PATHOGEN TMDLS FOR SELECTED REACHES

IN PLANNING SEGMENT 4E

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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 waterbodies. A TMDL establishes the amount of a pollutant that a waterbody 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 nonpoint 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 4E and is located within the Arkansas River Valley, the Boston Mountains, and the Delta ecoregions. The study area for this project is limited to ten Hydrologic Unit Code (HUC)-reaches in the Arkansas planning segment 4E (11010014-038, 11010014-028, 11010014-027, 11010014-012, 11010014-010, 11010014-009, 11010014-008, 11010014-007, 11010014-006, and 11010014-004) tributaries of the Little Red River in north central Arkansas. The Little Red River is a subbasin of the White River Basin. 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 4E include fishery, primary and secondary contact recreation; domestic, agricultural and industrial water supply; Extraordinary Resources Waters (ERW) and Ecologically Sensitive Waterbodies (ESW).

The numeric water quality criterion that apply to the impaired reaches in the White River Basin and that were used to calculate the total allowable loads are the primary contact water quality criteria for fecal coliform (FC) bacteria and *Escherichia coli* (E. coli). Extraordinary Resource Waters were calculated using specific standards. See section 2.5 for Water Quality Standards.

The TMDLs for FC and E. coli bacteria were developed using mass balance principles. This TMDL information has been displayed in the load duration curve method. This method illustrates allowable loading at a wide range of streamflow conditions. The seasonal FC and E. coli bacteria TMDLs were developed on the basis of analyses of the Primary Contract Recreation (PCR) water quality criteria, which specifies two seasons. Allowable loads for each season were calculated.

The TMDLs for fecal coliform and E. coli bacteria were separated into PCR summer (May 1 through September 30) and PCR winter (October 1 through April 30) data sets to accommodate the state's seasonal criteria. Secondary Contact Recreation (SCR) has year round criteria limits. The daily streamflow measurements from USGS gages were used to develop flows for each HUC-reach.

TableES.1 Summary of Bacteria TMDLs Planning Segment 4E

Arkansas HUC-Reach #	Pollutant	Criteria	MOS cfu/day	∑ WLA cfu/day	∑ LA cfu/day	TMDL cfu/day
	South Fork Little Red River					
11010014-038	FC	PCR-S	7.44E+10	4.09E+10	6.29E+11	7.44E+11
	FC	PCR-W/SCR	3.72E+11	2.05E+11	3.14E+12	3.72E+12
	E. coli	PCR-S	7.62E+10	4.19E+10	6.44E+11	7.62E+11
	E. coli	PCR-W/SCR	3.81E+11	2.09E+11	3.22E+12	3.81E+12
	Middle Fork Little Red River					
11010014-028	FC	PCR-S	1.18E+11	0	1.07E+12	1.18E+12
	FC	PCR-W/SCR	5.92E+11	0	5.33E+12	5.92E+12
	E. coli	PCR-S	8.82E+10	0	7.94E+11	8.82E+11
	E. coli	PCR-W/SCR	4.41E+11	0	3.97E+12	4.41E+12
	Middle Fork Little Red River					
11010014-027	FC	PCR-S	1.53E+11	0	1.38E+12	1.53E+12
	FC	PCR-W/SCR	7.67E+11	0	6.9E+12	7.67E+12
	E. coli	PCR-S	1.14E+11	0	1.03E+12	1.14E+12
	E. coli	PCR-W/SCR	5.71E+11	0	5.14E+12	5.71E+12
	Little Red River					
11010014-012	FC	PCR-S	9.23E+11	3.03E+09	8.31E+12	9.23E+12
	FC	PCR-W/SCR	4.62E+12	1.51E+10	4.16E+13	4.62E+13
	E. coli	PCR-S	9.46E+11	3.10E+09	8.51E+12	9.46E+12
	E. coli	PCR-W/SCR	4.73E+12	1.55E+10	4.26E+13	4.73E+13
	Little Red River					
11010014-010	FC	PCR-S	9.80E+11	0	8.82E+12	9.80E+12
	FC	PCR-W/SCR	4.90E+12	0	4.41E+13	4.90E+13
	E. coli	PCR-S	1.00E+12	0	9.00E+12	1.00E+13
	E. coli	PCR-W/SCR	5.02E+12	0	4.52E+13	5.02E+13
	Ten Mile Creek					
11010014-009	FC	PCR-S	1.88E+12	0	1.69E+13	1.88E+13
	FC	PCR-W/SCR	9.38E+12	0	8.44E+13	9.38E+13
	E. coli	PCR-S	1.92E+12	0	1.73E+13	1.92E+13
	E. coli	PCR-W/SCR	9.61E+12	0	8.65E+13	9.61E+13
	Little Red River					
11010014-008	FC	PCR-S	1.47E+12	0	1.32E+13	1.47E+13
	FC	PCR-W/SCR	7.34E+12	0	6.61E+13	7.34E+13
	E. coli	PCR-S	1.50E+12	0	1.35E+13	1.50E+13
	E. coli	PCR-W/SCR	7.52E+12	0	6.77E+13	7.52E+13

