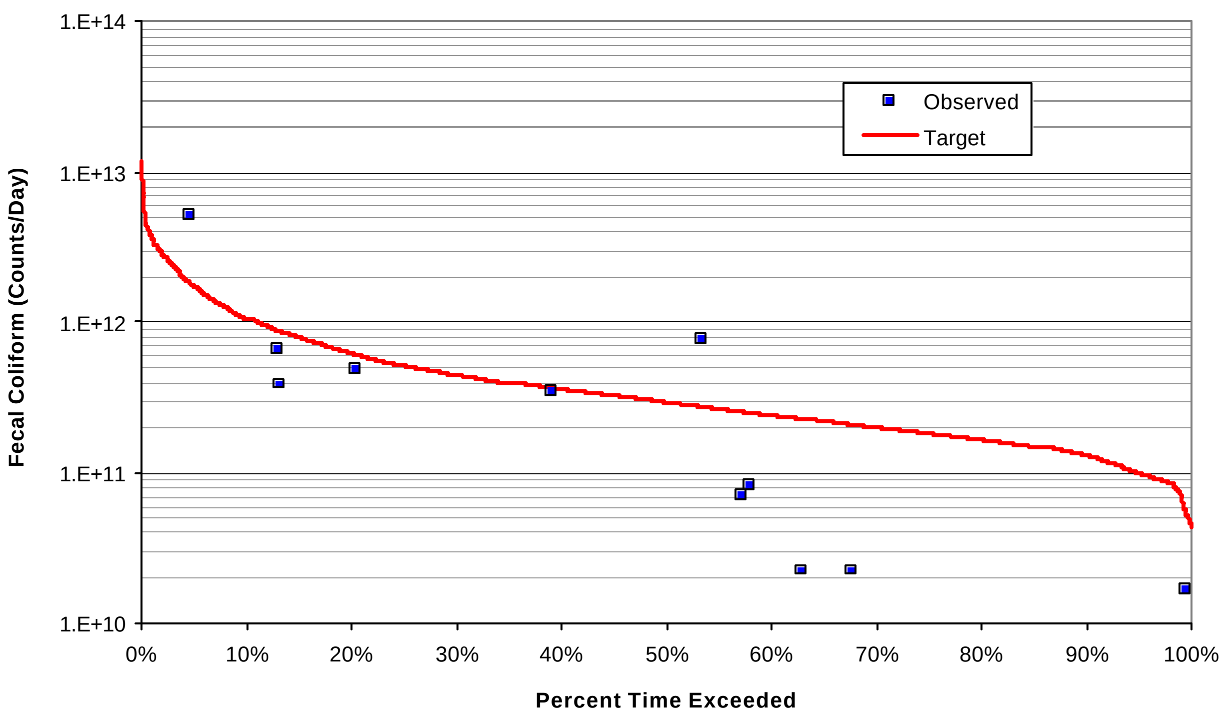



**Figure D-10. E. Coli Load Duration Curve for Mud Creek at Mile 4.7**

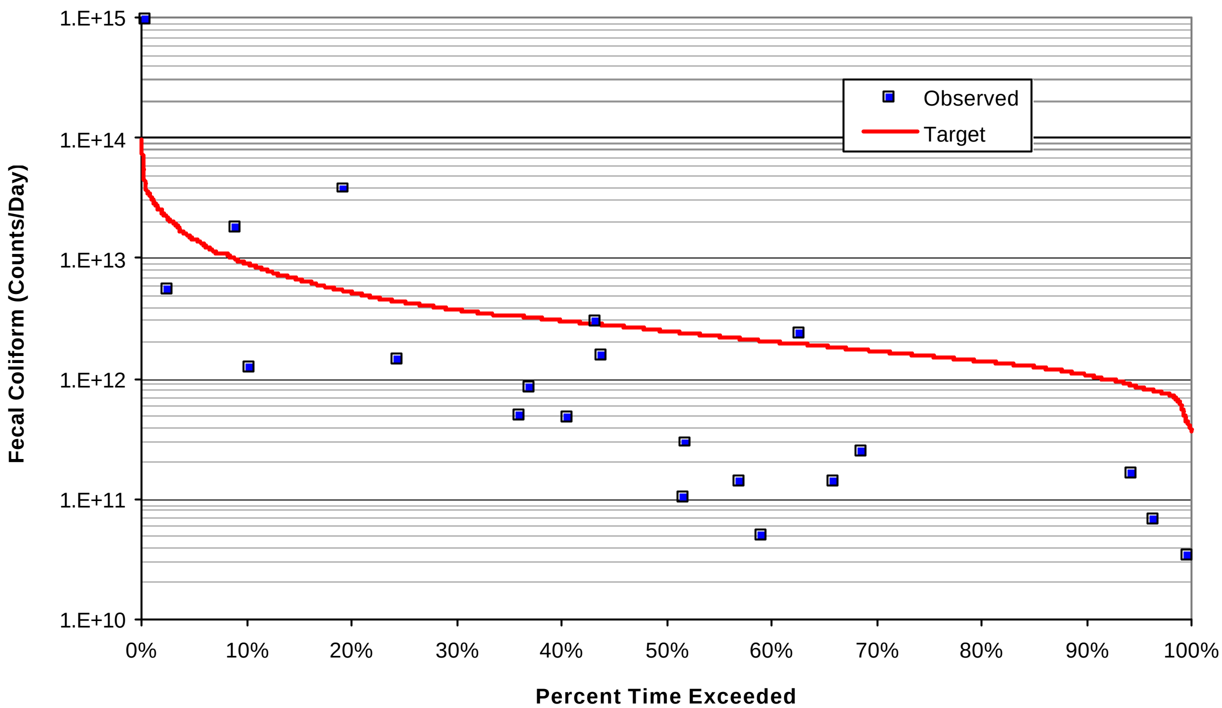



**Figure D-11. Fecal Coliform Load Duration Curve for Big Sandy River at Mile 45.2**

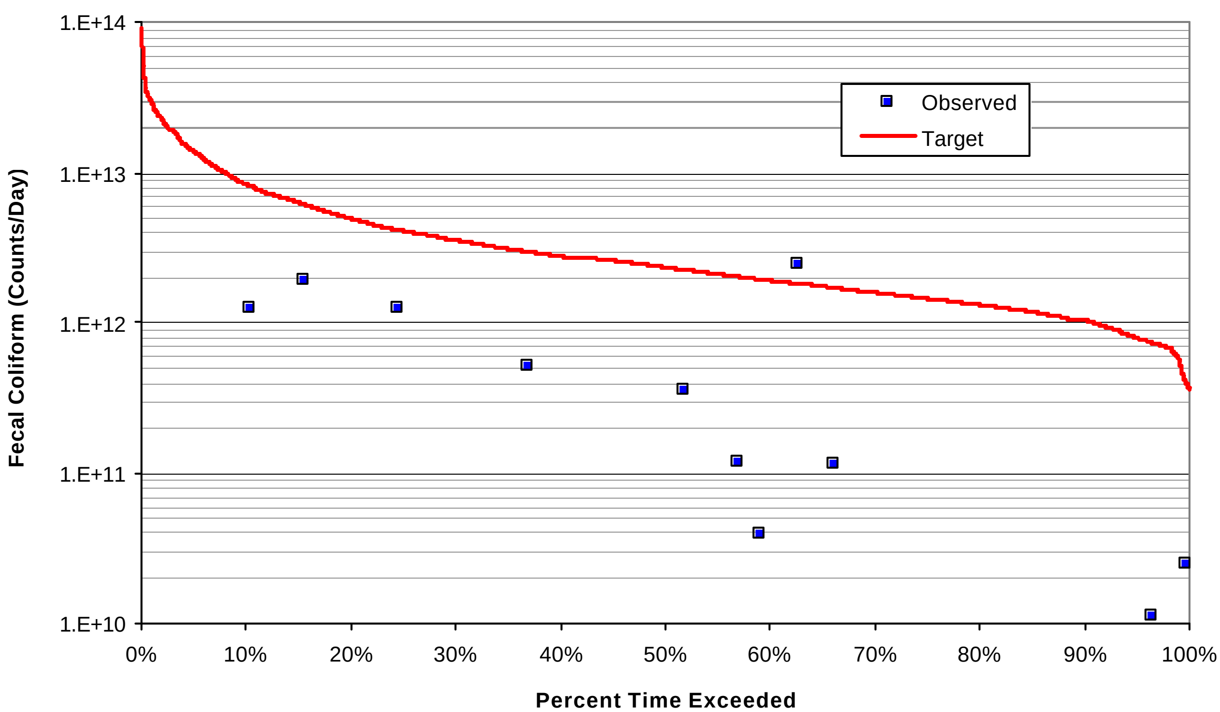



**Figure D-12. E. Coli Load Duration Curve for Big Sandy River at Mile 45.2**

**Table D-1. Required Load Reduction for Holly Fork Creek at Mile 4.0 – Fecal Coliform Analysis**

| Sample Date | Flow | PDFE | Fecal Coliform | | | |
|---|---|---|---|---|---|---|
| | | | Sample Conc. | Sample Load | Target Load | Required Load Reduction |
| | [cfs] | [%] | [cts/100 ml] | [cts/day] | [cts/day] | [%] |
| 4/11/00 | 294.733 | 4.032% | 210 | 6.863E+11 | 2.941E+12 | **NR** |
| 12/17/90 | 190.155 | 8.064% | 827 | 2.990E+12 | 3.254E+12 | **NR** |
| 11/28/90 | 183.935 | 8.661% | **20000** | 1.925E+13 | 8.662E+11 | 95.5 |
