# PATHOGEN TMDLS FOR SELECTED REACHES

# IN PLANNING SEGMENT 1C

**Prepared by**
**US EPA Region VI**
**Water Quality Protection Division**
**TMDL Team**
**Dallas, TX 75202**

**January 7, 2008**

This page intentionally left blank

# EXECUTIVE SUMMARY

Section 303(d) of the Clean Water Act and the U.S. Environmental Protection Agency's (EPA) Water Quality Planning and Management Regulations (Title 40 of the *Code of Federal Regulations* [CFR] Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for impaired water-bodies. A TMDL establishes the amount of a pollutant that a water-body can assimilate without exceeding its water quality standard for that pollutant. TMDLs provide the scientific basis for a state to establish water quality-based controls to reduce pollution from both point and non-point sources to restore and maintain the quality of the state's water resources (USEPA, 1991).

The study area is part of the Arkansas Department of Environmental Quality (ADEQ) Planning Segment 1C and is located in southwest Arkansas north of Texarkana and includes all of Sevier County and parts of Polk, Howard, Hempstead and Little River counties. The study area for this project is limited to two HUC-reaches in the Arkansas Planning Segment 1C (11140109-013 and 11140109-033). Land use in the study area consists mostly of pasture and forest. The designated beneficial uses that have been established by ADEQ for Planning Segment 1C include fishery, primary and secondary contact recreation; agricultural and industrial water supply.

The numeric water quality criteria that apply to the impaired reaches in the Saline River Basin and that were used to calculate the total allowable loads are the primary contact water quality criteria for fecal coliform bacteria and E. coli. The TMDLs for both fecal coliform and E. coli bacteria were developed based on mass balance principles. This TMDL information was based on load duration curve methodology. This method illustrates allowable loading at a wide range of stream-flow conditions. The seasonal fecal coliform and E. coli bacteria TMDLs were developed on the basis of analyses of the applicable water quality criteria (i.e., calculating allowable loads for both summer (May 1 – September 30) and winter (October 1 – April 30)). Table ES.1 presents TMDLs and allocations for the two HUC-reaches in Planning Segment 1C for each pollutant.

## Table ES.1 Summary of Bacteria TMDLs Planning Segment 1C

| Arkansas HUC-Reach # | Pollutant | Criteria | MOS cfu/day | ∑ WLA cfu/day | ∑ LA cfu/day | TMDL cfu/day |
|---|---|---|---|---|---|---|
| | **Holly Creek** | | | | | |
| 11140109-013 | FC | PCR-S | 4.22E+12 | 2.04E+10 | 3.79E+13 | 4.22E+13 |
| | FC | PCR-W/SCR | 2.11E+13 | 1.02E+11 | 1.90E+14 | 2.11E+14 |
| | E. coli | PCR-S | 4.32E+12 | 2.09E+10 | 3.89E+13 | 4.32E+13 |
| | E. coli | PCR-W/SCR | 2.16E+13 | 1.04E+11 | 1.94E+14 | 2.16E+14 |
| | **Mine Creek** | | | | | |
| 11140109-033 | FC | PCR-S | 7.34E+12 | 6.1254E+10 | 6.60E+13 | 7.34E+13 |
| | FC | PCR-W/SCR | 3.67E+13 | 3.0594E+11 | 3.30E+14 | 3.67E+14 |
| | E. coli | PCR-S | 7.52E+12 | 6.2783E+10 | 6.76E+13 | 7.52E+13 |
| | E. coli | PCR-W/SCR | 3.76E+13 | 3.1359E+11 | 3.38E+14 | 3.76E+14 |

**PCR-S** (primary contact recreation summer) criteria – between May 1 - Sept 30 for pathogens.
**PCR-W** (primary contact recreation winter) criteria - between Oct. 1 - April 30, criteria may not exceed SCR (secondary contact recreation) criteria limits
**SCR** - Year round criteria limits
**Cfu/day** = colony forming units/day

# TABLE OF CONTENTS

# LIST OF TABLES



# LIST FIGURES

# 1.0 INTRODUCTION

This report presents total maximum daily loads (TMDLs) for fecal coliform and *Escherichia coli* (E. coli) for 2 HUC-Reaches located in southwest Arkansas north of Texarkana. These HUC-Reaches were included on the Arkansas Department of Environmental Quality (ADEQ) 2004 Section 305(b) Report (ADEQ, 2005a) as not supporting their designated use of Primary Contact Recreation and/or Secondary Contact Recreation. The sources of contamination and causes of impairment from the 303(d) listing are shown below in Table1.0. The TMDLs in this report address the impairments due to pathogens and were developed in accordance with Section 303(d) of the Federal Clean Water Act and the Environmental Protection Agency's (EPA) regulations in 40 CFR 130.7.

**Table 1.0 Pathogen impaired HUC-Reaches**

| HUC-Reach Number | Waterbody Name | Impaired Use | Cause of Impairment | Suspected Source | Priority Ranking |
|---|---|---|---|---|---|
| 11140109-013 | Holly Creek | PCR | Pathogen | MP, IP | Medium |
| 11140109-033 | Mine Creek | PCR | Pathogen | IP | Medium |

SCR = Secondary Contact Recreation
PCR = Primary Contact Recreation
MP = Municipal point source
IP = Industrial point source

The purpose of a TMDL is to determine the pollutant loading that a waterbody can assimilate without exceeding the water quality standard for that pollutant and to establish the load reduction that is necessary to meet the standard in a waterbody. The TMDL is the sum of the wasteload allocation (WLA), the load allocation (LA), and a margin of safety (MOS). The WLA is the load allocated to point sources of the pollutant of concern. The LA is the load allocated to nonpoint sources (NPS), including natural background. The MOS is a percentage of the TMDL that takes into account any lack of knowledge concerning the relationship between pollutant loadings and water quality.

# 2.0 STUDY AREA INFORMATION

## 2.1 General Description

The planning segment for this project is located in the southwest Arkansas north of Texarkana, its tributaries from USGS Hydrologic Unit 11140109, and the Arkansas portion of the basin are designated by ADEQ as Planning Segment 1C. The drainage area of Saline River is 92.2 square miles. The Arkansas portion of the basin includes parts of Polk, Howard, Hempstead and Little River counties. The main tributaries of Little River in Arkansas are Rolling Fork, Cossatot River, Saline River and Mine Creek. The major reservoirs located in this segment include DeQueen, Gillham and Dierks Reservoirs, all of which drain into Millwood Reservoir. The waters within this segment have been designated as suitable for the propagation of fishery, primary and secondary contact recreation, and industrial and agricultural water supplies. Table 2.1 below shows designated uses on selected HUC-Reaches. The study area in the 1C segment is about 11.4 stream miles, all of which are being assessed using monitoring data (Figure 2.1 in Appendix A).

**Table 2.1 Designated Uses on Selected HUC-Reaches**

| HUC-Reaches | Waterbody Name | Designated Uses |
|---|---|---|
| 1114019-013 | Holly Creek | AWS, FS, IWS, PCR, SCR |
| 1114019-033 | Mine Creek | AWS, FS, IWS, PCR, SCR |

AWS Agricultural Water Supply
FS Fishery Stream
IWS Industrial Water Supply
PCR Primary Contact Recreation
SCR Secondary Contact Recreation

## 2.2 Soils and Topography

Soil characteristics for the watershed are also provided by the county soil surveys (USDA, 1976; USDA, 1979; USDA, 1981). Maps showing spatial distributions of soils information were developed using data in GIS format from the STATSGO database, which is maintained by the Natural Resources Conservation Service (NRCS). The published soil surveys for these counties provide soil mapping that is more detailed than the STATSGO data. The predominant soil series in the study area are shown on Figure 2.2 in Appendix A.

## 2.3 Land Use

Land use data for the Arkansas portion of the study area were obtained from the GEOSTOR database, which is maintained by the Center for Advanced Spatial Technology (CAST) at the University of Arkansas in Fayetteville. These data were based on satellite imagery from 1999. Because this data set included many detailed land use classifications, similar land uses were combined to reduce the number of different land uses. The spatial distribution of these land uses is shown on Figures 2.3 and 2.4 in Appendix A. Approximate percentages of these land uses in the watershed are listed below in Table 2.3. Forest occupies over 76.2% of the watershed. Cropland occupies almost 22.6% of the watershed and is located mainly along the east side of the watershed where the two reaches are located.

**Table 2.3 Land Use Percentages For The Study Area.**

| Land Use | Percentage of Study Area |
|---|---|
| Forest | 76.20% |
| Pasture | 22.60% |
| Urban | 1.00% |
| Water | 0.20% |
| Total | 100.00% |

## 2.4 Flow Characteristics

There were a number of USGS flow gages in Planning Segment 1C. There are 2 USGS flow gages has published daily stream flow data for Saline River. The locations of the gages are shown on Figure 2.1 in Appendix A. Basic information and summary statistics for these gages are summarized below in Table 2.4. Average annual precipitation for the Planning Segment is approximately 50-52 inches (Figure 2.5 in Appendix A).

**Table 2.4 Stream Flow Gage Stations (USGS 2001a and USGS 2001b)**

| | Saline River near Dierks, AR | Saline River near Lockesburg, AR |
|---|---|---|
| USGS gage number | 7341000 | 7341200 |
| Descriptive location | Howard County | Sevier County |
| Drainage area (mi2) | 124 | 256 |
| Period of record | Oct. 1938 to Oct. 2006 | July 1963 to Present |
| Mean annual flow (cfs) | 193 | 388 |

# 3.0 WATER QUALITY STANDARDS

## 3.1 Definitions

*Total Fecal coliform Bacteria*

Total coliform bacteria are a collection of relatively harmless microorganisms that live in large numbers in the intestines of man and warm- and cold-blooded animals. They aid in the digestion of food.

*Fecal coliform Bacteria*

These organisms may be separated from the total coliform group by their ability to grow at elevated temperatures and are associated only with the fecal material of warm-blooded animals.

*Escherichia coli (E. coli)*

E. coli is a subset of fecal coliform bacteria.

The presence of fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the fecal material of man or other animals. At the time this occurred, the source water might have been contaminated by pathogens or disease producing bacteria or viruses that can also exist in fecal material. Some waterborne pathogenic diseases include typhoid fever, viral and bacterial gastroenteritis and hepatitis A. The presence of fecal contamination is an indicator that a potential health risk exists for individuals exposed to this water. Fecal coliform bacteria may occur in ambient water as a result of the overflow of domestic sewage or non-point sources of human and animal waste (USEPA, 2001).

## 3.2 Water Quality Standards for Surface Waters of the State of Arkansas

There is no narrative criterion. The water use classification for the impaired water-bodies primary and secondary contact recreation. The fishery stream Gulf coastal classification is described in #014.00-002 of Arkansas's Pollution Control and Ecology Commission Regulations Establishing Water Quality Standard for Surface Waters of the State of Arkansas (Adopted on April 23, 2004 Amended April 28, 2006).

The following is an except for Arkansas Reg. 2.507 (APCEC, 2006) for the numeric criteria

"The Arkansas Department of Health has the responsibility of approving or disapproving surface waters for public water supply and of approving or disapproving the suitability of specifically delineated outdoor bathing places for body contact recreation, and it has issued rules and regulations pertaining to such uses.

For the purposes of this regulation, all streams with watersheds less than 10 $mi^2$ shall not be designated for primary contact unless and until site verification indicates that such use is attainable. No mixing zones are allowed for discharges of bacteria.

(A) Primary Contact Waters - Between May 1 and September 30, the fecal coliform content shall not exceed a geometric mean of 200 col/100 ml nor a monthly maximum of 400 col/100 ml. Alternatively, in these waters, *Escherichia coli (E. coli)* colony counts shall not exceed a geometric mean of more than 126 col/100 ml, or a monthly maximum value of not more than 298 col/100ml in lakes, reservoirs and Extraordinary Resource Waters or 410 col/100 ml in other rivers and streams. During the remainder of the calendar year, these criteria may be exceeded, but at no time shall these counts exceed the level necessary to support secondary contact recreation (below).

"(B) Secondary Contact Waters - The fecal coliform content shall not exceed a geometric mean of 1000 col/100 ml, nor a monthly maximum of 2000 col/100 ml. E. coli values shall not exceed the geometric mean of 630 col/100 ml. or a monthly maximum of 1490 col/100 ml for lakes, reservoirs and Extraordinary Resource Waters and 2050 col/100 me for other rivers and streams."

As specified in EPA's regulations at 40CFR 130.7(b)(2), applicable water quality standards include antidegradation requirements. Arkansas' antidegradation policy is summarized below.

Existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.

Water quality that exceeds standards shall be maintained and protected unless allowing lower water quality is necessary to accommodate important economic or social development, although water quality must still be adequate to fully protect existing uses.

For outstanding state or national resource waters, those uses and water quality for which the outstanding waterbody was designated shall be protected.

For potential water quality impairments associated with a thermal discharge, the antidegradation policy and implementing method shall be consistent with Section 316 of the Clean Water Act.

# 4.0 SOURCE ANALYSIS

Under the Clean Water Act, sources are classified as either point or nonpoint sources. An important part of TMDL analysis is the identification of individual sources, or source subcategories of pollutants in the watershed that affect pathogen loading and the amount of loading contributed by each of these sources. The subcategorization is mostly in the area of the TMDL implementation plan, which is outside the scope of this document.

## 4.1 Point Sources

Under 40CFR §122.2, a point source is defined as "any discernable, confined, and discrete conveyance, including but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discreet fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, vessel or other floating craft from which pollutants are or may be discharged." The National Pollutant Discharge Elimination System (NPDES) program regulates point source discharges. Point source discharges can be described by broad subcategories: 1) NPDES regulated municipal and industrial wastewater treatment facilities (WWTF); 2) NPDES regulated industrial and municipal storm water discharges; 3) NPDES regulated indirect industrial and industrial non-process wastewater discharges; and 4) NPDES regulated Concentrated Animal Feeding Operations (CAFOs). A TMDL usually provides Waste Load Allocations (WLAs) for all NPDES regulated point sources.

Both treated and untreated sanitary wastewater contains fecal coliform bacteria. If they are classified with a SIC code of 4952 (Sewerage Systems), they must have pathogen requirements in the effluent monitoring data, submitted on Discharge Monitoring Reports (DMR). Information for point source discharges in the study area was obtained by searching the Permit Compliance System on the EPA web site (PCS, 2005).

### 4.1.1 Stormwater and MS4s – Phase I

The scope of Phase I was described as follows: In response to the 1987 Amendments to the Clean Water Act (CWA), the U.S. Environmental Protection Agency (EPA) developed Phase I of the NPDES Storm Water Program in 1990. It was mandated that cities nationwide develop programs addressing the issue of storm water pollution. The Phase I program targeted sources of storm water runoff that had the greatest potential to negatively impact water quality. Under Phase I, EPA required permit coverage for storm water discharges from "Medium" and "Large" municipal separate storm sewer systems (MS4s) located in incorporated places or counties with populations of 100,000 or more; and eleven categories of industrial activity, including construction projects that disturbs five or more acres of land. A medium MS4 is a system that services a population between 100,000 and 249,999. Meanwhile, a large MS4 is a system that services a population of 250,000 or more (USEPA, 1996).

### 4.1.2 Stormwater and MS4s – Phase II

The contribution of fecal material is the same as described above under Phase I. The scope of Phase II is described as follows: Smaller entities will be soon implementing the Phase II storm-water regulations. Operators of small MS4s (primarily those located in urbanized areas are required to implement programs and practices to control polluted storm water runoff from the jurisdiction serviced by the MS4. The operator must design its storm water management program to satisfy applicable CWA water quality requirements and technology standards. The program must include the development and implementation of best management practices (BMPs) and measurable goals for the following six minimum measures, and include evaluation and reporting efforts:

- Public education and outreach

- Public participation/involvement
- Illicit discharge detection and elimination
- Construction site runoff control
- Post-construction runoff control
- Pollution prevention/good housekeeping for municipal operations.

All construction operators disturbing more than 1 acre and less than 5 acres are required to apply for an NPDES storm water permit for small construction activity. EPA already regulates construction activity disturbing more than 5 acres. A construction operator is usually the developer or landowner, but can also be the contractor or another party responsible for the operational control of erosion and sediment control practices on site (EPA, 2004).

### 4.1.3 Concentrated Animal Feeding Operations (CAFOs)

Animal feeding operations are agricultural enterprises where animals are kept and raised in confined situations. These operations congregate animals, feed, manure and urine, dead animals, and production operations on a small land area. Feed is brought to the animals rather than the animals grazing or otherwise seeking feed in pastures, fields, or on rangeland (USEPA, 2002). Best Management Practices (BMPs) are implemented as the pollution controls at these facilities. Animal waste shall be isolated from outside surface drainage by ditches, dikes, terraces or other such structures except for a twenty-five-year, twenty-four-hour rainfall event. No waters of the state shall come into direct contact with the animals confined on the animal feeding operations.

## 4.2 Non-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 usually provides a Load Allocation (LA) for these sources.

These sources generally, but not always, involve accumulation of fecal coliform bacteria on land surfaces and wash off as a result of storm events. Nonpoint sources of pathogen loading are associated with any land use that has wildlife, domestic animals, or uses animal waste for any reason. The vast majority of waterbodies identified on the 303(b) Report as impaired due to pathogens could be due to nonpoint agricultural or urban sources. The predominant land uses for the listed reaches in Planning Segment 1C are forest and pasture. Therefore, the most probable source of Fecal coliform and E. coli bacteria could be from wildlife and domestic animals living in the area. Run off from the pastures can contribute Fecal coliform and E. coli to the study area. It is presently unknown to what extent these sources contribute to pathogen loads.

Nonpoint source loading of fecal bacteria from urban land use areas is attributable to multiple sources. These include: storm water runoff, illicit discharges of sanitary waste, runoff from improper disposal of waste materials, and pets. Impervious surfaces in urban areas allow runoff to be conveyed to streams quickly, without infiltration through soils and interaction with groundwater.

### 4.2.1 Land Application Sites

Land application of municipal sludge is common in Arkansas. Municipal sewage sludge can be an important restorative for abused land and it can be substantially more effective than treatment of eroded areas that involves only grading and onetime fertilizing at planting. Sludge can improve soil condition, restore fertility, and maintain gentle contour while simultaneously solving the problem of disposal (Kessler, et al. 1985). One of the potential hazards associated with the application of sewage sludge to land is the possibility of human exposure to pathogens. Because of this hazard, sewage sludge must undergo additional treatment to reduce pathogens before it can be used for land application (Krogmann, et. al., 2003).

### 4.2.2 Agricultural Animals

Agricultural activities can be a significant source of fecal coliform bacteria loading to surface waters. The activities of greatest concern are typically those associated with livestock operations (Drapcho and Hubbs, 2002): Agricultural livestock grazing in pastures deposit manure containing fecal coliform bacteria onto land surfaces. This material accumulates during periods of dry weather and is available for washoff and transport to surface waters during storm events. The number of animals in pasture and the time spent grazing are important factors in determining the loading contribution.