Arkansas HUC-Reach #	Pollutant	Criteria	MOS cfu/day	∑ WLA cfu/day	∑ LA cfu/day	TMDL cfu/day
	Little Red River					
11010014-007	FC	PCR-S	1.88E+12	7.87E+10	1.68E+13	1.88E+13
	FC	PCR-W/SCR	9.38E+12	3.94E+11	8.4E+13	9.38E+13
	E. coli	PCR-S	1.92E+12	8.07E+10	1.72E+13	1.92E+13
	E. coli	PCR-W/SCR	9.61E+12	4.04E+11	8.61E+13	9.61E+13
	Overflow Creek					
11010014-006	FC	PCR-S	1.07E+11	0	9.63E+11	1.07E+12
	FC	PCR-W/SCR	5.34E+11	0	4.81E+12	5.34E+12
	E. coli	PCR-S	1.09E+11	0	9.81E+11	1.09E+12
	E. coli	PCR-W/SCR	5.47E+11	0	4.92E+12	5.47E+12
	Overflow Creek					
11010014-004	FC	PCR-S	1.56E+11	0	1.40E+12	1.56E+12
	FC	PCR-W/SCR	7.82E+11	0	7.04E+12	7.82E+12
	E. coli	PCR-S	1.60E+11	0	1.44E+12	1.60E+12
	E. coli	PCR-W/SCR	8.02E+11	0	7.22E+12	8.02E+12

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 (FC) and *Escherichia coli* (E. coli) for 10 stream reaches in the White River Basin in north central Arkansas. These stream reaches were included on the Arkansas Department of Environmental Quality (ADEQ) 2004 Integrated Report (ADEQ, 2004) as not supporting their designated use of primary contact recreation (PCR). The waterbodies, pollutants, and priority from the 303(d) list and other information from the Integrated Report are shown below in Table 1.1. 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.

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 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.

Table 1.1 Pathogen Impaired 4E HUC-Reaches Addressed

HUC-reach Number	Waterbody Name	Impaired Use	Cause of Impairment	Suspected Source	Priority Ranking
11010014-038	South Fork Little Red River	PCR	Pathogen	Unknown	Low
11010014-028	Middle Fork Little Red River	PCR	Pathogen	Unknown	Medium
11010014-027	Middle Fork Little Red River	PCR	Pathogen	Unknown	Medium
11010014-012	Little Red River	PCR	Pathogen	Unknown	Low
11010014-010	Little Red River	PCR	Pathogen	Unknown	Low
11010014-009	Ten Mile Creek	PCR	Pathogen	Unknown	Low
11010014-008	Little Red River	PCR	Pathogen	Unknown	Low
11010014-007	Little Red River	PCR	Pathogen	Unknown	Low
11010014-006	Overflow Creek	PCR	Pathogen	Unknown	Low
11010014-004	Overflow Creek	PCR	Pathogen	Unknown	Low

PCR = Primary Contact Recreation

2.0 STUDY AREA INFORMATION

2.1 General Description

The planning segment for this project is located in the White River Basin in north central Arkansas (see Figure A.1 in Appendix A). The portion of the White River Basin that is included in the study area is within the Arkansas River Valley, the Boston Mountains, and the Delta ecoregions. The Little Red River subbasin of the White River Basin is the United States Geological Survey (USGS) Hydrologic Unit 11010014, which is the ADEQ Planning Segment 4E. The segment contains the entire 81 mile length of the Little Red River and its major tributaries the Middle, South, North Forks, Big Creek, Devil’s Fork and Archey Creek. Planning Segment 4E includes portions of Searcy, Van Buren, Stone, Cleburne, and White Counties. See Table 1.1 for segment numbers and waterbody names.