| 4/10/91 | 105.306 | 17.770% | **1255** | 7.553E+12 | 5.417E+12 | 28.3 |
| 7/16/90 | 68.9713 | 29.144% | 10 | 1.917E+10 | 1.726E+12 | **NR** |
| 6/21/00 | 68.184 | 29.567% | 580 | 2.777E+13 | 4.310E+13 | **NR** |
| 3/13/91 | 64.4222 | 31.384% | 340 | 8.142E+12 | 2.155E+13 | **NR** |
| 3/20/91 | 56.3268 | 36.760% | 170 | 5.304E+11 | 2.808E+12 | **NR** |
| 5/17/00 | 51.4095 | 40.070% | 900 | 2.379E+12 | 2.379E+12 | **NR** |
| 3/27/91 | 44.6903 | 46.939% | 410 | 4.445E+12 | 9.757E+12 | **NR** |
| 12/20/91 | 43.7931 | 47.810% | 280 | 8.629E+11 | 2.774E+12 | **NR** |
| 12/11/90 | 41.6709 | 50.299% | 190 | 1.633E+11 | 7.737E+11 | **NR** |
| 5/10/90 | 41.1542 | 50.846% | 755 | 3.719E+11 | 4.433E+11 | **NR** |
| 7/12/00 | 33.732 | 61.648% | **1200** | 5.879E+12 | 4.409E+12 | 25.0 |
| 9/12/90 | 15.2976 | 98.432% | 310 | 7.371E+11 | 2.140E+12 | **NR** |