Processed agricultural manure from confined feeding operations is often applied to land surfaces and can provide a significant source of fecal bacteria loading. Agricultural livestock often have direct access to water-bodies and can provide a concentrated source of fecal loading directly to a stream.

### 4.2.3. Septic Systems

There are rural areas still relying on septic systems. The operation of some can reasonably be assumed to be discharging fecal coliform bacteria. Discharges of untreated sewage provide a concentrated source of fecal bacteria directly to water-bodies.

### 4.2.4 Wildlife

Fecal coliform bacteria are produced by all warm-blooded animals, including wildlife such as mammals and birds. When developing implementation plans for bacteria TMDLs, it is useful to identify the potential for bacteria contributions from wildlife by watershed. Wildlife is naturally attracted to riparian corridors of streams and rivers. Wildlife that has direct access to the stream channel can be a concentrated source of bacteria loading to a waterbody. Fecal coliform bacteria from wildlife are also deposited onto land surfaces, where it may be washed into nearby streams by rainfall runoff. There are insufficient data available to estimate populations of wildlife and avian species by watershed. Consequently, it is difficult to assess the magnitude of contributions from wildlife species as a general category.

# 5.0 CHARACTERIZATION OF EXISTING WATER QUALITY

## 5.1 Comparison of Observed Data to Criteria

Fecal coliform and E. coli bacteria monitoring data for each listed HUC-Reach were obtained from ADEQ (Table 5.1 in Appendix A). A map of the monitoring station is shown in Figure 2.1 of Appendix A. All the stations collected a number of samples from 1997 thru 2001.

As indicated in Table 5.2 in Appendix A, the samples collected at 4 stations had exceeded the primary contact recreation criterion of 400 colonies/100 ml during the summer months for fecal coliform, and they also exceeded the primary contact recreation winter/secondary contact criteria of 2000 colonies/100 ml from October through April timeframe. Station RED0034B had the most samples above the fecal coliform criterion, and its largest single sample concentration of greater than 6000 colonies/100 ml. Only one station (i.e., RED0048A) exceeded the E. coli primary contact recreation criterion of 410 colonies/100ml during the summer month.

## 5.2 Trends and Patterns in Observed Data

No distinct trends or patterns were found in the small data set of reported monitoring results. The highest fecal coliform bacteria concentrations were observed during the summer months and usually during low-flow conditions. Limited sample collection during high-flow periods limits the comparability of low-flow and high-flow monitoring results.

# 6.0 TMDL DEVELOPMENT

A TMDL is the total amount of a pollutant that can be assimilated by the receiving water-body while still achieving water quality standards. In TMDL development, allowable loadings from all pollutant sources that cumulatively amount to no more than the TMDL must be established and thereby provide the basis for establishing water quality-based controls.

A TMDL for a given pollutant and water-body is composed of the sum of individual waste-load allocations (WLAs) for point sources, and load allocations (LAs) for non-point sources and natural background levels. In addition, the TMDL must include an implicit or explicit margin of safety (MOS) to account for the lack of knowledge of the relationship between effluent limitation and water quality. The TMDL components are illustrated using the following equation:

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

TMDLs for some pollutants are expressed as a mass loading (e.g., kilograms per day). TMDLs for bacteria can be expressed in terms of colony forming units per day, in accordance with 40CFR 130.2(l).

The federal regulations at 40CFR 130.7 require that TMDLs shall be established at levels necessary to attain the applicable national numerical water quality standard with seasonal variations and take into account critical conditions for stream-flow, loading, and water quality parameters. These TMDL fecal coliform and E. coli bacteria loadings for segments with primary contact recreation as the designated use were determined for winter and summer on the basis of seasonal water quality criteria, thus accounting for seasonality. Critical conditions are accounted for by displaying the loads at water quality load duration curves for infrequent occurrences and not only for average conditions criteria.

## 6.1 Load Duration Curves (LDC)

Historically, in developing WLAs for pollutants from point sources, it was customary to designate a critical low flow condition (*e.g.*, 7Q2) at which the maximum permissible loading was calculated. As water quality management efforts expanded in scope to quantitatively address non-point sources of pollution and types of pollutants, it became clear that this single critical low flow condition was inadequate to ensure adequate water quality across a range of flow conditions. Use of the LDC removes the need to determine a design storm or selected flow recurrence interval with which to characterize the appropriate flow level for the assessment of critical conditions. The "non-point source critical condition" would typically occur during high flows, when rainfall runoff would contribute the bulk of the pollutant load. The "point source critical condition" would typically occur during low flows, when treatment plant effluents would dominate the base flow. LDCs display the maximum allowable load over the complete range of flow conditions by a line using the calculation of flow multiplied by the water quality criterion. The TMDLs can be expressed as a continuous function of flow, equal to the line, or as discrete values derived from each specific flow value.

The load duration curve (LDC) was used to develop TMDLs for Segment 1C. LDCs facilitate rapid development of TMDLs and are effective at identifying whether impairments are associated with point or non-point sources. Because loading capacity varies as a function of the flow present in the stream, these TMDLs represent a continuum of loads over all flow conditions, rather than fixed at a single value. The technical approach for using LDCs for TMDL development includes the following steps:

i) Developing flow duration curves (FDCs) for gaged and un-gaged HUC-Reach;

ii) Convert the FDCs to load duration curves (LDCs) for each HUC-Reach within Planning Segment 1C; and,

iii) Interpreting LDCs to derive TMDL elements – WLA, LA and MOS

### 6.1.1 Flow Duration Curves Development

Flow duration curves are graphical representations of the flow characteristics of a stream at a given site. Flow duration curves utilize the historical hydrologic record from stream USGS gages to forecast future recurrence frequencies. There is a number of WQM stations throughout Arkansas do not have long term flow data and therefore, flow frequencies must be estimated using a standard drainage area ratio method. The most basic method to estimate flows at an un-gaged site involves 1) identifying an upstream or downstream flow gage; 2) calculating the contributing drainage areas of the un-gage sites and the flow gage; and 3) calculating daily flows at the un-gage site by using the flow at the gage site multiplied by the drainage area ratio. More complex approaches may also consider watershed differences in rainfall, land use, and the hydrologic properties of soil that govern runoff and retention. More than one upstream watershed may also be considered. Flow duration curves are a type of cumulative distribution function.

The flow duration curve represents the fraction of flow observations that exceed a given flow at the site of interest. Daily stream flow measurements were sorted in increasing order, and the percentile ranking of each flow was calculated. The observed flow values are first ranked from highest to lowest, then, for each observation, the percentage of observations exceeding that flow is calculated. The flow value is read from the ordinate (y-axis), which is typically on a logarithmic scale since the high flows would otherwise overwhelm the low flows. The flow exceedance frequency is read from the abscissa (x-axis), which is numbered from 0 to 100 percent, and is not logarithmic. The lowest measured flow occurs at an exceedance frequency of 100 percent indicating that flow has equaled or exceeded this value 100 percent of the time, while the highest measured flow is found at an exceedance frequency of 0 percent. The median flow occurs at a flow exceedance frequency of 50 percent. The flow exceedance percentiles for each HUC-Reach addressed in this report are provided in Appendix B. The number of observations required to develop a flow duration curve is not rigorously specified, a flow duration curve is usually based on more than 1 year of observations, and encompasses inter-annual and seasonal variation. The drought of record and flood of record are included in the observations. The long term flow gage stations operated by the USGS are utilized (USGS 2005a). A typical semi-log flow duration curve exhibits a sigmoid shape, bending upward near the flow duration of 0 percent and downward at a frequency near 100 percent, often with a relatively constant slope in between. The curve will intersect the abscissa at a frequency less than 100 percent for sites that on occasion exhibit no flow. The line of the LDC tends to appear smoother as the number of observations at a site increases. At extreme low and high flow values, flow duration curves may exhibit a "stair step" effect due to the USGS flow data rounding conventions near the limits of quantization. The flow rate (e.g., cubic feet per second) and the percentage of days on which the plotted flow is exceeded are typically plotted on the Y-axis and the X-axis, respectively. The flow exceedance range of flow duration curves was subdivided into five hydrologic condition classes (see Table 6.1 below). The hydrologic classes selected facilitate the diagnostic and analytical uses of flow and LDCs. Flow duration curves (Figures B.1 through B.4) generated for HUC-Reaches using the described method are displayed in Appendix B.

**Table 6.1 Hydrologic Classification Scheme Flow Duration Interval**

| | |
|---|---|
| 0-10% | High flows |
| 10-40% | Moist Conditions |
| 40-60% | Mid-Range Conditions |
| 60-90% | Dry Conditions |
| 90-100% | Low Flows |

**6.1.2 Development of Load Duration Curve**

Load Duration Curves (LDCs) were developed for each season numeric criterion for each bacterium (i.e., fecal coliform and E. coli). The load duration curve presents corresponding flow information and monitoring results plotted as a load. This approach allows the monitoring data to be placed in relation to their place in the flow continuum. Assumptions of the probable source or sources of the impairment can then be made from the plotted data. The load duration curve shows the calculation of the TMDL at any flow rather than at a single critical flow. The official TMDL number is reported as a single number, but the curve is provided to demonstrate the value of the acceptable load at any flow. This will allow analysis of load cases in the future for different flow regimes.

The flows rate from the flow duration curves was multiplied by the appropriate fecal coliform and E. coli bacteria numeric criterion concentrations to compute an allowable load. For instance, the curve represents the single sample water quality criterion for fecal coliform (400 cfu/100 ml), *E. coli* (410 cfu/100 ml) expressed in terms of a load through multiplication by the continuum of flows historically observed at this site. Each load duration curve is a plot of mass per day versus the percent flow exceedance from the flow duration curves. In addition, LDCs have similar in appearance to flow duration curves; however, the ordinate is expressed in terms of a bacteria load in cfu per day (cfu/day). Each curve was assumed applicable at all sampling stations.

The culmination of these steps is expressed in the following formula which is displayed on the LDC as the TMDL curve:

***TMDL (cfu/day) = WQS * flow (cfs) * Unit Conversion Factor***

Where: WQS = 400 cfu /100 ml (Fecal coliform); 410 cfu/100 ml (E. coli);
Unit Conversion Factor = 24,465,525 ml*s / ft3*day

The flow exceedance frequency (x-value of each point) is obtained by looking up the historical exceedance frequency of the measured flow, in other words, the percent of historical observations that equal or exceed the measured flow

- matching the water quality observations with the flow data from the same date;
- multiplying the flow by the water quality parameter concentration to calculate daily loads; then
- plotting the flow exceedance percentiles and daily load observations in a load duration plot.

Tables A.1 – A.4 in Appendix A provide flow rate and load data which were used to develop the flow and pathogen load duration curves for HUC-Reaches. Figures C.1-C.8 in Appendix C are pathogen load duration curves plots developed for both HUC-Reaches.

### 6.1.3 Estimation of Loading/Identifying Critical Conditions

Another key step in the use of LDCs for TMDL development is the estimation of existing bacteria loading by displaying this loading in relation to the TMDL line. WWTPs that discharge treated sanitary wastewater must meet the state WQSs for bacteria at the point of discharge. Data necessary for this calculation were extracted from each point source's DMR from 1998 through 2004.

Estimated existing loading was calculated by multiplying the concentration of bacteria grab samples by the flow matched to the specific sampling date. The period of record for the bacteria data set varies from WQM station to WQM station. Bacteria data after 1997 were used to estimate existing loading. Existing loads were estimated by plotting on the LDC. The existing instream fecal coliform/E. coli load is compared the allowable load for that flow. Any existing loads above the allowable LDC (or the water quality criterion line) represent an exceedance of the WQS.

In some cases, inspection of the LDC will reveal a critical condition related to exceedances of WQSs. If criteria exceedances occur more frequently in wet weather, low flow conditions, or after large rainfall events, the critical conditions are such that if WQSs were met under those conditions. WQSs would likely be met overall.

## 6.2 Total Maximum Daily Loads (TMDLs)

The LDC approach recognizes that the assimilative capacity of a water-body depends on the flow, and that maximum allowable loading will vary with flow condition. Because loading capacity varies as a function of the flow present in the stream, these TMDLs represent a continuum of loads over all flow conditions, rather than fixed at a single value. TMDLs can be expressed in terms of maximum allowable concentrations, or as different maximum loads allowable under different flow conditions, rather than single maximum load values. This approach meets the requirements of 40CFR, 130.2(i) for expressing TMDLs “in terms of mass per time, toxicity, or other appropriate measures” and is consistent with USEPA’s Protocol for Developing Pathogen TMDLs (USEPA 2001). Each TMDL was calculated as the mass balance. The 50% flow exceedance value load was used. For tabulation, Table 6.2 below presents the TMDLs and allocations for the HUC-Reaches.

**Table 6.2- Summary of Bacteria TMDLs Planning Segment 1C**

| Arkansas HUC-Reach # | Pollutant | Criteria | MOS cfu/day | ∑ WLA cfu/day | ∑ LA cfu/day | TMDL cfu/day |
|---|---|---|---|---|---|---|
| | **Holly Creek** | | | | | |
| 11140109-013 | FC | PCR-S | 4.22E+12 | 2.04E+10 | 3.79E+13 | 4.22E+13 |
| | FC | PCR-W/SCR | 2.11E+13 | 1.02E+11 | 1.90E+14 | 2.11E+14 |
| | E. coli | PCR-S | 4.32E+12 | 2.09E+10 | 3.89E+13 | 4.32E+13 |
| | E. coli | PCR-W/SCR | 2.16E+13 | 1.04E+11 | 1.94E+14 | 2.16E+14 |
| | **Mine Creek** | | | | | |
| 11140109-033 | FC | PCR-S | 7.34E+12 | 6.1254E+10 | 6.60E+13 | 7.34E+13 |
| | FC | PCR-W/SCR | 3.67E+13 | 3.0594E+11 | 3.30E+14 | 3.67E+14 |
| | E. coli | PCR-S | 7.52E+12 | 6.2783E+10 | 6.76E+13 | 7.52E+13 |
| | E. coli | PCR-W/SCR | 3.76E+13 | 3.1359E+11 | 3.38E+14 | 3.76E+14 |

**PCR-S** (primary contact recreation summer) criteria – between May 1 - Sept 30 for pathogens.
**PCR-W** (primary contact recreation winter) criteria - between Oct. 1 - April 30, criteria may not exceed SCR (secondary contact recreation) criteria limits
**SCR** - Year round criteria limits
**Cfu/day** = colony forming units/day

## 6.3 Waste Load Allocation (WLA)

The WLA portion of the TMDL equation is the total loading of a pollutant that is assigned to point sources. A point source can be either a wastewater (continuous) or storm-water (MS4) discharge.

Storm-water point sources are typically associated with urban and industrialized areas, and recent USEPA guidance includes permitted storm-water discharges as point source discharges and, therefore, part of the WLA. There are seven permitted facilities discharging sanitary wastewater into two HUC-Reaches in Segment 1C. Weyerhaeuser Co-Dierks (1.115 MGD) and City of Dierks (0.23 MGD) are the two of seven permitted facilities discharging into Holly Creek. Discharging into Mine Creek, there are City of Nashville (2.3 MGD), Tyson Foods Inc. (1.53 MGD), City of Mineral Springs (0.2 MGD), Dalton Mobile Home (0.0054 MGD) and City of Tollette (0.01 MGD).

A WLA may be calculated for each active NPDES wastewater discharger using a mass balance approach as shown in the equation below. The permitted average flow rate used for each point source discharge and the water quality criterion concentration are used to estimate the WLA for each wastewater facility.

***WLA (cfu/day) = WQS * flow * Unit Conversion Factor***

Where: WQC = 400 cfu /100 ml (Fecal coliform); 410 cfu/100 ml (E. coli)
flow (mgd) = permitted flow or design flow (if unavailable)
Unit Conversion Factor = 37,854,120 100-ml/mg

## 6.4 Load Allocation (LA)

The load allocation is the portion of the TMDL assigned to natural background loadings as well as non-point sources such as septic tanks, wildlife, and agricultural practices. The LA was calculated by subtracting the WLA, and MOS from the total TMDL. LAs were not allocated to separate nonpoint sources; due to the lack of available source characterization data. LAs can be calculated under different flow conditions as the TMDL minus the WLA and MOS. The LA is graphically represented by the vertical distance under the LDC but above the WLA and MOS. The LA at any particular flow exceedance is calculated as shown in the equation below.

$$LA = TMDL - MOS - \sum WLA$$

## 6.5 Margin of Safety (MOS)

Both section 303(d) of the Clean Water Act and the regulations at 40CFR 130.7 require that TMDLs include an MOS to account for lack of knowledge of the relationship between effluent limitation and water quality. The MOS may be expressed explicitly as unallocated assimilative capacity or implicitly using conservative assumptions in establishing the TMDL.

There are two ways to incorporate the MOS (USEPA 1991). One way is to implicitly incorporate the MOS by using conservative model assumptions to develop allocations. The other way is to explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations.

A typical explicit approach would reserve some fraction of the TMDL (*e.g.*, 10%) as the MOS. In an implicit approach, conservative assumptions used in developing the TMDL are relied upon to provide an MOS to assure that WQSs are attained. An explicit MOS of 10 percent of the TMDL value was applied in this report. Using 10 percent of the TMDL load provides an additional level of protection to the designated uses of the water-bodies of concern.

### 6.6 Future Growth

Compliance with these TMDLs is based on keeping the bacteria concentrations in the selected waters below the criterion limits that were set for the sites. Future growth for existing or new point sources is not limited by these TMDLs as long as they do not cause bacteria to exceed the criterion limits. The assimilative capacity of the streams will increase as the amount of flow in the stream increases. Increases in flow will allow for increased loadings. The LDC and tables will guide the determination of the assimilative capacity of the stream including the future growth.

## 7.0 OTHER RELEVANT INFORMATION

In accordance with Section 106 of the federal Clean Water Act and under its own authority, ADEQ has established a comprehensive program for monitoring the quality of the State’s surface waters. ADEQ collects surface water samples at various locations, utilizing appropriate sampling methods and procedures for ensuring the quality of the data collected. The objectives of the surface water monitoring program are to determine the quality of the state’s surface waters, to develop a long-term data base for long term trend analysis, and to monitor the effectiveness of pollution controls. The data obtained through the surface water monitoring program is used to develop the state’s biennial 305(b) report (Water Quality Inventory) and the 303(d) list of impaired waters, which are issued as a single document titled Arkansas Integrated Water Quality Monitoring and Assessment Report.

# 8.0 REFERENCES

ADEQ. 2002a. 2002 Integrated Water Quality Monitoring and Assessment Report. Prepared pursuant to Section 305(b) of the Federal Water Pollution Control Act. Published by Arkansas Department of Environmental Quality.