2.2 Soils and Topography

The soils and topography information was obtained from soil surveys for parts of Searcy, Van Buren, Stone, Cleburne, and White Counties (USDA 1984, USDA 1984a, USDA 1984b, USDA 1984c). The soils in the study area range from deep stony soils to shallow clay and loamy soils. The topography of the study area is characterized by rolling hills, steep valleys, and ridges.

2.3 Land Use

Land use data for 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. The land use percentages for Planning Segment 4E are shown in Table 2.1. These data indicate that forest (70.08%) and pasture (23.67%) are the predominant land uses.

Table 2.1 Land Use Percentages for Planning Segment 4E

Land use	Percentage of study area
Forest (all types)	70.08%
Pasture	23.67%
Urban	4.10%
Barren	1.66%
Crops	0.49%
Total	100.00%

2.4 Flow Characteristics

There are four USGS flow gages used in the study area: South Fork Little Red River at Clinton, AR (USGS 07075300), Little Red River near Searcy, AR (USGS 07076620), Middle Fork of Little Red River at Shirley, AR (USGS 0705000), and Little Red River near Dewey, AR (07076517). Information for these flow gages is summarized in Table 2.2.

Table 2.2 Information for Stream Flow Gage Stations

Gage Name	South Fork of Little Red River at Clinton, AR	Middle Fork of Little Red River at Shirley, AR
Gage Number	7075300	705000
Location	South Fork of Little Red River at Hwy. 65 at Clinton, Arkansas (Van Buren County)	Middle Fork of Little Red River at Shirley, AR (Van Buren County)
Period of record	Oct. 1961 to Sept.2005	March 1939 to Oct.2006
Drainage area	148 square miles	302 square miles

Gage Name	Little Red River near Dewey, AR	Little Red River near Searcy, AR
Gage Number	7076517	7076620
Location	Little Red River near Dewey, AR (White County)	Little Red River near Searcy, AR (White County)
Period of record	June 1997 to Jan. 2007	May 1983 to Sept. 1996
Drainage area	1340 square miles	1648 square miles

2.5 Water Quality Standards

The beneficial uses by HUC-Reach number are shown below in Table 2.3. There is no narrative criterion for pathogens in the Water Quality Standards for Surface Waters of the State of Arkansas. Below are the numeric criteria for Pathogens from the Arkansas Pollution Control and Ecology Commission Regulation No. 2 (APCEC, 2006).

"Reg. 2.507 Bacteria

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* 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/100 ml 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 ml for other rivers and streams."

As specified in EPA's regulations at 40 CFR 130.7(b) (2), applicable water quality standards include antidegradation requirements. Arkansas' antidegradation policy is listed in Sections 2.201 through 2.204 of Regulation No. 2 (APCEC, 2006). These sections are 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.

Beneficial uses are listed below in Table 2.3.

Table 2.3 Designated Uses on Selected HUC-Reaches

HUC-Reach Numbers	Designated Uses
11010014-038	AWS, DWS, ESW, FS, IWS, PCR, SCR
11010014-028	AWS, DWS, ERW, ESW, FS, IWS, PCR, SCR
11010014-027	AWS, DWS, ERW, ESW, FS, IWS, PCR, SCR
11010014-012	AWS, DWS, ESW, FT, IWS, PCR, SCR
11010014-010	AWS, DWS, ESW, FT, IWS, PCR, SCR
11010014-009	AWS, DWS, ESW, FS, IWS, PCR, SCR
11010014-008	AWS, DWS, ESW, FT, IWS, PCR, SCR
11010014-007	AWS, DWS, ESW, FT, IWS, PCR, SCR
11010014-006	AWS, DWS, ESW, FS, IWS, PCR, SCR
11010014-004	AWS, DWS, ESW, FS, IWS, PCR, SCR