| | NR = Not Required | | | **Geometric Mean** | | **40.7** |

**Table D-2. Required Load Reduction for Holly Fork Creek at Mile 4.0 – E. Coli Analysis**

| Sample Date | Flow | PDFE | E. Coli | | | |
|---|---|---|---|---|---|---|
| | | | Sample Conc. | Sample Load | Target Load | Required Load Reduction |
| | [cfs] | [%] | [cts/100 ml] | [cts/day] | [cts/day] | [%] |
| 4/11/00 | 294.733 | 4.032% | 190 | 6.210E+11 | 2.941E+12 | **NR** |
| 5/23/00 | 76.7982 | 25.884% | **1733** | 6.265E+12 | 3.254E+12 | 48.1 |
| 6/21/00 | 68.184 | 29.567% | **1120** | 1.078E+12 | 8.662E+11 | 19.6 |
| 5/17/00 | 51.4095 | 40.070% | 816 | 4.911E+12 | 5.417E+12 | **NR** |
| 7/12/00 | 33.732 | 61.648% | 921 | 1.766E+12 | 1.726E+12 | **NR** |
| 4/11/00 | 294.733 | 4.032% | 190 | 6.210E+11 | 2.941E+12 | **NR** |
| | NR = Not Required | | | **Geometric Mean** | | **30.7** |