APCEC. 2006. Regulation No. 2, As Amended. Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas. Published by Arkansas Department of Environmental Quality. April 28, 2006.

APCEC. 2004b. Regulation No. 6, Regulations for State Administration of the National Pollutant Discharge Elimination System (NPDES). Adopted by the Arkansas Pollution Control and Ecology Commission on March 26, 2004.

ADEQ. 2005b. Surface Water Quality Monitoring Data web site. Maintained by Technical Services Division, Arkansas Department of Environmental Quality. www.adeq.state.ar.us/techsvs/water_quality/monitors.asp

C. M. Drapcho, A. K. B. Hubbs, 2002, Fecal Coliform Concentration In Runoff From Fields With Applied Dairy Manure, Retrieved July 2, 2004, From Http://Www.Lwrri.Lsu.Edu/Downloads/Drapcho_Annual%20report01-02.Pdf

FTN. 2001. TMDLs for Turbidity and Fecal Coliforms for L'Anguille River, AR. Report prepared for U.S. EPA Region 6 by FTN Associates. Final report dated October 2001.

KDHE. 2005. "Kansas TMDL Curve Methodology". Web site maintained by Kansas Department of Health and Environment. Dated December 1, 2005. www.kdheks.gov/tmdl/Data.htm

Kessler, Edwin, and Kirkham, M.B., 1985, Restoration Of Eroded Prairie With Digested Sludge

Krogmann, Uta, 2003, Land Application Of Sewage Sludge (Biosolids) #8: Pathogens, Solid Waste Management, Rutgers Cooperative Extension, 4p.

PCS. 2005. Permit Compliance System web site. Maintained by U.S. Environmental Protection Agency.  www.epa.gov/enviro/html/pcs/adhoc.html

APHAAWWA&WEF, 1999. Standard Methods for the Examination of Water and Wastewater. 20th Edition. Published by American Public Health Association, American Water Works Association, and Water Environment Federation.

USDA. 1976. Soil Survey for Drew County, Arkansas. Published by Soil Conservation Service, U.S. Department of Agriculture in cooperation with Arkansas Agricultural Experiment Station. December 1976.

USDA. 1978. Soil Survey for Lawrence County, Arkansas. Published by Soil Conservation Service, U.S. Department of Agriculture in cooperation with Arkansas Agricultural Experiment Station. June 1978.

USDA. 1979. Soil Survey for Ashley County, Arkansas. Published by Soil Conservation Service, U.S. Department of Agriculture in cooperation with Arkansas Agricultural Experiment Station. December 1979.

USDA. 1981. Soil Survey for Lincoln and Jefferson Counties, Arkansas. Published by Soil Conservation Service, U.S. Department of Agriculture in cooperation with Arkansas Agricultural Experiment Station. December 1981.

USDA. 1984a. Soil Survey for Fulton and Izard County, Arkansas. Published by Soil Conservation Service, U.S. Department of Agriculture in cooperation with Arkansas Agricultural Experiment Station. April 1984.

USDA. 1984b. Soil Survey for Sharp County, Arkansas. Published by Soil Conservation Service, U.S. Department of Agriculture in cooperation with Arkansas Agricultural Experiment Station. September 1984.

USEPA 1991. Guidance for Water Quality-. Based Decisions: The TMDL Process. Office of Water, USEPA 440/4-91-001.

USEPA, 1996. Overview of The Stormwater Program, Environmental Protection Agency Office Of Water, 42 P.

USEPA 2001. 2001 Protocol for Developing Pathogen TMDLs. First Edition. Office of Water, USEPA 841-R-00-002.

USEPA. 2002. Total Maximum Daily Load (TMDL) for TSS, Turbidity, and Siltation for 13 Subsegments in the Ouachita River Basin. Prepared by U.S. EPA Region 6. May 31,2002. Printed from EPA web site (http://www.epa.gov/earth1r6/6wq/ecopro/latmdl/ouachitatss(f).pdf)

USGS. 1971. Drainage Area of Louisiana Streams. Basic Records Report No. 6, published by U.S. Geological Survey in cooperation with Louisiana Department of Transportation and Development. Reprinted 1991.

USGS. 1985. Average Annual Precipitation and Runoff for Arkansas, 1951-1980. Water-Resources Investigations Report 84-4363. Prepared by D.A. Freiwald, U.S. Geological Survey, Little Rock, Arkansas.

USGS. 2001b. Water Resources Data Louisiana Water Year 2000. Water-Data Report LA-00-1. U.S. Geological Survey, Little Rock, AR. Prepared in cooperation with the Louisiana Department of Transportation and Development and with other State and Federal agencies.

USGS. 2005. Water Resources Data Arkansas Water Year 2004. Water-Data Report AR-04-1. U.S. Geological Survey, Little Rock, AR.

Zar, J.H., 1996. Biostatistical Analysis (3rd ed.). New Jersey: Prentice Hall.

Schueler, TR, 2000. Microbes and Urban Watersheds: Concentrations, Sources, and

Pathways. In the Practice of Watershed Protection, TR Schueler and HK Holland, eds. Center for Watershed Protection, Ellicott City, MD

# Appendix A

**Table 5.1 Summary of Fecal Coliform and E. Coli Bacteria Monitored data**

| Station No. | Station Name | Period of Record | No. of Obs. | Min. MPN/ 100 mL | Max. MPN/ 100 mL | # of Obs. Above PCR Summer criteria | # of Obs. Above PCR Winter/SCR criteria |
|---|---|---|---|---|---|---|---|
| **Fecal Coliform** | | | | | | | |
| RED0034A | Holly Creek | 4/97 - 9/97 | 8 | ~14 | >6000 | 2 | 1 |
| RED0034B | Holly Creek | 3/91 - 9/97 | 27 | ~29 | >6000 | 4 | 3 |
| RED0048A | Mine Creek | 8/00 –11/01 | 6 | ~22 | >2000 | 2 | 1 |
| RED0048B | Mine Creek | 9/97 –11/01 | 7 | ~77 | >2000 | 1 | 1 |
| **E. Coli** | | | | | | | |
| RED0034B | Holly Creek | 3/91 - 2/97 | 18 | ~24 | ~1600 | 0 | 0 |
| RED0048A | Mine Creek | 8/00 –11/01 | 5 | ~26 | >2000 | 1 | 0 |
| RED0048B | Mine Creek | 1/01 –11/01 | 5 | ~61 | >2000 | 0 | 0 |

## Table 5.2 Monitoring Data

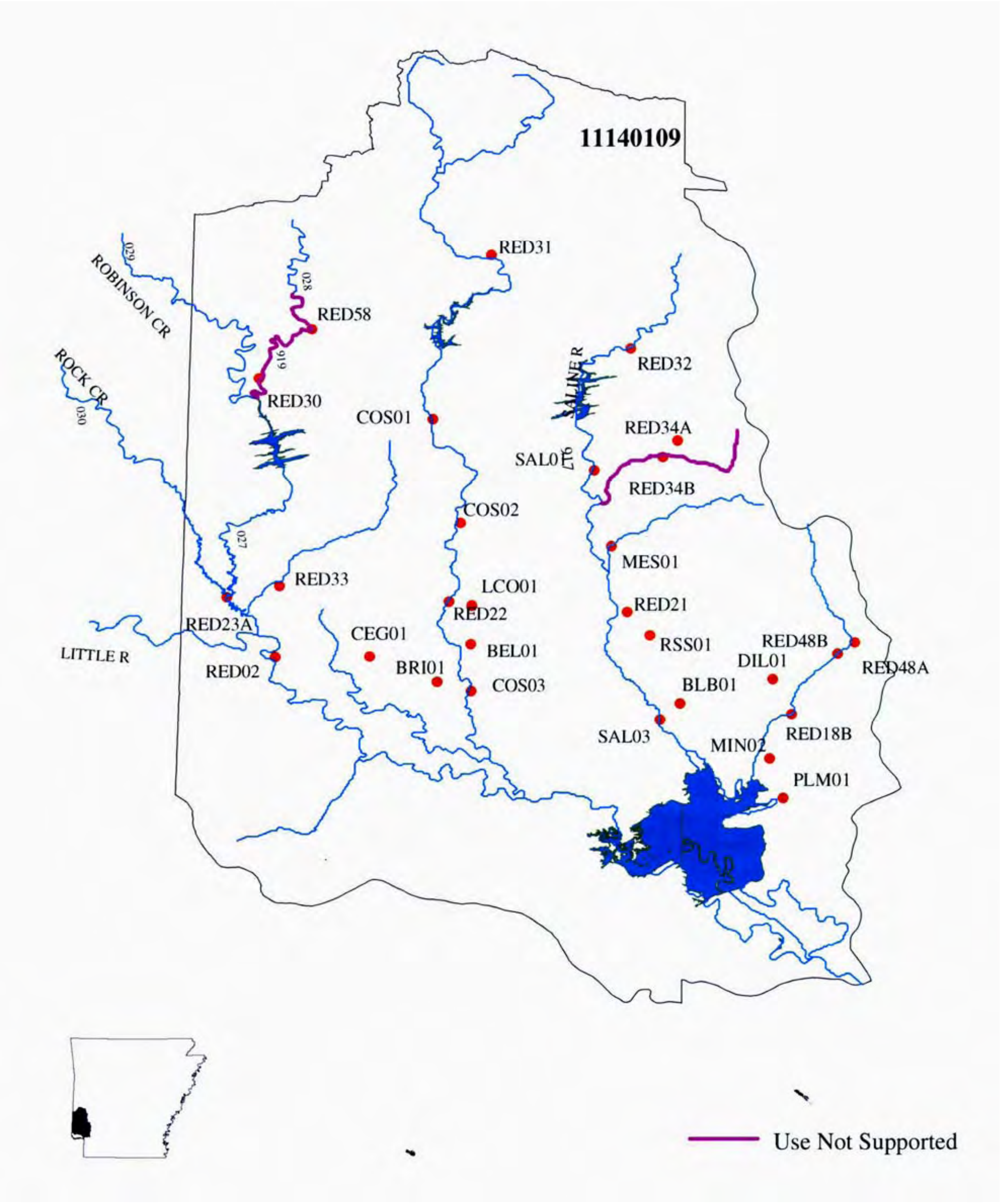
### Holly Creek

| StationID | LogNumber | SampleType | DateCollected | FecalColiform | E_Coli |
|---|---|---|---|---|---|
| RED0034A | 77544 | BWR | 23-Apr-97 | ~645 | |
| RED0034A | 77742 | WWR | 13-May-97 | 132 | |
| RED0034A | 78123 | WWR | 17-Jun-97 | 2000 | |
| RED0034A | 78436 | WWR | 14-Jul-97 | >6000 | |
| RED0034A | 78651 | BWR | 29-Jul-97 | 189 | |
| RED0034A | 78886 | WWR | 26-Aug-97 | ~14 | |
| RED0034A | 79124 | WWR | 16-Sep-97 | ~14 | |
| RED0034A | 79217 | BWR | 09-Sep-97 | ~77 | |
| RED0034B | 50285 | BWR | 06-Mar-91 | 215 | 120 |
| RED0034B | 50356 | BWR | 30-Apr-91 | 770 | 630 |
| RED0034B | 52216 | BWR | 03-Oct-91 | 229 | N/A |
| RED0034B | 52335 | BWR | 04-Dec-91 | 420 | 297 |
| RED0034B | 53085 | BWR | 24-Feb-92 | 213 | 148 |
| RED0034B | 54544 | BWR | 23-Jun-92 | >600 | 204 |
| RED0034B | 55786 | BWR | 17-Sep-92 | ~710 | 320 |
| RED0034B | 57524 | BWR | 16-Feb-93 | 570 | 490 |
| RED0034B | 57999 | BWR | 15-Apr-93 | 2100 | ~1600 |
| RED0034B | 58842 | BWR | 09-Jun-93 | 204 | 96 |
| RED0034B | 59377 | BWR | 20-Jul-93 | 92 | ~24 |
| RED0034B | 60342 | BWR | 05-Oct-93 | >600 | >600 |
| RED0034B | 61009 | BWR | 17-Nov-93 | ~1300 | 410 |
| RED0034B | 61464 | BWR | 11-Jan-94 | >600 | >600 |
| RED0034B | 62807 | BWR | 28-Apr-94 | 370 | 104 |
| RED0034B | 63426 | BWR | 08-Jun-94 | 140 | ~49 |
| RED0034B | 63993 | BWR | 20-Jul-94 | 220 | ~27 |
| RED0034B | 66444 | BWR | 05-Dec-94 | 160 | 104 |
| RED0034B | 76927 | BWR | 19-Feb-97 | 152 | 128 |
| RED0034B | 77545 | BWR | 23-Apr-97 | 2300 | |
| RED0034B | 77743 | WWR | 13-May-97 | 144 | |
| RED0034B | 78124 | WWR | 17-Jun-97 | >6000 | |
| RED0034B | 78437 | WWR | 14-Jul-97 | >600 | |
| RED0034B | 78652 | BWR | 29-Jul-97 | ~43 | |
| RED0034B | 78885 | WWR | 26-Aug-97 | 96 | |
| RED0034B | 79125 | WWR | 16-Sep-97 | ~29 | |
| RED0034B | 79218 | BWR | 09-Sep-97 | ~263 | |

### Mine Creek

| StationID | LogNumber | SampleType | DateCollected | FecalColiform | E_Coli |
|---|---|---|---|---|---|
| RED0048A | 91818 | WWR | 01-Aug-00 | 310 | |
| RED0048A | 93528 | WWR | 08-Jan-01 | ~22 | ~26 |
| RED0048A | 94293 | WWR | 12-Mar-01 | >2000 | >2000 |
| RED0048A | 95526 | WWR | 18-Jun-01 | ~432 | 90 |
| RED0048A | 96715 | WWR | 04-Sep-01 | 940 | 433 |
| RED0048A | 97693 | WWR | 27-Nov-01 | 215 | 120 |
| RED0048B | 79119 | WWR | 15-Sep-97 | ~77 | |
| RED0048B | 91817 | WWR | 01-Aug-00 | 500 | |
| RED0048B | 93527 | WWR | 08-Jan-01 | 733 | ~475 |
| RED0048B | 94292 | WWR | 12-Mar-01 | >2000 | >2000 |
| RED0048B | 95525 | WWR | 18-Jun-01 | 210 | 95 |
| RED0048B | 96714 | WWR | 04-Sep-01 | 235 | 135 |
| RED0048B | 97694 | WWR | 27-Nov-01 | ~87 | ~61 |

