# TOTAL MAXIMUM DAILY LOAD (TMDL)

## for

## E. Coli

## in the

## Obion River Watershed (HUC 08010202)

## Dyer, Gibson, Henry, Lake, Lauderdale, Obion,

## and Weakley Counties, Tennessee

**FINAL**


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

## SUMMARY SHEET

### Total Maximum Daily Load for E. Coli in Selected Waterbodies of the Obion River Watershed (HUC 08010202)

**Impaired Waterbody Information**

State: Tennessee
Counties: Obion, and Weakley
Watershed: Obion River (HUC 08010202)
Constituents of Concern: E. coli

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

| Waterbody ID | Waterbody | RM not Fully Supporting |
|---|---|---|
| TN08010202001 – 4000 | OBION RIVER* | 7.6 |
| TN08010202009 – 0700 | BIGGS CREEK | 2.2 |
| TN08010202009 – 0710 | HURRICANE CREEK | 13.6 |
| TN08010202036 – 1000 | REELFOOT CREEK | 8.0 |

* A 7.6 mile segment from the confluence of Mill Creek to the confluence of North and South Forks Obion River.

Designated Uses:

The designated use classifications for all impaired waterbodies in the Obion River watershed include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation.

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.

TMDL Scope:

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

Analysis/Methodology:

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

Critical Conditions:

Water quality data collected over a period of up to 10 years for load duration curve analysis were used to assess the water quality standards representing a range of hydrologic and meteorological conditions.

Seasonal Variation:

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

Margin of Safety (MOS):

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

## TMDLs, WLAs, & LAs

**Summary of TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Obion River Watershed (HUC 08010202)**

| HUC-12 Subwatershed (08010202__) | Impaired Waterbody Name | Impaired Waterbody ID | TMDL | MOS | WLAs[a] | | | LAs |
|---|---|---|---|---|---|---|---|---|
| | | | | | WWTFs[b] | Leaking Collection Systems | CAFOs | |
| | | | [CFU/day] | [CFU/day] | [CFU/day] | [CFU/day] | [CFU/day] | [CFU/day/acre] |
| 0104 | Biggs Creek | TN08010202009 – 0700 | $2.30 \times 10^{10} * Q$ | $2.30 \times 10^{9} * Q$ | NA | NA | NA | $1.934 \times 10^{6} * Q$ |
| | Hurricane Creek | TN08010202009 – 0710 | $2.30 \times 10^{10} * Q$ | $2.30 \times 10^{9} * Q$ | NA | NA | NA | $2.049 \times 10^{6} * Q$ |
| 0201/0301 | Obion River | TN08010202001 – 4000 | $1.19 \times 10^{10} * Q$ | $1.19 \times 10^{9} * Q$ | $3.874 \times 10^{11}$ | 0 | NA | $1.424 \times 10^{4} * Q – 5.145 \times 10^{5}$ |
| 0401/0403 | Reelfoot Creek | TN08010202036 – 1000 | $2.30 \times 10^{10} * Q$ | $2.30 \times 10^{9} * Q$ | NA | NA | 0 | $2.773 \times 10^{5} * Q$ |

*Note: NA = Not applicable.*
*Q = Mean Daily In-stream Flow (cfs).*
*a. There are no MS4s in impaired subwatersheds of the Obion River watershed.*
*b. WLAs for WWTFs expressed as E. coli loads (CFU/day). Future WWTFs must meet water quality standards at the point of discharge as specified in their NPDES permits. At no time shall concentration exceed appropriate, site-specific (487 CFU/100 mL or 941 CFU/100 mL) water quality standards.*

# E. COLI TOTAL MAXIMUM DAILY LOAD (TMDL)
# OBION RIVER WATERSHED (HUC 08010202)

## 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 Obion River Watershed identified on the Final 2006 303(d) List as not supporting designated uses due to Escherichia coli (E. coli). The Obion River watershed lies primarily in the state of Tennessee with a portion located in Kentucky. TMDL analyses were performed on a waterbody drainage area basis.

## 3.0 WATERSHED DESCRIPTION

The Obion River watershed (HUC 08010202) is located primarily in northwestern Tennessee (Figure 1), with a small portion in southwestern Kentucky, and lies within the Level III Southeastern Plains (65), Mississippi Alluvial Plain (73), and Mississippi Valley Loess Plains (74) ecoregions as shown in Figure 2 (USEPA, 1997). The impaired subwatersheds lie in the Level IV Northern Mississippi Alluvial Plain (73a), Bluff Hills (74a), and Loess Plains (74b) ecoregions:

- Within Tennessee, the Northern Mississippi Alluvial Plain (73a) is a relatively homogenous region of Quaternary alluvial deposits of sand, silt, clay, and gravel. It is bounded distinctly on the east by the Bluff Hills (74a) and on the west by the Mississippi River. The two main distinctions in the Tennessee portion of the ecoregion are between areas of loamy, silty, and sandy soils with better drainage, and areas of more clayey soils of poor drainage that may contain wooded swampland and oxbow lakes.

- Along the western edge of the Bluff Hills (74a) ecoregion, bordering the Mississippi Alluvial Plain, are deep loess hilly areas, often called bluff hills. Consisting of sand, clay, silt, and lignite, the bluffs are capped by loess greater than 60 feet deep. The disjunct ecoregion in Tennessee encompasses those thick loess areas that are generally the steepest, most dissected, and forested. Smaller streams of the Bluff Hills have localized reaches of increased gradient and small areas of gravel substrate that create aquatic habitats that are distinct from those of the Loess Plains (74b) to the east.

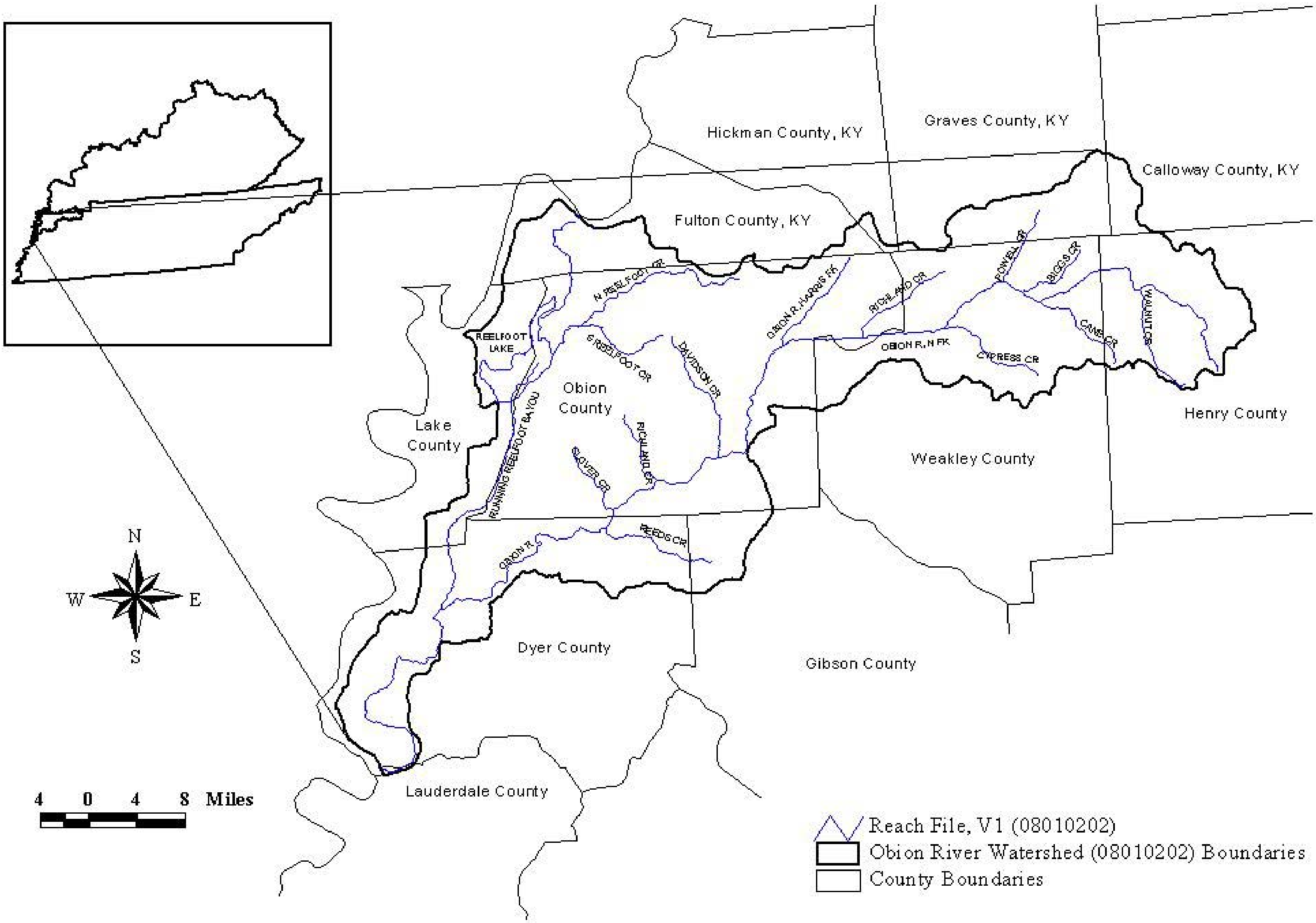


**Figure 1. Location of the Obion River Watershed.**

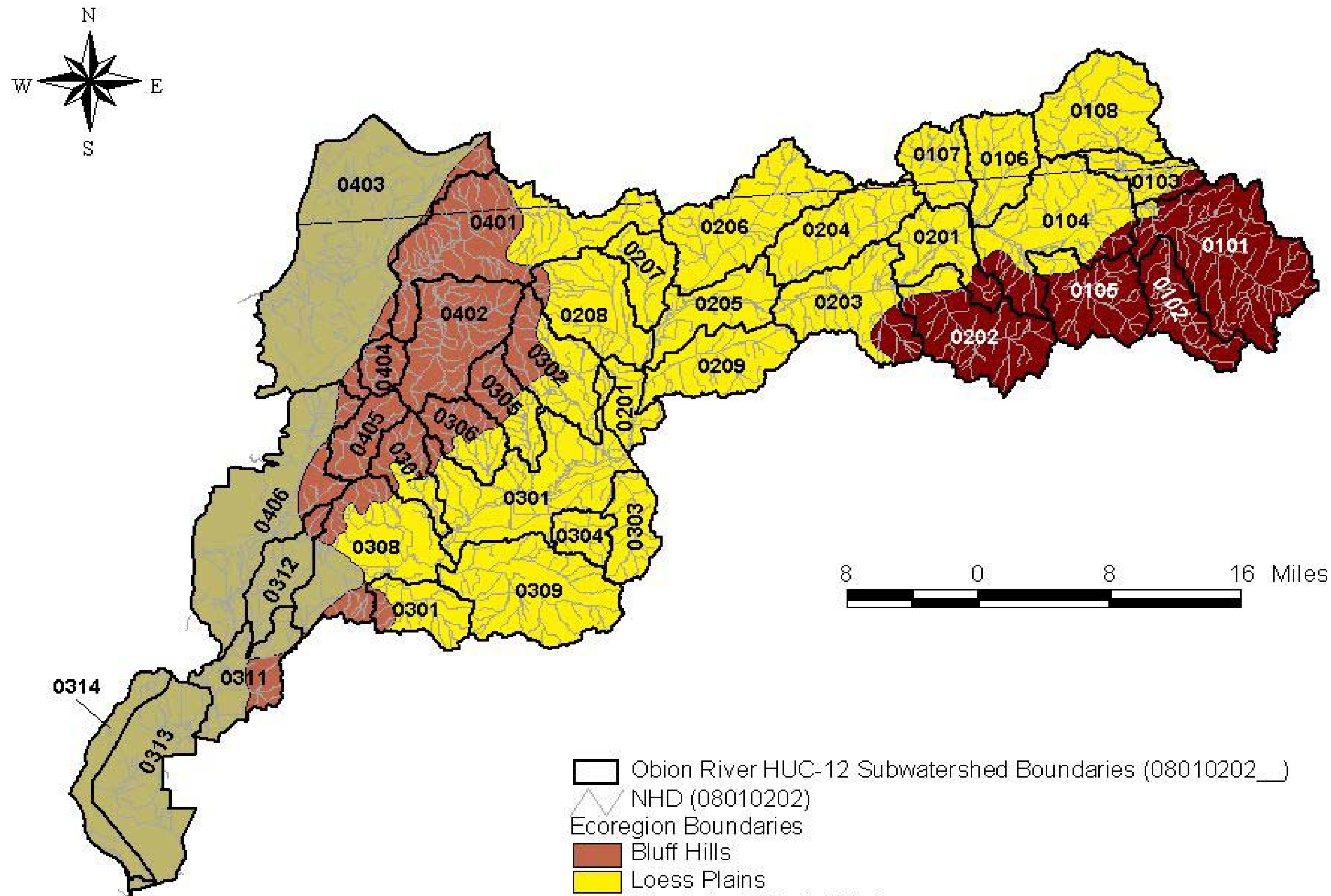


**Figure 2. Level IV Ecoregions in the Obion River Watershed.**

- The Loess Plains (74b) ecoregion within Tennessee consists of gently rolling, irregular plains, with 100-200 feet of local relief. The loess can be over 50 feet thick. Several large river systems and their tributaries cross the ecoregion with wide flood plains that are distinct from the adjacent uplands. Streams of the ecoregion are low-gradient and murky, with silt and sand bottoms. Many of the streams have been deforested and channelized. Valley plugs or channel blockages, where channel aggradation and driftwood accumulation combine to change flow patterns, are common along the low-gradient alluvial streams in this region.

The Obion River watershed, located in Dyer, Gibson, Henry, Lake, Lauderdale, Obion, and Weakley Counties, Tennessee, and Calloway, Fulton, Graves, and Hickman Counties, Kentucky, has a drainage area of approximately 1313 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 Obion River watershed have occurred since 1993 as a result of development, this is the most current land use data available. Land use for the Obion River watershed is summarized in Table 1 and shown in Figure 3. Predominate land use in the Obion River watershed is agriculture (68.2%) followed by forest (28.7%). Urban areas represent approximately 1.1% of the total drainage area of the watershed. Details of land use distribution of E. coli-impaired subwatersheds in the Obion River watershed are presented in Appendix A.

## 4.0 PROBLEM DEFINITION

The State of Tennessee's Final 2006 303(d) List (TDEC, 2006) was approved by the U.S. Environmental Protection Agency (EPA), Region IV in October of 2006. The list identified four (4) waterbody segments in the Obion River watershed as not fully supporting designated use classifications due, in part, to E. coli. See Table 2 and Figure 4. The designated use classifications for these waterbodies include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation.