**Table D-3. Required Load Reduction for Little Beaver Creek at Mile 1.3 – Fecal Coliform Analysis**

| Sample Date | Flow | PDFE | E. Coli | | | |
|---|---|---|---|---|---|---|
| | | | Sample Conc. | Sample Load | Target Load | Required Load Reduction |
| | [cfs] | [%] | [cts/100 ml] | [cts/day] | [cts/day] | [%] |
| 12/15/99 | 15.1708 | 10.926% | 510 | 1.667E+12 | 2.941E+12 | **NR** |
| 2/15/00 | 14.4524 | 11.523% | **3100** | 1.121E+13 | 3.254E+12 | 71.0 |
| 3/16/00 | 13.0256 | 13.041% | **6400** | 6.160E+12 | 8.662E+11 | 85.9 |
| 4/13/00 | 12.9772 | 13.091% | 760 | 4.574E+12 | 5.417E+12 | **NR** |
| 10/13/99 | 7.60332 | 25.709% | **2500** | 4.793E+12 | 1.726E+12 | 64.0 |
| 6/22/00 | 5.58333 | 37.855% | 350 | 1.676E+13 | 4.31E+13 | **NR** |
| 1/13/00 | 4.16842 | 52.688% | 72 | 1.724E+12 | 2.155E+13 | **NR** |
| 5/18/00 | 4.05888 | 53.833% | 300 | 9.360E+11 | 2.808E+12 | **NR** |
| 11/9/99 | 3.34955 | 64.410% | 250 | 6.608E+11 | 2.379E+12 | **NR** |
| NR = Not Required | | | | **Geometric Mean** | | **73.1** |

**Table D-4. Required Load Reduction for Little Beaver Creek at Mile 1.3 – E. Coli Analysis**

| Sample Date | Flow | PDFE | Fecal Coliform | | | |
|---|---|---|---|---|---|---|
| | | | Sample Conc. | Sample Load | Target Load | Required Load Reduction |
| | [cfs] | [%] | [cts/100 ml] | [cts/day] | [cts/day] | [%] |
| 12/15/99 | 15.1708 | 10.926% | **1046** | 3.419E+12 | 2.941E+12 | 14.0 |
| 2/15/00 | 14.4524 | 11.523% | **>2419** | 8.746E+12 | 3.254E+12 | 62.8 |
| 3/16/00 | 13.0256 | 13.041% | **>2419** | 2.328E+12 | 8.662E+11 | 62.8 |
| 4/13/00 | 12.9772 | 13.091% | 613 | 3.689E+12 | 5.417E+12 | **NR** |
| 10/13/99 | 7.60332 | 25.709% | 479 | 9.184E+11 | 1.726E+12 | **NR** |
| 6/22/00 | 5.58333 | 37.855% | 727 | 3.481E+13 | 4.31E+13 | **NR** |
| 1/13/00 | 4.16842 | 52.688% | 83 | 1.988E+12 | 2.155E+13 | **NR** |
| 5/18/00 | 4.05888 | 53.833% | 344 | 1.073E+12 | 2.808E+12 | **NR** |
| 11/9/99 | 3.34955 | 64.410% | 201 | 5.312E+11 | 2.379E+12 | **NR** |
| 12/15/99 | 15.1708 | 10.926% | **1046** | 3.419E+12 | 2.941E+12 | 14.0 |
| NR = Not Required | | | | **Geometric Mean** | | **>38.0** |