**Figure 2.1 Planning Segment 1 C**



## Figure 2.2 Predominant Soil Types Surrounding Holly and Mine Creeks

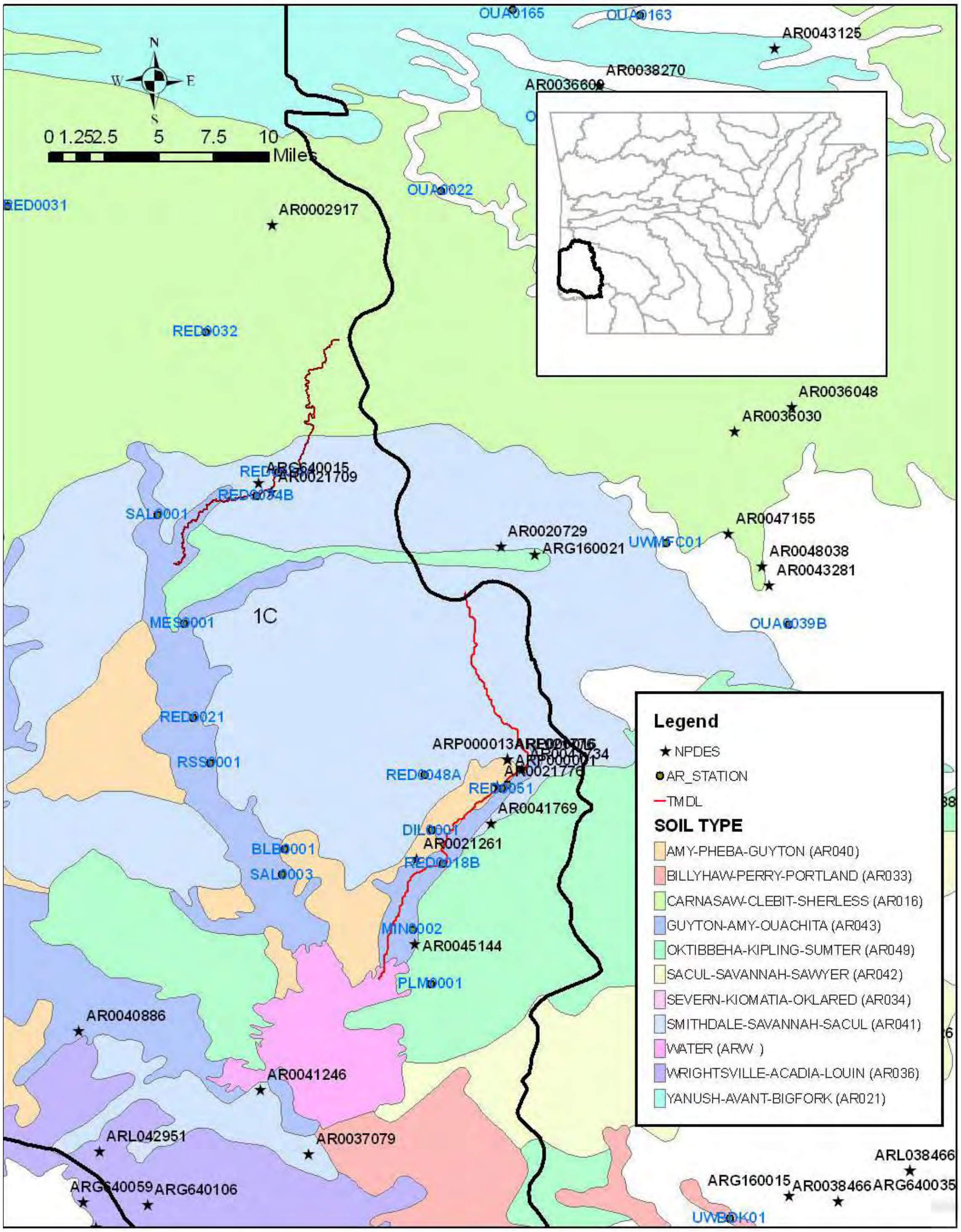


**Figure 2.3 Land Uses Surrounding Holly and Mine Creeks**

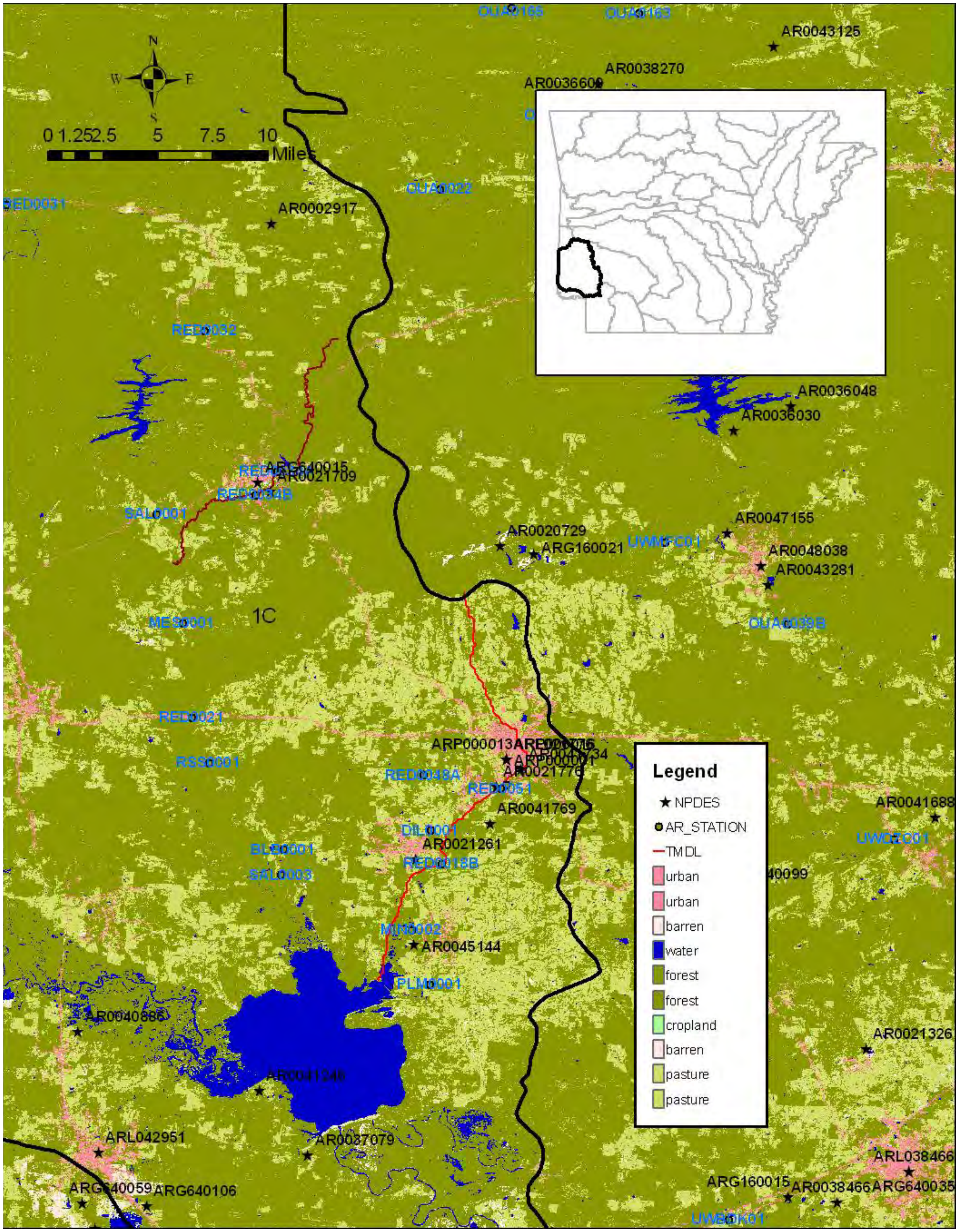


**Figure 2.4 Land Uses in Planning Segment 1 C**

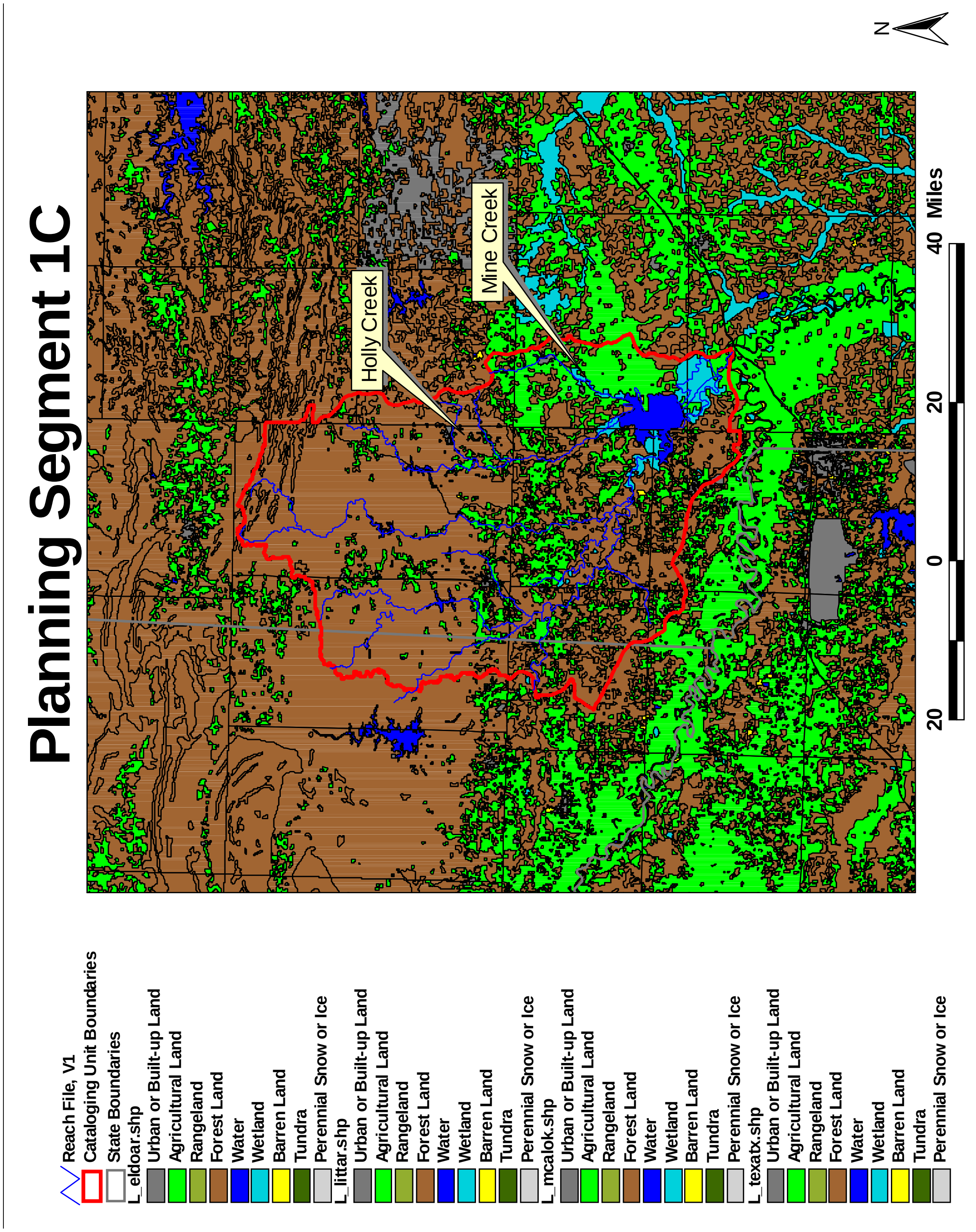


**Figure 2.5 Arkansas Annual Precipitation**

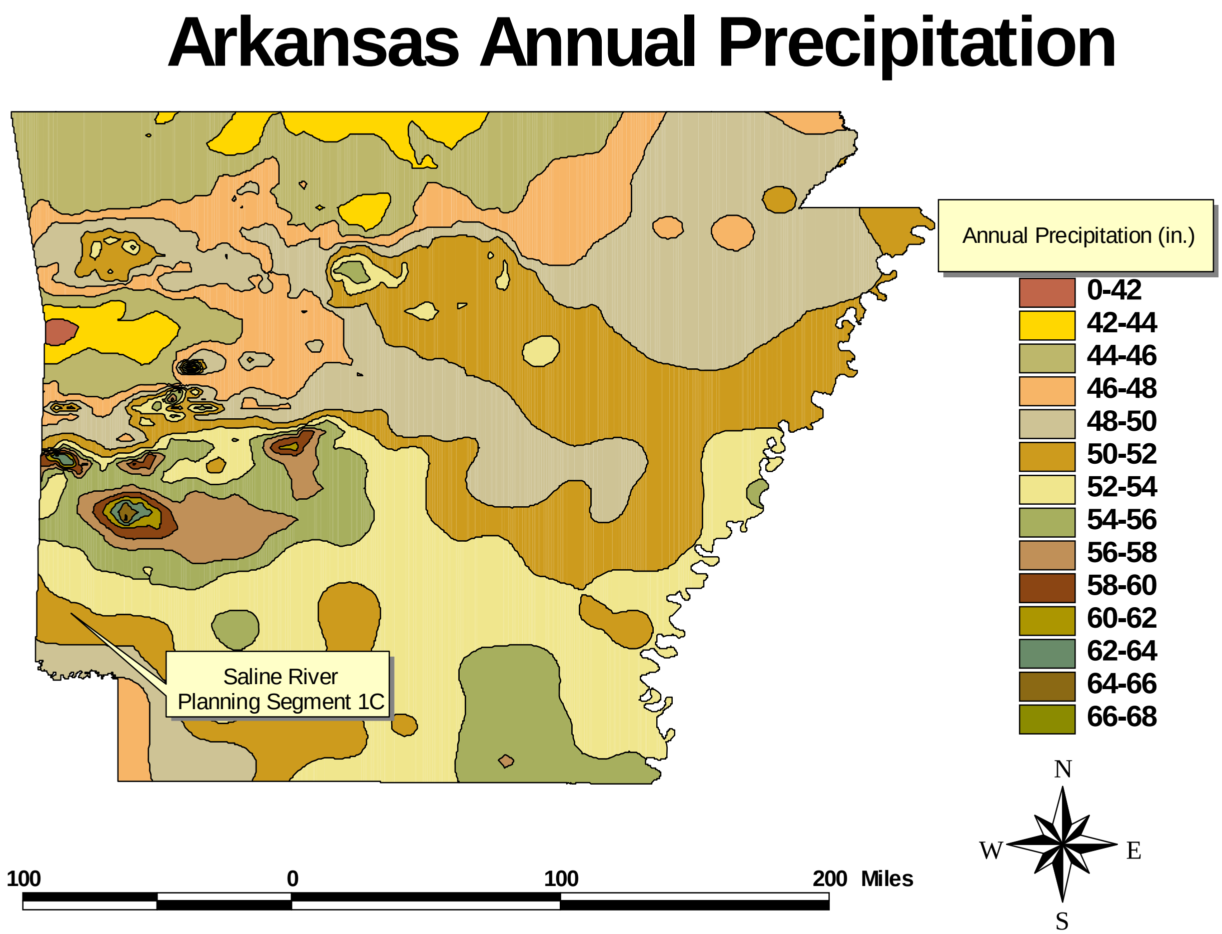


**Table A.1**
**Mine Creek (HUC-Reach 11140109-033)**
**Fecal Coliform: 400 col/100 ml (PCR-Summer) and 2000 col/100 ml (PCR-Winter/SCR)**

| Flow Exceedence Frequency | Flow (cfs) | Load-PCR Sum (cfu/day) | Load-PCR Winter/SCR (cfu/day) |
|---|---|---|---|
| 0 | 321000 | 3.14E+15 | 1.57E+16 |
| 1 | 114000 | 1.12E+15 | 5.58E+15 |
| 2 | 94000 | 9.20E+14 | 4.60E+15 |
| 3 | 82900 | 8.11E+14 | 4.06E+15 |
| 4 | 74000 | 7.24E+14 | 3.62E+15 |
| 5 | 67800 | 6.64E+14 | 3.32E+15 |
| 6 | 62200 | 6.09E+14 | 3.04E+15 |
| 7 | 57500 | 5.63E+14 | 2.81E+15 |
| 8 | 53550 | 5.24E+14 | 2.62E+15 |
| 9 | 49800 | 4.87E+14 | 2.44E+15 |
| 10 | 46200 | 4.52E+14 | 2.26E+15 |
| 11 | 43200 | 4.23E+14 | 2.11E+15 |
| 12 | 41000 | 4.01E+14 | 2.01E+15 |
| 13 | 38000 | 3.72E+14 | 1.86E+15 |
| 14 | 35700 | 3.49E+14 | 1.75E+15 |
| 15 | 33500 | 3.28E+14 | 1.64E+15 |
| 16 | 31600 | 3.09E+14 | 1.55E+15 |
| 17 | 30000 | 2.94E+14 | 1.47E+15 |
| 18 | 28300 | 2.77E+14 | 1.38E+15 |
| 19 | 26800 | 2.62E+14 | 1.31E+15 |
| 20 | 25200 | 2.47E+14 | 1.23E+15 |
| 21 | 24000 | 2.35E+14 | 1.17E+15 |
| 22 | 23000 | 2.25E+14 | 1.13E+15 |
| 23 | 21800 | 2.13E+14 | 1.07E+15 |
| 24 | 20900 | 2.05E+14 | 1.02E+15 |
| 25 | 19800 | 1.94E+14 | 9.69E+14 |
| 26 | 18800 | 1.84E+14 | 9.20E+14 |
| 27 | 18000 | 1.76E+14 | 8.81E+14 |
| 28 | 17000 | 1.66E+14 | 8.32E+14 |
| 29 | 16000 | 1.57E+14 | 7.83E+14 |
| 30 | 15400 | 1.51E+14 | 7.54E+14 |
| 31 | 14800 | 1.45E+14 | 7.24E+14 |
| 32 | 14000 | 1.37E+14 | 6.85E+14 |
| 33 | 13500 | 1.32E+14 | 6.61E+14 |
| 34 | 13000 | 1.27E+14 | 6.36E+14 |
| 35 | 12400 | 1.21E+14 | 6.07E+14 |
| 36 | 12000 | 1.17E+14 | 5.87E+14 |
| 37 | 11500 | 1.13E+14 | 5.63E+14 |
| 38 | 11000 | 1.08E+14 | 5.38E+14 |
| 39 | 10800 | 1.06E+14 | 5.28E+14 |
| 40 | 10300 | 1.01E+14 | 5.04E+14 |
| 41 | 9950 | 9.74E+13 | 4.87E+14 |
| 42 | 9640 | 9.43E+13 | 4.72E+14 |
| 43 | 9380 | 9.18E+13 | 4.59E+14 |
| 44 | 9020 | 8.83E+13 | 4.41E+14 |
| 45 | 8800 | 8.61E+13 | 4.31E+14 |
| 46 | 8500 | 8.32E+13 | 4.16E+14 |
| 47 | 8230 | 8.05E+13 | 4.03E+14 |
| 48 | 8000 | 7.83E+13 | 3.91E+14 |
| 49 | 7710 | 7.55E+13 | 3.77E+14 |
| 50 | 7500 | 7.34E+13 | 3.67E+14 |

**Table A.1 (Continued)**
**Mine Creek (HUC-Reach 11140109-033)**
**Fecal Coliform: 400 col/100 ml (PCR-Summer) and 2000 col/100 ml (PCR-Winter/SCR)**

| Flow Exceedence Frequency | Flow (cfs) | Load-PCR Sum (cfu/day) | Load-PCR Winter/SCR (cfu/day) |
|---|---|---|---|
| 51 | 7300 | 7.14E+13 | 3.57E+14 |
| 52 | 7100 | 6.95E+13 | 3.47E+14 |
| 53 | 6900 | 6.75E+13 | 3.38E+14 |
| 54 | 6735 | 6.59E+13 | 3.30E+14 |
| 55 | 6500 | 6.36E+13 | 3.18E+14 |
| 56 | 6320 | 6.18E+13 | 3.09E+14 |
| 57 | 6160 | 6.03E+13 | 3.01E+14 |
| 58 | 5980 | 5.85E+13 | 2.93E+14 |
| 59 | 5800 | 5.68E+13 | 2.84E+14 |
| 60 | 5600 | 5.48E+13 | 2.74E+14 |
| 61 | 5490 | 5.37E+13 | 2.69E+14 |
| 62 | 5310 | 5.20E+13 | 2.60E+14 |
| 63 | 5200 | 5.09E+13 | 2.54E+14 |
| 64 | 5040 | 4.93E+13 | 2.47E+14 |
| 65 | 4900 | 4.80E+13 | 2.40E+14 |
| 66 | 4770 | 4.67E+13 | 2.33E+14 |
| 67 | 4635 | 4.54E+13 | 2.27E+14 |
| 68 | 4500 | 4.40E+13 | 2.20E+14 |
| 69 | 4420 | 4.33E+13 | 2.16E+14 |
| 70 | 4300 | 4.21E+13 | 2.10E+14 |
| 71 | 4200 | 4.11E+13 | 2.06E+14 |
| 72 | 4100 | 4.01E+13 | 2.01E+14 |
| 73 | 4000 | 3.91E+13 | 1.96E+14 |
| 74 | 3900 | 3.82E+13 | 1.91E+14 |
| 75 | 3800 | 3.72E+13 | 1.86E+14 |
| 76 | 3700 | 3.62E+13 | 1.81E+14 |
| 77 | 3600 | 3.52E+13 | 1.76E+14 |
| 78 | 3510 | 3.43E+13 | 1.72E+14 |
| 79 | 3400 | 3.33E+13 | 1.66E+14 |
| 80 | 3350 | 3.28E+13 | 1.64E+14 |
| 81 | 3280 | 3.21E+13 | 1.60E+14 |
| 82 | 3200 | 3.13E+13 | 1.57E+14 |
| 83 | 3100 | 3.03E+13 | 1.52E+14 |
| 84 | 3000 | 2.94E+13 | 1.47E+14 |
| 85 | 2900 | 2.84E+13 | 1.42E+14 |
| 86 | 2800 | 2.74E+13 | 1.37E+14 |
| 87 | 2685 | 2.63E+13 | 1.31E+14 |
| 88 | 2580 | 2.52E+13 | 1.26E+14 |
| 89 | 2440 | 2.39E+13 | 1.19E+14 |
| 90 | 2300 | 2.25E+13 | 1.13E+14 |
| 91 | 2160 | 2.11E+13 | 1.06E+14 |
| 92 | 1980 | 1.94E+13 | 9.69E+13 |
| 93 | 1800 | 1.76E+13 | 8.81E+13 |
| 94 | 1660 | 1.62E+13 | 8.12E+13 |
| 95 | 1470 | 1.44E+13 | 7.19E+13 |
| 96 | 1300 | 1.27E+13 | 6.36E+13 |
| 97 | 1160 | 1.14E+13 | 5.68E+13 |
| 98 | 1040 | 1.02E+13 | 5.09E+13 |
| 99 | 808 | 7.91E+12 | 3.95E+13 |
| 100 | 400 | 3.91E+12 | 1.96E+13 |