AWS Agricultural Water Supply
DWS Domestic Water Supply
ERW Extraordinary Resource Waters
ESW Ecologically Sensitive Waterbody
FS Fishery Stream
FT Fishery Trout
IWS Industrial Water Supply
PCR Primary Contact Recreation
SCR Secondary Contact Recreation

2.6 Source Analysis

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

2.7 Nonpoint Sources

Fecal coliform and E. coli bacteria are produced by all warm-blooded animals, including wildlife such as mammals and birds. In developing bacteria TMDLs, it is essential to identify the potential for bacteria contributions from wildlife by watershed. Wildlife is naturally attracted to riparian corridors of streams and rivers. With direct access to the stream channel, wildlife 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. Currently 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.

The predominant land uses for the listed reaches in planning segment 4E are forest (70.08%) and pasture (23.67%); therefore, the most probable source of Fecal coliform and E. coli bacteria are 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. The Arkansas Water Quality Standard does not provide exclusion for wildlife and domestic animal bacteria contributions. Therefore, there is no compelling reason to identify the quantity of these sub-sources

2.8 Point Sources

Both treated and untreated sanitary wastewater contains fecal coliform and E. coli 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, 2006) and the Arkansas 2004 Integrated Report (ADEQ, 2004). The search yielded 8 point source dischargers at this time for the planning segment 4E. See Table 2.4 below. Permits that are actively discharging to the waterbody reaches in this study will be given individual wasteload allocations. There are no known municipal separate storm sewer (MS4) permits in the 10 Arkansas waterbody reaches addressed in this TMDL report. See appendix A Figure A for map.

Table 2.4 Inventory of Point Sources

NPDES Permit No.	Facility	Flow (mgd)	Receiving Waters	River Reach ID	Date Permit Expires
AR0048747	Clinton, City of - West WWTP	1.5	South Fork Little Red River	AR11010014-038	July 31, 2010
AR0048836	Clinton, City of - East WWTP	1.2	South Fork Little Red River	AR11010014-038	July 31, 2010
AR0039233	Pangburn, City of -WWTP	0.2	Little Red River	AR11010014-012	Nov. 30, 2010
AR0035742	Judsonia, City of - WWTP	0.2	Little Red River	AR11010014-007	Aug. 31, 2008
AR0021601	Searcy, City of - WWTP	5	Little Red River	AR11010014-007	Nov. 30, 2007
AR0034657	Leslie , City of - WWTP	0.17	Middle Fork Little Red River		
AR0022381	Heber Springs, City of - WWTP	1.75	Little Red River		June 30, 2007
AR0029181	USDI BSFW-Greers F.Nat. Fishery	15	Little Red River		March 31, 2008

3.0 EXISTING WATER QUALITY

Total fecal 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.

A specific subgroup of this collection is the fecal coliform bacteria, the most common member being E. coli. 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. 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).

Ten reaches of the White River Basin are included on the 2004 Arkansas 303(d) list due to exceedences of numeric criteria for pathogens (ADEQ, 2004). ADEQ historical water quality data was analyzed.

3.1 Observed Data

Fecal coliform bacteria monitoring data for five listed reaches were obtained from ADEQ (PCS, 2005) (Table 3.1). The samples collected at all stations from October through April did not have any exceedances of the water quality criterion of 2,000 colonies/100 ml. Each sampling location had exceedances of the primary contact criterion of 400 colonies/100 ml during the May 1 through September 30. The percentage of exceedances ranged from 28.6 percent (at stations WHI059); 36.4 percent (at station UWSRR02); 37.5 percent (at station UWOFC01); 40 percent (at station UWTMC01); to 50 percent (at station WHI043).