**Table D-5. Required Load Reduction for Mud Creek at Mile 4.7 – Fecal Coliform Analysis**

| Sample Date | Flow | PDFE | Fecal Coliform | | | |
|---|---|---|---|---|---|---|
| | | | Sample Conc. | Sample Load | Target Load | Required Load Reduction |
| | [cfs] | [%] | [cts/100 ml] | [cts/day] | [cts/day] | [%] |
| 12/18/90 | 250.41 | 0.324% | **20000** | 6.536E+13 | 2.941E+12 | 95.5 |
| 2/21/91 | 123.247 | 2.439% | 136 | 4.917E+11 | 3.254E+12 | **NR** |
| 12/14/99 | 86.975 | 4.629% | **1200** | 1.155E+12 | 8.662E+11 | 25 |
| 3/28/91 | 56.1161 | 8.785% | 100 | 6.019E+11 | 5.417E+12 | **NR** |
| 4/13/00 | 41.6005 | 13.016% | 810 | 1.553E+12 | 1.726E+12 | **NR** |
| 10/12/99 | 41.3748 | 13.191% | 660 | 3.160E+13 | 4.310E+13 | **NR** |
| 11/29/90 | 30.6711 | 19.313% | **20000** | 4.789E+14 | 2.155E+13 | 95.5 |
| 2/16/00 | 29.5035 | 20.309% | **1600** | 4.992E+12 | 2.808E+12 | 43.75 |
| 6/22/00 | 17.3983 | 38.975% | 580 | 1.533E+12 | 2.379E+12 | **NR** |
| 5/9/90 | 16.7845 | 40.692% | 73 | 7.914E+11 | 9.757E+12 | **NR** |
| 3/14/91 | 16.0452 | 43.181% | 50 | 1.541E+11 | 2.774E+12 | **NR** |
| 4/11/91 | 15.8238 | 43.902% | **1055** | 9.069E+11 | 7.737E+11 | 14.69 |
| 3/21/91 | 13.5884 | 51.568% | 40 | 1.970E+10 | 4.433E+11 | **NR** |
| 5/18/00 | 13.1102 | 53.410% | **1300** | 6.369E+12 | 4.409E+12 | 30.77 |
| 11/8/99 | 12.1716 | 57.143% | 310 | 7.371E+11 | 2.140E+12 | **NR** |
| 3/14/00 | 11.9968 | 57.815% | 70 | 6.837E+11 | 8.790E+12 | **NR** |
| 1/11/00 | 11.0031 | 62.842% | 120 | 2.577E+11 | 1.933E+12 | **NR** |
| 7/13/00 | 10.0362 | 67.670% | 380 | 8.671E+11 | 2.054E+12 | **NR** |
| 12/12/90 | 9.83998 | 68.741% | 736 | 1.940E+12 | 2.372E+12 | **NR** |
| 9/13/90 | 4.93878 | 94.276% | 30 | 1.065E+11 | 3.195E+12 | **NR** |
| 9/14/99 | 2.60261 | 99.477% | 270 | 5.464E+11 | 1.821E+12 | **NR** |
| NR = Not Required | | | | **Geometric Mean** | | **40.6** |

**Table D-6. Required Load Reduction for Mud Creek at Mile 15.8 – E. Coli Analysis**

| Sample Date | Flow | PDFE | E. Coli | | | |
|---|---|---|---|---|---|---|
| | | | Sample Conc. | Sample Load | Target Load | Required Load Reduction |
| | [cfs] | [%] | [cts/100 ml] | [cts/day] | [cts/day] | [%] |
| 12/14/99 | 86.975 | 4.629% | **>2419** | 7.906E+12 | 2.941E+12 | 62.8 |
| 4/13/00 | 41.6005 | 13.016% | 648 | 2.343E+12 | 3.254E+12 | **NR** |
| 10/12/99 | 41.3748 | 13.191% | 387 | 3.725E+11 | 8.662E+11 | **NR** |
| 2/16/00 | 29.5035 | 20.309% | 687 | 4.135E+12 | 5.417E+12 | **NR** |
| 6/22/00 | 17.3983 | 38.975% | 816 | 1.565E+12 | 1.726E+12 | **NR** |
| 5/18/00 | 13.1102 | 53.410% | **2419** | 1.158E+14 | 4.310E+13 | 62.8 |
| 11/8/99 | 12.1716 | 57.143% | 238 | 5.699E+12 | 2.155E+13 | **NR** |

**Table D-6. Required Load Reduction for Mud Creek at Mile 15.8 – E. Coli Analysis (Cont.)**

| Sample Date | Flow | PDFE | E. Coli | | | |
|---|---|---|---|---|---|---|
| | | | Sample Conc. | Sample Load | Target Load | Required Load Reduction |
| | [cfs] | [%] | [cts/100 ml] | [cts/day] | [cts/day] | [%] |
| 3/14/00 | 11.9968 | 57.815% | 285 | 8.892E+11 | 2.808E+12 | **NR** |
| 1/11/00 | 11.0031 | 62.842% | 84 | 2.220E+11 | 2.379E+12 | **NR** |
| 7/13/00 | 10.0362 | 67.670% | 91 | 9.866E+11 | 9.757E+12 | **NR** |
| 9/14/99 | 2.60261 | 99.477% | 261 | 8.043E+11 | 2.774E+12 | **NR** |
| | NR = Not Required | | | **Geometric Mean** | | **>62.8** |