**Table 1. MRLC Land Use Distribution – Obion River Watershed**

| Land Use | Area | |
|---|---|---|
| | [acres] | [%] |
| Bare Rock/Sand/Clay | 1 | 0.0* |
| Deciduous Forest | 125,595 | 14.9 |
| Evergreen Forest | 8,030 | 1.0 |
| High Intensity Commercial/ Industrial/Transportation | 2,873 | 0.3 |
| High Intensity Residential | 894 | 0.1 |
| Low Intensity Residential | 4,831 | 0.6 |
| Mixed Forest | 40,636 | 4.8 |
| Open Water | 15,773 | 1.9 |
| Other Grasses (Urban/recreational) | 980 | 0.1 |
| Pasture/Hay | 233,063 | 27.7 |
| Quarries/Strip Mines/Gravel Pits | 82 | 0.0* |
| Row Crops | 334,025 | 39.8 |
| Small Grains | 5,850 | 0.7 |
| Transitional | 393 | 0.0* |
| Woody Wetlands | 64,182 | 7.6 |
| Emergent Herbaceous Wetlands | 3,064 | 0.4 |
| **Total** | **840,272** | **100.00** |

* < 0.05%

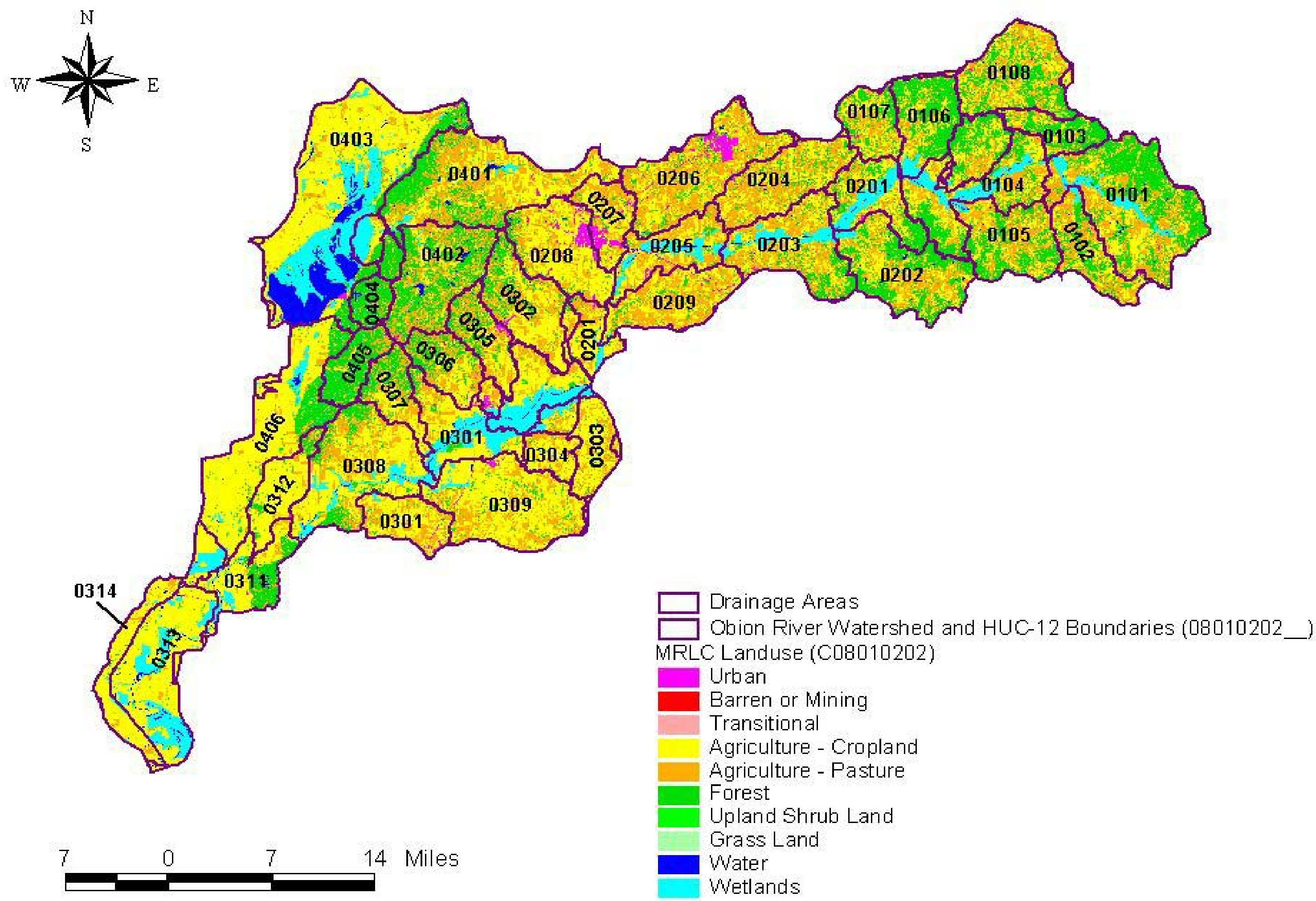


**Figure 3. Land Use Characteristics of the Obion River Watershed.**

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

| Waterbody ID | Impacted Waterbody | Miles/Acres Impaired | CAUSE / TMDL Priority | Pollutant Source |
|---|---|---|---|---|
| TN08010202001 – 4000 | OBION RIVER | 7.6 | Loss of biological integrity due to Siltation<br>Physical Substrate Habitat Alterations<br>Escherichia coli | Nonirrigated Crop Production<br>Channelization<br>Undetermined Source |
| TN08010202009 – 0700 | BIGGS CREEK | 2.2 | Escherichia coli | Agriculture |
| TN08010202009 –0710 | HURRICANE CREEK | 13.6 | Nutrients<br>Loss of biological integrity due to siltation<br>Habitat loss due to alteration in stream-side or littoral vegetative cover<br>Escherichia coli | Agriculture<br>Nonirrigated Crop Production<br>Channelization |
| TN08010202036 – 1000 | REELFOOT CREEK | 8.0 | Loss of biological integrity due to Siltation<br>Nutrients<br>Habitat loss due to stream flow alteration<br>Escherichia coli | Nonirrigated Crop Production<br>Upstream Impoundment<br>Channelization |

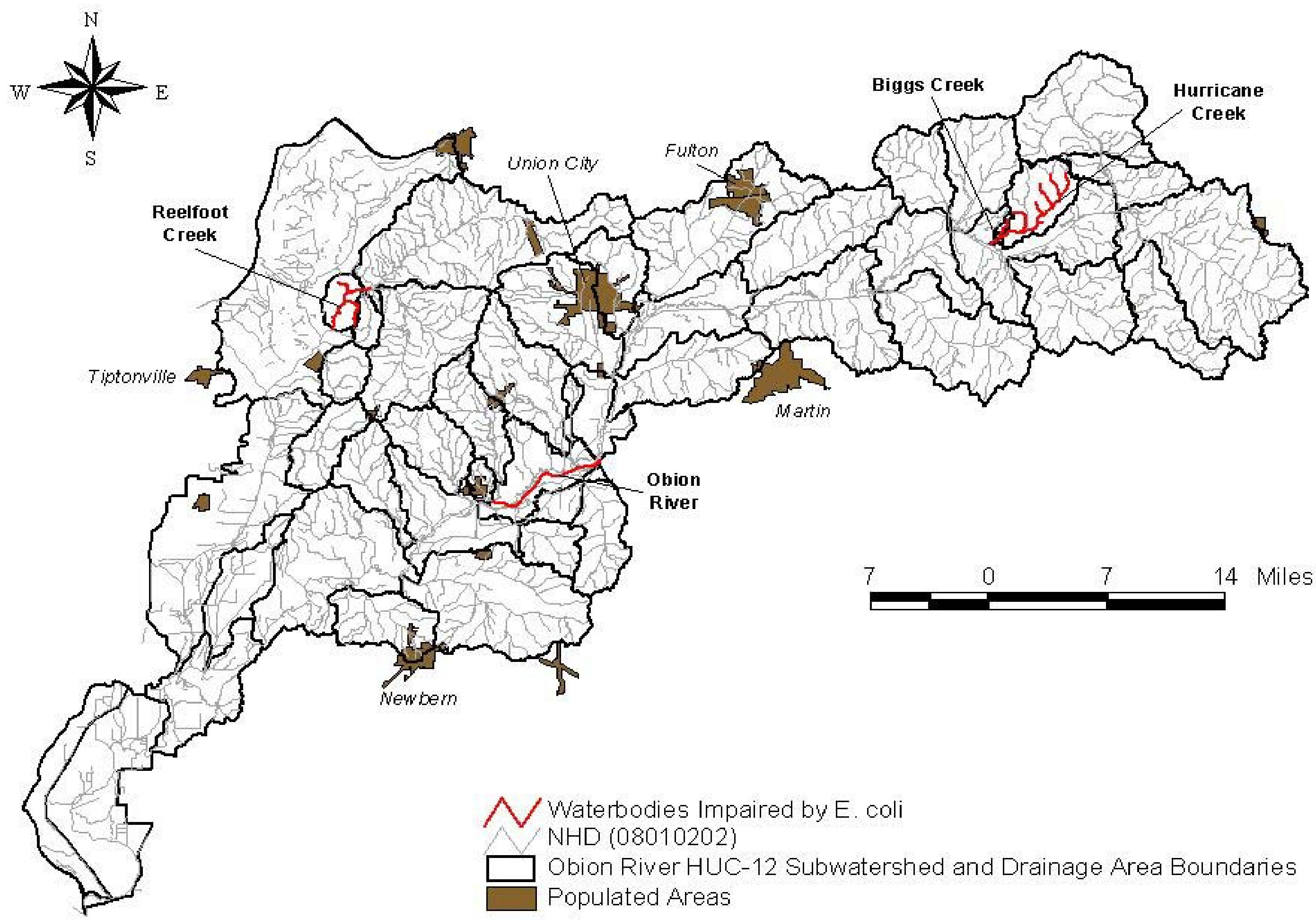


**Figure 4. Waterbodies Impaired by E. Coli (as Documented on the Final 2006 303(d) List).**

## 5.0 WATER QUALITY CRITERIA & TMDL TARGET

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

A portion of the Obion River within the Gooch Wildlife Management Area and the Obion River Wildlife Management Area has been designated as a Tier II stream. As of February 2, 2006, none of the other E. coli impaired waterbodies in the Obion River watershed have been designated as either State Scenic River, Tier II, or Tier III streams.

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

## 6.0 WATER QUALITY ASSESSMENT AND DEVIATION FROM TARGET

There are several water quality monitoring stations that provide data for waterbodies identified as impaired for E. coli in the Obion River watershed: Monitoring stations located on Tier II waterbodies have been italicized:

- HUC-12 080102020104:
  - HURRI000.7WY – Hurricane Creek, at Donoho Levee Road
- HUC-12s 080102020201/080102020301:
  - *OBION062.5OB – Obion River, at Hwy 51*
- HUC-12s 080102020401/080102020403:
  - REELF004.2OB – Reelfoot Creek, at Hwy 22

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

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

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

Note: Hurricane Creek is a tributary to Biggs Creek. There are no water quality monitoring data available on Biggs Creek. Therefore, water quality data for Hurricane Creek (HURRI000.7WY) were used for TMDL development and calculation of load reduction for Biggs Creek.

**Table 3. Summary of Water Quality Monitoring Data**

| Monitoring Station | E. Coli (Single Sample Max. WQ Target = 941 CFU/100 mL)* | | | | | |
|---|---|---|---|---|---|---|
| | Data Pts. | Date Range | [CFU/100 mL] | | | Exceed WQ Max. Target |
| | | | Min. | Avg. | Max. | |
| HURRI000.7WY | 15 | 2/01-12/05 | 20 | 695.5 | 6586 | 2 |
| *OBION062.5OB* | *6* | *7/05-12/05* | *23* | *590.5* | *>2419.2* | *2* |
| REELF004.2OB | 12 | 5/00-4/01 | 33 | 667.1 | >2419.2 | 3 |

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

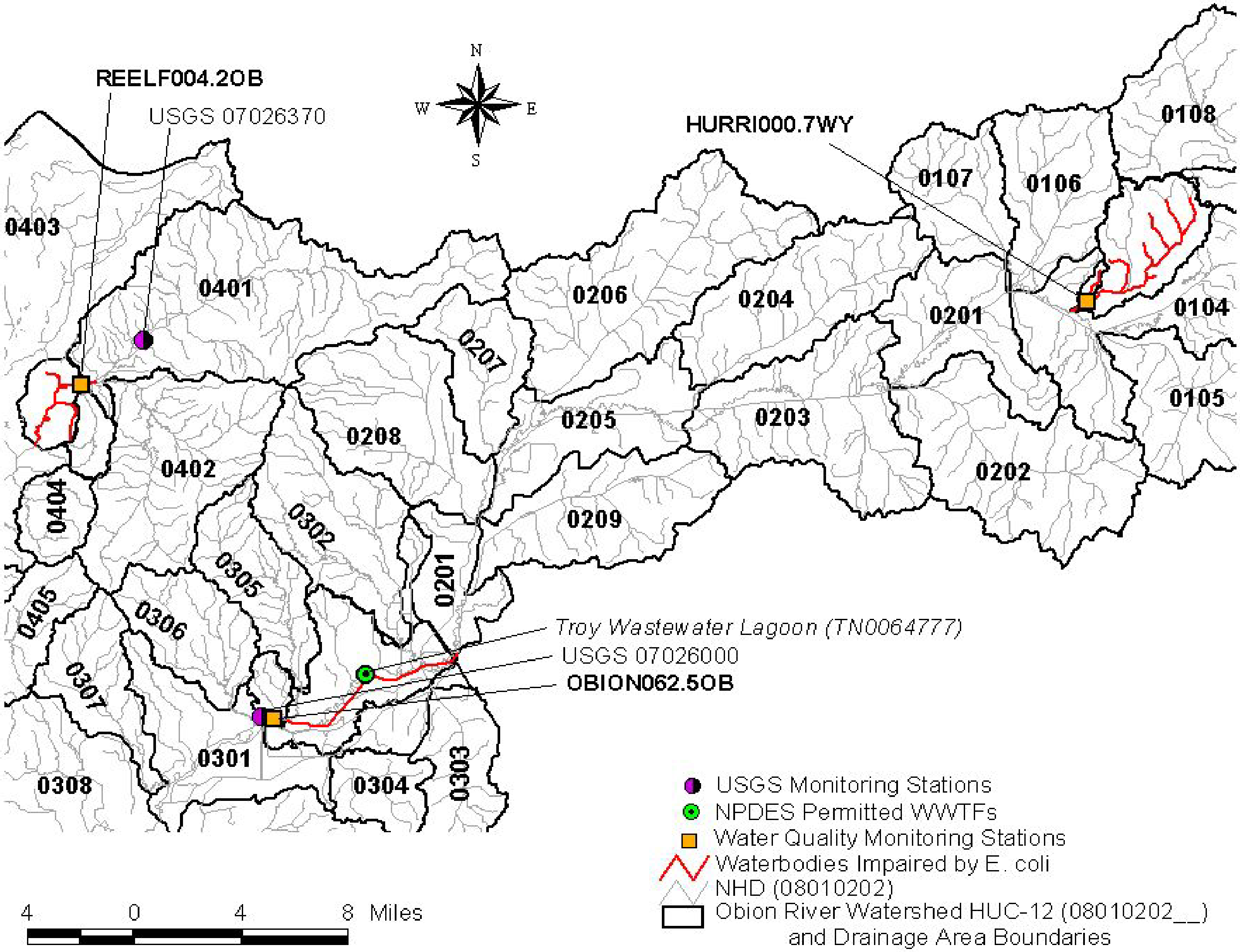


**Figure 5. Monitoring Stations and NPDES permitted WWTFs in the Obion River Watershed.**

## 7.0 SOURCE ASSESSMENT

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

Under the Clean Water Act, sources are classified as either point or nonpoint sources. Under 40 CFR §122.2, 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 WLAs for all NPDES regulated point sources. Nonpoint sources are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. For the purposes of this TMDL, all sources of pollutant loading not regulated by NPDES permits are considered nonpoint sources. The TMDL must provide a LA for these sources.

### 7.1 Point Sources

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

Both treated and untreated sanitary wastewater contain coliform bacteria. There was one (1) NPDES permitted WWTF in the Tennessee portion of the impaired subwatersheds of the Obion River watershed authorized to discharge treated sanitary wastewater during the TMDL analysis period. This facility, the Troy Wastewater Lagoon, NPDES permit number TN0064777 (Figure 5) has a design flow capacity equal to 0.2 million gallons per day (MGD) and discharges to the Obion River at mile 61.2. The permit limits for discharges from this WWTF are in accordance with the coliform criteria specified in Tennessee Water Quality Standards for protection of the recreation use classification.

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

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

#### 7.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

Municipal Separate Storm Sewer Systems (MS4s) are considered to be point sources of E. coli. Discharges from MS4s occur in response to storm events through road drainage systems, curb and gutter systems, ditches, and storm drains. Phase I of the EPA storm water program requires large and medium MS4s to obtain NPDES storm water permits. Large and medium MS4s are those located in incorporated places or counties serving populations greater than 100,000 people. At present, there are no MS4s of this size in the Obion River watershed.

As of March 2003, regulated small MS4s in Tennessee must also obtain NPDES permits in accordance with the Phase II storm water program. A small MS4 is designated as *regulated* if: a) it is located within the boundaries of a defined urbanized area that has a residential population of at least 50,000 people and an overall population density of 1,000 people per square mile; b) it is located outside of an urbanized area but within a jurisdiction with a population of at least 10,000 people, a population density of 1,000 people per square mile, and has the potential to cause an adverse impact on water quality; or c) it is located outside of an urbanized area but contributes substantially to the pollutant loadings of a physically interconnected MS4 regulated by the NPDES storm water program. Most regulated small MS4s in Tennessee obtain coverage under the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (TDEC, 2003). There are no permitted Phase II MS4s located in the drainage areas of (E. coli) 303(d)-listed waterbodies in the Obion River watershed.

The Tennessee Department of Transportation (TDOT) has been issued an individual MS4 permit (TNS077585) that authorizes discharges of storm water runoff from State road and interstate highway right-of-ways that TDOT owns or maintains, discharges of storm water runoff from TDOT owned or operated facilities, and certain specified non-storm water discharges. This permit covers all eligible TDOT discharges statewide, including those located outside of urbanized areas.

Information regarding storm water permitting in Tennessee may be obtained from the Tennessee Department of Environment and Conservation (TDEC) website at:

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

7.1.3 NPDES Concentrated Animal Feeding Operations (CAFOs)

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

As of August 14, 2006, there were seven (7) Class II CAFOs in the Obion River watershed with coverage under the general NPDES permit. Of the seven, only one (TNA000013) is located in the drainage area of a (E. coli) 303(d)-listed waterbody. In addition, there were five (5) Class I CAFOs with individual permits located in the Obion River watershed. None of these five are located in drainage areas of (E. coli) 303(d)-listed waterbodies. The locations of CAFOs in the Obion River watershed are shown in Figure 6.