Table 3.1 Observed Data for Fecal Coliform Bacteria

FY2002-03 Bimonthly Water Routes Fecal Coliform Bacteria Data					
Primary Contact Recreation	May 1 to September 30				
11010014 plus reach	-009	-027	-038	-006	-007
YYMMDD	UWTMC01	WHI043	UWSRR02	UWOFC01	WHI059
02-May 21-22	172		23	740	
02-July 29-30	140		256	96	
02-September 23-24	410		33	360	
03-April 29-30 SCR	2664	2664	64	1199	666
03-May 19-21	200	130	966	515	2664
03-June 23-24	2664	2664	2664		200
03-July 8-9	160	2664	43	46	96
03-July 22-23	1132	212	64	2664	1232
03-August 12-13	70	2664	833	57	17
03-August 25-26	401	433	68	29	200
03-September 15-16,22	140	14	504		
26-Sep-03				void	46
# samples exceeding	4	4	4	3	2
# samples collected	10	7	11	9	7
min. # exceedances needed for list	4	3	4	3	
% exceedance	40%	57%	36.40%	37.50%	28.60%
	list	list	list	list	list

3.2 Trends and Patterns in Observed Data

Because of the limited number of samples, no distinct trends or patterns were found in the reported monitoring results. The highest fecal coliform bacteria concentrations were observed during the summer months and usually during low-flow conditions. Limited sample collection data during high-flow periods limit the comparability of low-flow and high-flow monitoring results.

4.0 TMDL DEVELOPMENT

A TMDL is the total amount of a pollutant that can be assimilated by the receiving waterbody 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 (USEPA, 1991).

A TMDL for a given pollutant and waterbody is composed of the sum of individual wasteload allocations (WLAs) for point sources, and load allocations (LAs) for nonpoint sources and natural background levels. The TMDL must include an implicit or explicit margin of safety (MOS) to account for the lack of knowledge in the relationship between pollutant loads and the quality of the receiving waterbody. The TMDL components are illustrated using the following equation:

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

The TMDLs for some pollutants are expressed as a mass loading (e.g., pounds per day). TMDLs for bacteria can be expressed in terms of organism counts per day, in accordance with 40 CFR 130.2(l).

4.1 TMDL Analytical Approach

The methodology used for the TMDLs in the report is the load duration curve (LDC). Because loading capacity varies as a function of the flow present in the stream, these TMDLs represent a continuum of desired loads over all flow conditions, rather than fixed at a single value. The basic elements of this procedure are documented on the Kansas Department of Health and Environment web site (KDHE, 2005). This method was used to illustrate allowable loading at a wide range of flows. The steps for how this methodology was applied for the TMDLs in this report can be summarized as follows:

Develop a flow duration curve.
Convert the flow duration curve to load duration curve for each impairment.
Plot observed loads with load duration curves.
Calculate TMDL, MOS, WLA, and LA (see Section 4.2).

4.2 Flow Duration Curve

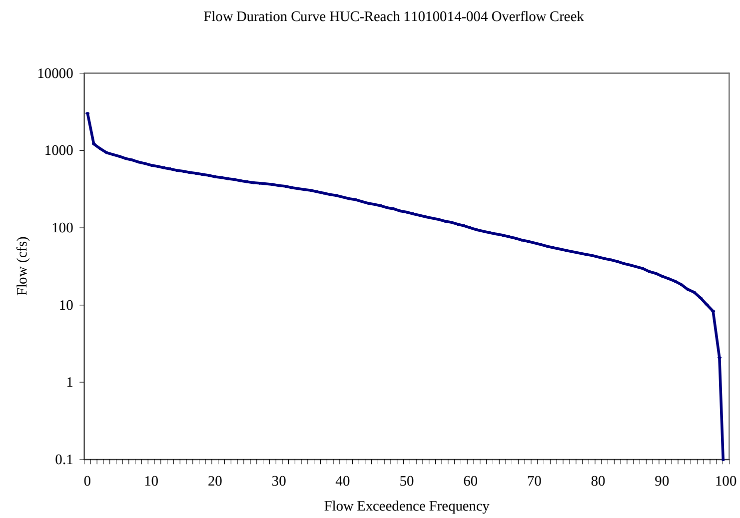
Flow duration curves are graphical representations of the flow characteristics of a stream at a given site. Flow duration curves utilize the historical hydrologic record from stream USGS gages to forecast future recurrence frequencies. The most basic method to estimate flows at an un-gaged site involves 1) identifying an upstream or downstream flow gage; 2) calculating the contributing drainage areas of the un-gaged sites and the flow gage; and 3) calculating daily flows at the un-gaged 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.