**Table A.2**
**Mine Creek (HUC-Reach 11140109-033)**
**E. Coli: 410 col/100 ml (PCR-Summer) and 2050 col/100 ml (PCR-Winter/SCR)**

| Flow Exceedence Frequency | Flow (cfs) | Load-PCR Sum (cfu/day) | Load-PCR Winter/SCR (cfu/day) |
|---|---|---|---|
| 0 | 321000 | 3.22E+15 | 1.61E+16 |
| 1 | 114000 | 1.14E+15 | 5.72E+15 |
| 2 | 94000 | 9.43E+14 | 4.71E+15 |
| 3 | 82900 | 8.32E+14 | 4.16E+15 |
| 4 | 74000 | 7.42E+14 | 3.71E+15 |
| 5 | 67800 | 6.80E+14 | 3.40E+15 |
| 6 | 62200 | 6.24E+14 | 3.12E+15 |
| 7 | 57500 | 5.77E+14 | 2.88E+15 |
| 8 | 53550 | 5.37E+14 | 2.69E+15 |
| 9 | 49800 | 5.00E+14 | 2.50E+15 |
| 10 | 46200 | 4.63E+14 | 2.32E+15 |
| 11 | 43200 | 4.33E+14 | 2.17E+15 |
| 12 | 41000 | 4.11E+14 | 2.06E+15 |
| 13 | 38000 | 3.81E+14 | 1.91E+15 |
| 14 | 35700 | 3.58E+14 | 1.79E+15 |
| 15 | 33500 | 3.36E+14 | 1.68E+15 |
| 16 | 31600 | 3.17E+14 | 1.58E+15 |
| 17 | 30000 | 3.01E+14 | 1.50E+15 |
| 18 | 28300 | 2.84E+14 | 1.42E+15 |
| 19 | 26800 | 2.69E+14 | 1.34E+15 |
| 20 | 25200 | 2.53E+14 | 1.26E+15 |
| 21 | 24000 | 2.41E+14 | 1.20E+15 |
| 22 | 23000 | 2.31E+14 | 1.15E+15 |
| 23 | 21800 | 2.19E+14 | 1.09E+15 |
| 24 | 20900 | 2.10E+14 | 1.05E+15 |
| 25 | 19800 | 1.99E+14 | 9.93E+14 |
| 26 | 18800 | 1.89E+14 | 9.43E+14 |
| 27 | 18000 | 1.81E+14 | 9.03E+14 |
| 28 | 17000 | 1.71E+14 | 8.53E+14 |
| 29 | 16000 | 1.60E+14 | 8.02E+14 |
| 30 | 15400 | 1.54E+14 | 7.72E+14 |
| 31 | 14800 | 1.48E+14 | 7.42E+14 |
| 32 | 14000 | 1.40E+14 | 7.02E+14 |
| 33 | 13500 | 1.35E+14 | 6.77E+14 |
| 34 | 13000 | 1.30E+14 | 6.52E+14 |
| 35 | 12400 | 1.24E+14 | 6.22E+14 |
| 36 | 12000 | 1.20E+14 | 6.02E+14 |
| 37 | 11500 | 1.15E+14 | 5.77E+14 |
| 38 | 11000 | 1.10E+14 | 5.52E+14 |
| 39 | 10800 | 1.08E+14 | 5.42E+14 |
| 40 | 10300 | 1.03E+14 | 5.17E+14 |
| 41 | 9950 | 9.98E+13 | 4.99E+14 |
| 42 | 9640 | 9.67E+13 | 4.83E+14 |
| 43 | 9380 | 9.41E+13 | 4.70E+14 |
| 44 | 9020 | 9.05E+13 | 4.52E+14 |
| 45 | 8800 | 8.83E+13 | 4.41E+14 |
| 46 | 8500 | 8.53E+13 | 4.26E+14 |
| 47 | 8230 | 8.26E+13 | 4.13E+14 |
| 48 | 8000 | 8.02E+13 | 4.01E+14 |
| 49 | 7710 | 7.73E+13 | 3.87E+14 |
| 50 | 7500 | 7.52E+13 | 3.76E+14 |

**Table A.2 (Continued)**
**Mine Creek (HUC-Reach 11140109-033)**
**E. Coli: 410 col/100 ml (PCR-Summer) and 2050 col/100 ml (PCR-Winter/SCR)**

| Flow Exceedence Frequency | Flow (cfs) | Load-PCR Sum (cfu/day) | Load-PCR Winter/SCR (cfu/day) |
|---|---|---|---|
| 51 | 7300 | 7.32E+13 | 3.66E+14 |
| 52 | 7100 | 7.12E+13 | 3.56E+14 |
| 53 | 6900 | 6.92E+13 | 3.46E+14 |
| 54 | 6735 | 6.76E+13 | 3.38E+14 |
| 55 | 6500 | 6.52E+13 | 3.26E+14 |
| 56 | 6320 | 6.34E+13 | 3.17E+14 |
| 57 | 6160 | 6.18E+13 | 3.09E+14 |
| 58 | 5980 | 6.00E+13 | 3.00E+14 |
| 59 | 5800 | 5.82E+13 | 2.91E+14 |
| 60 | 5600 | 5.62E+13 | 2.81E+14 |
| 61 | 5490 | 5.51E+13 | 2.75E+14 |
| 62 | 5310 | 5.33E+13 | 2.66E+14 |
| 63 | 5200 | 5.22E+13 | 2.61E+14 |
| 64 | 5040 | 5.06E+13 | 2.53E+14 |
| 65 | 4900 | 4.92E+13 | 2.46E+14 |
| 66 | 4770 | 4.78E+13 | 2.39E+14 |
| 67 | 4635 | 4.65E+13 | 2.32E+14 |
| 68 | 4500 | 4.51E+13 | 2.26E+14 |
| 69 | 4420 | 4.43E+13 | 2.22E+14 |
| 70 | 4300 | 4.31E+13 | 2.16E+14 |
| 71 | 4200 | 4.21E+13 | 2.11E+14 |
| 72 | 4100 | 4.11E+13 | 2.06E+14 |
| 73 | 4000 | 4.01E+13 | 2.01E+14 |
| 74 | 3900 | 3.91E+13 | 1.96E+14 |
| 75 | 3800 | 3.81E+13 | 1.91E+14 |
| 76 | 3700 | 3.71E+13 | 1.86E+14 |
| 77 | 3600 | 3.61E+13 | 1.81E+14 |
| 78 | 3510 | 3.52E+13 | 1.76E+14 |
| 79 | 3400 | 3.41E+13 | 1.71E+14 |
| 80 | 3350 | 3.36E+13 | 1.68E+14 |
| 81 | 3280 | 3.29E+13 | 1.65E+14 |
| 82 | 3200 | 3.21E+13 | 1.60E+14 |
| 83 | 3100 | 3.11E+13 | 1.55E+14 |
| 84 | 3000 | 3.01E+13 | 1.50E+14 |
| 85 | 2900 | 2.91E+13 | 1.45E+14 |
| 86 | 2800 | 2.81E+13 | 1.40E+14 |
| 87 | 2685 | 2.69E+13 | 1.35E+14 |
| 88 | 2580 | 2.59E+13 | 1.29E+14 |
| 89 | 2440 | 2.45E+13 | 1.22E+14 |
| 90 | 2300 | 2.31E+13 | 1.15E+14 |
| 91 | 2160 | 2.17E+13 | 1.08E+14 |
| 92 | 1980 | 1.99E+13 | 9.93E+13 |
| 93 | 1800 | 1.81E+13 | 9.03E+13 |
| 94 | 1660 | 1.67E+13 | 8.33E+13 |
| 95 | 1470 | 1.47E+13 | 7.37E+13 |
| 96 | 1300 | 1.30E+13 | 6.52E+13 |
| 97 | 1160 | 1.16E+13 | 5.82E+13 |
| 98 | 1040 | 1.04E+13 | 5.22E+13 |
| 99 | 808 | 8.11E+12 | 4.05E+13 |
| 100 | 400 | 4.01E+12 | 2.01E+13 |

**Table A.3**
**Holly Creek (HUC-Reach 11140109-013)**
**Fecal Coliform: 400 col/100 ml (PCR-Summer) and 2000 col/100 ml (PCR-Winter/SCR)**

| Flow Exceedence Frequency | Flow (cfs) | Load-PCR Sum (cfu/day) | Load-PCR Winter/SCR (cfu/day) |
|---|---|---|---|
| 0 | 184464.79 | 1.80523E+15 | 9.02614E+15 |
| 1 | 65510.86 | 6.41109E+14 | 3.20554E+15 |
| 2 | 54017.727 | 5.28634E+14 | 2.64317E+15 |
| 3 | 47639.038 | 4.6621E+14 | 2.33105E+15 |
| 4 | 42524.593 | 4.16158E+14 | 2.08079E+15 |
| 5 | 38961.722 | 3.81291E+14 | 1.90646E+15 |
| 6 | 35743.645 | 3.49798E+14 | 1.74899E+15 |
| 7 | 33042.758 | 3.23366E+14 | 1.61683E+15 |
| 8 | 30772.865 | 3.01153E+14 | 1.50576E+15 |
| 9 | 28617.902 | 2.80063E+14 | 1.40032E+15 |
| 10 | 26549.138 | 2.59818E+14 | 1.29909E+15 |
| 11 | 24825.168 | 2.42947E+14 | 1.21473E+15 |
| 12 | 23560.923 | 2.30574E+14 | 1.15287E+15 |
| 13 | 21836.953 | 2.13703E+14 | 1.06851E+15 |
| 14 | 20515.243 | 2.00768E+14 | 1.00384E+15 |
| 15 | 19250.998 | 1.88396E+14 | 9.4198E+14 |
| 16 | 18159.151 | 1.77711E+14 | 8.88555E+14 |
| 17 | 17239.7 | 1.68713E+14 | 8.43564E+14 |
| 18 | 16262.784 | 1.59152E+14 | 7.95762E+14 |
| 19 | 15400.799 | 1.50717E+14 | 7.53584E+14 |
| 20 | 14481.348 | 1.41719E+14 | 7.08594E+14 |
| 21 | 13791.76 | 1.3497E+14 | 6.74852E+14 |
| 22 | 13217.103 | 1.29347E+14 | 6.46733E+14 |
| 23 | 12527.515 | 1.22598E+14 | 6.1299E+14 |
| 24 | 12010.324 | 1.17537E+14 | 5.87683E+14 |
| 25 | 11378.202 | 1.11351E+14 | 5.56753E+14 |
| 26 | 10803.545 | 1.05727E+14 | 5.28634E+14 |
| 27 | 10343.82 | 1.01228E+14 | 5.06139E+14 |
| 28 | 9769.1633 | 9.5604E+13 | 4.7802E+14 |
| 29 | 9194.5067 | 8.99802E+13 | 4.49901E+14 |
| 30 | 8849.7127 | 8.66059E+13 | 4.3303E+14 |
| 31 | 8504.9187 | 8.32317E+13 | 4.16158E+14 |
| 32 | 8045.1933 | 7.87327E+13 | 3.93663E+14 |
| 33 | 7757.865 | 7.59208E+13 | 3.79604E+14 |
| 34 | 7470.5367 | 7.31089E+13 | 3.65545E+14 |
| 35 | 7125.7427 | 6.97347E+13 | 3.48673E+14 |
| 36 | 6895.88 | 6.74852E+13 | 3.37426E+14 |
| 37 | 6608.5517 | 6.46733E+13 | 3.23366E+14 |
| 38 | 6321.2233 | 6.18614E+13 | 3.09307E+14 |
| 39 | 6206.292 | 6.07366E+13 | 3.03683E+14 |
| 40 | 5918.9637 | 5.79248E+13 | 2.89624E+14 |
| 41 | 5717.8338 | 5.59564E+13 | 2.79782E+14 |
| 42 | 5539.6903 | 5.42131E+13 | 2.71065E+14 |
| 43 | 5390.2795 | 5.27509E+13 | 2.63754E+14 |
| 44 | 5183.4031 | 5.07263E+13 | 2.53632E+14 |
| 45 | 5056.9787 | 4.94891E+13 | 2.47446E+14 |
| 46 | 4884.5817 | 4.7802E+13 | 2.3901E+14 |
| 47 | 4729.4244 | 4.62836E+13 | 2.31418E+14 |
| 48 | 4597.2533 | 4.49901E+13 | 2.24951E+14 |
| 49 | 4430.6029 | 4.33592E+13 | 2.16796E+14 |
| 50 | 4309.925 | 4.21782E+13 | 2.10891E+14 |

**Table A.3 (Continued)**
**Holly Creek (HUC-Reach 11140109-013)**
**Fecal Coliform: 400 col/100 ml (PCR-Summer) and 2000 col/100 ml (PCR-Winter/SCR)**

| Flow Exceedence Frequency | Flow (cfs) | Load-PCR Sum (cfu/day) | Load-PCR Winter/SCR (cfu/day) |
|---|---|---|---|
| 51 | 4194.9937 | 4.10535E+13 | 2.05267E+14 |
| 52 | 4080.0623 | 3.99287E+13 | 1.99644E+14 |
| 53 | 3965.131 | 3.8804E+13 | 1.9402E+14 |
| 54 | 3870.3127 | 3.7876E+13 | 1.8938E+14 |
| 55 | 3735.2683 | 3.65545E+13 | 1.82772E+14 |
| 56 | 3631.8301 | 3.55422E+13 | 1.77711E+14 |
| 57 | 3539.8851 | 3.46424E+13 | 1.73212E+14 |
| 58 | 3436.4469 | 3.36301E+13 | 1.68151E+14 |
| 59 | 3333.0087 | 3.26178E+13 | 1.63089E+14 |
| 60 | 3218.0773 | 3.14931E+13 | 1.57465E+14 |
| 61 | 3154.8651 | 3.08745E+13 | 1.54372E+14 |
| 62 | 3051.4269 | 2.98622E+13 | 1.49311E+14 |
| 63 | 2988.2147 | 2.92436E+13 | 1.46218E+14 |
| 64 | 2896.2696 | 2.83438E+13 | 1.41719E+14 |
| 65 | 2815.8177 | 2.75564E+13 | 1.37782E+14 |
| 66 | 2741.1123 | 2.68253E+13 | 1.34127E+14 |
| 67 | 2663.5337 | 2.60661E+13 | 1.30331E+14 |
| 68 | 2585.955 | 2.53069E+13 | 1.26535E+14 |
| 69 | 2539.9825 | 2.4857E+13 | 1.24285E+14 |
| 70 | 2471.0237 | 2.41822E+13 | 1.20911E+14 |
| 71 | 2413.558 | 2.36198E+13 | 1.18099E+14 |
| 72 | 2356.0923 | 2.30574E+13 | 1.15287E+14 |
| 73 | 2298.6267 | 2.24951E+13 | 1.12475E+14 |
| 74 | 2241.161 | 2.19327E+13 | 1.09663E+14 |
| 75 | 2183.6953 | 2.13703E+13 | 1.06851E+14 |
| 76 | 2126.2297 | 2.08079E+13 | 1.0404E+14 |
| 77 | 2068.764 | 2.02455E+13 | 1.01228E+14 |
| 78 | 2017.0449 | 1.97394E+13 | 9.8697E+13 |
| 79 | 1953.8327 | 1.91208E+13 | 9.5604E+13 |
| 80 | 1925.0998 | 1.88396E+13 | 9.4198E+13 |
| 81 | 1884.8739 | 1.84459E+13 | 9.22297E+13 |
| 82 | 1838.9013 | 1.7996E+13 | 8.99802E+13 |
| 83 | 1781.4357 | 1.74337E+13 | 8.71683E+13 |
| 84 | 1723.97 | 1.68713E+13 | 8.43564E+13 |
| 85 | 1666.5043 | 1.63089E+13 | 8.15446E+13 |
| 86 | 1609.0387 | 1.57465E+13 | 7.87327E+13 |
| 87 | 1542.9532 | 1.50998E+13 | 7.5499E+13 |
| 88 | 1482.6142 | 1.45093E+13 | 7.25465E+13 |
| 89 | 1402.1623 | 1.3722E+13 | 6.86099E+13 |
| 90 | 1321.7103 | 1.29347E+13 | 6.46733E+13 |
| 91 | 1241.2584 | 1.21473E+13 | 6.07366E+13 |
| 92 | 1137.8202 | 1.11351E+13 | 5.56753E+13 |
| 93 | 1034.382 | 1.01228E+13 | 5.06139E+13 |
| 94 | 953.93007 | 9.33545E+12 | 4.66772E+13 |
| 95 | 844.7453 | 8.26693E+12 | 4.13347E+13 |
| 96 | 747.05367 | 7.31089E+12 | 3.65545E+13 |
| 97 | 666.60173 | 6.52356E+12 | 3.26178E+13 |
| 98 | 597.64293 | 5.84871E+12 | 2.92436E+13 |
| 99 | 464.32259 | 4.544E+12 | 2.272E+13 |
| 100 | 229.86267 | 2.24951E+12 | 1.12475E+13 |