**Table D-7. Required Load Reduction for Big Sandy River at Mile 45.2 – Fecal Coliform Analysis**

| Sample Date | Flow | PDFE | Fecal Coliform | | | |
|---|---|---|---|---|---|---|
| | | | Sample Conc. | Sample Load | Target Load | Required Load Reduction |
| | [cfs] | [%] | [cts/100 ml] | [cts/day] | [cts/day] | [%] |
| 12/18/90 | 1956.94 | 0.324% | **20000** | 6.536E+13 | 2.941E+12 | 95.5 |
| 2/21/91 | 978.639 | 2.439% | 230 | 8.315E+11 | 3.254E+12 | **NR** |
| 3/28/91 | 443.075 | 8.860% | **1654** | 1.592E+12 | 8.662E+11 | 45.6 |
| 12/15/99 | 399.141 | 10.329% | 130 | 7.824E+11 | 5.417E+12 | **NR** |
| 11/29/90 | 245.968 | 19.164% | **6300** | 1.208E+13 | 1.726E+12 | 85.7 |
| 10/13/99 | 200.227 | 24.415% | 300 | 1.437E+13 | 4.310E+13 | **NR** |
| 7/18/90 | 147.754 | 36.063% | 136 | 3.257E+12 | 2.155E+13 | **NR** |
| 6/21/00 | 145.102 | 36.884% | 230 | 7.176E+11 | 2.808E+12 | **NR** |
| 5/9/90 | 133.566 | 40.642% | 145 | 3.832E+11 | 2.379E+12 | **NR** |
| 3/14/91 | 127.506 | 43.206% | 936 | 1.015E+13 | 9.757E+12 | **NR** |
| 4/11/91 | 125.947 | 43.902% | 510 | 1.572E+12 | 2.774E+12 | **NR** |
| 3/21/91 | 108.015 | 51.593% | 40 | 3.439E+10 | 7.737E+11 | **NR** |
| 5/17/00 | 107.708 | 51.767% | 110 | 5.418E+10 | 4.433E+11 | **NR** |
| 11/8/99 | 97.1748 | 56.919% | 58 | 2.842E+11 | 4.409E+12 | **NR** |
| 3/15/00 | 93.2557 | 59.059% | 22 | 5.231E+10 | 2.140E+12 | **NR** |
| 1/11/00 | 87.7792 | 62.643% | **1100** | 1.074E+13 | 8.790E+12 | 18.2 |
| 7/12/00 | 82.6981 | 65.978% | 70 | 1.504E+11 | 1.933E+12 | **NR** |
| 12/12/90 | 78.3603 | 68.566% | 127 | 2.898E+11 | 2.054E+12 | **NR** |
| 9/13/90 | 39.3338 | 94.301% | 170 | 4.480E+11 | 2.372E+12 | **NR** |
| 8/18/99 | 35.1319 | 96.466% | 76 | 2.698E+11 | 3.195E+12 | **NR** |
| 9/15/99 | 20.1311 | 99.527% | 68 | 1.376E+11 | 1.821E+12 | **NR** |
| | NR = Not Required | | | **Geometric Mean** | | **51.0** |

**Table D-8. Required Load Reduction for Big Sandy River at Mile 45.2 – E. Coli Analysis**

| Sample Date | Flow | PDFE | Fecal Coliform | | | |
|---|---|---|---|---|---|---|
| | | | Sample Conc. | Sample Load | Target Load | Required Load Reduction |
| | [cfs] | [%] | [cts/100 ml] | [cts/day] | [cts/day] | [%] |
| 12/15/99 | 399.141 | 10.329% | 128 | 4.183E+11 | 2.941E+12 | **NR** |
| 4/11/00 | 292.709 | 15.431% | 272 | 9.834E+11 | 3.254E+12 | **NR** |
| 10/13/99 | 200.227 | 24.415% | 261 | 2.512E+11 | 8.662E+11 | **NR** |
| 6/21/00 | 145.102 | 36.884% | 145 | 8.727E+11 | 5.417E+12 | **NR** |
| 5/17/00 | 107.708 | 51.767% | 135 | 2.588E+11 | 1.726E+12 | **NR** |
| 11/8/99 | 97.1748 | 56.919% | 50 | 2.394E+12 | 4.310E+13 | **NR** |
| 3/15/00 | 93.2557 | 59.059% | 17 | 4.071E+11 | 2.155E+13 | **NR** |
| 1/11/00 | 87.7792 | 62.643% | **1120** | 3.494E+12 | 2.808E+12 | 19.6 |
| 7/12/00 | 82.6981 | 65.978% | 57 | 1.507E+11 | 2.379E+12 | **NR** |
| 8/18/99 | 35.1319 | 96.466% | 13 | 1.409E+11 | 9.757E+12 | **NR** |
| 9/15/99 | 20.1311 | 99.527% | 51 | 1.572E+11 | 2.774E+12 | **NR** |
| NR = Not Required | | | | **Geometric Mean** | | **19.6** |