A flow duration curve was developed for each USGS gage for the TMDLs. Daily streamflow measurements from USGS gages for each data set were sorted in increasing order, and the percentile ranking of each flow was calculated.

In the event no coincident flow data are available for a segment, but flow gage(s) are present upstream and/or downstream, flows will be estimated for the segment from an upstream or downstream gage using a watershed area ratio method derived by delineating subwatersheds. Drainage subbasins will first be delineated for all impaired 303(d)-listed segments, along with all USGS flow stations located in the 8-digit HUCs with impaired streams.

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. More specifically, 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 (cubic feet per second) 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 exceedence 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 exceedence frequency of 0 percent. The median flow occurs at a flow exceedence frequency of 50 percent. The flow exceedence percentiles for each HUC-reach addressed in this report are provided in Appendix B. While 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. Ideally, 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, 2005). 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. For sites that on occasion exhibit no flow, the curve will intersect the abscissa at a frequency less than 100 percent. As the number of observations at a site increases, the line of the LDC tends to appear smoother. However, 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. Figure 4.1 is an example of a flow duration curve. The plot shows the flow on the Y-axis. The X-axis shows the frequency on which the plotted flow is exceeded. Points at the left end of the plot (0 through 10 percent) represent high-flow conditions where only 0 through 10 percent of the flow exceeds the plotted point. Points on the right end of the plot (90 to 100 percent) represent low-flow conditions.

Figure 4.1 Example of Flow Duration Curve.



4.3 Load Duration Curve

The flows from the flow duration curves were multiplied by the appropriate fecal coliform and E. coli bacteria numeric criterion concentration (Section 2.4) to compute an allowable load duration curve (LDC). Each LDC is a plot of colony forming units (cfu) per day versus the flow exceedence frequency from the flow duration curves.

A typical semi-log flow duration curve exhibits a sigmoidal 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. 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 quantitation.

4.4 Observed Loads

Observed loads were calculated by multiplying the observed concentration of the parameter of concern by the flow on the sampling day for each sampling station and season. These observed loads were then plotted versus the flow exceedence frequency of the flow on the sampling day and placed on the same plot as the LDC.

These plots provide visual comparisons between observed and allowable loads under different flow conditions. Observed loads that are plotted above the LDC represent conditions where observed water quality concentrations exceed the numeric criterion. Observed loads plotted below the LDC represent conditions where observed water quality concentrations were less than numeric criterion.

The LDC is beneficial when analyzing monitoring data to develop an implementation plan, because it 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.

4.5 TMDLs

The LDC 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 flows. The tables in Appendix B are provided for calculating the load at any flow for each HUC-Reach. Curves are displayed in Appendix C.

The fecal coliform and E. coli loads (or the y-value of each point) are calculated by multiplying the numeric criterion by the instantaneous flow (cubic feet per second) from the same site and time, with appropriate volumetric and time unit conversions.

TMDL (cfu/day) = Numeric Criteria * flow (cfs) * unit conversion factor

Where: Numeric Criteria PCR-S = 400 cfu/100ml (fecal coliform) or 410 cfu/100ml (E. coli) or 298 cfu/100ml (E. coli Extraordinary Resource Waters)

Numeric Criteria PCR-W/SCR = 2,000 cfu/100ml (fecal coliform) or 2,050 cfu/100ml (E. coli) or 1,490 cfu/100ml (E. coli Extraordinary Resource Waters)

Unit conversion factor = 24,465,751 100 ml /cfs

Each TMDL for the table was calculated as the 50^{th} percentile on the LDC. Table 4.2 presents the TMDLs and allocations for the subsegments in this report.