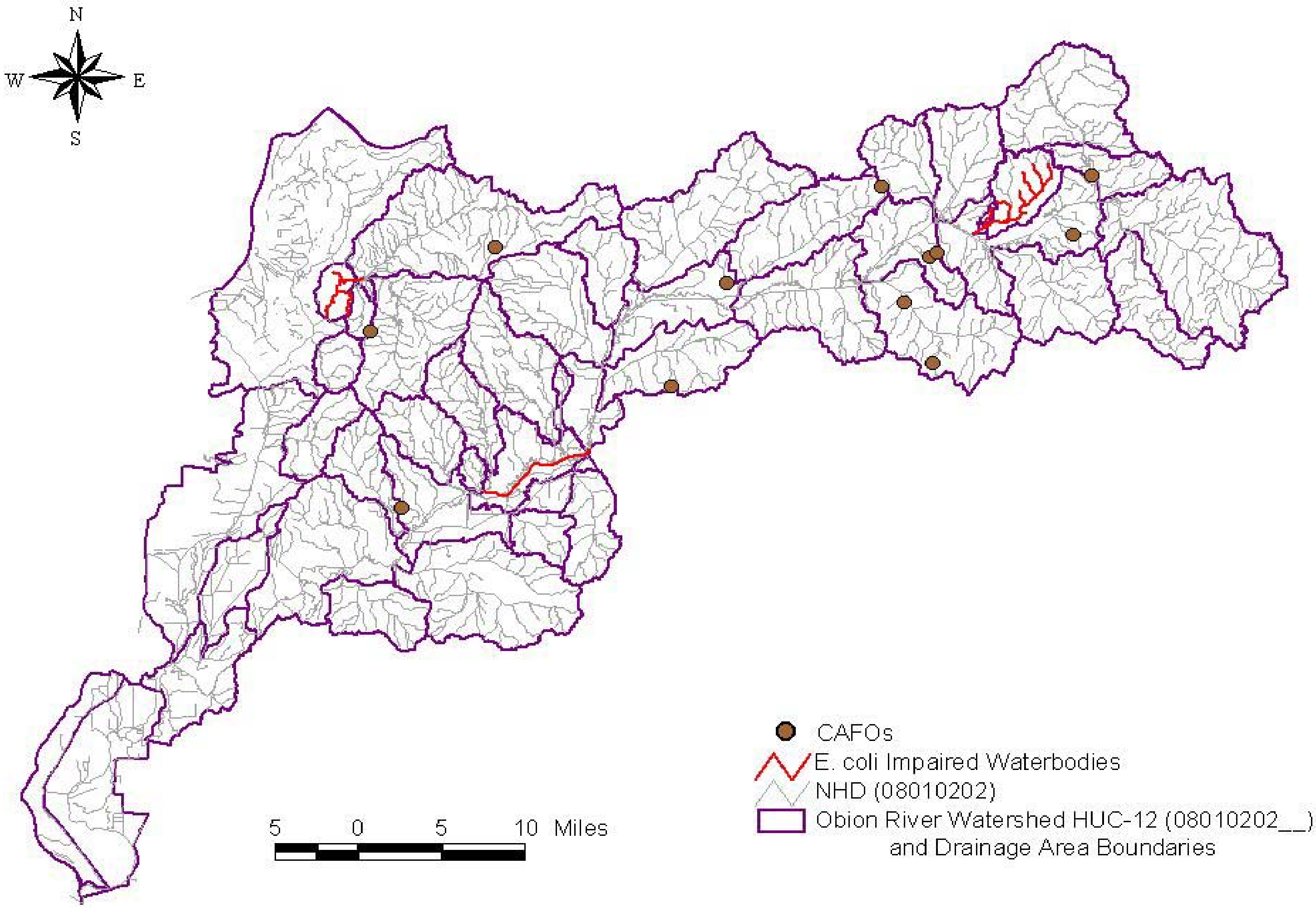


**Figure 6. Location of CAFOs in the Obion River Watershed.**

## 7.2 Nonpoint Sources

Nonpoint sources of coliform bacteria are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. These sources generally, but not always, involve accumulation of coliform bacteria on land surfaces and wash off as a result of storm events. Nonpoint sources of E. coli loading are primarily associated with agricultural and urban land uses. The vast majority of waterbodies identified on the Final 2006 303(d) List as impaired due to E. coli are attributed to nonpoint agricultural or urban sources.

### 7.2.1 Wildlife

Wildlife deposit coliform bacteria, with their feces, onto land surfaces where it can be transported during storm events to nearby streams. The overall deer density for Tennessee was estimated by the Tennessee Wildlife Resources Agency (TWRA) to be 23 animals per square mile. In addition, Wildlife Management Areas (WMAs) (e.g., the Gooch WMA, located in the vicinity of the 303(d)-listed segment of the Obion River) have significant seasonal populations of ducks and geese.

### 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 and dry litter from confined feeding operations is often applied to land surfaces and can provide a significant source of coliform bacteria loading. Guidance for issues relating to manure application is available through the University of Tennessee Agricultural Extension Service and the Natural Resources Conservation Service (NRCS).
- Agricultural livestock and other unconfined animals (i.e., deer and other wildlife) often have direct access to waterbodies and can provide a concentrated source of coliform bacteria loading directly to a stream.

Data sources related to livestock operations include the 2002 Census of Agriculture. Livestock data, for counties containing E. coli-impaired subwatersheds, are summarized in Table 4. Note that, due to confidentiality issues, any tabulated item that identifies data reported by a respondent or allows a respondent's data to be accurately estimated or derived is suppressed and coded with a 'D' (USDA, 2004).

**Table 4. Livestock Distribution in the Obion River Watershed**

| County Name | Livestock Population (2002 Census of Agriculture)* | | | | | | |
|---|---|---|---|---|---|---|---|
| | Beef Cow | Milk Cow | Hogs | Sheep | Poultry (Layers) | Poultry (Broilers) | Horses |
| Obion | (D) | (D) | (D) | 481 | (D) | 775,315 | 918 |
| Weakley | 8,304 | 1,126 | 51,302 | 335 | (D) | 526,997 | 1,622 |

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

### 7.2.3 Failing Septic Systems

Some coliform loading in the Obion River watershed can be attributed to failure of septic systems and illicit discharges of raw sewage. Estimates from 2000 county census data of people utilizing septic systems, for counties containing E. coli-impaired subwatersheds in the Obion River watershed, were compiled using the WCS and are summarized in Table 5. In western Tennessee, it is estimated that there are approximately 2.37 people per household on septic systems, some of which can be reasonably assumed to be failing. As with livestock in streams, discharges of raw sewage provide a concentrated source of coliform bacteria directly to waterbodies.

**Table 5. Population on Septic Systems in the Obion River Watershed**

| County Name | Population on Septic Systems |
|---|---|
| Obion | 2,285 |
| Weakley | 23,552 |

### 7.2.4 Urban Development

Nonpoint source loading of coliform bacteria from urban land use areas is attributable to multiple sources. These include: stormwater runoff, illicit discharges of sanitary waste, runoff from improper disposal of waste materials, leaking septic systems, and domestic animals. Impervious surfaces in urban areas allow runoff to be conveyed to streams quickly, without interaction with soils and groundwater. The Obion River drainage area (near Obion) has the highest percentage of urban land area for impaired subwatersheds in the Obion River watershed, with approximately 0.2%. Land use for the Obion River impaired drainage areas is summarized in Figures 7 and 8 and tabulated in Appendix A.

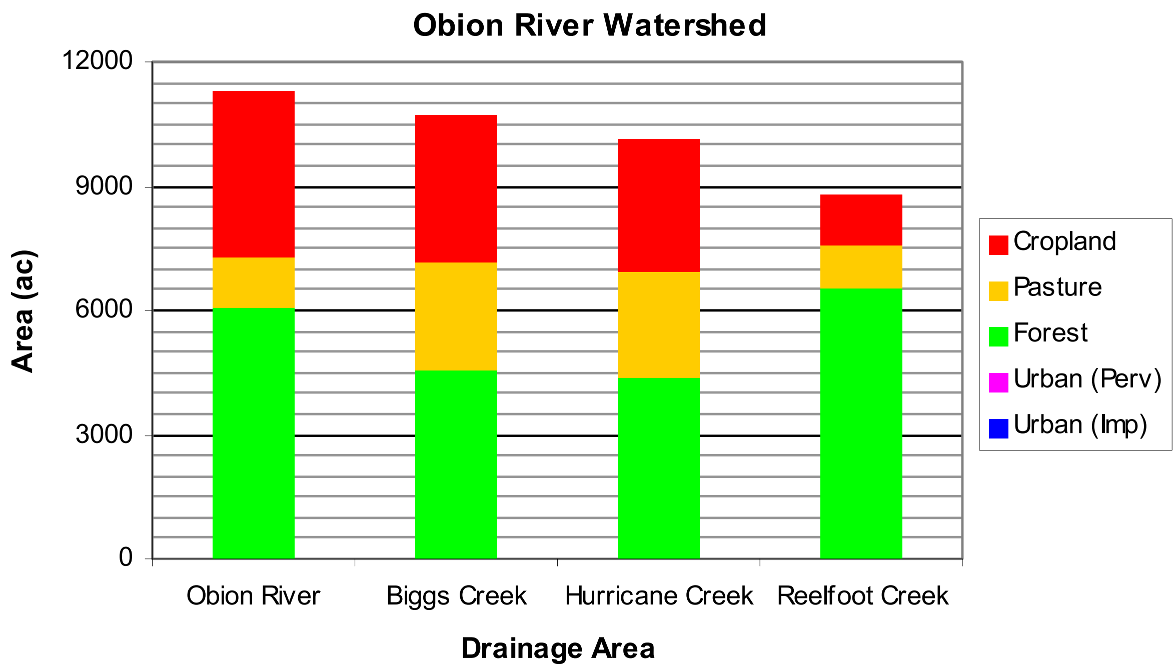


**Figure 7. Land Use Area of Obion River Watershed Drainage Areas Obion River, Biggs Creek, Hurricane Creek, and Reelfoot Creek.**

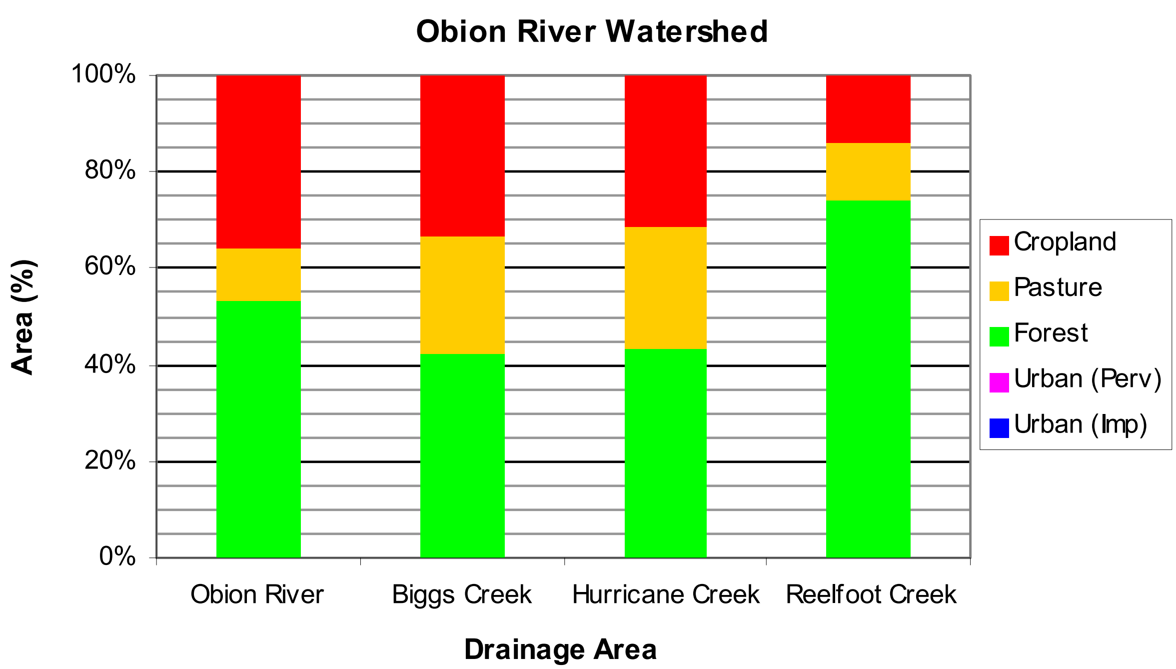


**Figure 8. Land Use Percent of Obion River Watershed Drainage Areas Obion River, Biggs Creek, Hurricane Creek, and Reelfoot Creek.**

## 8.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOAD

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

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

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

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

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

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

### 8.2 Area Basis for TMDL Analysis

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

### 8.3 TMDL Analysis Methodology

TMDLs for the Obion River watershed were developed using load duration curves for analysis of impaired waterbody drainage areas. A load duration curve (LDC) is a cumulative frequency graph that illustrates existing water quality conditions (as represented by loads calculated from monitoring data), how these conditions compare to desired targets, and the portion of the waterbody flow regime represented by these existing loads. Load duration curves are considered to be well suited for analysis of periodic monitoring data collected by grab sample. LDCs were developed at monitoring site locations in impaired waterbodies and a daily loading function and an overall load reduction were calculated to meet E. coli targets according to the methods described in Appendix C.

## 8.4 Critical Conditions and Seasonal Variation

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

The ten-year period from January 1, 1996 to December 31, 2005 was used to simulate flow. This 10-year period contained a range of hydrologic conditions that included both low and high streamflows. Critical conditions are accounted for in the load duration curve analyses by using the entire period of flow and water quality data available for the impaired waterbodies. In most subwatersheds, water quality data have been collected during most flow ranges. Based on the location of the water quality exceedances on the load duration curves, no one delivery mode for E. coli appears to be dominant (see Section 9.3 and Appendix C).

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

## 8.5 Margin of Safety

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

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

MOS = 49 CFU/100 ml

Instantaneous Maximum (other): MOS = 94 CFU/100 ml

30-Day Geometric Mean: MOS = 13 CFU/100 ml

## 8.6 Determination of TMDLs

E. coli daily loading functions and percent load reductions were calculated for impaired segments in the Obion River watershed using LDCs to evaluate compliance with the single sample maximum target concentrations according to the procedure in Appendix C. These TMDL loading functions for impaired segments and subsequent subwatersheds are shown in Table 6. When sufficient data were available, percent load reductions (only) were also calculated to achieve the 30-day geometric mean target loading. Both in-stream percent load reductions (where applicable) for a particular waterbody were compared and the largest calculated percent load reduction was selected for TMDL implementation. In cases where the geometric mean could not be calculated, it is assumed that achieving the percent load reduction based on the single sample maximum target concentrations should result in attainment of the geometric mean criteria.

## 8.7 Determination of WLAs & LAs

WLAs for MS4s and LAs for precipitation induced sources of E. coli loading were determined according to the procedures in Appendix C. These allocations represent the allowable loads and subsequent percent load reductions required to achieve in-stream targets after application of the explicit MOS. WLAs for existing WWTFs are equal to their existing NPDES permit limits. Since WWTF permit limits require that E. coli concentrations must comply with water quality criteria (TMDL targets) at the point of discharge and recognition that loading from these facilities is generally small in comparison to other loading sources, further reductions were not considered to be warranted. WLAs for CAFOs and LAs for “other direct sources” (non-precipitation induced) are equal to zero. WLAs & LAs are summarized in Table 6.

**Table 6. Summary of TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Obion River Watershed (HUC 08010202)**

| HUC-12 Subwatershed (08010202__) | Impaired Waterbody Name | Impaired Waterbody ID | TMDL | MOS | WLAs[a] | | | LAs |
|---|---|---|---|---|---|---|---|---|
| | | | | | WWTFs[b] | Leaking Collection Systems | CAFOs | |
| | | | [CFU/day] | [CFU/day] | [CFU/day] | [CFU/day] | [CFU/day] | [CFU/day/acre] |
| 0104 | Biggs Creek | TN08010202009 – 0700 | $2.30 \times 10^{10} * Q$ | $2.30 \times 10^{9} * Q$ | NA | NA | NA | $1.934 \times 10^{6} * Q$ |
| | Hurricane Creek | TN08010202009 – 0710 | $2.30 \times 10^{10} * Q$ | $2.30 \times 10^{9} * Q$ | NA | NA | NA | $2.049 \times 10^{6} * Q$ |
| 0201/0301 | Obion River | TN08010202001 – 4000 | $1.19 \times 10^{10} * Q$ | $1.19 \times 10^{9} * Q$ | $3.874 \times 10^{11}$ | 0 | NA | $1.424 \times 10^{4} * Q – 5.145 \times 10^{5}$ |
| 0401/0403 | Reelfoot Creek | TN08010202036 – 1000 | $2.30 \times 10^{10} * Q$ | $2.30 \times 10^{9} * Q$ | NA | NA | 0 | $2.733 \times 10^{5} * Q$ |

*Note:* *NA = Not applicable.*
*Q = Mean Daily In-stream Flow (cfs).*

a. *There are no MS4s in impaired subwatersheds of the Obion River watershed.*

b. *WLAs for WWTFs expressed as E. coli loads (CFU/day). Future WWTFs must meet water quality standards at the point of discharge as specified in their NPDES permits. At no time shall concentration exceed appropriate, site-specific (487 CFU/100 mL or 941 CFU/100 mL) water quality standards.*

## 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 Obion River watershed through reduction of excessive E. coli loading. Adaptive management methods, within the context of the State's rotating watershed management approach, will be used to modify TMDLs, WLAs, and LAs as required to meet water quality goals.