**Table A.4**
**Holly Creek (HUC-Reach 11140109-013)**
**E. Coli: 410 col/100 ml (PCR-Summer) and 2050 col/100 ml (PCR-Winter/SCR)**

| Flow Exceedence Frequency | Flow (cfs) | Load-PCR Sum (cfu/day) | Load-PCR Winter/SCR (cfu/day) |
|---|---|---|---|
| 0 | 184464.79 | 1.85036E+15 | 9.25179E+15 |
| 1 | 65510.86 | 6.57137E+14 | 3.28568E+15 |
| 2 | 54017.727 | 5.4185E+14 | 2.70925E+15 |
| 3 | 47639.038 | 4.77865E+14 | 2.38933E+15 |
| 4 | 42524.593 | 4.26562E+14 | 2.13281E+15 |
| 5 | 38961.722 | 3.90823E+14 | 1.95412E+15 |
| 6 | 35743.645 | 3.58543E+14 | 1.79272E+15 |
| 7 | 33042.758 | 3.31451E+14 | 1.65725E+15 |
| 8 | 30772.865 | 3.08681E+14 | 1.54341E+15 |
| 9 | 28617.902 | 2.87065E+14 | 1.43532E+15 |
| 10 | 26549.138 | 2.66313E+14 | 1.33157E+15 |
| 11 | 24825.168 | 2.4902E+14 | 1.2451E+15 |
| 12 | 23560.923 | 2.36339E+14 | 1.18169E+15 |
| 13 | 21836.953 | 2.19046E+14 | 1.09523E+15 |
| 14 | 20515.243 | 2.05788E+14 | 1.02894E+15 |
| 15 | 19250.998 | 1.93106E+14 | 9.6553E+14 |
| 16 | 18159.151 | 1.82154E+14 | 9.10768E+14 |
| 17 | 17239.7 | 1.72931E+14 | 8.64654E+14 |
| 18 | 16262.784 | 1.63131E+14 | 8.15657E+14 |
| 19 | 15400.799 | 1.54485E+14 | 7.72424E+14 |
| 20 | 14481.348 | 1.45262E+14 | 7.26309E+14 |
| 21 | 13791.76 | 1.38345E+14 | 6.91723E+14 |
| 22 | 13217.103 | 1.3258E+14 | 6.62901E+14 |
| 23 | 12527.515 | 1.25663E+14 | 6.28315E+14 |
| 24 | 12010.324 | 1.20475E+14 | 6.02375E+14 |
| 25 | 11378.202 | 1.14134E+14 | 5.70671E+14 |
| 26 | 10803.545 | 1.0837E+14 | 5.4185E+14 |
| 27 | 10343.82 | 1.03758E+14 | 5.18792E+14 |
| 28 | 9769.1633 | 9.79941E+13 | 4.8997E+14 |
| 29 | 9194.5067 | 9.22297E+13 | 4.61149E+14 |
| 30 | 8849.7127 | 8.87711E+13 | 4.43855E+14 |
| 31 | 8504.9187 | 8.53125E+13 | 4.26562E+14 |
| 32 | 8045.1933 | 8.0701E+13 | 4.03505E+14 |
| 33 | 7757.865 | 7.78188E+13 | 3.89094E+14 |
| 34 | 7470.5367 | 7.49366E+13 | 3.74683E+14 |
| 35 | 7125.7427 | 7.1478E+13 | 3.5739E+14 |
| 36 | 6895.88 | 6.91723E+13 | 3.45861E+14 |
| 37 | 6608.5517 | 6.62901E+13 | 3.31451E+14 |
| 38 | 6321.2233 | 6.34079E+13 | 3.1704E+14 |
| 39 | 6206.292 | 6.22551E+13 | 3.11275E+14 |
| 40 | 5918.9637 | 5.93729E+13 | 2.96864E+14 |
| 41 | 5717.8338 | 5.73554E+13 | 2.86777E+14 |
| 42 | 5539.6903 | 5.55684E+13 | 2.77842E+14 |
| 43 | 5390.2795 | 5.40697E+13 | 2.70348E+14 |
| 44 | 5183.4031 | 5.19945E+13 | 2.59972E+14 |
| 45 | 5056.9787 | 5.07263E+13 | 2.53632E+14 |
| 46 | 4884.5817 | 4.8997E+13 | 2.44985E+14 |
| 47 | 4729.4244 | 4.74407E+13 | 2.37203E+14 |
| 48 | 4597.2533 | 4.61149E+13 | 2.30574E+14 |
| 49 | 4430.6029 | 4.44432E+13 | 2.22216E+14 |
| 50 | 4309.925 | 4.32327E+13 | 2.16163E+14 |

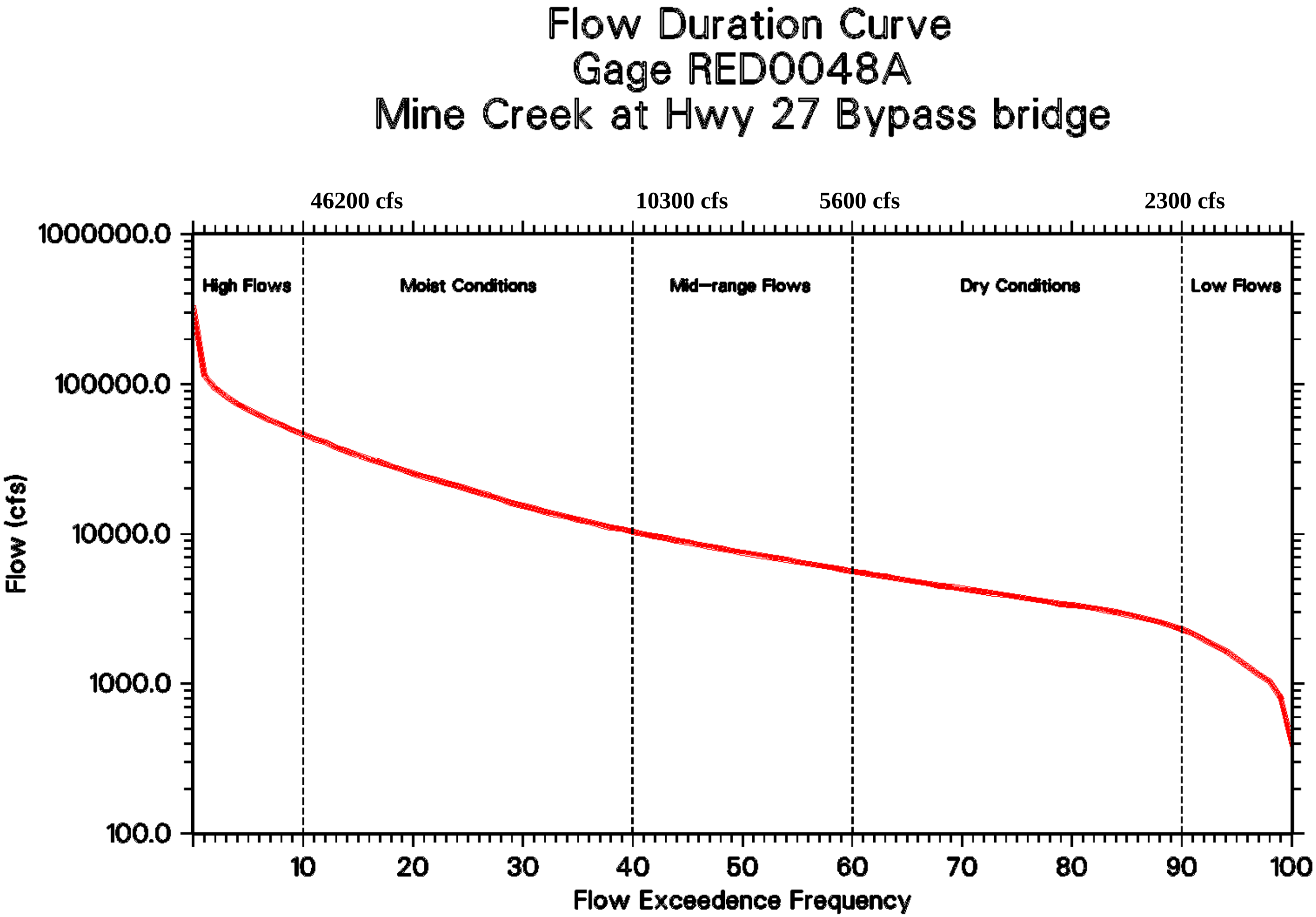
**Table A.4 (Continued)**
**Holly Creek (HUC-Reach 11140109-013)**
**E. Coli: 410 col/100 ml (PCR-Summer) and 2050 col/100 ml (PCR-Winter/SCR)**

| Flow Exceedence Frequency | Flow (cfs) | Load-PCR Sum (cfu/day) | Load-PCR Winter/SCR (cfu/day) |
|---|---|---|---|
| 51 | 4194.9937 | 4.20798E+13 | 2.10399E+14 |
| 52 | 4080.0623 | 4.09269E+13 | 2.04635E+14 |
| 53 | 3965.131 | 3.97741E+13 | 1.9887E+14 |
| 54 | 3870.3127 | 3.88229E+13 | 1.94115E+14 |
| 55 | 3735.2683 | 3.74683E+13 | 1.87342E+14 |
| 56 | 3631.8301 | 3.64307E+13 | 1.82154E+14 |
| 57 | 3539.8851 | 3.55084E+13 | 1.77542E+14 |
| 58 | 3436.4469 | 3.44709E+13 | 1.72354E+14 |
| 59 | 3333.0087 | 3.34333E+13 | 1.67166E+14 |
| 60 | 3218.0773 | 3.22804E+13 | 1.61402E+14 |
| 61 | 3154.8651 | 3.16463E+13 | 1.58232E+14 |
| 62 | 3051.4269 | 3.06087E+13 | 1.53044E+14 |
| 63 | 2988.2147 | 2.99747E+13 | 1.49873E+14 |
| 64 | 2896.2696 | 2.90524E+13 | 1.45262E+14 |
| 65 | 2815.8177 | 2.82453E+13 | 1.41227E+14 |
| 66 | 2741.1123 | 2.7496E+13 | 1.3748E+14 |
| 67 | 2663.5337 | 2.67178E+13 | 1.33589E+14 |
| 68 | 2585.955 | 2.59396E+13 | 1.29698E+14 |
| 69 | 2539.9825 | 2.54785E+13 | 1.27392E+14 |
| 70 | 2471.0237 | 2.47867E+13 | 1.23934E+14 |
| 71 | 2413.558 | 2.42103E+13 | 1.21051E+14 |
| 72 | 2356.0923 | 2.36339E+13 | 1.18169E+14 |
| 73 | 2298.6267 | 2.30574E+13 | 1.15287E+14 |
| 74 | 2241.161 | 2.2481E+13 | 1.12405E+14 |
| 75 | 2183.6953 | 2.19046E+13 | 1.09523E+14 |
| 76 | 2126.2297 | 2.13281E+13 | 1.06641E+14 |
| 77 | 2068.764 | 2.07517E+13 | 1.03758E+14 |
| 78 | 2017.0449 | 2.02329E+13 | 1.01164E+14 |
| 79 | 1953.8327 | 1.95988E+13 | 9.79941E+13 |
| 80 | 1925.0998 | 1.93106E+13 | 9.6553E+13 |
| 81 | 1884.8739 | 1.89071E+13 | 9.45355E+13 |
| 82 | 1838.9013 | 1.84459E+13 | 9.22297E+13 |
| 83 | 1781.4357 | 1.78695E+13 | 8.93475E+13 |
| 84 | 1723.97 | 1.72931E+13 | 8.64654E+13 |
| 85 | 1666.5043 | 1.67166E+13 | 8.35832E+13 |
| 86 | 1609.0387 | 1.61402E+13 | 8.0701E+13 |
| 87 | 1542.9532 | 1.54773E+13 | 7.73865E+13 |
| 88 | 1482.6142 | 1.4872E+13 | 7.43602E+13 |
| 89 | 1402.1623 | 1.4065E+13 | 7.03252E+13 |
| 90 | 1321.7103 | 1.3258E+13 | 6.62901E+13 |
| 91 | 1241.2584 | 1.2451E+13 | 6.22551E+13 |
| 92 | 1137.8202 | 1.14134E+13 | 5.70671E+13 |
| 93 | 1034.382 | 1.03758E+13 | 5.18792E+13 |
| 94 | 953.93007 | 9.56883E+12 | 4.78442E+13 |
| 95 | 844.7453 | 8.4736E+12 | 4.2368E+13 |
| 96 | 747.05367 | 7.49366E+12 | 3.74683E+13 |
| 97 | 666.60173 | 6.68665E+12 | 3.34333E+13 |
| 98 | 597.64293 | 5.99493E+12 | 2.99747E+13 |
| 99 | 464.32259 | 4.6576E+12 | 2.3288E+13 |
| 100 | 229.86267 | 2.30574E+12 | 1.15287E+13 |