Table 4.1 Summary of Bacteria TMDLs for Reaches in Study Area

Arkansas HUC-Reach #	Pollutant	Criteria	MOS cfu/day	∑ WLA cfu/day	∑ LA cfu/day	TMDL cfu/day
	South Fork Little Red River					
11010014-038	FC	PCR-S	7.44E+10	4.09E+10	6.29E+11	7.44E+11
	FC	PCR-W/SCR	3.72E+11	2.05E+11	3.14E+12	3.72E+12
	E. coli	PCR-S	7.62E+10	4.19E+10	6.44E+11	7.62E+11
	E. coli	PCR-W/SCR	3.81E+11	2.09E+11	3.22E+12	3.81E+12
	Middle Fork Little Red River					
11010014-028	FC	PCR-S	1.18E+11	0	1.07E+12	1.18E+12
	FC	PCR-W/SCR	5.92E+11	0	5.33E+12	5.92E+12
	E. coli	PCR-S	8.82E+10	0	7.94E+11	8.82E+11
	E. coli	PCR-W/SCR	4.41E+11	0	3.97E+12	4.41E+12
	Middle Fork Little Red River					
11010014-027	FC	PCR-S	1.53E+11	0	1.38E+12	1.53E+12
	FC	PCR-W/SCR	7.67E+11	0	6.9E+12	7.67E+12
	E. coli	PCR-S	1.14E+11	0	1.03E+12	1.14E+12
	E. coli	PCR-W/SCR	5.71E+11	0	5.14E+12	5.71E+12
	Little Red River					
11010014-012	FC	PCR-S	9.23E+11	3.03E+09	8.31E+12	9.23E+12
	FC	PCR-W/SCR	4.62E+12	1.51E+10	4.16E+13	4.62E+13
	E. coli	PCR-S	9.46E+11	3.10E+09	8.51E+12	9.46E+12
	E. coli	PCR-W/SCR	4.73E+12	1.55E+10	4.26E+13	4.73E+13
	Little Red River					
11010014-010	FC	PCR-S	9.80E+11	0	8.82E+12	9.80E+12
	FC	PCR-W/SCR	4.90E+12	0	4.41E+13	4.90E+13
	E. coli	PCR-S	1.00E+12	0	9.00E+12	1.00E+13
	E. coli	PCR-W/SCR	5.02E+12	0	4.52E+13	5.02E+13
	Ten Mile Creek					
11010014-009	FC	PCR-S	1.88E+12	0	1.69E+13	1.88E+13
	FC	PCR-W/SCR	9.38E+12	0	8.44E+13	9.38E+13
	E. coli	PCR-S	1.92E+12	0	1.73E+13	1.92E+13
	E. coli	PCR-W/SCR	9.61E+12	0	8.65E+13	9.61E+13
	Little Red River					
11010014-008	FC	PCR-S	1.47E+12	0	1.32E+13	1.47E+13
	FC	PCR-W/SCR	7.34E+12	0	6.61E+13	7.34E+13
	E. coli	PCR-S	1.50E+12	0	1.35E+13	1.50E+13
	E. coli	PCR-W/SCR	7.52E+12	0	6.77E+13	7.52E+13

Arkansas HUC-Reach #	Pollutant	Criteria	MOS cfu/day	∑ WLA cfu/day	∑ LA cfu/day	TMDL cfu/day
	Little Red River					
11010014-007	FC	PCR-S	1.88E+12	7.87E+10	1.68E+13	1.88E+13
	FC	PCR-W/SCR	9.38E+12	3.94E+11	8.4E+13	9.38E+13
	E. coli	PCR-S	1.92E+12	8.07E+10	1.72E+13	1.92E+13
	E. coli	PCR-W/SCR	9.61E+12	4.04E+11	8.61E+13	9.61E+13
	Overflow Creek					
11010014-006	FC	PCR-S	1.07E+11	0	9.63E+11	1.07E+12
	FC	PCR-W/SCR	5.34E+11	0	4.81E+12	5.34E+12
	E. coli	PCR-S	1.09E+11	0	9.81E+11	1.09E+12
	E. coli	PCR-W/SCR	5.47E+11	0	4.92E+12	5.47E+12
	Overflow Creek					
11010014-004	FC	PCR-S	1.56E+11	0	1.40E+12	1.56E+12
	FC	PCR-W/SCR	7.82E+11	0	7.04E+12	7.82E+12
	E. coli	PCR-S	1.60E+11	0	1.44E+12	1.60E+12
	E. coli	PCR-W/SCR	8.02E+11	0	7.22E+12	8.02E+12