### 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, including elimination of bypasses and overflows. In Tennessee, permit limits for treated sanitary wastewater require compliance with coliform water quality standards (ref: Section 5.0) prior to discharge. No additional reduction is required. WLAs for WWTFs are derived from facility design flows and permitted E. coli limits and are expressed as average loads in CFU per day.

#### 9.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

For future regulated discharges from municipal separate storm sewer systems, WLAs are and will be implemented through Phase I & II MS4 permits. These permits will require the development and implementation of a Storm Water Management Plan (SWMP) that will reduce the discharge of pollutants to the "maximum extent practicable" and not cause or contribute to violations of State water quality standards. Both the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (TDEC, 2003) and the TDOT individual MS4 permit (TNS077585) require SWMPs to include the following six minimum control measures:

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

The permits also contain requirements regarding control of discharges of pollutants of concern into impaired waterbodies, implementation of provisions of approved TMDLs, and descriptions of methods to evaluate whether storm water controls are adequate to meet the requirements of approved TMDLs.

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

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

- Analytical monitoring of pollutants of concern in receiving waterbodies, both upstream and downstream of MS4 discharges, over an extended period of time.

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

9.1.3 NPDES Regulated Concentrated Animal Feeding Operations (CAFOs)

WLAs provided to CAFOs will be implemented through NPDES Permit No. TNA000000, General NPDES Permit for *Class II Concentrated Animal Feeding Operation* or the facility's individual permit. Among the provisions of the general permit are:

- Development and implementation of a site-specific Nutrient Management Plan (NMP) that:

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

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

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

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

Provisions of individual CAFO permits are similar. NPDES Permit No. TNA000000, *Class II Concentrated Animal Feeding Operation General Permit* is available on the TDEC website at http://state.tn.us/environment/wpc/ppo/CAFO%20Final%20PDF%20Modified.pdf.

## 9.2 Nonpoint Sources

The Tennessee Department of Environment & Conservation has no direct regulatory authority over most nonpoint source (NPS) discharges. Reductions of E. coli loading from nonpoint sources will be achieved using a phased approach. Voluntary, incentive-based mechanisms will be used to implement NPS management measures in order to assure that measurable reductions in pollutant loadings can be achieved for the targeted impaired waters. Cooperation and active participation by the general public and various industry, business, and environmental groups is critical to successful implementation of TMDLs. Local citizen-led and implemented management measures have the potential to provide the most efficient and comprehensive avenue for reduction of loading rates from nonpoint sources. 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 non-governmental levels to be successful.

BMPs have been utilized in the Obion River watershed to reduce the amount of coliform bacteria transported to surface waters from agricultural sources. These BMPs (e.g., pasture and hayland planting, cropland conversion, critical area treatment, fencing, etc.) may have contributed to reductions in in-stream concentrations of coliform bacteria in one or more Obion River E. coli-impaired subwatersheds during the TMDL evaluation period. The Tennessee Department of Agriculture (TDA) keeps a database of BMPs implemented in Tennessee. Those listed in the Obion River watershed are shown in Figure 9. It is recommended that additional information (e.g., livestock access to streams, manure application practices, etc.) be provided and evaluated to better identify and quantify agricultural sources of coliform bacteria loading in order to minimize uncertainty in future TMDL analysis efforts.

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

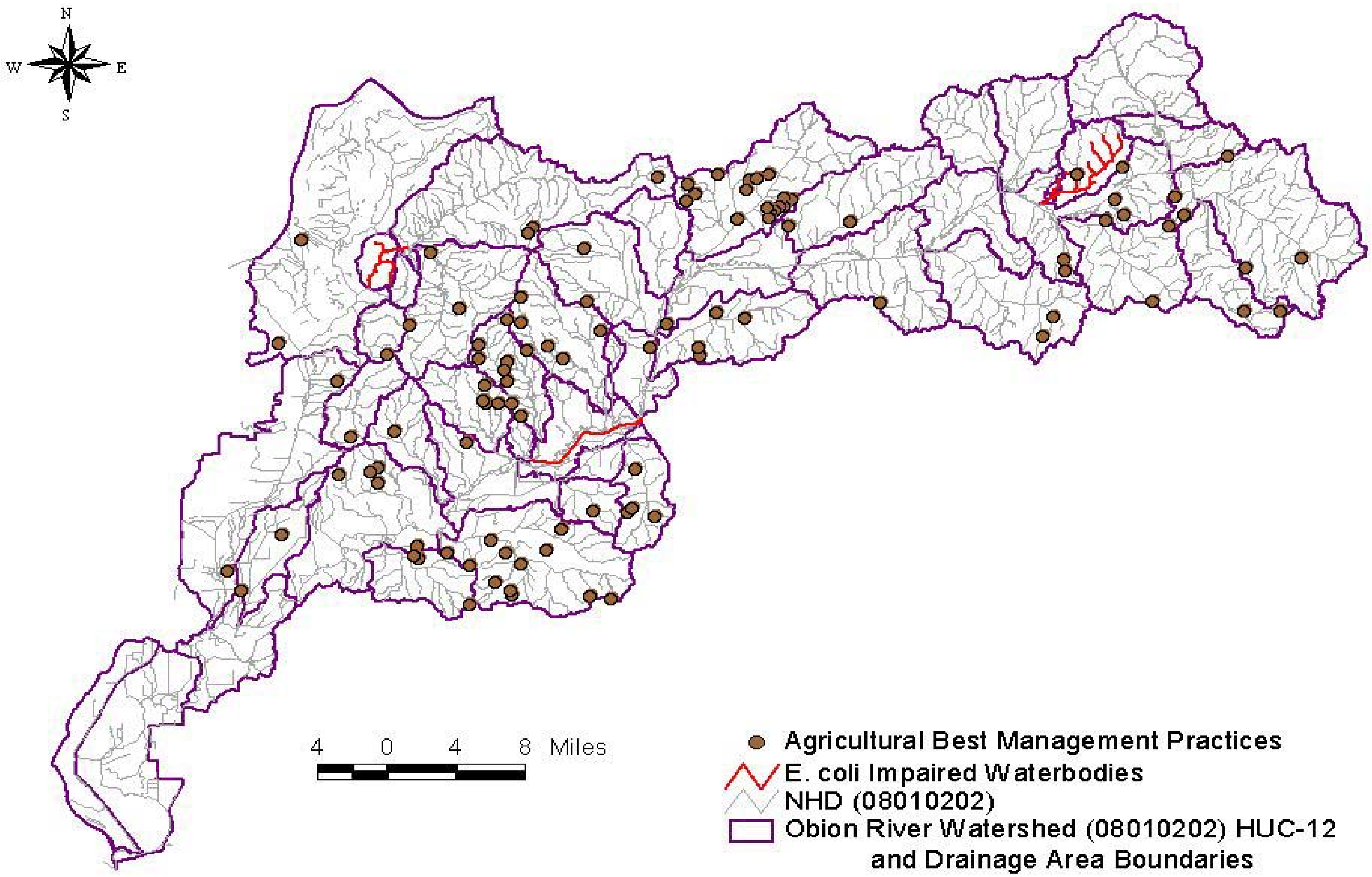


**Figure 9. Tennessee Department of Agriculture Best Management Practices in the Obion River Watershed.**

9.3 Example Application of Load Duration Curves for Implementation Planning

The Load Duration Curve methodology (Appendix C) is a form of water quality analysis and presentation of data that aids in guiding implementation by targeting strategies to appropriate flow conditions. One of the strengths of this method is that it can be used to interpret possible delivery mechanisms of E. coli by differentiating between point and non-point problems. The load duration curve analysis can be utilized for implementation planning. The E. coli load duration curve for Hurricane Creek at Mile 0.7 (Figure 10) was analyzed to determine the frequency with which water quality monitoring data exceed the E. coli target maximum concentration of 941 CFU/100 mL under five flow conditions (low, dry, mid-range, moist, and high). Observation of the plot suggests the Hurricane Creek subwatershed is impacted by point and non-point-type sources.

Table 7 presents Load Duration Curve analysis statistics for E. coli and example 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 implementation strategy for the Hurricane Creek subwatershed will require BMPs targeting point sources (dominant under low flow/baseflow conditions) and non-point sources (dominant under high flow/runoff conditions). The implementation strategies listed in Table 7 are a subset of the categories of BMPs and implementation strategies available for application to the Obion River subwatersheds for reduction of E. coli loading and mitigation of water quality impairment.

See Appendix C for a detailed discussion of the Load Duration Curve Methodology applied to the Obion River watershed.

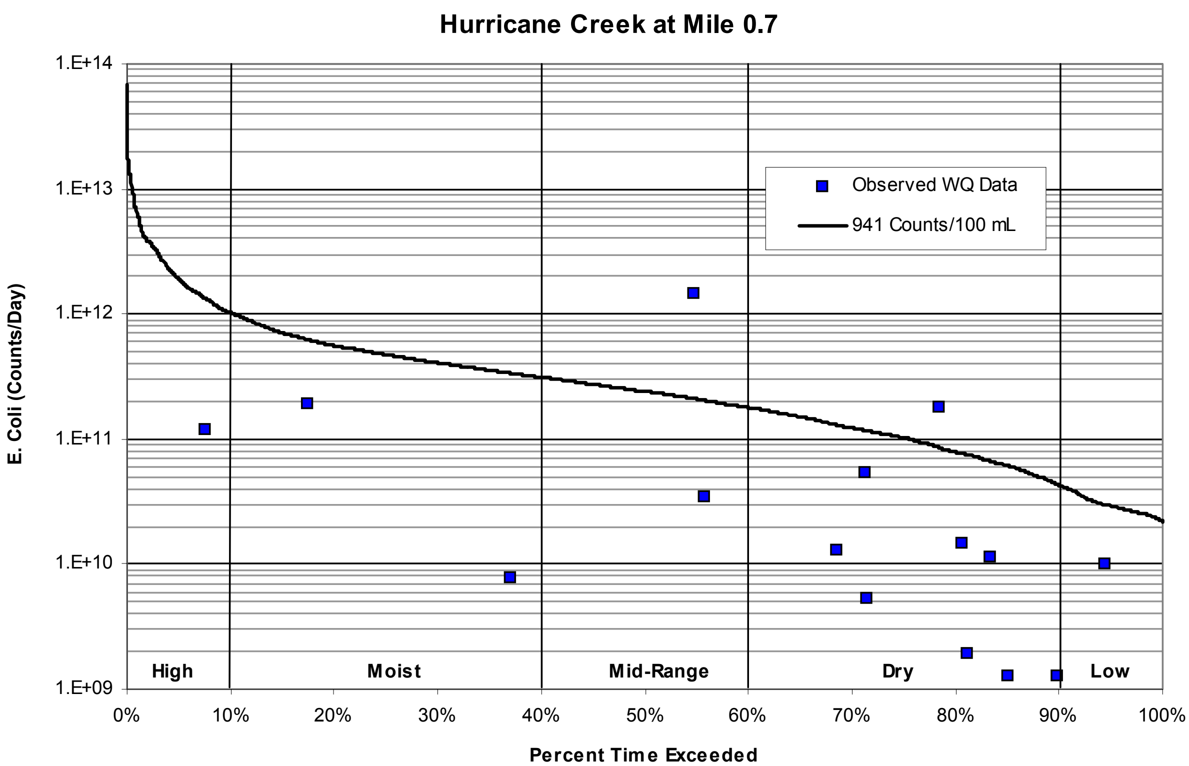


**Figure 10. Load Duration Curve for Implementation Planning.**

**Table 7. Example Implementation Strategies**

| Flow Condition | High | Moist | Mid-range | Dry | Low |
|---|---|---|---|---|---|
| % Time Flow Exceeded | 0-10 | 10-40 | 40-60 | 60-90 | 90-100 |
| 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[1] | | | M | H | H |
| Pasture Management/Land Application of Manure[1] | H | H | M | L | |
| Riparian Buffers[1] | | H | H | H | |
| Potential for source area contribution under given hydrologic condition (H: High; M: Medium; L: Low) | | | | | |

[1] Example Best Management Practices for Agricultural Source reduction. Actual BMPs applied may vary.

9.4 Additional Monitoring

Documenting progress in reducing the quantity of E. coli entering the Obion River 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 in-stream water quality targets for E. coli. Future monitoring activities should also be adequate to assess water quality using the 30-day geometric mean standard.

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

Additional monitoring and assessment activities are recommended for the Obion River watershed E. coli-impaired subwatersheds to verify the assessment status of the stream reaches identified on the Final 2006 303(d) List as impaired due to E. coli. If it is determined that these stream reaches are still not fully supporting designated uses, then sufficient data to enable development of a TMDL must be acquired. Future monitoring activities should be representative of all seasons and a full range of flow and meteorological conditions. In addition, collection of E. coli data at sufficient frequency to support calculation of the geometric mean, as described in Tennessee's General Water Quality Criteria (TDEC, 2004a), is encouraged. Finally, for individual monitoring locations, where historical E. coli data are greater than 1000 colonies/100 mL (or future samples are anticipated to be), a 1:100 dilution should be performed as described in Protocol A of the *Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water* (TDEC, 2004b).

## 9.5 Source Identification

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

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

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

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

## 9.6 Evaluation of TMDL Implementation Effectiveness

The effectiveness of the TMDL implementation 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 E. coli 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 E. coli loading. These TMDLs will be re-evaluated during subsequent watershed cycles and revised as required to assure compliance with applicable water quality standards.

## 10.0 PUBLIC PARTICIPATION

In accordance with 40 CFR §130.7, the proposed E. coli TMDLs for the Obion River watershed were placed on Public Notice for a 35-day period and comments solicited. Steps that were taken in this regard included:

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

2) Notice of the availability of the proposed TMDLs (similar to the website announcement) was included in one of the NPDES permit Public Notice mailings which was sent to approximately 90 interested persons or groups who have requested this information.

3) A draft copy of the proposed TMDLs was sent to the Tennessee Department of Transportation.

4) A letter was sent to the Troy Wastewater Lagoon (TN0064777), located in an E. coli-impaired subwatershed in the Obion River watershed and permitted to discharge treated effluent containing E. coli, 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.

## 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 Obion River Watershed

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

| Land Use | Subwatershed Drainage Area | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Obion River[1] | | Biggs Creek | | Hurricane Creek | | Reelfoot Creek | |
| | [acres] | [%] | [acres] | [%] | [acres] | [%] | [acres] | [%] |
| Bare Rock/Sand/Clay | 0 | 0 | 0 | 0 | 0 | 0 | 62 | 0.1 |
| Deciduous Forest | 164,645 | 21.9 | 4018 | 37.5 | 3961 | 39.2 | 9379 | 12.5 |
| Emergent Herbaceous Wetlands | 0 | 0 | 0 | 0 | 0 | 0 | 226 | 0.3 |
| Evergreen Forest | 18,598 | 2.5 | 44 | 0.4 | 40 | 0.4 | 1037 | 1.4 |
| High Intensity Commercial/Industrial/Transportation | 3,183 | 0.4 | 0 | 0 | 0 | 0 | 352 | 0.5 |
| High Intensity Residential | 1,093 | 0.1 | 0 | 0 | 0 | 0 | 7 | 0.0[2] |
| Low Intensity Residential | 9,037 | 1.2 | 0 | 0 | 0 | 0 | 511 | 0.7 |
| Mixed Forest | 42,574 | 5.7 | 296 | 2.8 | 281 | 2.8 | 6769 | 9.1 |
| Open Water | 4,587 | 0.6 | 1 | 0.0[2] | 1 | 0.0[2] | 531 | 0.7 |
| Other Grasses (Urban/recreational) | 461 | 0.1 | 0 | 0 | 0 | 0 | 15,193 | 20.3 |
| Pasture/Hay | 257,931 | 34.3 | 2618 | 24.4 | 2536 | 25.1 | 16,669 | 22.3 |
| Quarries/Strip Mines/Gravel Pits | 450 | 0.1 | 0 | 0 | 0 | 0 | 4 | 0.0[2] |
| Row Crops | 199,834 | 26.5 | 3559 | 33.2 | 3191 | 31.6 | 5932 | 7.9 |
| Small Grains | 0 | 0 | 0 | 0 | 0 | 0 | 2816 | 3.8 |
| Transitional | 1,315 | 0.2 | 13 | 0.1 | 13 | 0.1 | 47 | 0.1 |
| Woody Wetlands | 49,212 | 6.5 | 165 | 1.5 | 91 | 0.9 | 15,205 | 20.3 |
| Total | 752,919 | 100 | 10,714 | 100 | 10,114 | 100 | 74,741 | 100 |

[1] Includes the drainage area of the South Fork Obion River watershed.

[2] <0.05.