# Appendix B

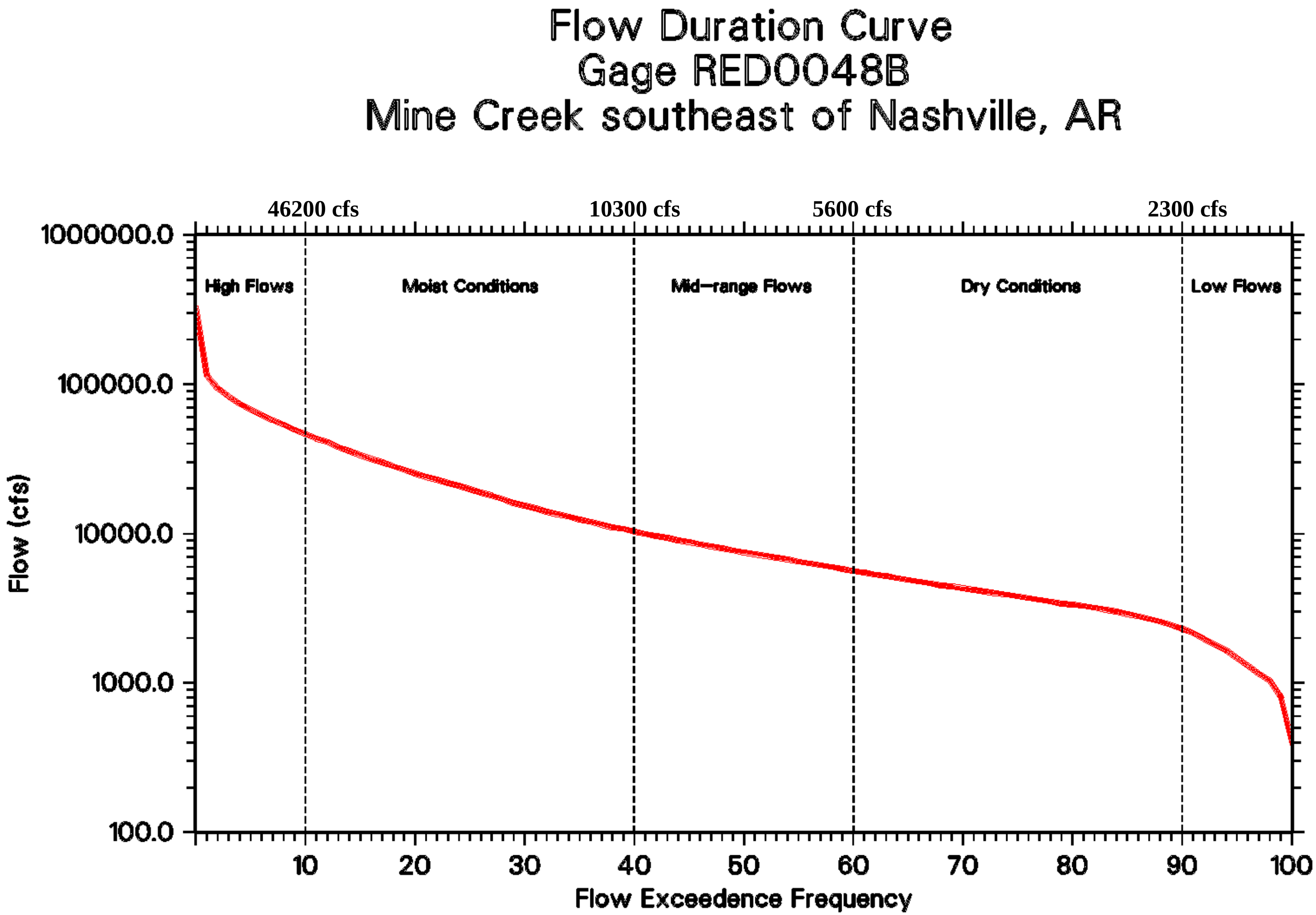
## Flow Duration Curves

**Figure B.1**



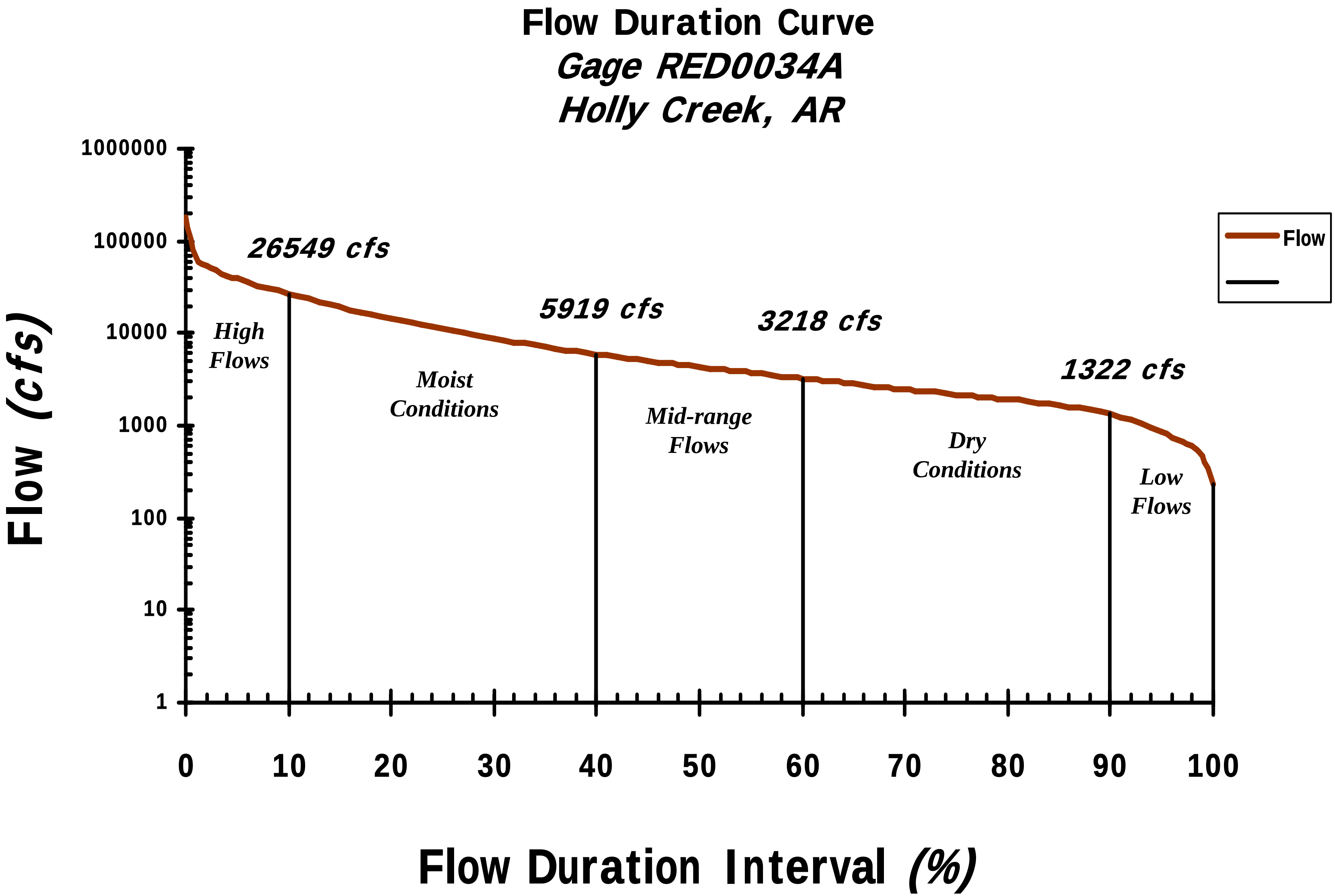

NOTE: Flows Projected From RED0046

**Figure B.2**



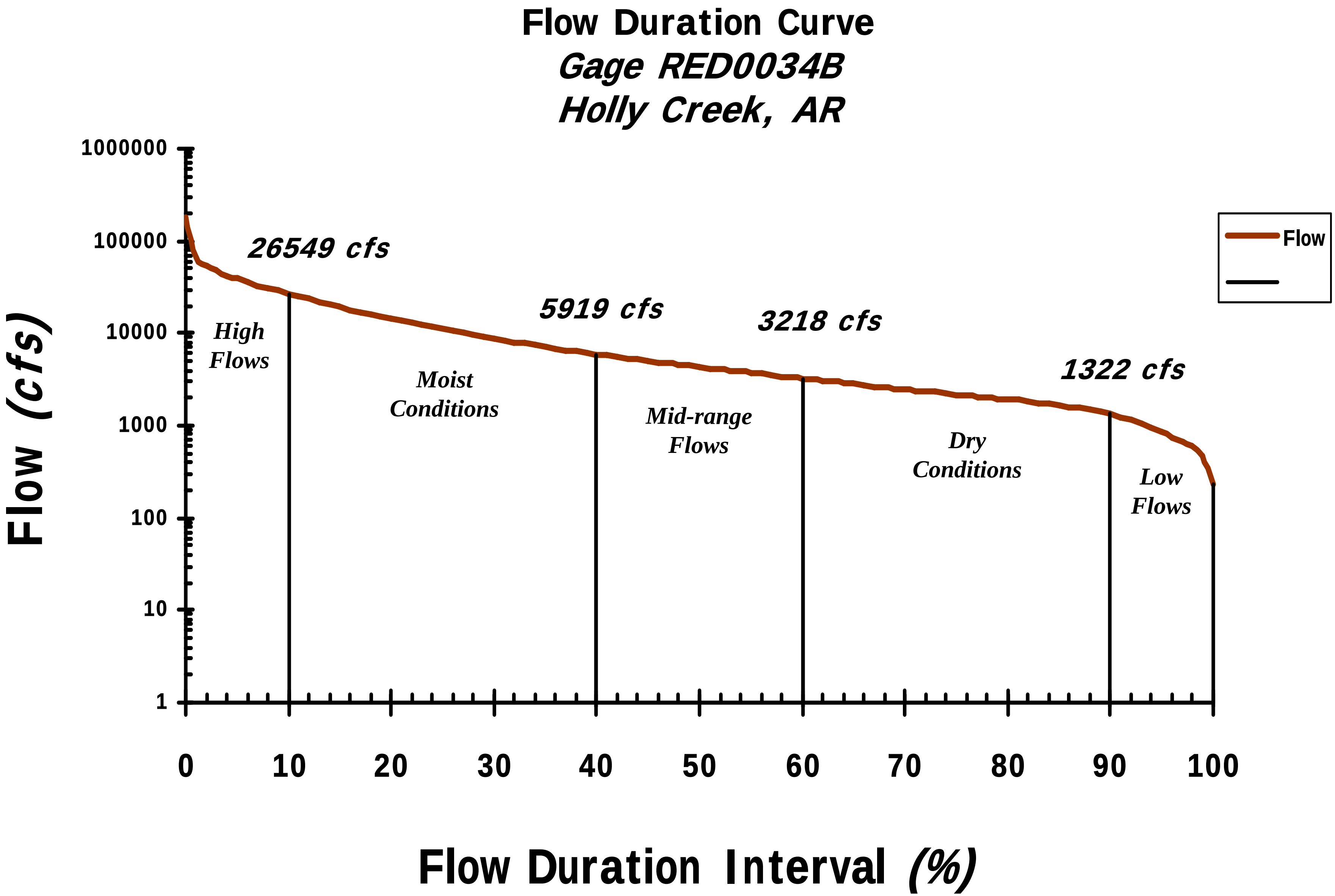

NOTE: Flows Projected From RED0046

**Figure B.3**




USGS Flow Data

**Figure B.4**




USGS Flow Data

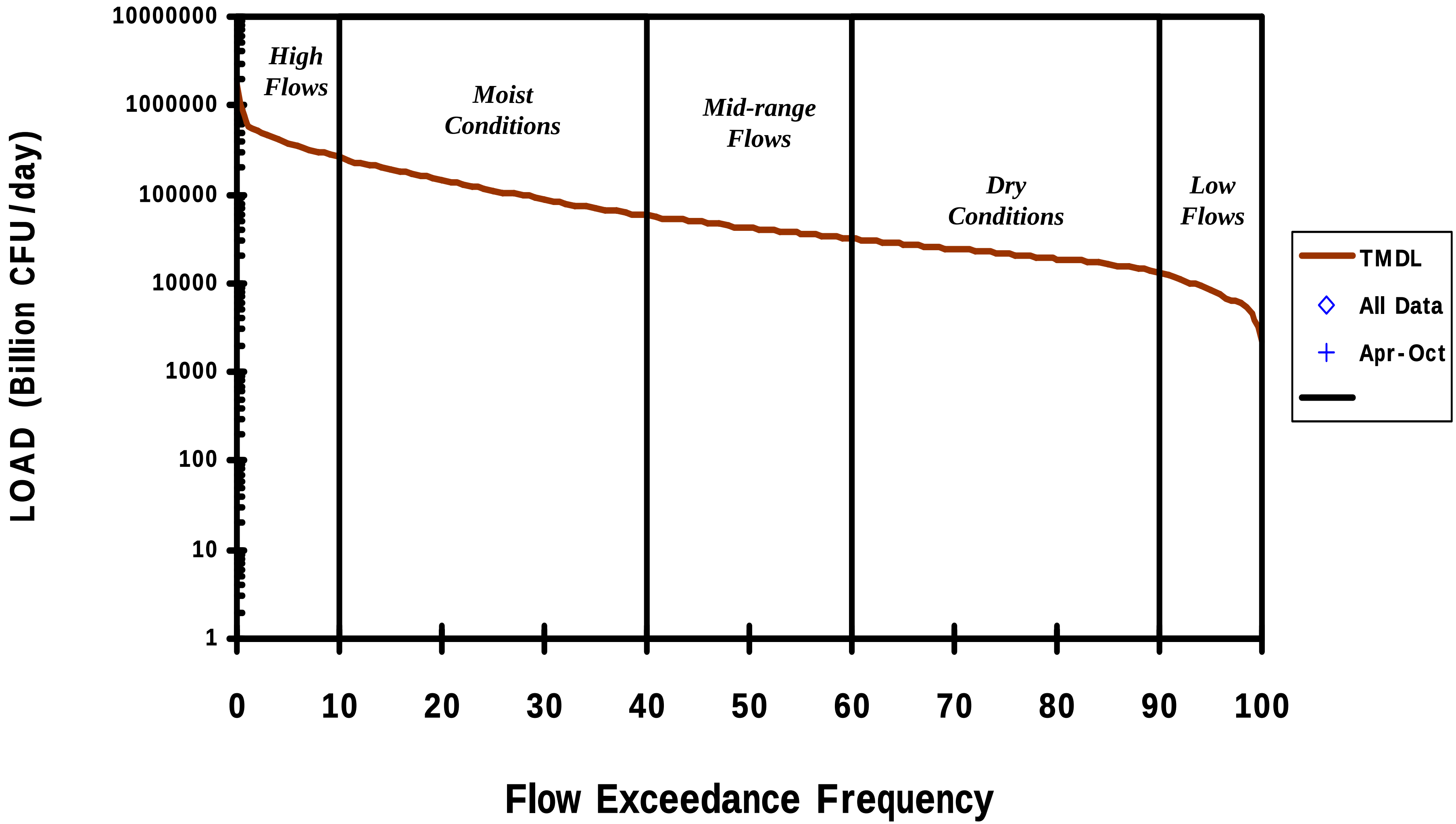
# Appendix C

## Load Duration Curves for Fecal Coliform and E. coli Bacteria

**Figure C.1**

# PCR Summer Season Load Duration Curve

***Fecal Coliform***
***Holly Creek, AR***
***(11140109-013)***

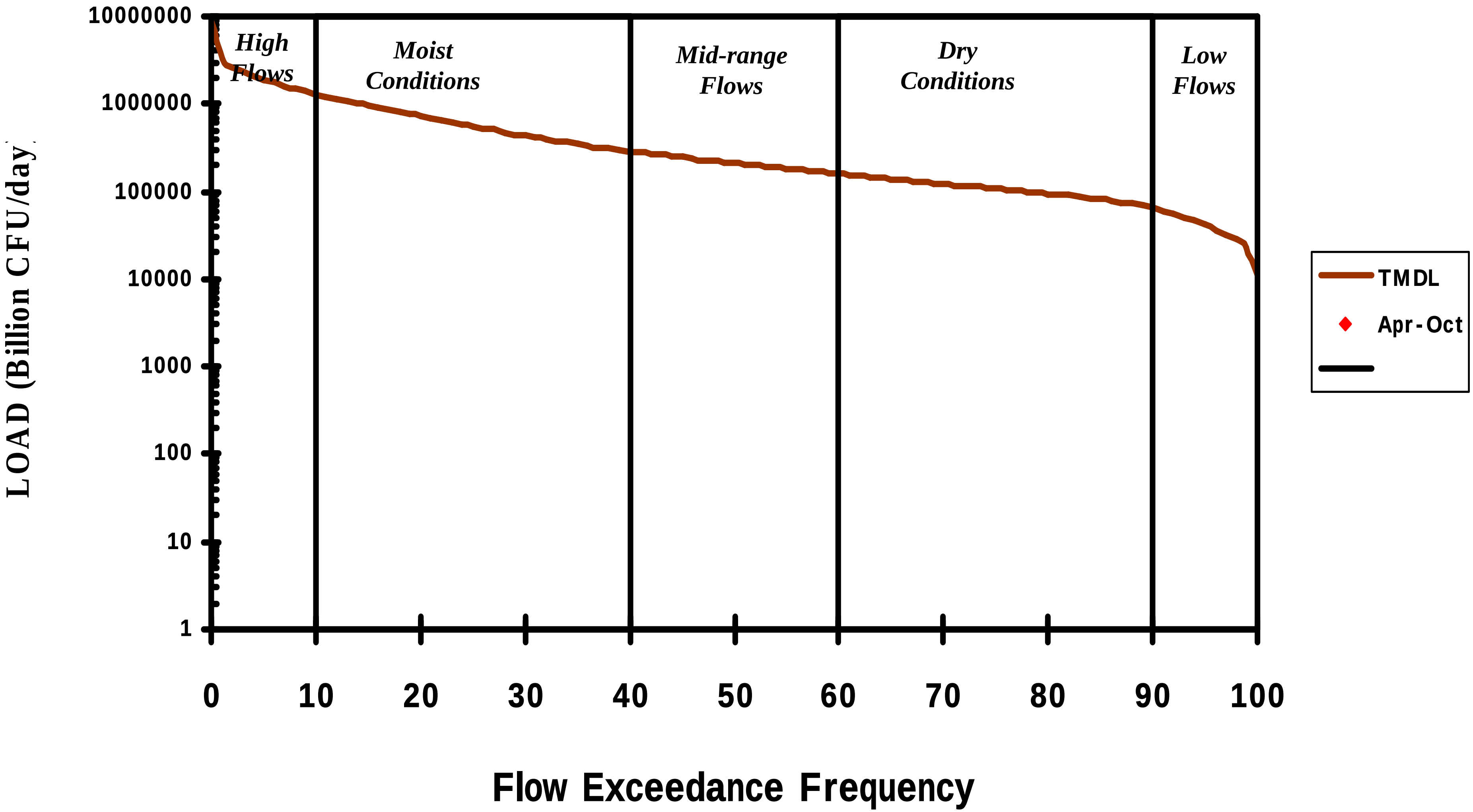



***USGS Data***

**Figure C.2**

# PCR Winter/SCR Season Load Duration Curve

*Fecal Coliform*
*Holly Creek, AR*
*(11140109-013)*




*USGS Data*

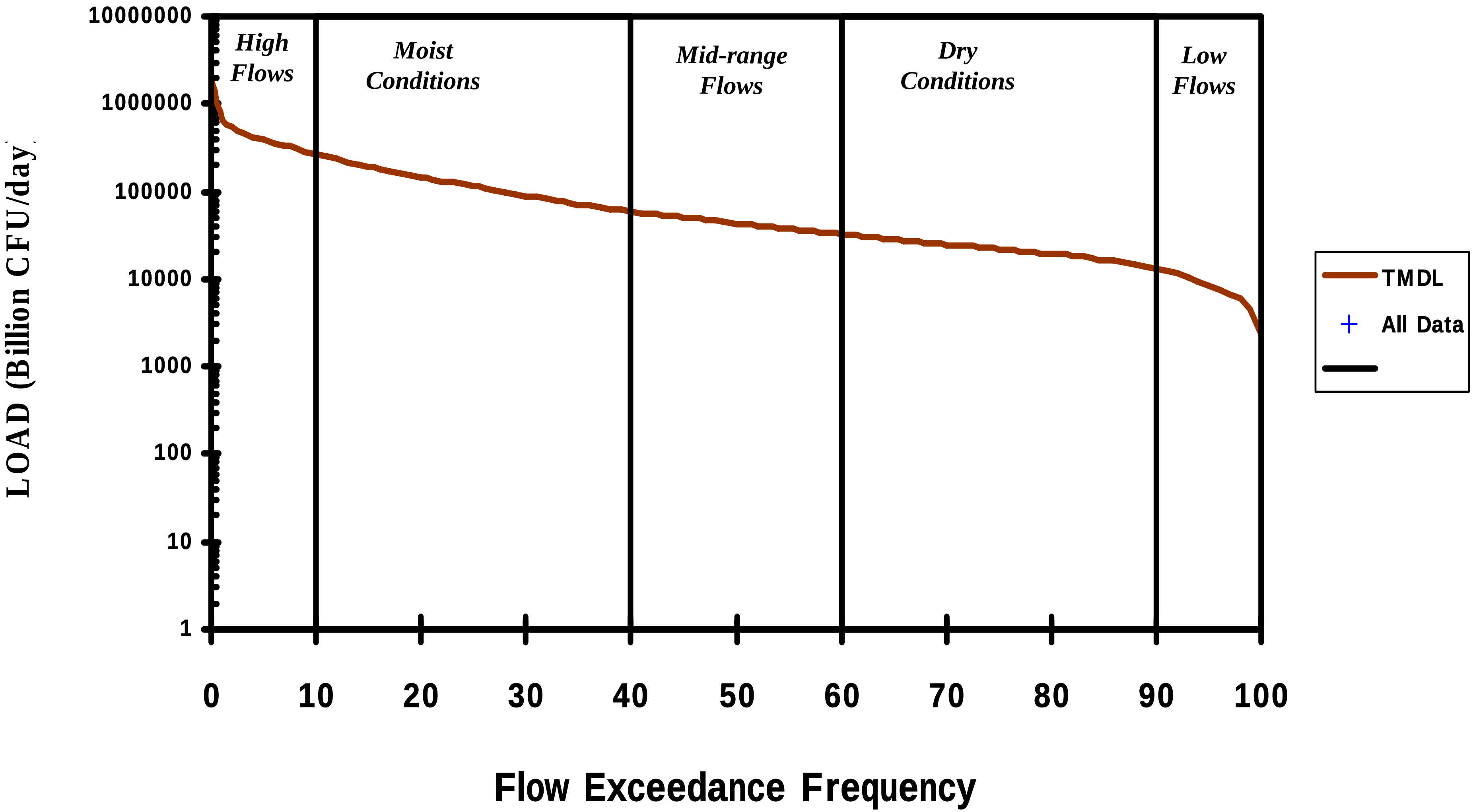
<u>Figure C.3</u>

**PCR Summer Season Load Duration Curve**

***E. Coli***

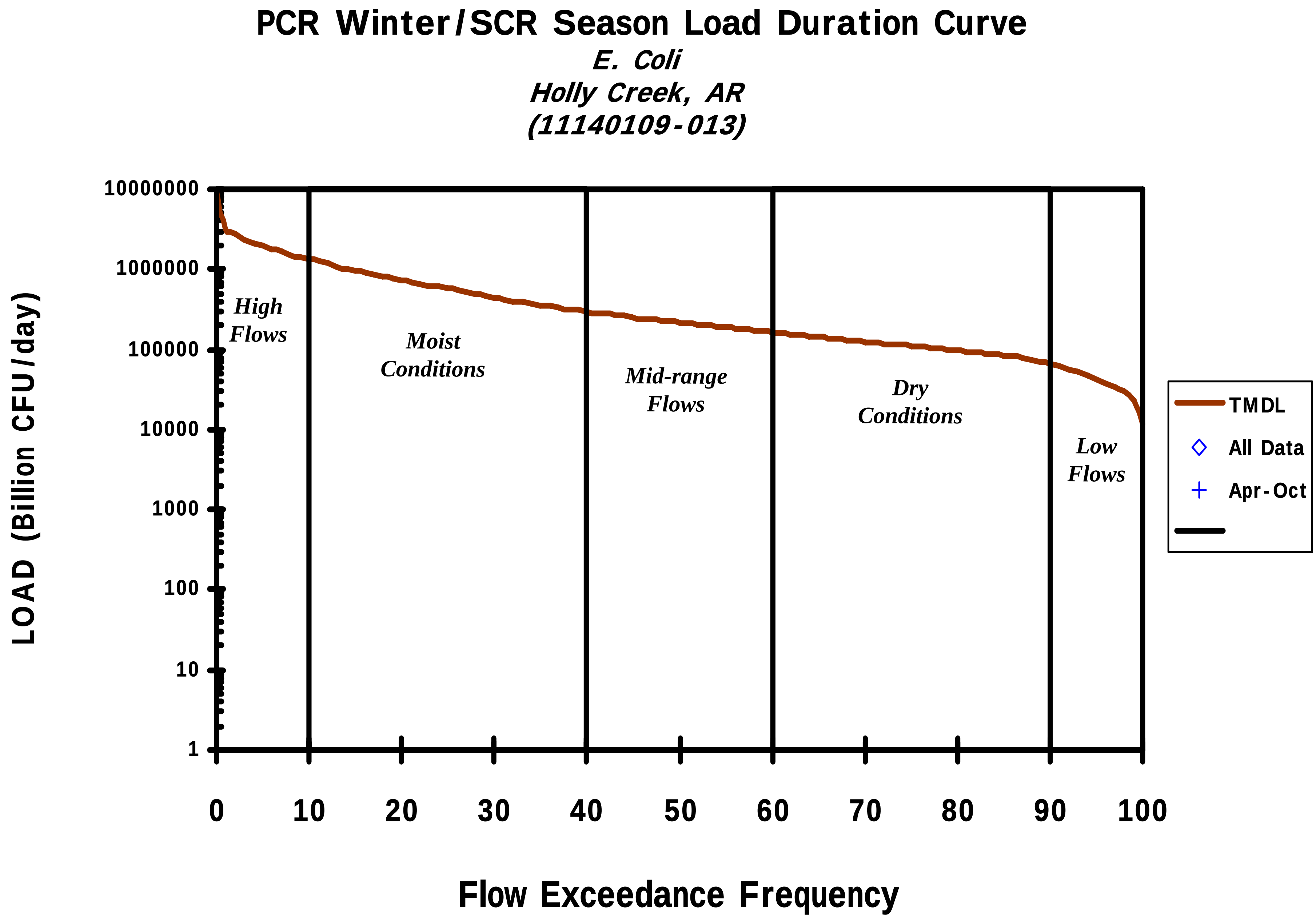
***Holy Creek, AR***

***(11140109-013)***




***USGS Data***

Figure C.4

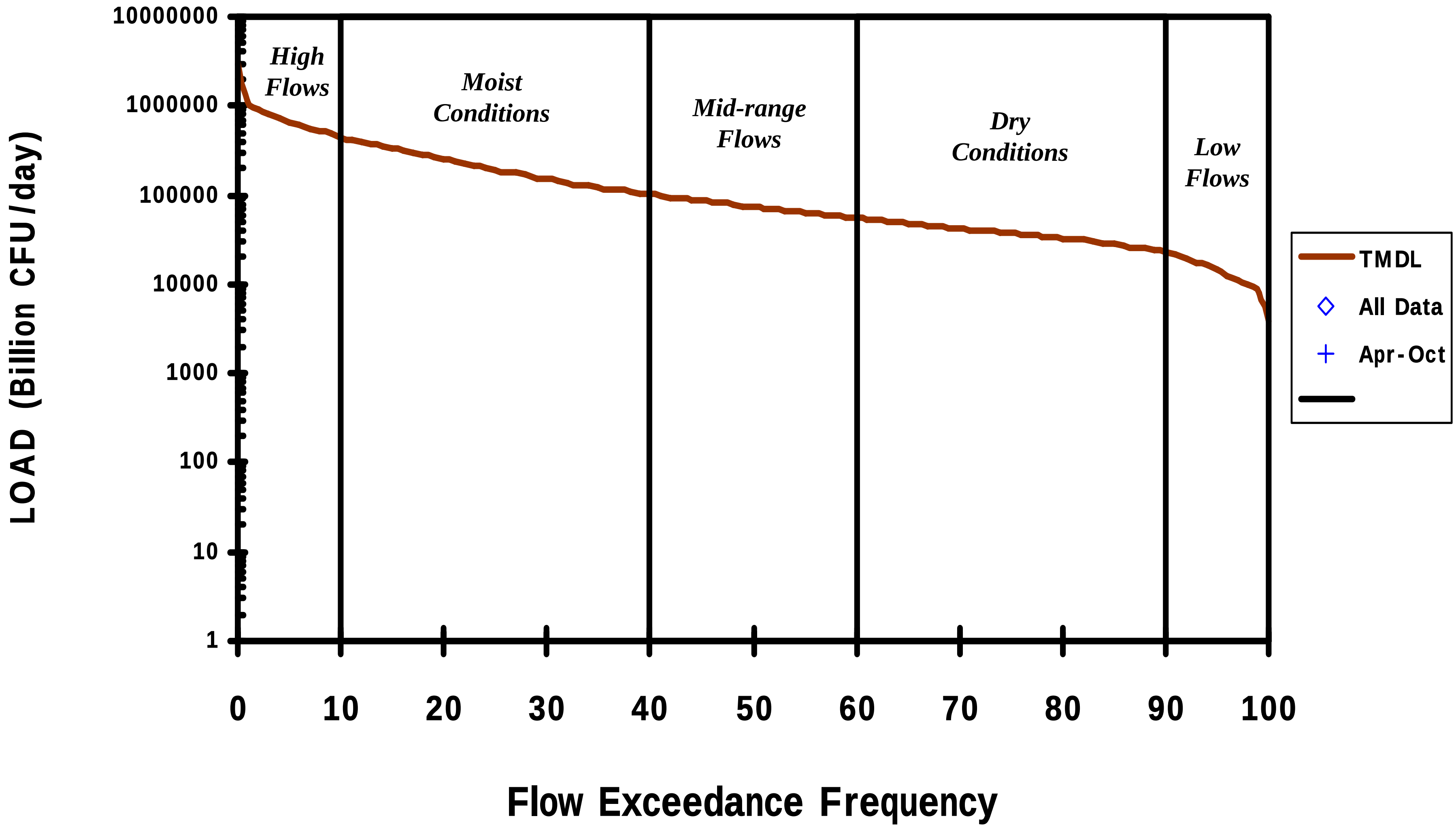



USGS Data

**Figure C.5**

# PCR Summer Season Load Duration Curve

*Fecal Coliform*
*Mine Creek, AR*
*(11140109-033)*

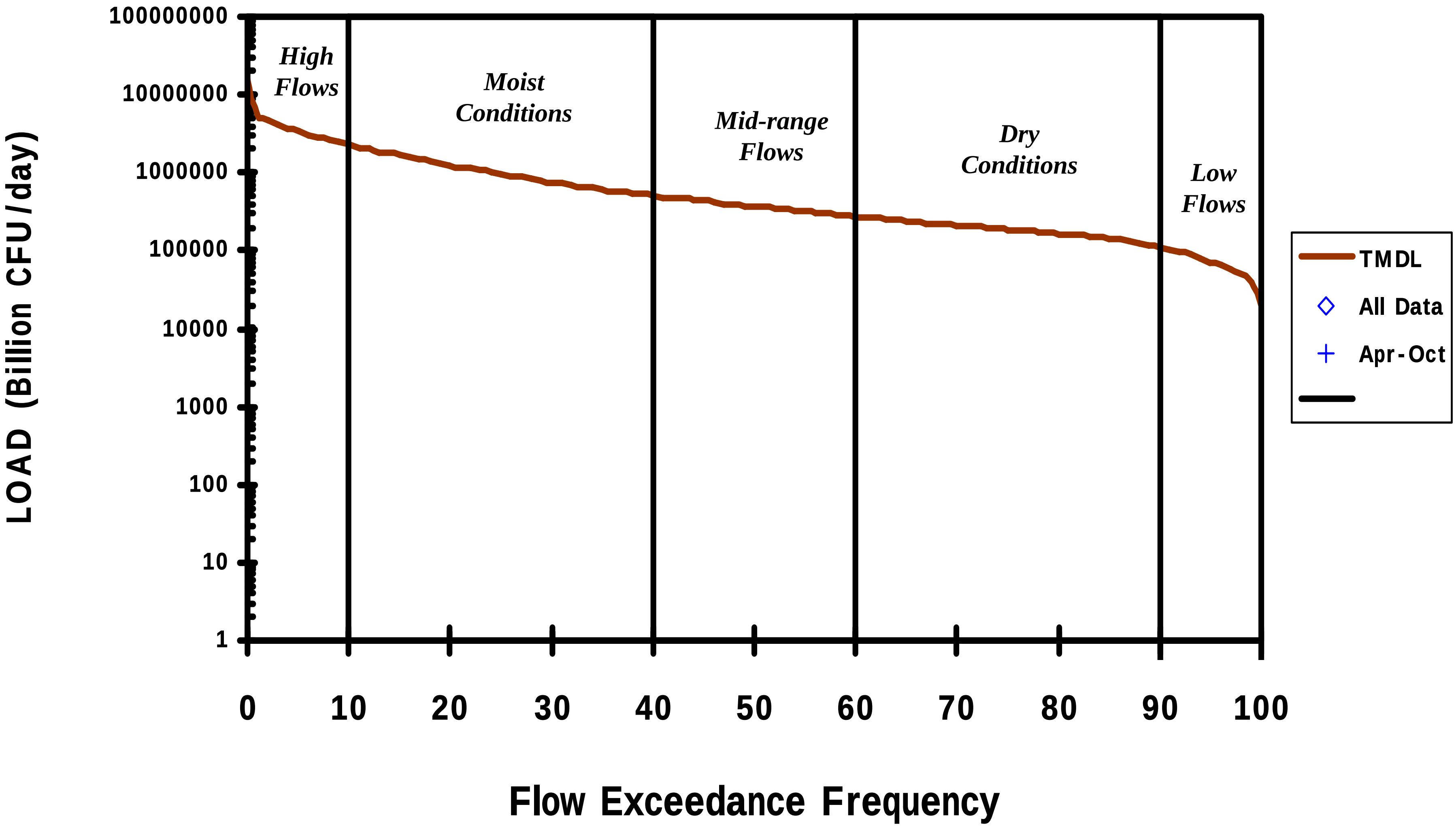



*USGS Data*

## Figure C.6

# PCR Winter/SCR Season Load Duration Curve

*Fecal Coliform*
*Mine Creek, AR*
*(11140109-033)*




*USGS Data*

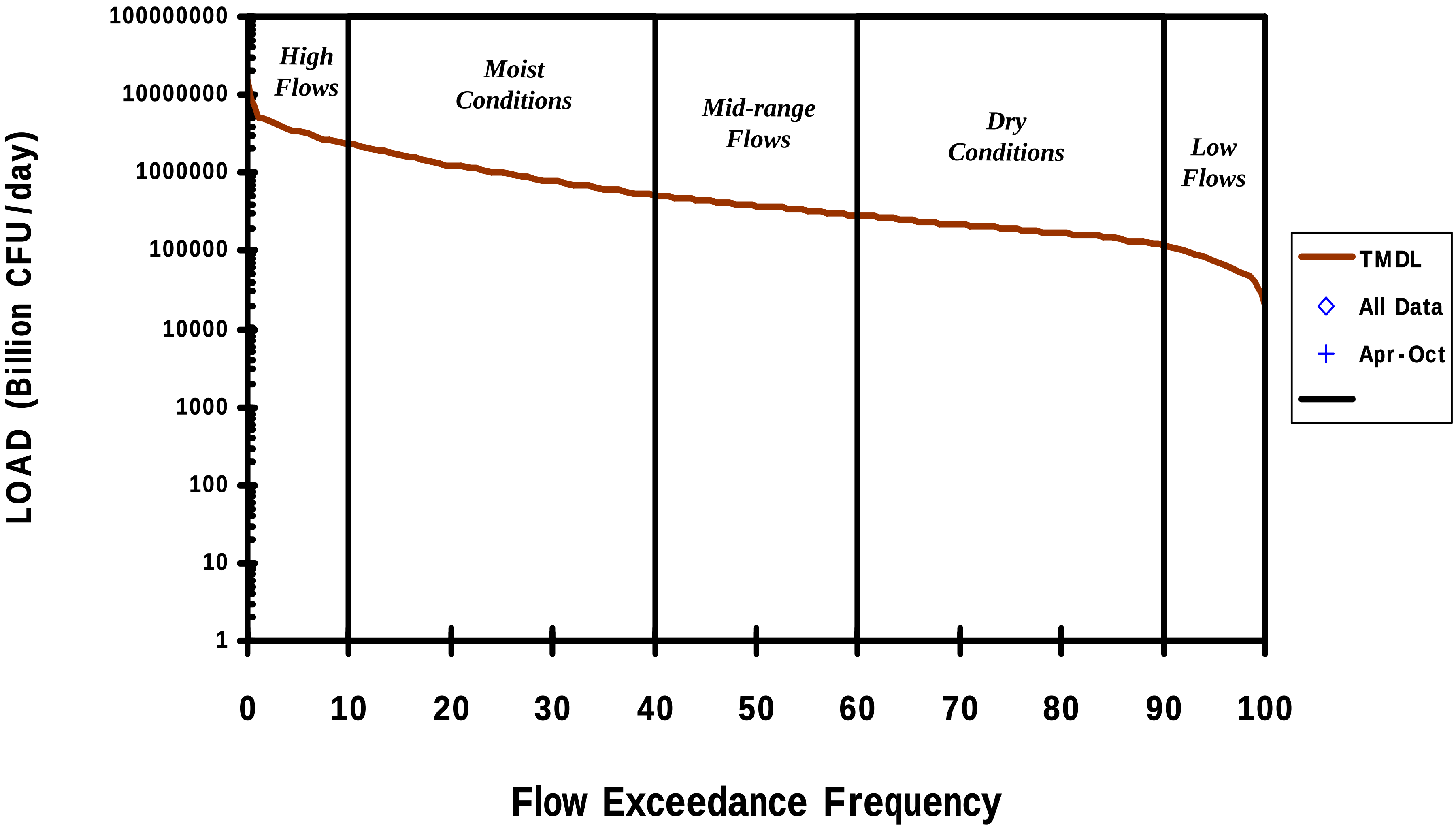
**Figure C.7**

# PCR Winter/SCR Season Load Duration Curve

***E. Coli***

***Mine Creek, AR***

***(11140109-033)***

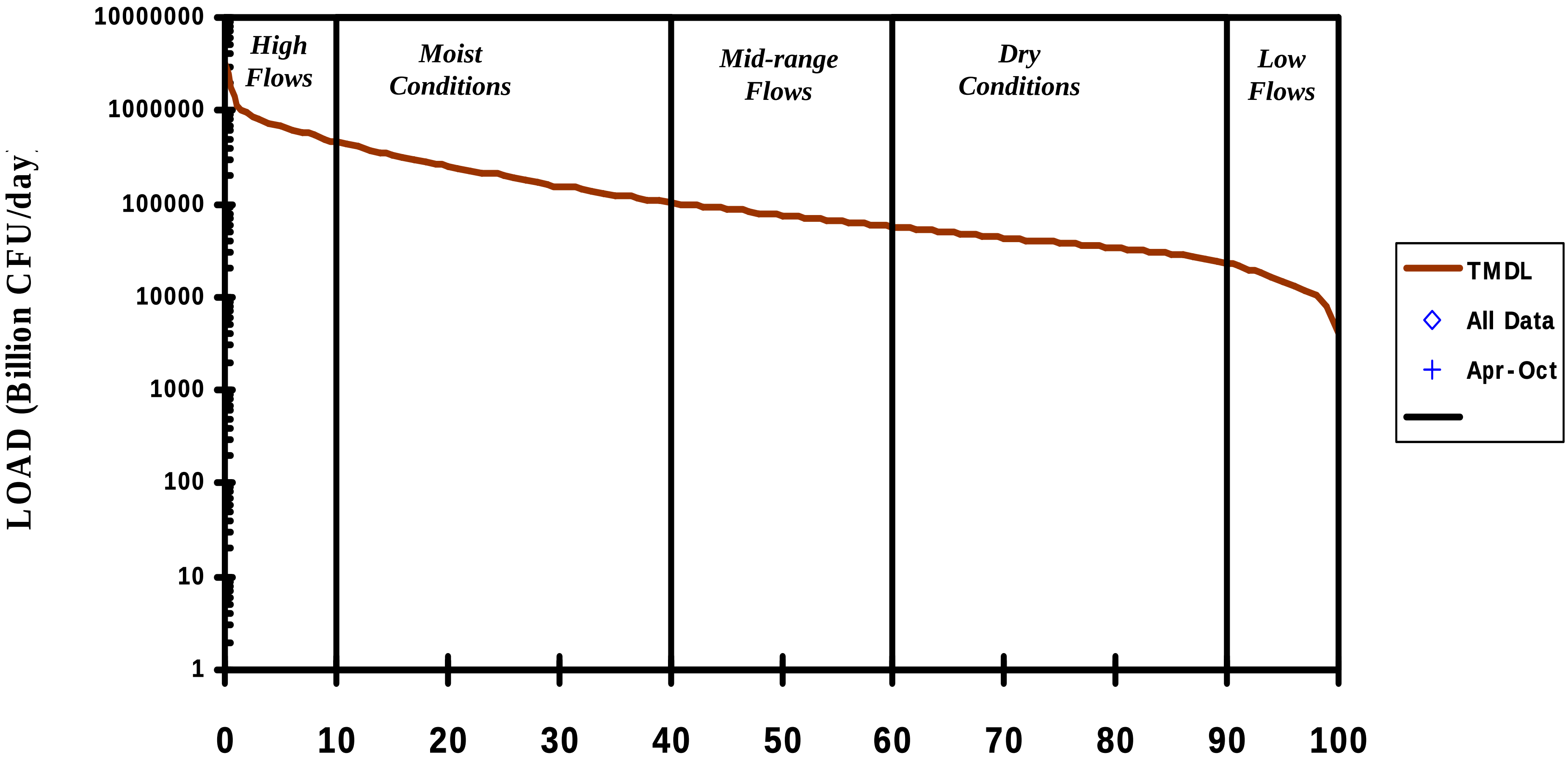



