Pathogen TMDLs

For

Planning Segments 4G Reaches

Segments

AR11010009-902, AR11010012-016, AR11010012-015, AR11010012-014, AR11010012-011, AR11010012-010, AR11010012-008, AR11010012-003

June 1, 2007

Prepared by
EPA Region VI
Water Quality Protection Division
Permits, Oversight, and TMDL Team
Dallas, TX 75202

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 non-point sources to restore and maintain the quality of the state's water resources (USEPA 1991).

A TMDL for a given pollutant and waterbody is composed of the sum of individual waste-load allocations (WLAs) for point sources, 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 uncertainty in the relationship between pollutant loads and the quality of the receiving water-body and may include a future growth (FG) component. The TMDL components are illustrated using the following equation: TMDL = Σ WLAs + Σ LAs + MOS + FG

The study area is part of the Arkansas Department of Environmental Quality (ADEQ) Planning Segment 4G and is located within both the Ozark Highlands and the Mississippi Alluvial plains ecoregion. The study area for this project is limited to eight reaches in the Arkansas planning segment 4G (**11010009-902, 1010012-016, 11010012-015, 11010012-014, 11010012-011, 11010012-010, 11010012-008, and 11010012-003**). Land use in the study area consists mostly of forest and pastureland. The designated beneficial uses that have been established by ADEQ for Planning Segment 4G include propagation of fish and wildlife, primary and secondary contact recreation; domestic, agricultural and industrial water supply. Two of the planning 4G segments have been designed as extraordinary resource waters, ecologically sensitive waters, and natural and scenic waterways.

The TMDLs in this report were developed using the load duration curve methodology. This method illustrates allowable loading at a wide range of stream flow conditions. The numeric water quality criteria that apply to the impaired reaches in the Strawberry River Subbasin can be found in Section 2.6.1 of the TMDL report.

The seasonal fecal coliform bacteria TMDLs were developed on the basis of analyses of the applicable water quality criteria (i.e., calculating allowable loads and percent reductions for both summer and winter).

Table ES-1 Summary of Fecal Coliform TMDLs, (Primary Contact Recreation)-Summer

Arkansas Reach ID	Stream Name	Explicit MOS*	WLA*	LA*	TMDL*
11010009-902	Dota Creek	2.51E+10	0	2.26E+11	2.51E+11
11010012-015	Caney Creek	5.67E+09	0	5.10E+10	5.67E+10
11010012-016	Mill Creek	4.18E+09	0	3.76E+10	4.18E+10
11010012-014	Reed's Creek	1.57E+10	0	1.41E+11	1.57E+11
11010012-010	Little Strawberry River	1.62E+10	5.31E+09	1.40E+11	1.62E+11
11010012-003	Cooper Creek	2.09E+10	0	1.88E+11	2.09E+11

cfu/day = colony forming units per day

Table ES-2 Summary of Fecal Coliform TMDLs, (Primary Contact Recreation)-Winter

Arkansas Reach ID	Stream Name	Explicit MOS*	WLA*	LA*	TMDL*
11010009-902	Dota Creek	1.26E+11	0	1.13E+12	1.26E+12
11010012-015	Caney Creek	2.84E+10	0	2.55E+11	2.84E+11
11010012-016	Mill Creek	2.09E+10	0	1.88E+11	2.09E+11
11010012-014	Reed's Creek	7.84E+10	0	7.06E+11	7.84E+11
11010012-010	Little Strawberry River	8.10E+10	2.65E+10	7.02E+11	8.10E+11
11010012-003	Cooper Creek	1.05E+11	0	9.42E+11	1.05E+12

cfu/day = colony forming units per day

Table ES-3 Summary of E. Coli TMDLs (Primary Contact Recreation)-Summer

Arkansas Reach ID	Stream Name	Explicit MOS*	WLA*	LA*	TMDL*
11010009-902	Dota Creek	2.57E+10	0	2.32E+11	2.57E+11
11010012-015	Caney Creek	5.81E+09	0	5.23E+10	5.81E+10
11010012-016	Mill Creek	4.28E+09	0	3.85E+10	4.28E+10
11010012-014	Reed's Creek	1.61E+10	0	1.45E+11	1.61E+11
11010012-011	Strawberry River	2.87E+10	0	2.59E+11	2.87E+11
11010012-010	Little Strawberry River	1.66E+10	5.44E+09	1.44E+11	1.66E+11
11010012-008	Strawberry River	1.06E+10	0	9.56E+10	1.06E+11
11010012-003	Cooper Creek	2.15E+10	0	1.93E+11	2.15E+11

cfu/day = colony forming units per day

Table ES-4 Summary of E. Coli TMDLs (Primary Contact Recreation)-Winter

Arkansas Reach ID	Stream Name	Explicit MOS*	WLA*	LA*	TMDL*
11010009-902	Dota Creek	1.29E+11	0	1.16E+12	1.29E+12
11010012-015	Caney Creek	2.91E+10	0	2.62E+11	2.91E+11
11010012-016	Mill Creek	2.14E+10	0	1.93E+11	2.14E+11
11010012-014	Reed's Creek	8.04E+10	0	7.24E+11	8.04E+11
11010012-011	Strawberry River	1.44E+11	0	1.29E+12	1.44E+12
11010012-010	Little Strawberry River	8.30E+10	2.72E+10	7.20E+11	8.30E+11
11010012-008	Strawberry River	5.31E+10	0	4.78E+11	5.31E+11
11010012-003	Cooper Creek	1.07E+11	0	9.66E+11	1.07E+12

cfu/day = colony forming units per day

TABLE OF CONTENTS

TABLES

APPENDICES

Appendix A:

Appendix B:
Load Duration Curve and Plots for Fecal Coliform and E.coli

Appendix C:
Stream Flow Duration Curve and Streamflow Duration Curve Data

1.0 INTRODUCTION

This report presents total maximum daily loads (TMDLs) for fecal coliform and *Escherichia coli* (E. coli) for 8 stream reaches in the Strawberry River Basin in northern Arkansas. These stream reaches were included on the Arkansas Department of Environmental Quality (ADEQ) 2004 Section 305(b) Report (ADEQ 2004a) as not supporting their designated use of primary contact recreation. The suspected sources of contamination and causes of impairment from the 303(d) listing are shown below in Table 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 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.

Table 1- Pathogen Impaired 4G reaches

HUC-Reach Number	Waterbody Name	Impaired Use	Pollutant	Suspected Source	Priority Ranking
11010009-902	Dota Creek	PCR	Pathogen	Unknown	Low
11010012-015	Caney Creek	PCR	Pathogen	Unknown	High
11010012-016	Mill Creek	PCR	Pathogen	Unknown	High
11010012-014	Reeds' Creek	PCR	Pathogen	Unknown	High
11010012-011	Strawberry River	PCR	Pathogen	Unknown	High
11010012-010	Little Strawberry River	PCR	Pathogen	Unknown	High
11010012-008	Strawberry River	PCR	Pathogen	Unknown	High
11010012-003	Cooper Creek	PCR	Pathogen	Unknown	High

PCR = Primary Contact Recreation

2.0 STUDY AREA INFORMATION

2.1 General Description

The Strawberry River and its tributaries are part of the White River Basin (USGS Hydrologic Unit 110100012) (Appendix A, Figure A-1). The Black River and its tributaries are also a part of the White River Basin (USGS Hydrologic Unit 110100009). The State of Arkansas Department of Environmental Quality (DEQ) has designated the Strawberry River, the Black River

and its tributaries as planning segment 4G. The drainage area of Strawberry River Basin is 774 square miles (Table 2).

Table 2- Impaired Stream Miles in the Strawberry River and Black River Subbasins

HUC-Reach Number	Watershed	303(d) Listed Stream Miles (mi.)	Drainage (sq. mi^2)
Black River Subbasin			
11010009-902	Dota Creek	21.8	63.56
Strawberry River Subbasin			
11010012-015	Caney Creek	11.6	14.4
11010012-003	Cooper Creek	11.8	53.0
11010012-010	Little Strawberry River	16	42.2
11010012-016	Mill Creek	9.9	10.6
11010012-014	Reed's Creek	15	39.7
11010012-008	Strawberry River	7.93	97.6
11010012-011	Strawberry River	20.3	39.1

Source: EPA, BASINS

The impaired 4G planning segment contains a total of 114 stream miles, all of which are being assessed using monitoring data.

2.2 Soils and Topography

Impaired waters in planning unit 4G are located within both the Ozark Highlands and Mississippi Alluvial Plains ecoregions (i.e. Mississippi Delta). The soils and topography information was obtained from soil surveys for Fulton, Izard, Sharp, and Lawrence Counties (USDA 1984a, USDA 1984b, USDA 1978). 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 (Appendix A, Figure A-2).

2.3 Land Use

The Strawberry and Black River subbasins are located in the White River Basin in Clay, Fulton, Independence, Izard, Randolph, Sharp, and Lawrence counties. Populated cities and towns in these subbasins are identified in Table 3 (Appendix A, Figure A-3). The largest city in this subbasin is the City of Horseshoe Bend, with a population of 2,278 people.

Table 3- Populated Cities and Towns in the Strawberry and Black River Subbasins

HUC-Reach Number	Watershed	Cities / Towns	Population*
11010012-015	Caney Creek	Town of Mount Pleasant	401
11010012-003	Cooper Creek	Town of Smithville	73
11010012-010	Little Strawberry River	City of Horseshoe Bend	2278
11010012-014	Reed's Creek	Town of Strawberry	283
11010012-008	Upper Strawberry River	City of Oxford	1535

Source: EPA, BASIN, 2007

Land use data for the impaired watersheds were obtained from the National Land Use Classification Data (NLCD). These data were based on satellite imagery from 1999. The spatial distribution of these land uses is shown in Appendix A (Figure A-4). Approximate acreage and percentages of these land uses for each watershed is listed in Table 4.

Table 4- Land Use Acres (Percents) in the Strawberry and Black River Subbasins (NLCD).