# APPENDIX B

## Water Quality Monitoring Data

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

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

| Monitoring Station | Date | E. Coli [CFU/100 mL] |
|---|---|---|
| **OBION062.5OB** | 7/12/05 | **>2419.2** |
| | 8/11/05 | 278 |
| | 9/21/05 | **648.8** |
| | 10/4/05 | 140 |
| | 11/1/05 | 23 |
| | 12/6/05 | 34 |
| **HURRI000.7WY** | 2/6/01 | 93.3 |
| | 5/22/01 | **6586** |
| | 10/9/01 | 314 |
| | 12/11/01 | 292.4 |
| | 2/12/02 | 21.8 |
| | 4/2/02 | 83.9 |
| | 6/4/02 | 162.4 |
| | 8/9/05 | 435.2 |
| | 9/7/05 | 42.8 |
| | 9/14/05 | **1986.3** |
| | 9/20/05 | 162.4 |
| | 9/28/05 | 180 |
| | 10/11/05 | 24 |
| | 11/8/05 | 28 |
| | 12/13/05 | 20 |

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

| Monitoring Station | Date | E. Coli [CFU/100 mL] |
|---|---|---|
| **REELF004.2OB** | 3/14/01 | **1203.3** |
| | 6/12/01 | 410.6 |
| | 10/16/01 | 816.4 |
| | 4/9/02 | **1413.6** |
| | 7/12/05 | **>2419.2** |
| | 8/11/05 | 240 |
| | 8/14/05 | 307.6 |
| | 9/7/05 | 108.6 |
| | 9/14/05 | 228.2 |
| | 9/20/05 | 259.5 |
| | 9/28/05 | 770 |
| | 10/4/05 | 520 |
| | 11/1/05 | 33 |
| | 12/6/05 | 54 |

# APPENDIX C

## Load Duration Curve Development
## and
## Determination of Daily Loads and Required Load Reductions

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

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

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

## C.1 Development of TMDLs and Load Reductions

E. coli TMDLs, WLAs, and LAs were developed for impaired subwatersheds in the Obion River watershed using Load Duration Curves (LDCs). Daily loads for TMDLs, WLAs, and LAs are expressed as a function of daily mean in-stream flow (daily loading function). In addition, in order to facilitate implementation, corresponding percent reductions in loading required to decrease existing, in-stream E. coli loads to TMDL target levels were calculated.

### C.1.1 Development of Flow Duration Curves

A flow duration curve is a cumulative frequency graph, constructed from historic flow data at a particular location, that represents the percentage of time a particular flow rate is equaled or exceeded. Flow duration curves are developed for a waterbody from daily discharges of flow over 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 U.S. Geological Survey (USGS) continuous-record stations located on the waterbody of interest. For ungaged streams, alternative methods must be used to estimate daily mean flow. These include: 1) regression equations (using drainage area as the independent variable) developed from continuous record stations in the same ecoregion; 2) drainage area extrapolation of data from a nearby continuous-record station of similar size and topography; and 3) calculation of daily mean flow using a dynamic computer model, such as the Loading Simulation Program C++ (LSPC).

Flow duration curves for impaired waterbodies in the Obion River watershed were derived from LSPC hydrologic simulations based on parameters derived from calibration at four USGS monitoring stations (07024300, Beaver Creek at Huntingdon; 07024500, South Fork Obion River near Greenfield; 07026000, Obion River at Obion; and 07026370, North Reelfoot Creek at Hwy. 22 near Clayton). See Appendix D for details of calibration. The data used included the period of record from 1/1/96 – 12/31/05. For example, a flow-duration curve for Hurricane Creek at mile 0.7 was constructed using simulated daily mean flow for the period from 1/1/96 through 12/31/05 (mile 0.7 corresponds to the location of monitoring station HURRI000.7WY). This flow duration curve is shown in Figure C-1 and represents the cumulative distribution of daily discharges arranged to show percentage of time specific flows were exceeded during the period of record (the highest daily mean flow during this period is exceeded 0% of the time and the lowest daily mean flow is equaled or exceeded 100% of the time). Flow duration curves for other impaired waterbodies were derived using a similar procedure.

### C.1.2 Development of Load Duration Curves and Determination of Required Load Reductions

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

E. coli load duration curves for impaired waterbodies in the Obion River watershed were developed from the flow duration curves developed in Section C.1.1, E. coli target concentrations, and available water quality monitoring data. Load duration curves, daily loading functions, and required load reductions were developed using the following procedures (Hurricane Creek at mile 0.7 [HURRI000.7WY] is shown as an example):

1. A target load duration curve (LDC) was generated for Hurricane Creek at mile 0.7 by applying the E. coli target concentration of 941 CFU/100 mL to each of the ranked flows used to generate the flow duration curve (ref.: Section C.1.1) and plotting the results. The E. coli target maximum load corresponding to each ranked daily mean flow is:

   $$(\text{Target Load})_{\text{HURRI000.7WY}} = (941\ \text{CFU/100 mL}) \times (Q) \times (\text{UCF})$$

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

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

2. Daily loads were calculated for each of the water quality samples collected at monitoring station HURRI000.7WY (ref.: Table B-1) by multiplying the sample concentration by the daily mean flow for the sampling date and the required unit conversion factor. HURRI000.7WY was selected for LDC analysis because it has numerous sampling points, well distributed across the full range of flow conditions, and multiple exceedances of the target concentration.

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

   Example (9/14/05 sampling event):
   Modeled Flow = 3.717 cfs
   Concentration = 1986.3 CFU/100 mL
   Daily Load = $1.807 \times 10^{11}$ CFU/day

3. Using the flow duration curves developed in Section C.1.1, the "percent of days the flow was exceeded" (PDFE) was determined for each sampling event. Each sample load was then plotted on the load duration curves developed in Step 1 according to the PDFE. The resulting E. coli load duration curve for Hurricane Creek at mile 0.7 is shown in Figure C-2.

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

   Example (9/14/05 sampling event):
   Target Concentration = 941 CFU/100 mL
   Measured Concentration = 1986.3 CFU/100 mL
   Reduction to Target = 52.6%

5. The $90^{th}$ percentile value for all of the E. coli sampling data at HURRI000.7WY monitoring site was determined. If the $90^{th}$ percentile value exceeded the target maximum E. coli concentration, the reduction required to reduce the $90^{th}$ percentile value to the target maximum concentration was calculated (Table C-1).

   Example: Target Concentration = 941 CFU/100 mL
   $90^{th}$ Percentile Concentration = 1366 CFU/100 mL
   Reduction to Target = 31.1%

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

   Example: Insufficient monitoring data were available for Hurricane Creek at Mile 0.7. Sufficient data were available for Reelfoot Creek at mile 2.4:

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

7. The load reductions required to meet the target maximum (Step 5) and target 30-day geometric mean concentrations (Step 6) of E. coli were compared and the load reduction of the greatest magnitude selected for Hurricane Creek at mile 0.7.

Load duration curves and required load reductions of other impaired waterbodies were derived in a similar manner and are shown in Figures C-2 through C-5 and Tables C-1 through C-4.

## C.2 Development of WLAs, LAs, and MOS

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

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

Expanding the terms:

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

For E. coli 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 in-stream water quality standards at the point of discharge, no additional load reduction is required. WLAs for WWTFs are calculated from the facility design flow and the Monthly Average permit limit.

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

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

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

LA terms include:

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

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

Since WWTFs discharge must comply with in-stream water quality criteria (TMDL target) at the point of discharge, $[WLAs]_{CAFO} = 0$, and $[LAs]_{DS} = 0$, the expression relating TMDLs to precipitation-based point and nonpoint sources may be simplified to:

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

### C.2.1 Daily Load Calculation

WLAs for MS4s and LAs for precipitation-based nonpoint sources are equal and expressed as the daily allowable load per unit area (acre) resulting from a decrease in in-stream E. coli concentrations to TMDL target values minus MOS:

WLA[MS4] = LA = {TMDL – MOS – WLA[WWTFs]} / DA

where: DA = drainage area (acres)

Using Hurricane Creek at mile 0.7 as an example:

$TMDL_{HURRI000.7WY}$ = (941 CFU/100 mL) x (Q) x (UCF)

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

$MOS_{HURRI000.7WY}$ = TMDL x 0.10

**MOS = $2.30 \times 10^{9}$ x Q**

$WLA[MS4]_{HURRI000.7WY} = LA_{HURRI000.7WY}$

= {TMDL – MOS – WLA[WWTFs]} / DA

= {($2.30 \times 10^{10}$ x Q) – ($2.30 \times 10^{9}$ x Q) – (0)} / (10,114)

**WLA[MS4] = LA = $2.049 \times 10^{6}$ x Q**

TMDLs, WLAs, & LAs for other impaired subwatersheds and drainage areas were derived in a similar manner and are summarized in Table C-5.

### C.2.2 Percent Load Reduction Calculations

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

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

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

Target – MOS = 438 CFU/100 ml

Instantaneous Maximum (other):

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

Target – MOS = 847 CFU/100 ml

30-Day Geometric Mean:

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

Target – MOS = 113 CFU/100 ml

Required load reductions for precipitation-based nonpoint sources were developed using methods similar to those described in Section C.1.2 (again, using Hurricane Creek at mile 0.7 as an example):

8. For cases where the existing load exceeded the “target maximum load – MOS” at a particular PDFE, the reduction required to reduce the sample load to the “target – MOS” load was calculated.

Example – 9/14/05 sampling event:
Target Concentration – MOS = 847 CFU/100 mL
Measured Concentration = 1986.3 CFU/100 mL
Reduction to Target – MOS = 57.4%

9. If the 90$^{th}$ percentile value for all of the E. coli sampling data at HURRI000.7WY monitoring site (calculated in Step 5) exceeded the "target maximum – MOS" E. coli concentration, the reduction required to reduce the 90$^{th}$ percentile value to the "target maximum – MOS" concentration was calculated (Table C-1).

   Example: Target Concentration – MOS = 847 CFU/100 mL
   90$^{th}$ Percentile Concentration = 1366 CFU/100 mL
   Reduction to Target – MOS = 38.0%

10. For cases where five or more samples were collected over a period of not more than 30 consecutive days, the geometric mean E. coli concentration was determined and compared to the "target geometric mean E. coli concentration – MOS" of 113 CFU/100 mL. If the sample geometric mean exceeded the "target geometric mean – MOS" concentration, the reduction required to reduce the sample geometric mean value to the "target geometric mean – MOS" concentration was calculated.

    Example: Insufficient monitoring data were available for Hurricane Creek at Mile 0.7. Sufficient data were available for Reelfoot Creek at mile 2.4:

    Sampling Period = 9/7/05 – 10/4/05 (5 samples: 108.6, 228.2, 259.5, 770, 520)
    Geometric Mean Concentration = 303 CFU/100 mL
    Target Concentration – MOS = 113 CFU/100 mL
    Reduction to Target – MOS = 62.7%

11. The load reductions required to meet the "target maximum – MOS" (Step 10) and "target 30-day geometric mean – MOS" concentrations (Step 11) of E. coli were compared and the load reduction of the greatest magnitude selected as the WLA for MS4s and/or LA for precipitation-based nonpoint sources for Hurricane Creek at mile 0.7.

Required load reductions of other impaired waterbodies were derived in a similar manner and are summarized in Table C-6.