***USGS Data***

Figure C.8

## PCR Summer Season Load Duration Curve

*E. Coli*
*Mine Creek, AR*
*(11140109-033)*




*USGS Data*

## Appendix D

# Sample Waste Load Allocations Based on Available Flows

**Table 1 Waste Load Allocation for NPDES Permits - Holly Creek**

| NPDES Permit Number | Facility Name | Flow (MGD) | Fecal Coli-Summer (cfu/day) | Fecal Coli-Winter/SCR (cfu/day) | E.Coli-Summer (cfu/day) | E. Coli-Winter/SCR (cfu/day) |
|---|---|---|---|---|---|---|
| AR00002917 | Weyerhaeuser Co-Dierks | 1.115 | 1.69E+10 | 8.44E+10 | 1.73E+10 | 8.65E+10 |
| AR00021709 | City of Dierks | 0.23 | 3.48E+09 | 1.74E+10 | 3.57E+09 | 1.78E+10 |

**Cfu/day** = colony forming units/day

**Table 2 Waste Load Allocation for NPDES Permits - Mine Creek**

| NPDES Permit Number | Facility Name | Flow (MGD) | Fecal Coli-Summer (cfu/day) | Fecal Coli-Winter/SCR (cfu/day) | E.Coli-Summer (cfu/day) | E. Coli-Winter/SCR (cfu/day) |
|---|---|---|---|---|---|---|
| AR0021261 | City of Mineral Springs | 0.2 | 3.03E+09 | 1.51E+10 | 3.10E+09 | 1.55E+10 |
| AR0021776 | City of Nashville | 2.3 | 3.48E+10 | 1.74E+11 | 3.57E+10 | 1.78E+11 |
| AR0041734 | Tyson Foods Inc - Nashville | 1.53 | 2.32E+10 | 1.15834E+11 | 2.37E+10 | 1.19E+11 |
| AR0045144 | City of Tollette | 0.01 | 1.51E+08 | 7.57E+08 | 1.55E+08 | 7.76E+08 |
| AR0041796 | Dalton Mobile Home | 0.0054 | 8.18E+07 | 8.18E+07 | 8.18E+07 | 8.18E+07 |

**Cfu/day** = colony forming units/day