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

4.6 Wasteload Allocation

The WLA portion of the TMDL equation is the total loading of a pollutant that is assigned to point sources. There are five known permitted facilities discharging sanitary wastewater discharging into the South Fork Little Red River and the Little Red River reaches 11010014-038, -012, and -007.

Point Source Loading = monthly average flow rates (mgd) * monthly maximum corresponding fecal coliform or E. coli criteria (cfu/100ml) * unit conversion factor (100ml/mgd)

Where:

Unit conversion factor = 37,854,120 100 ml/mgd

The WLA's are shown below in Table 4.2. These loads are also shown on the TMDL Table 4.1 under their respective HUC-Reach.

Table 4.2 Wasteload Allocations for NPDES Permits

NPDES Permit No.	Facility	PCR-S FC	PCR-W FC	PCR-S E coli	PCR-W E coli
		Wasteload Allocations - (cfu/day)			
		River Reach AR11010014-038			
AR0048747	Clinton, City of - West WWTP	2.27 E+10	11.36 E+10	2.33E+10	11.6E+10
AR0048836	Clinton, City of - East WWTP	1.82 E+10	9.09 E+10	1.86E+10	9.31E+10
		River Reach AR11010014-012			
AR0039233	Pangburn, City of -WWTP	3.03 E+9	1.51 E+10	3.10E+09	1.55E+10
		River Reach AR11010014-007			
AR0035742	Judsonia, City of - WWTP	3.03 E+9	1.51 E+10	3.10E+09	1.55E+10
AR0021601	Searcy, City of - WWTP	7.57 E+10	3.79 E+11	7.76E+10	3.88E+11

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

4.7 Load Allocation

The load allocation is the portion of the TMDL assigned to natural background loadings as well as nonpoint 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. The LAs are presented in Table 4.1.

4.8 Seasonality and Critical Conditions

The federal regulations at 40 CFR 130.7 require that TMDLs be established at levels necessary to attain and maintain the applicable narrative and numerical WQS with seasonal variations. Determinations of TMDLs shall take into account critical conditions for stream flow, loading, and water quality parameters. For this TMDL, FC and E coli bacteria loadings for waterbody reaches with primary contact recreation (between May 1 and September 30) as the designated use were determined for winter and summer on the basis of seasonal water quality criteria, thus accounting for seasonality.

By accounting for critical conditions, the TMDL makes sure that water quality standards are maintained for infrequent occurrences and not only for average conditions. The LDC includes all flows, so it includes any critical conditions. The LDC method has the benefit of including more than one critical condition.

4.9 Margin of Safety

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

4.10 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.

5.0 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 (ADEQ, 2004).

6.0 PUBLIC PARTICIPATION

When EPA establishes TMDLs, federal regulations require EPA to publicly notice and seek comment concerning the TMDLs. Pursuant to a May 2000 consent decree, these TMDLs were prepared by EPA. After development of the draft version of these TMDLs, EPA prepared a notice seeking comments, information, and data from the general public and any other interested parties. No comments, data, or information were submitted during the public comment period. EPA has transmitted the final TMDLs to the ADEQ for implementation and incorporation into ADEQ's current water quality management plan.

REFERENCES

ADEQ. 2004. 2004 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. 303(d) list portion EPA Action on October 16, 2006.

ADEQ. 2005. 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

APCEC. 2004. 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.

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. Amended April 28, 2006.

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

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

Standard Methods. 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. 1984. Soil Survey for Van Buren County, Arkansas. Published by Soil Conservation Service, U.S. Department of Agriculture in cooperation with Arkansas Agricultural Experiment Station. June 1984.

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

USDA. 1984c. Soil Survey for Searcy 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. EPA 440/-4-91-001. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

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

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.