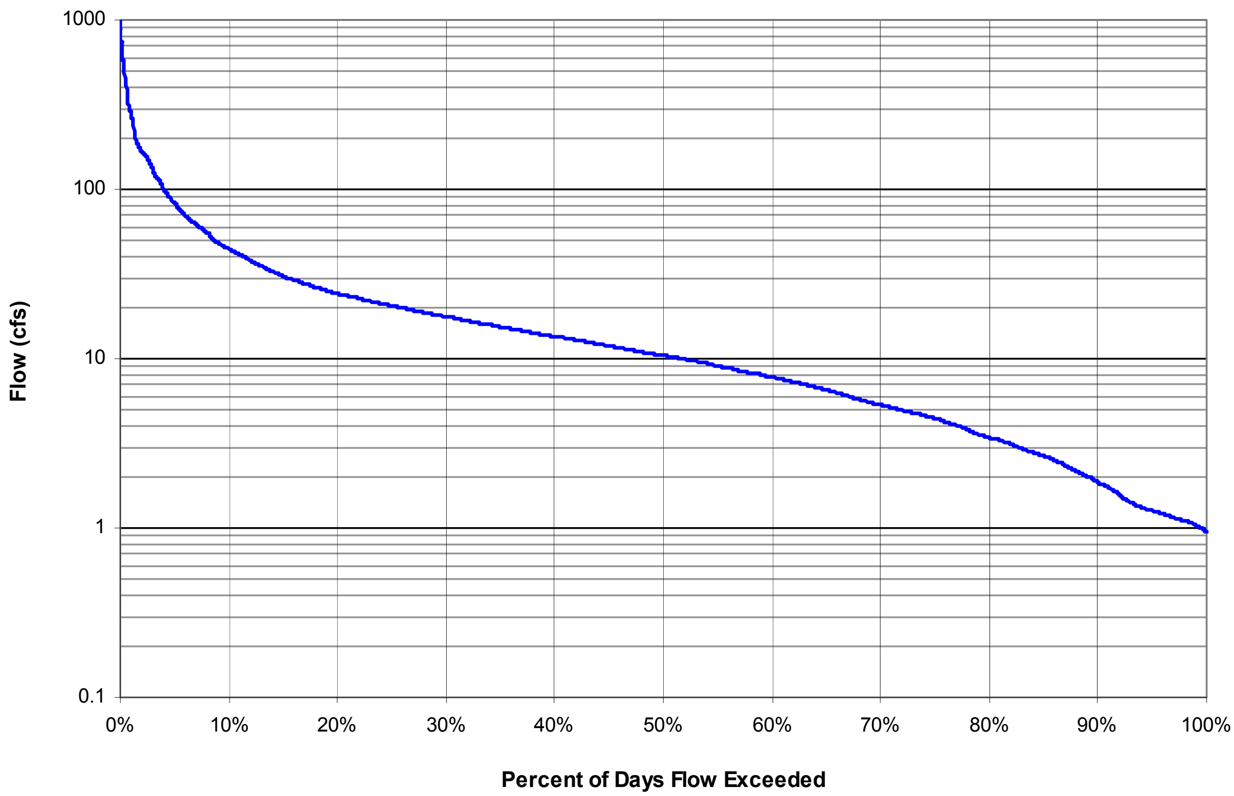



**Figure C-1. Flow Duration Curve for Hurricane Creek at Mile 0.7**

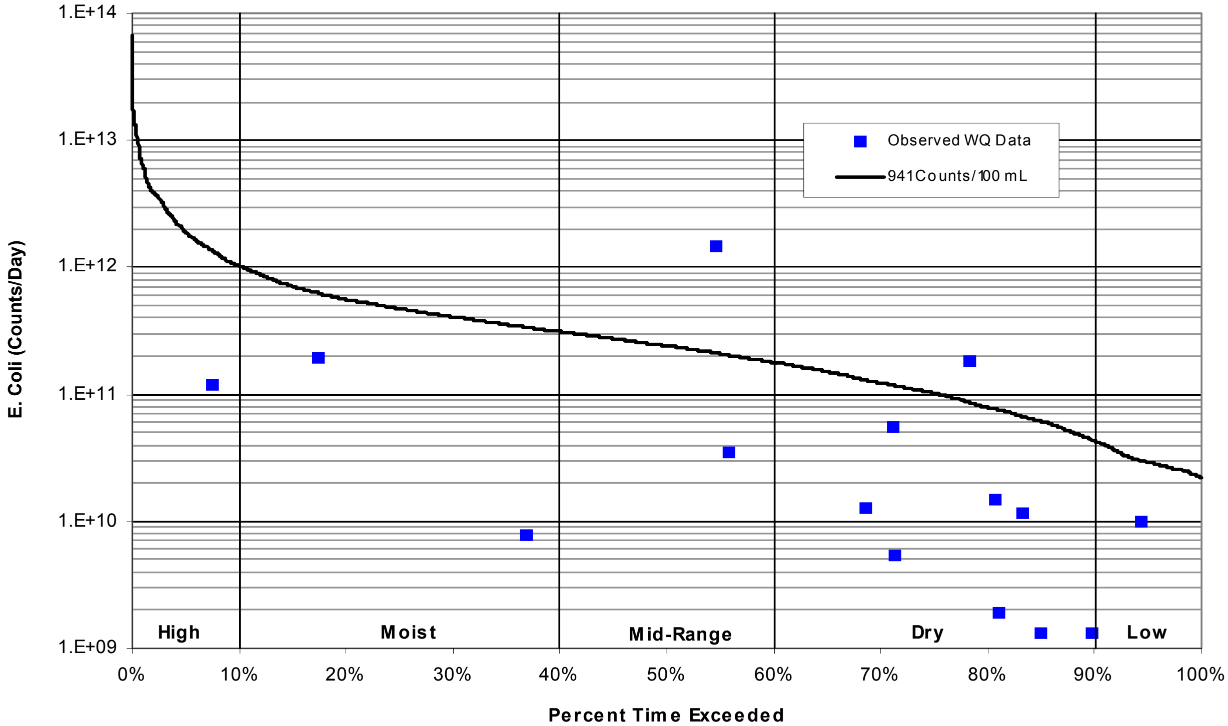



**Figure C-2. E. Coli Load Duration Curve for Hurricane Creek at Mile 0.7**

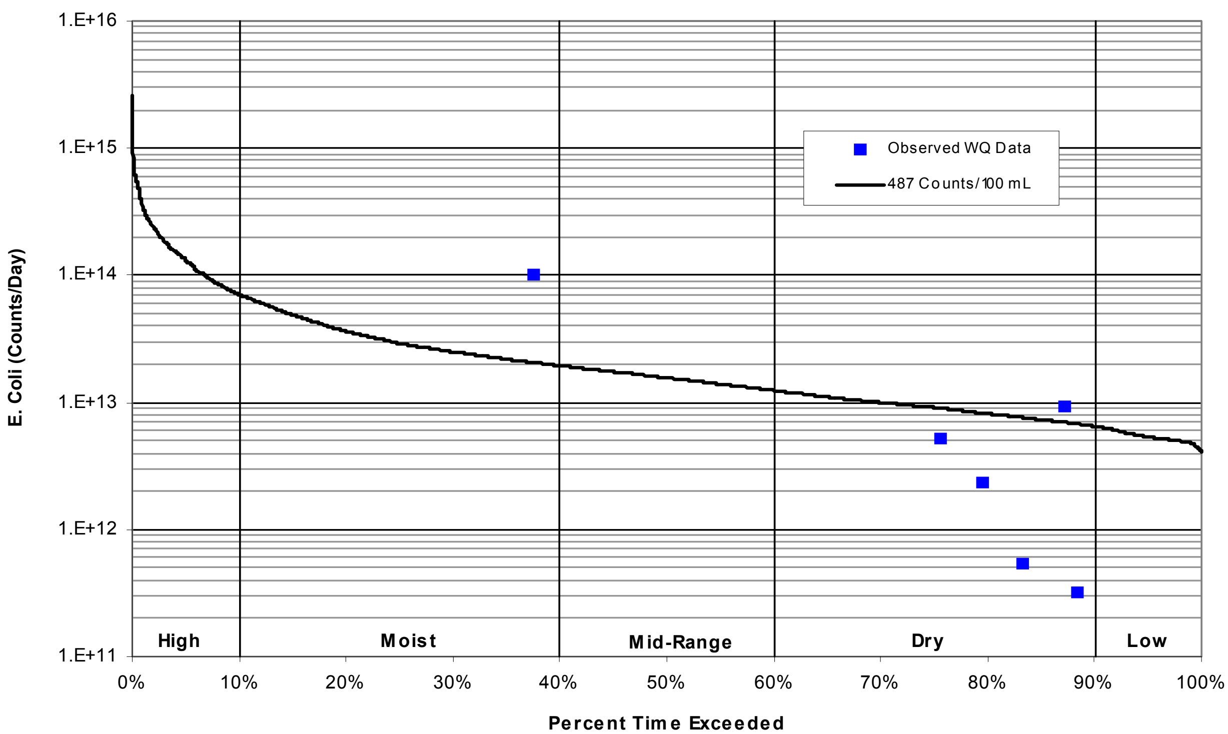



**Figure C-3. E. Coli Load Duration Curve for Obion River at Mile 62.5**

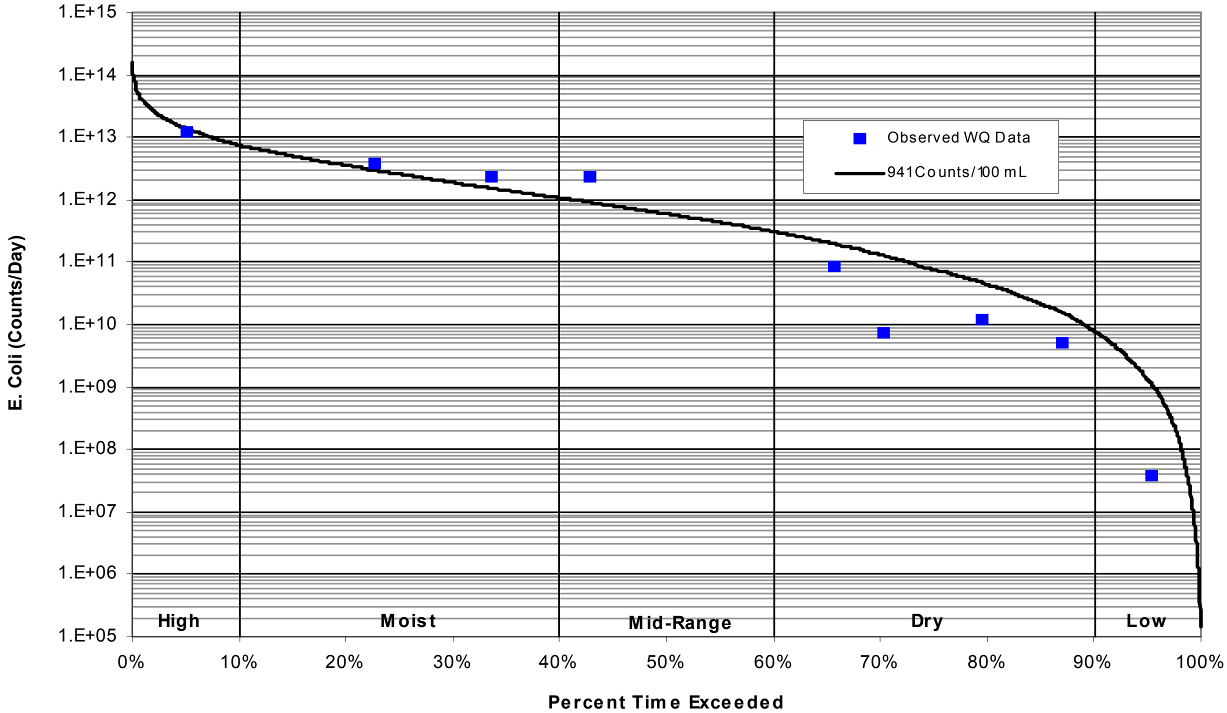



**Figure C-4. E. Coli Load Duration Curve for Reelfoot Creek at Mile 4.2**

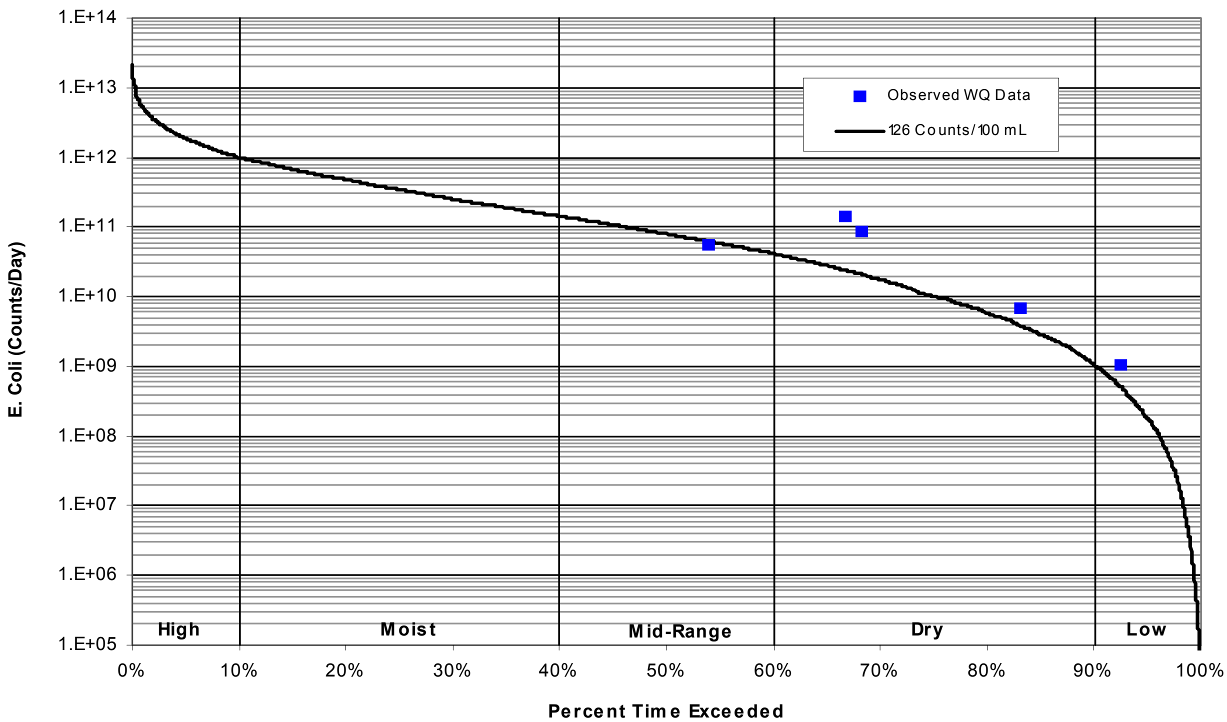



**Figure C-5. E. Coli Load Duration Curve for Reelfoot Creek at Mile 4.2 (Geometric Mean data [9/7/05-10/4/05])**

**Table C-1. Required Load Reduction for Hurricane Creek at Mile 0.7 – E. Coli Analysis**

| PDFE | Flow | Sample Date | E. Coli | |
|---|---|---|---|---|
| | | | Sample Conc. | Required Load Reduction |
| [%] | [cfs] | | [CFU/100 ml] | [%] |
| 7.528% | 58.5059 | 4/2/02 | 83.9 | **NR** |
| 17.383% | 27.2614 | 12/11/01 | 292.4 | **NR** |
| 36.929% | 14.6586 | 2/12/02 | 21.8 | **NR** |
| 54.667% | 9.16236 | 5/22/01 | **6586** | **85.7** |
| 55.762% | 8.83077 | 6/4/02 | 162.4 | **NR** |
| 68.546% | 5.63827 | 2/6/01 | 93.3 | **NR** |
| 71.229% | 5.11641 | 8/9/05 | 435.2 | **NR** |
| 71.311% | 5.09682 | 9/7/05 | 42.8 | **NR** |
| 78.347% | 3.71687 | 9/14/05 | **1986.3** | **52.6** |
| 80.646% | 3.35207 | 9/28/05 | 180 | **NR** |
| 81.057% | 3.27478 | 10/11/05 | 24 | **NR** |
| 83.274% | 2.90127 | 9/20/05 | 162.4 | **NR** |
| 84.999% | 2.6699 | 12/13/05 | 20 | **NR** |
| 89.817% | 1.8985 | 11/8/05 | 28 | **NR** |
| 94.306% | 1.3036 | 10/9/01 | 314 | **NR** |
| | **90th Percentile (all)** | | **1366** | **31.1** |

**Table C-2. Required Load Reduction for Obion River at Mile 62.5 – E. Coli Analysis**

| PDFE | Flow | Sample Date | E. Coli | |
|---|---|---|---|---|
| | | | Sample Conc. | Required Load Reduction |
| [%] | [cfs] | | [CFU/100 ml] | [%] |
| 37.503% | 1733.29 | 7/12/05 | **>2419.2** | **79.9** |
| 75.582% | 756.535 | 8/11/05 | 278 | **NR** |
| 79.578% | 691.065 | 10/4/05 | 140 | **NR** |
| 83.301% | 638.468 | 12/6/05 | 34 | **NR** |
| 87.134% | 586.453 | 9/21/05 | **648.8** | **24.9** |
| 88.448% | 568.518 | 11/1/05 | 23 | **NR** |
| | **90th Percentile (all)** | | **1534** | **68.3** |

**Table C-3. Required Load Reduction for Reelfoot Creek at Mile 4.2 – E. Coli Analysis**

| PDFE | Flow | Sample Date | E. Coli | |
|---|---|---|---|---|
| | | | Sample Conc. | Required Load Reduction |
| [%] | [cfs] | | [CFU/100 ml] | [%] |
| 5.064% | 602.973 | 10/16/01 | 816.4 | **NR** |
| 22.694% | 127.791 | 3/14/01 | **1203.3** | **21.8** |
| 33.561% | 67.06 | 4/9/02 | **1413.6** | **33.4** |
| 42.814% | 39.4176 | 7/12/05 | **>2419.2** | **61.1** |
| 65.645% | 8.61191 | 6/12/01 | 410.6 | **NR** |
| 70.381% | 5.5298 | 12/6/05 | 54 | **NR** |
| 79.578% | 2.0094 | 8/11/05 | 240 | **NR** |
| 87.079% | 0.658815 | 8/14/05 | 307.6 | **NR** |
| 95.428% | 0.046571 | 11/1/05 | 33 | **NR** |
| | **90$^{th}$ Percentile (all)** | | **1615** | **41.7** |

**Table C-4. Required Load Reduction for Reelfoot Creek at Mile 12.5 – E. Coli Analysis (Geometric Mean Data [9/7/05-10/4/05])**

| PDFE | Flow | Sample Date | E. Coli | | |
|---|---|---|---|---|---|
| | | | Sample Conc. | Geometric Mean | Required Load Reduction |
| [%] | [cfs] | | [CFU/100 ml] | [CFU/100 mL] | [%] |
| 53.983% | 20.3763 | 9/7/05 | 108.6 | | |
| 66.767% | 7.70112 | 9/28/05 | **770** | | |
| 68.327% | 6.85314 | 10/4/05 | **520** | | |
| 83.165% | 1.23037 | 9/14/05 | **228.2** | | |
| 92.445% | 0.169221 | 9/20/05 | **259.5** | **303.5** | **58.5** |

**Table C-5. TMDLs, WLAs, & LAs for Obion River Watershed**

| HUC-12 Subwatershed (08010202__) | Impaired Waterbody Name | Impaired Waterbody ID | TMDL | MOS | WLAs[a] | | | LAs |
|---|---|---|---|---|---|---|---|---|
| | | | | | WWTFs[b] | Leaking Collection Systems | CAFOs | |
| | | | [CFU/day] | [CFU/day] | [CFU/day] | [CFU/day] | [CFU/day] | [CFU/day/acre] |
| 0104 | Biggs Creek | TN08010202009 – 0700 | $2.30 \times 10^{10} * Q$ | $2.30 \times 10^{9} * Q$ | NA | NA | NA | $1.934 \times 10^{6} * Q$ |
| | Hurricane Creek | TN08010202009 – 0710 | $2.30 \times 10^{10} * Q$ | $2.30 \times 10^{9} * Q$ | NA | NA | NA | $2.049 \times 10^{6} * Q$ |
| 0201/0301 | Obion River | TN08010202001 – 4000 | $1.19 \times 10^{10} * Q$ | $1.19 \times 10^{9} * Q$ | $3.874 \times 10^{11}$ | 0 | NA | $1.424 \times 10^{4} * Q – 5.145 \times 10^{5}$ |
| 0401/0403 | Reelfoot Creek | TN08010202036 – 1000 | $2.30 \times 10^{10} * Q$ | $2.30 \times 10^{9} * Q$ | NA | NA | 0 | $2.773 \times 10^{5} * Q$ |

*Note:* *NA = Not applicable.*
*Q = Mean Daily In-stream Flow (cfs).*
*a.* *There are no MS4s in impaired subwatersheds of the Obion River watershed.*
*b.* *WLAs for WWTFs expressed as E. coli loads (CFU/day). Future WWTFs must meet water quality standards at the point of discharge as specified in their NPDES permits. At no time shall concentration exceed appropriate, site-specific (487 CFU/100 mL or 941 CFU/100 mL) water quality standards.*

**Table C-6. Required Reductions to Achieve TMDLs, WLAs, & LAs for Obion River Watershed**

| HUC-12 Subwatershed (08010202__) | Impaired Waterbody Name | Impaired Waterbody ID | % Red. to Achieve TMDL | WLAs[a] | | | | % Red. to Achieve LAs |
|---|---|---|---|---|---|---|---|---|
| | | | | WWTFs[b] | | Leaking Collection Systems | CAFOs | |
| | | | | Monthly Avg. [CFU/day] | Daily Max. [CFU /day] | [CFU /day] | [CFU /day] | |
| 0104 | Biggs Creek | TN08010202009 – 0700 | 31.1 | NA | NA | NA | NA | 38.0 |
| | Hurricane Creek | TN08010202009 – 0710 | 31.1 | NA | NA | NA | NA | 38.0 |
| 0201/0301 | Obion River | TN08010202001 – 4000 | 68.3 | $5.187 \times 10^{10}$ | $3.874 \times 10^{11}$ | 0 | NA | 71.4 |
| 0401/0403 | Reelfoot Creek | TN08010202036 – 1000 | 58.5 | NA | NA | NA | 0 | 62.8 |

*Note: NA = Not applicable.*
*a. There are no MS4s in impaired subwatersheds of the Obion River watershed.*
*b. WLAs for WWTFs expressed as E. coli loads (CFU/day). Future WWTFs must meet water quality standards at the point of discharge as specified in their NPDES permits. At no time shall concentration exceed appropriate, site-specific (487 CFU/100 mL or 941 CFU/100 mL) water quality standards.*

# APPENDIX D

## Hydrodynamic Modeling Methodology

## D.1 Model Selection

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

## D.2 Model Set Up

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

Several computer-based tools were utilized to generate input data for the LSPC model. The Watershed Characterization System (WCS), a geographic information system (GIS) tool, was used to display, analyze, and compile available information to support water quality model simulations for selected subwatersheds. This information includes land use categories, point source dischargers, soil types and characteristics, population data (human and livestock), and stream characteristics.