# APPENDIX E

## 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 fecal coliform 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. Since discharges from a CAFO liquid waste handling facility to waters of the state during a chronic or catastrophic rainfall event (in excess of a 25-year, 24-hour rainfall event), or as a result of an unpermitted discharge, upset, or bypass of the system, are not to cause or contribute to an exceedance of Tennessee water quality standards, the WLA = 0.

- $[\sum WLAs]_{MS4}$ is the required load reduction for discharges from MS4s. Fecal coliform 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 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 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 and Appendix D. TMDLs, WLAs, & LAs are applied to the entire subwatershed. WLAs & LAs for Kentucky Lake waterbodies are summarized in Table E-1.

**Table E-1. WLAs & LAs for Kentucky Lake, Tennessee**

| Impaired Waterbody Name | Impaired Waterbody ID | WLAs | | | | | LAs | |
|---|---|---|---|---|---|---|---|---|
| | | WWTFs [a] (Monthly Avg.) | | Leaking Collection Systems[b] | CAFOs | MS4s[c] | Precipitation Induced Nonpoint Sources | Other Direct Sources[d] |
| | | Fecal Coliform | E. Coli | | | | | |
| | | [cts./day] | [cts./day] | [cts./day] | [cts./day] | [% Red.] | [% Red.] | [cts./day] |
| HOLLY FORK CREEK | TN06040005024 – 1000 | **$1.893 \times 10^{10}$** | **$1.193 \times 10^{10}$** | **0** | **0** | **NA** | **75.1** | **0** |
| LITTLE BEAVER CREEK | TN06040005032 – 0710 | **0** | **0** | **NA** | **NA** | **NA** | **74.1** | **0** |
| MUD CREEK | TN06040005032 – 0900 | **0** | **0** | **NA** | **NA** | **NA** | **52.3** | **0** |
| BIG SANDY RIVER | TN06040005032 – 1000 | **0** | **0** | **NA** | **NA** | **NA** | **44.8** | **0** |
| BIG SANDY RIVER | TN06040005032 – 2000 | **0** | **0** | **NA** | **NA** | **NA** | **56.9** | **0** |

Note: NA = Not applicable.

a. WLAs for WWTFs expressed as fecal coliform and 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 pathogens.

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 pathogens.

# APPENDIX F

## Public Notice of Proposed Total Maximum Daily Loads (TMDLs) for Pathogens in the Kentucky Lake Watershed (HUC 06040005)

**DIVISION OF WATER POLLUTION CONTROL**

**PUBLIC NOTICE OF AVAILABILITY OF PROPOSED TOTAL MAXIMUM DAILY LOAD (TMDL) FOR PATHOGENS IN THE KENTUCKY LAKE WATERSHED (HUC 06040005), TENNESSEE**

Announcement is hereby given of the availability of Tennessee's proposed total maximum daily load (TMDL) for pathogens in the Kentucky Lake watershed, located in northwest 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.

Holly Fork Creek, Little Beaver Creek, Mud Creek, and Big Sandy River 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 grazing. The TMDL utilizes Tennessee's general water quality criteria, recently collected site specific water quality data, continuous flow data from a USGS discharge monitoring station located in the watershed, and a calibrated dynamic water quality model to establish allowable loadings of pathogens which will result in reduced in-stream concentrations and attainment of water quality standards. The TMDL requires reductions on the order of 44.8% - 75.1% for the impaired waterbodies.

The proposed Kentucky Lake pathogen TMDL document can be downloaded from the following website:

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

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

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

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

Persons wishing to comment on the proposed TMDL are invited to submit their comments in writing no later than December 13, 2004 to:

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

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

The TMDL and supporting information are on file at the Division of Water Pollution Control, 7th Floor L & C Annex, 401 Church Street, Nashville, Tennessee. They may be inspected during normal office hours. Copies of the information on file are available on request.