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

## D.3 Model Calibration

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

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

The results of the hydrologic calibrations for Beaver Creek at Huntingdon (USGS 07024300), South Fork Obion River near Greenfield (USGS 07024500), Obion River at Obion (USGS 07026000), and North Reelfoot Creek at Hwy. 22 near Clayton (USGS 07026370) are shown in Tables D-1 through D-4 and Figures D-1 through D-4, respectively. Note: Figure D-4, North Reelfoot Creek at Hwy. 22 near Clayton (USGS 07026370), is plotted in arithmetic scale due to the occurrence of daily flows equal to zero (cannot be plotted on logarithmic scale).

**Table D-1. Hydrologic Calibration Summary: Beaver Creek at Huntingdon (USGS 07024300)**

| | | | |
|---|---|---|---|
| **Simulation Name:** | **GS4300a (calibration)** | **Simulation Period:** | |
| | Beaver Creek at Huntingdon | **Watershed Area (ac):** | 35520.00 |
| ***Period for Flow Analysis*** | (USGS 07024300) | | |
| ***Begin Date:*** | **01/01/81** | **Baseflow PERCENTILE:** | 2.5 |
| ***End Date:*** | **12/31/87** | *Usually 1%-5%* | |
| Total Simulated In-stream Flow: | **167.72** | Total Observed In-stream Flow: | **172.84** |
| Total of highest 10% flows: | **93.10** | Total of Observed highest 10% flows: | **98.44** |
| Total of lowest 50% flows: | **26.07** | Total of Observed Lowest 50% flows: | **27.56** |
| Simulated Summer Flow Volume ( months 7-9): | **15.54** | Observed Summer Flow Volume (7-9): | **21.03** |
| Simulated Fall Flow Volume (months 10-12): | **55.79** | Observed Fall Flow Volume (10-12): | **53.15** |
| Simulated Winter Flow Volume (months 1-3): | **47.66** | Observed Winter Flow Volume (1-3): | **48.29** |
| Simulated Spring Flow Volume (months 4-6): | **48.73** | Observed Spring Flow Volume (4-6): | **50.37** |
| Total Simulated Storm Volume: | **129.67** | Total Observed Storm Volume: | **133.53** |
| Simulated Summer Storm Volume (7-9): | **5.95** | Observed Summer Storm Volume (7-9): | **11.18** |
| *Errors (Simulated-Observed)* | | *Recommended Criteria* | Last run |
| Error in total volume: | **-2.96** | 10 | |
| Error in 50% lowest flows: | **-5.41** | 10 | |
| Error in 10% highest flows: | **-5.42** | 15 | |
| Seasonal volume error - Summer: | **-26.09** | 30 | |
| Seasonal volume error - Fall: | **4.96** | 30 | |
| Seasonal volume error - Winter: | **-1.31** | 30 | |
| Seasonal volume error - Spring: | **-3.25** | 30 | |
| Error in storm volumes: | **-2.89** | 20 | |
| Error in summer storm volumes: | **-46.80** | 50 | |

**Table D-2. Hydrologic Calibration Summary: South Fork Obion River near Greenfield (USGS 07024500)**

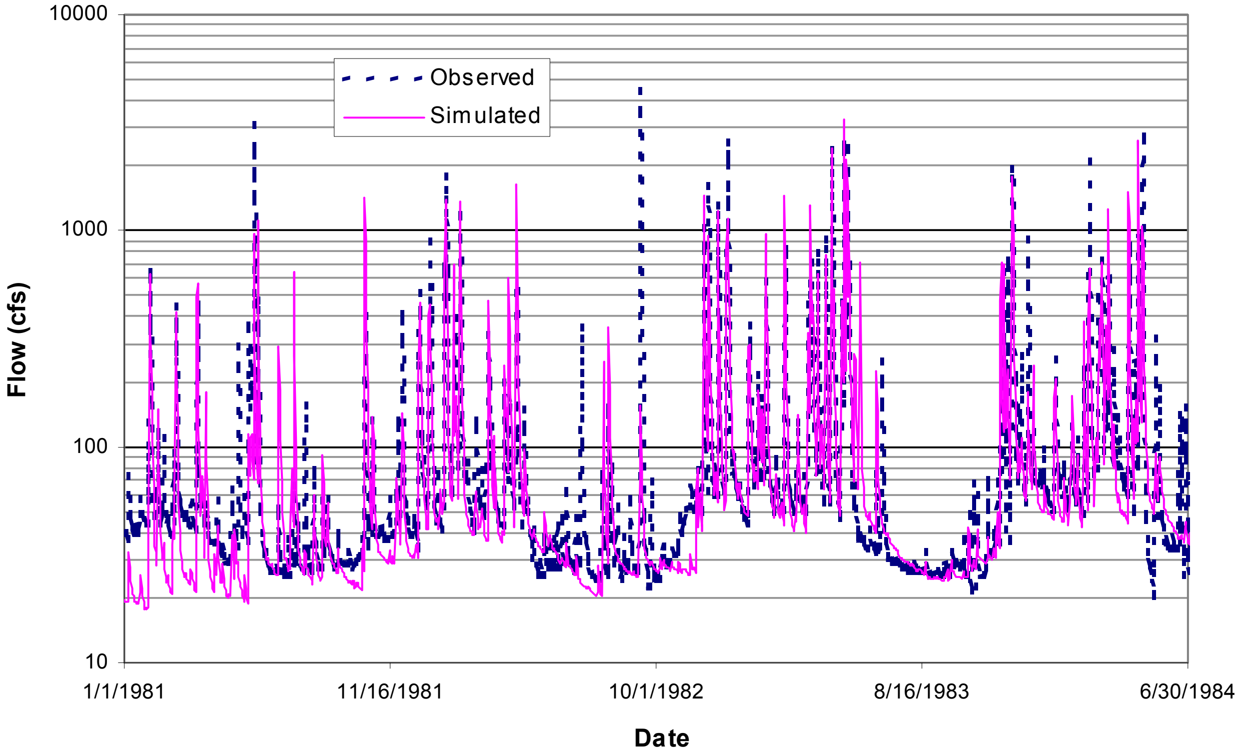
| | | | |
|---|---|---|---|
| **Simulation Name:** | **GS45007 (calibration)** | **Simulation Period:** | |
| | S.F. Obion near Greenfield | **Watershed Area (ac):** | 245120.00 |
| ***Period for Flow Analysis*** | (USGS 07024500) | | |
| ***Begin Date:*** | **01/01/81** | **Baseflow PERCENTILE:** | 2.5 |
| ***End Date:*** | **12/31/87** | *Usually 1%-5%* | |
| Total Simulated In-stream Flow: | **143.12** | Total Observed In-stream Flow: | **136.40** |
| Total of highest 10% flows: | **74.23** | Total of Observed highest 10% flows: | **70.12** |
| Total of lowest 50% flows: | **20.46** | Total of Observed Lowest 50% flows: | **19.75** |
| Simulated Summer Flow Volume (months 7-9): | **13.62** | Observed Summer Flow Volume (7-9): | **15.05** |
| Simulated Fall Flow Volume (months 10-12): | **47.19** | Observed Fall Flow Volume (10-12): | **37.43** |
| Simulated Winter Flow Volume (months 1-3): | **40.40** | Observed Winter Flow Volume (1-3): | **40.66** |
| Simulated Spring Flow Volume (months 4-6): | **41.91** | Observed Spring Flow Volume (4-6): | **43.26** |
| Total Simulated Storm Volume: | **119.09** | Total Observed Storm Volume: | **112.18** |
| Simulated Summer Storm Volume (7-9): | **7.58** | Observed Summer Storm Volume (7-9): | **9.00** |
| *Errors (Simulated-Observed)* | | *Recommended Criteria* | Last run |
| Error in total volume: | **4.93** | 10 | |
| Error in 50% lowest flows: | **3.61** | 10 | |
| Error in 10% highest flows: | **5.87** | 15 | |
| Seasonal volume error - Summer: | **-9.49** | 30 | |
| Seasonal volume error - Fall: | **26.08** | 30 | |
| Seasonal volume error - Winter: | **-0.65** | 30 | |
| Seasonal volume error - Spring: | **-3.10** | 30 | |
| Error in storm volumes: | **6.17** | 20 | |
| Error in summer storm volumes: | **-15.75** | 50 | |

**Table D-3. Hydrologic Calibration Summary: Obion River at Obion (USGS 07026000)**

| | | | |
|---|---|---|---|
| **Simulation Name:** | **GS6000a2 (calibration)** | **Simulation Period:** | |
| | Obion River at Obion | **Watershed Area (ac):** | 1185280.00 |
| ***Period for Flow Analysis*** | (USGS 07026000) | | |
| ***Begin Date:*** | **01/01/81** | **Baseflow PERCENTILE:** | 2.5 |
| ***End Date:*** | **12/31/90** | *Usually 1%-5%* | |
| Total Simulated In-stream Flow: | **213.84** | Total Observed In-stream Flow: | **222.89** |
| Total of highest 10% flows: | **115.01** | Total of Observed highest 10% flows: | **119.41** |
| Total of lowest 50% flows: | **27.54** | Total of Observed Lowest 50% flows: | **26.22** |
| Simulated Summer Flow Volume (months 7-9): | **22.60** | Observed Summer Flow Volume (7-9): | **21.87** |
| Simulated Fall Flow Volume (months 10-12): | **70.38** | Observed Fall Flow Volume (10-12): | **63.48** |
| Simulated Winter Flow Volume (months 1-3): | **65.29** | Observed Winter Flow Volume (1-3): | **79.20** |
| Simulated Spring Flow Volume (months 4-6): | **55.56** | Observed Spring Flow Volume (4-6): | **58.34** |
| Total Simulated Storm Volume: | **184.27** | Total Observed Storm Volume: | **188.14** |
| Simulated Summer Storm Volume (7-9): | **15.18** | Observed Summer Storm Volume (7-9): | **13.13** |
| *Errors (Simulated-Observed)* | | *Recommended Criteria* | Last run |
| Error in total volume: | **-4.06** | 10 | |
| Error in 50% lowest flows: | **5.01** | 10 | |
| Error in 10% highest flows: | **-3.69** | 15 | |
| Seasonal volume error - Summer: | **3.38** | 30 | |
| Seasonal volume error - Fall: | **10.86** | 30 | |
| Seasonal volume error - Winter: | **-17.56** | 30 | |
| Seasonal volume error - Spring: | **-4.76** | 30 | |
| Error in storm volumes: | **-2.05** | 20 | |
| Error in summer storm volumes: | **15.64** | 50 | |

**Table D-4. Hydrologic Calibration Summary: North Reelfoot Creek at Hwy. 22 near Clayton (USGS 07026370)**

| | | | |
|---|---|---|---|
| **Simulation Name:** | **GS6370d (calibration)** | **Simulation Period:** | |
| | North Reelfoot Creek at Hwy 22 | **Watershed Area (ac):** | 36032.00 |
| ***Period for Flow Analysis*** | (USGS 07026370) | | |
| ***Begin Date:*** | **10/01/80** | **Baseflow PERCENTILE:** | 2.5 |
| ***End Date:*** | **09/30/89** | *Usually 1%-5%* | |
| Total Simulated In-stream Flow: | **143.41** | Total Observed In-stream Flow: | **140.28** |
| Total of highest 10% flows: | **98.36** | Total of Observed highest 10% flows: | **97.42** |
| Total of lowest 50% flows: | **2.55** | Total of Observed Lowest 50% flows: | **2.40** |
| Simulated Summer Flow Volume (months 7-9): | **5.54** | Observed Summer Flow Volume (7-9): | **8.58** |
| Simulated Fall Flow Volume (months 10-12): | **45.40** | Observed Fall Flow Volume (10-12): | **39.54** |
| Simulated Winter Flow Volume (months 1-3): | **45.50** | Observed Winter Flow Volume (1-3): | **51.22** |
| Simulated Spring Flow Volume (months 4-6): | **46.97** | Observed Spring Flow Volume (4-6): | **40.93** |
| Total Simulated Storm Volume: | **143.40** | Total Observed Storm Volume: | **140.28** |
| Simulated Summer Storm Volume (7-9): | **5.54** | Observed Summer Storm Volume (7-9): | **8.58** |
| *Errors (Simulated-Observed)* | | *Recommended Criteria* | Last run |
| Error in total volume: | **2.24** | 10 | |
| Error in 50% lowest flows: | **6.19** | 10 | |
| Error in 10% highest flows: | **0.96** | 15 | |
| Seasonal volume error - Summer: | **-35.47** | 30 | |
| Seasonal volume error - Fall: | **14.83** | 30 | |
| Seasonal volume error - Winter: | **-11.17** | 30 | |
| Seasonal volume error - Spring: | **14.76** | 30 | |
| Error in storm volumes: | **2.23** | 20 | |
| Error in summer storm volumes: | **-35.51** | 50 | |



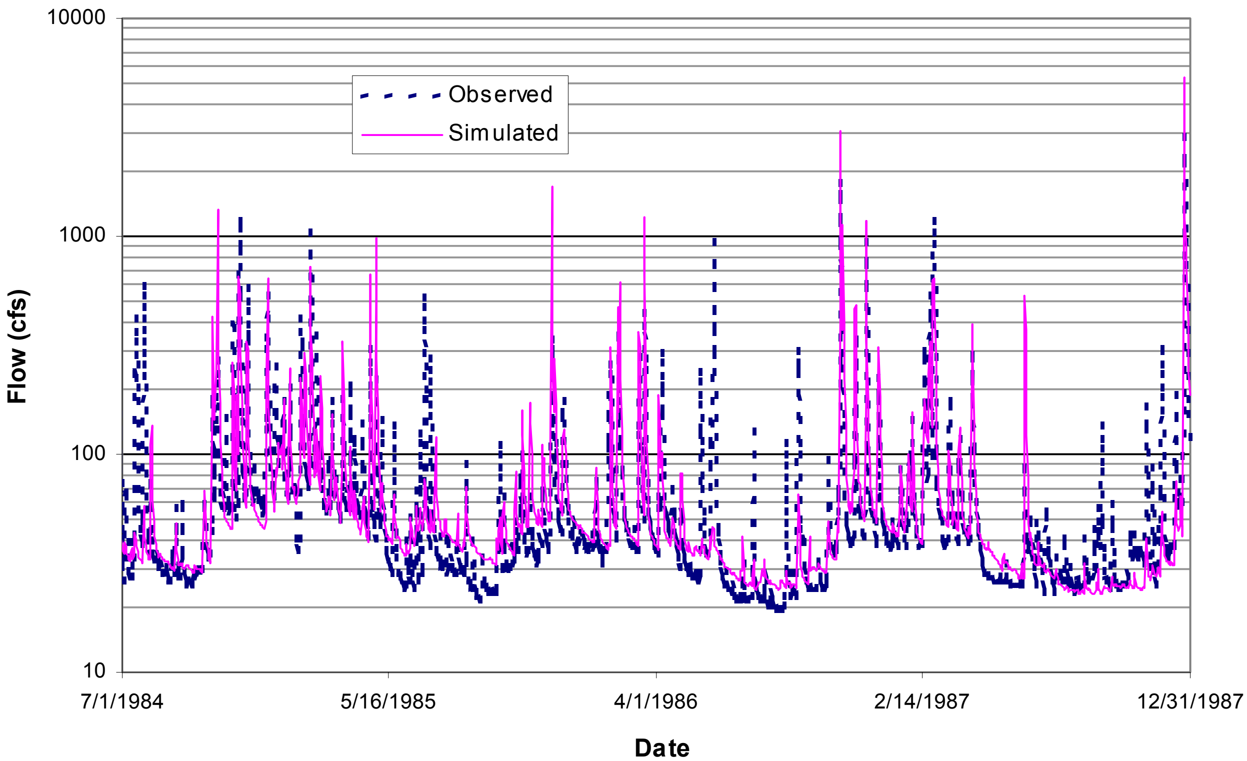
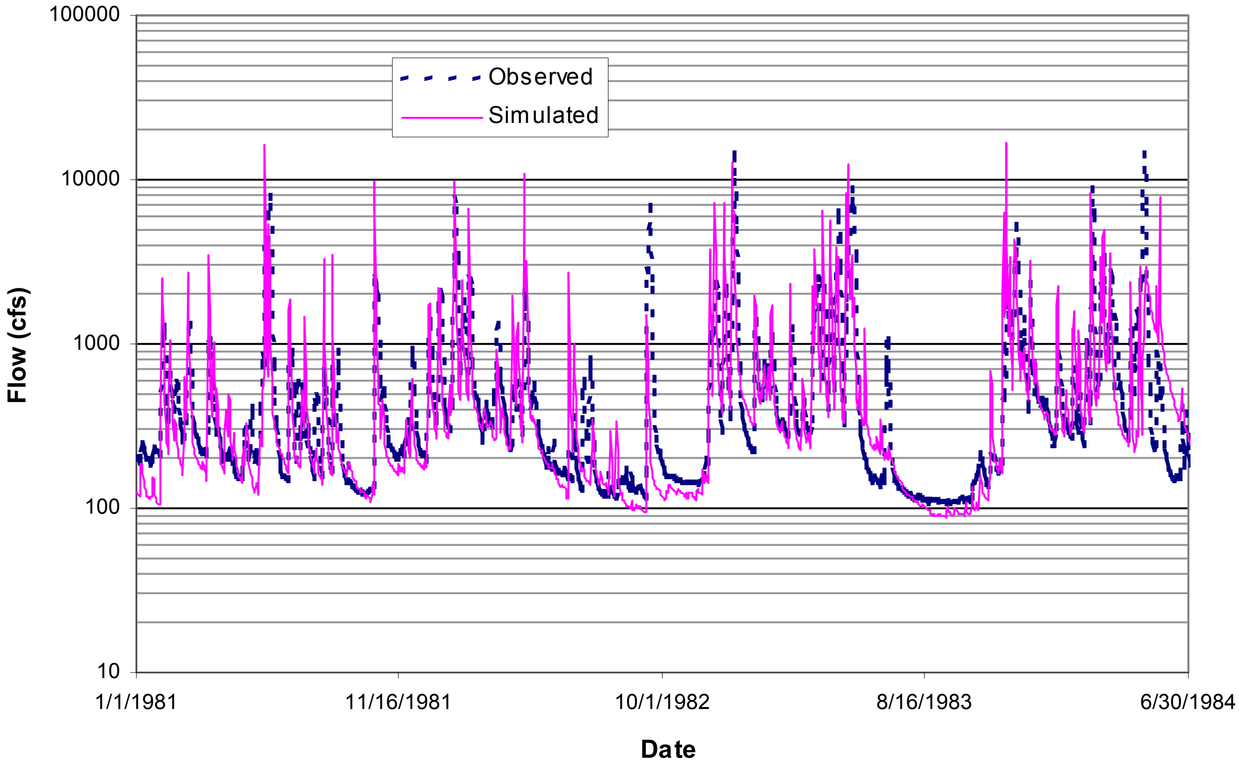




**Figure D-1. Hydrologic Calibration: Beaver Creek at Huntingdon (USGS 07024300)**



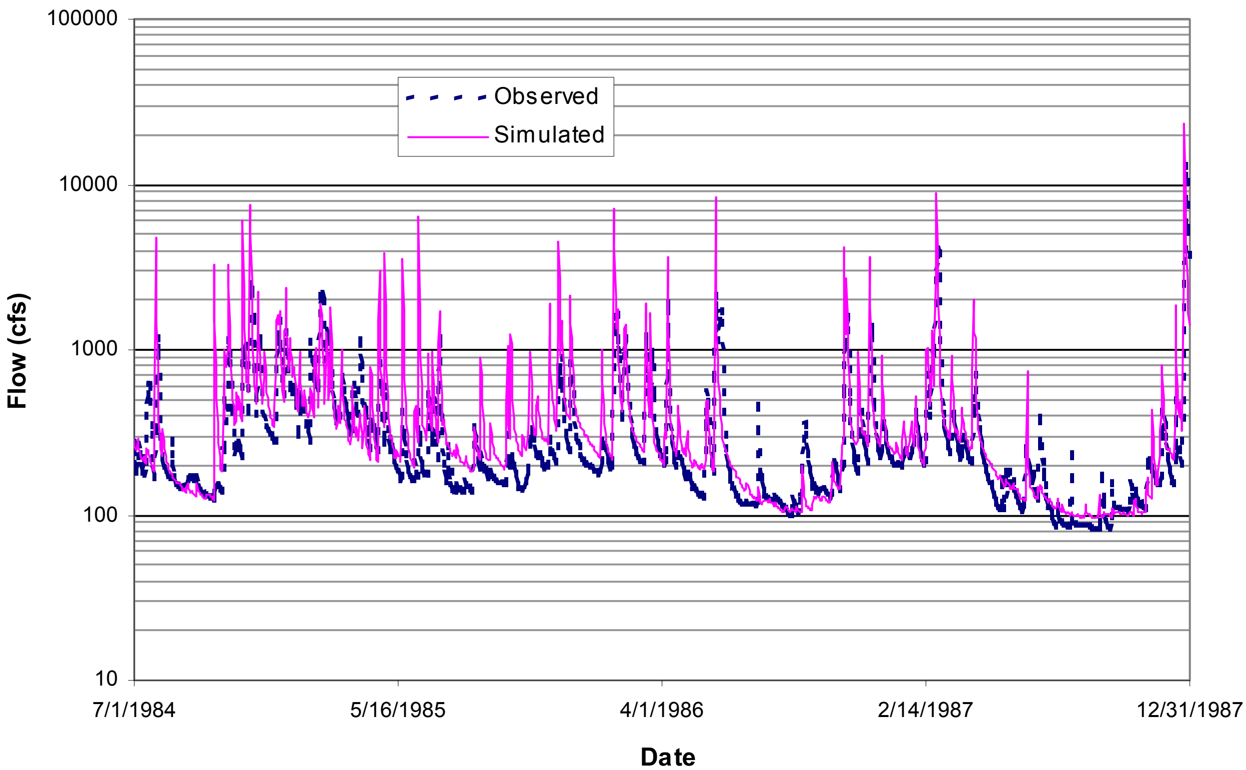




**Figure D-2. Hydrologic Calibration: South Fork Obion River near Greenfield (USGS 07024500)**

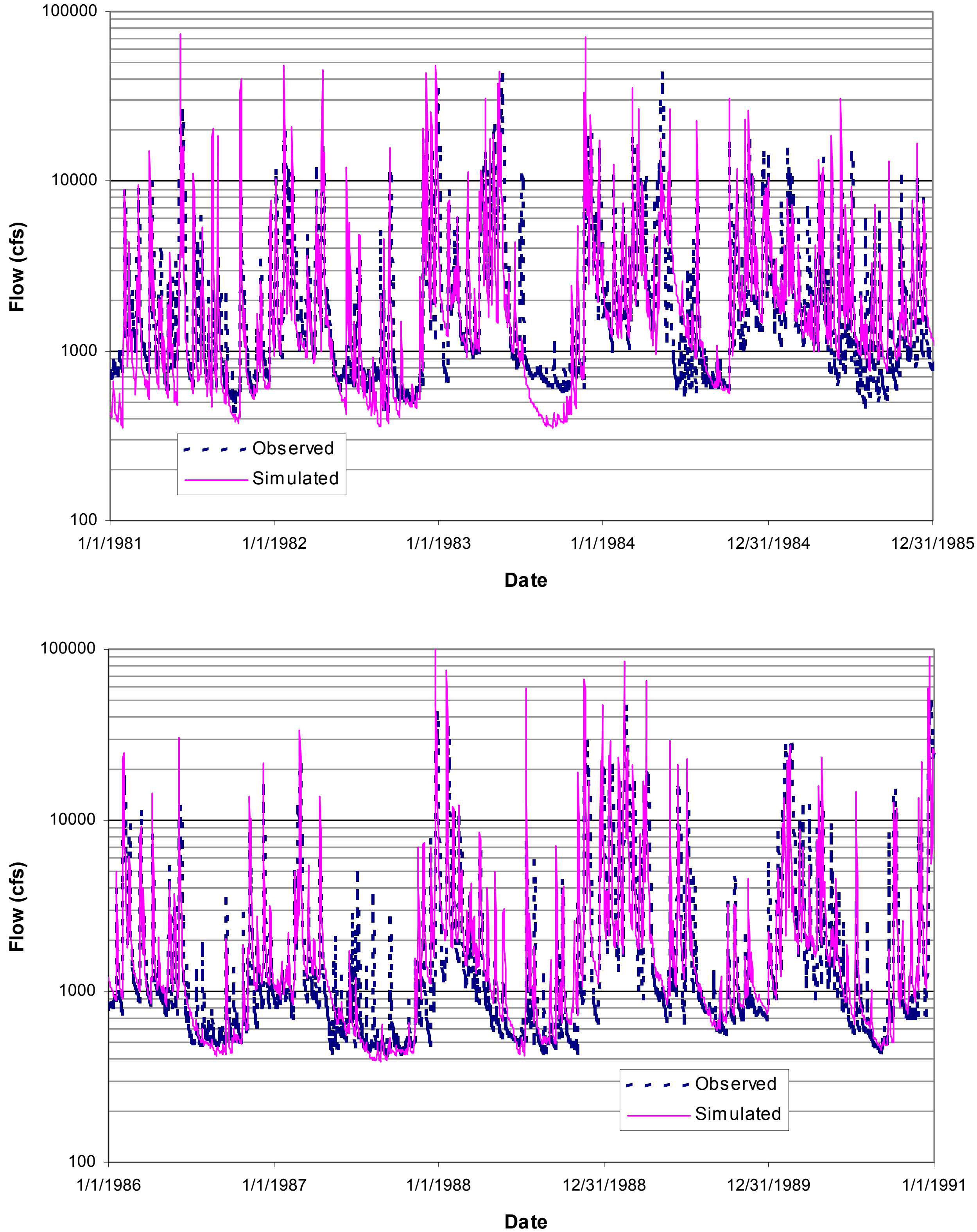
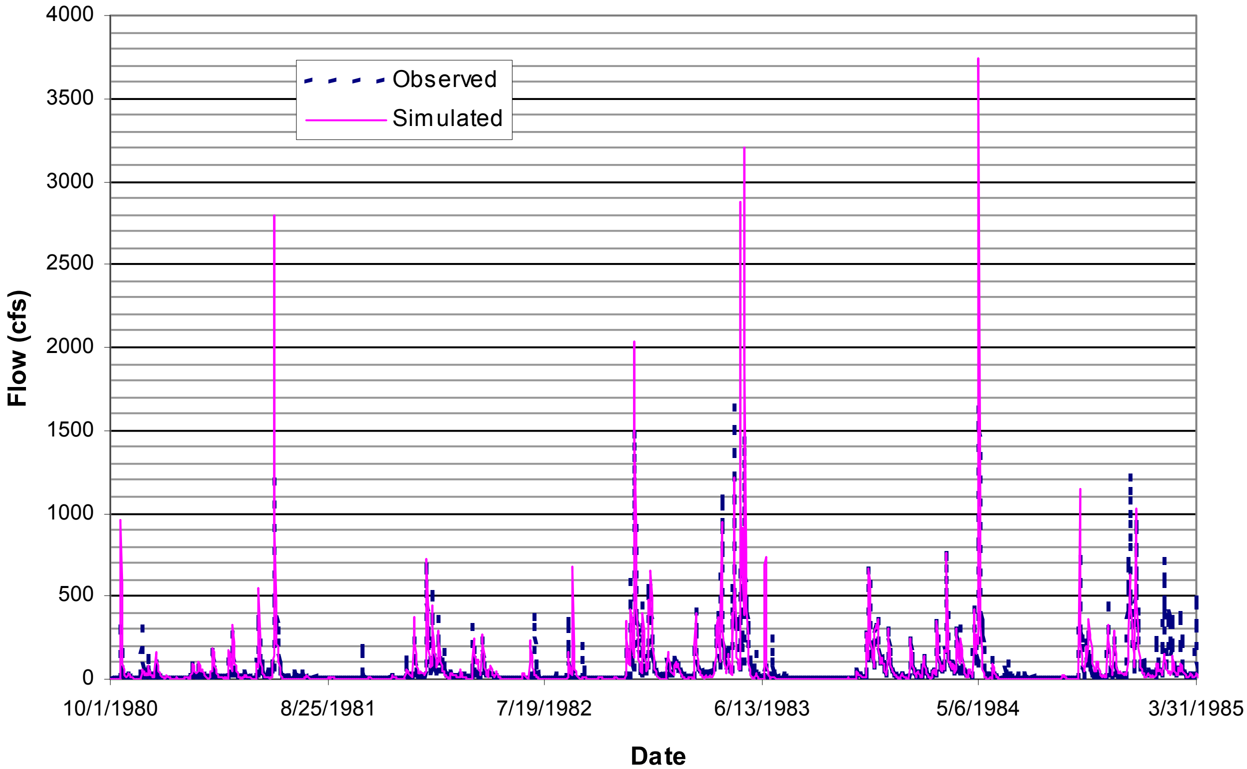



**Figure D-3. Hydrologic Calibration: Obion River at Obion (USGS 07026000)**



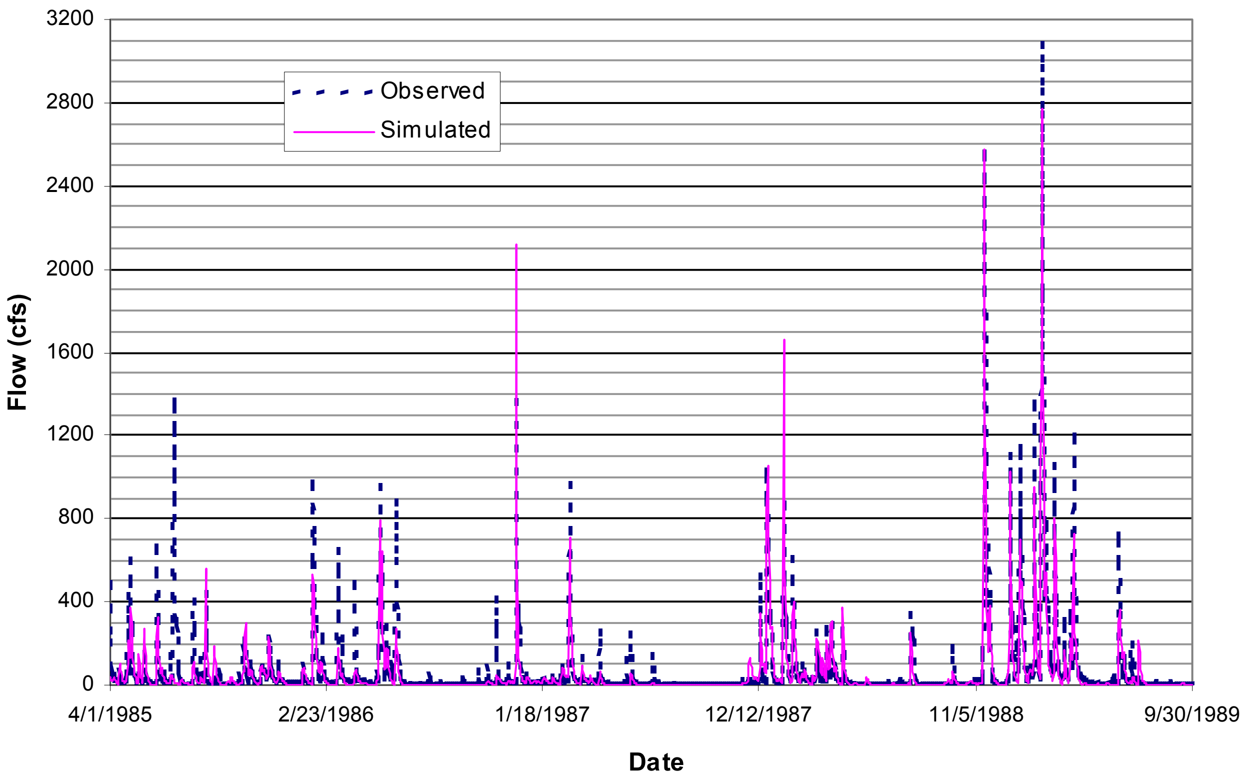




**Figure D-4. Hydrologic Calibration: North Reelfoot Creek at Hwy. 22 near Clayton (USGS 07026370)**

## APPENDIX E

**Public Notice of Proposed Total Maximum Daily Loads (TMDLs) for E. Coli in the Obion River Watershed (HUC 08010202)**

## DIVISION OF WATER POLLUTION CONTROL

## PUBLIC NOTICE OF AVAILABILITY OF PROPOSED TOTAL MAXIMUM DAILY LOAD (TMDL) FOR E. COLI IN THE OBION RIVER WATERSHED (HUC 08010202), TENNESSEE

Announcement is hereby given of the availability of Tennessee's proposed total maximum daily load (TMDL) for E. coli in the Obion River watershed, located in western Tennessee. Section 303(d) of the Clean Water Act requires states to develop TMDLs for waters on their impaired waters list. TMDLs must determine the allowable pollutant load that the water can assimilate, allocate that load among the various point and nonpoint sources, include a margin of safety, and address seasonality.

A number of waterbodies are listed on Tennessee's Final 2006 303(d) list as not supporting designated use classifications due, in part, to discharge of E. coli from agriculture and undetermined fecal/pathogen sources. The TMDL utilizes Tennessee's general water quality criteria, recently collected site specific water quality data, continuous flow data from USGS discharge monitoring stations located in the watershed, a calibrated hydrologic model, and load duration curves to establish allowable loadings of E. coli which will result in reduced in-stream concentrations and attainment of water quality standards. The TMDL requires reductions of E. coli loading on the order of 31-68% for the listed waterbodies.

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

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

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

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

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

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

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

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

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