Watersheds	Land Use Categories (Acres / (Percent Area))							
	Barren	Cropland	Forest	Pasture	Transitional	Urban	Water/ Wetlands	Total
Black River Subbasin								
Dota Creek	0 (0%)	0 (0%)	18095 (44.5%)	22522 (55.4%)	0 (1.6%)	0 (0%)	68 (0.01%)	40685 (100%)
Strawberry River Subbasin								
Caney Creek 11010012-016	0 (0%)	149 (3.2%)	2635 (57.5%)	1724 (37.7%)	71 (1.6%)	8 (0%)	4 (0%)	4591 (100%)
Cooper Creek 11010012-003	12482 (74%)	617 (4%)	132 (1%)	3598 (21%)	0 (0%)	8 (0%)	124 (1%)	16,961 (100%)
Little Strawberry River 11010012-010	0 (0%)	732 (3%)	15875 (66%)	7397 (31%)	66 (0%)	66 (0%)	49 (0%)	24,185 (100%)
Mill Creek 11010012-016	0 (0%)	37 (1%)	2910 (86%)	411 (12%)	20 (1%)	0 (0%)	0 (0%)	3,378 (100%)
Reed's Creek 11010012-014	0 (0%)	1072 (8%)	7905 (62%)	3655 (29%)	44 (0%)	1 (0%)	13 (0%)	12,690 (100%)
Strawberry River 11010012-011	8 (0%)	1426 (3%)	27379 (66%)	12435 (30%)	350 (1%)	54 (0%)	42 (0%)	41,694 (100%)
Strawberry River 11010012-008	0 (0%)	228 (2%)	9289 (80.4%)	1742 (15.1%)	199 (2%)	7 (0%)	86 (0.01%)	11551 (100%)

Source: EPA, BASINS, 2007

For most of the impaired watersheds identified in Table 4, the predominate landuse is forest. Pastureland is the second most prevalent landuse present in the impaired watersheds.

2.4 Climatic Characteristic

Precipitation estimates for the Strawberry River subbasin are estimated using the Newport, Mammoth Springs, and Mountain Home weather stations. Annual average rainfall is approximately 40 inches. Mean monthly precipitation totals for the three weather stations are shown in Appendix A (Figure A-5). The mean monthly precipitation values are the lowest in January highest during the months March through August.

2.5 Flow Characteristics

The USGS has published stream flow data for waters in the Strawberry River subbasin at 5

locations. The locations of the gages are shown in Appendix A (Figure A-6). The only active gage in the study area is Strawberry River near Poughkeepsie, AR (USGS 07074000). Information for these flow gages is summarized below in Table 5.

Table 5- Streamflow Gage Stations

Watershed	Stream Gage Name	Stream Gage Number	Gage Type		Period of Record
			C	P	
Strawberry River	Strawberry River Near Evening Shade	07073000	C	P	1939-1980
Piney Fork River	Piney Fork River @ Evening Shade	07073500	C	P	1939-1985
Strawberry River	Strawberry River Near Poughkeepsie	07074000	C	P	1939-Present
Dry Branch	Dry Branch Tributary Near Sidney	07074200		P	1961-1985
Reeds Creek	Reeds Creek at Strawberry	07074250		P	1963-1982

Note: C = Continuous gage, P= Peaklfow gage

2.6 Water Quality Standards

2.6.1 Water Quality Standards for Surface Waters of the State of Arkansas

Arkansas standards for pathogenic organisms are found in the Arkansas's Pollution Control and Ecology Commission Regulations Establishing Water Quality Standards for Surface Waters of the State of Arkansas *(*Adopted on April 23, 2004, Amended April 28, 2006).

2.6.2 Designated Uses for Impaired Waters

The use classifications for the impaired waterbodies are shown in Table 6 below.

Table 6- Designated Uses in the Strawberry and Black River Subbasins

HUC-Reach Number	Waterbody Name	Impaired Use	Other Designed Uses*						
			ERW	NSW	ESW	PCR	SCR	D,I,A, WS	F
11010009-902	Dota Creek	PCR				X	X	X	X
11010012-015	Caney Creek	PCR				X	X	X	X
11010012-016	Mill Creek	PCR				X	X	X	X
11010012-014	Reeds' Creek	PCR				X	X	X	X
11010012-011	Strawberry River	PCR	X	X	X	X	X	X	X
11010012-010	Little Strawberry River	PCR				X	X	X	X
11010012-008	Strawberry River	PCR	X	X	X	X	X	X	X
11010012-003	Cooper Creek	PCR				X	X	X	X

*(ERW) Extraordinary Resource Water, (NWS) Natural and Scenic Waters, (ESW) Ecologically Sensitive Water, (PCR) Primary Contact Recreation, (SCR) Secondary Contact Recreation, (D,I,A, WS) Domestic, Industrial, Agricultural Water Supply, (F) Fisheries

2.6.3 Numeric Criterion for Bacteria

As specified in the State of Arkansas Water Quality Standards, 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.*
>
> *(C) For assessment of ambient waters as impaired by bacteria, the above listed applicable values shall not be exceeded in more than 25% of samples in no less than eight (8) samples taken during the primary contact season or during the secondary contact season."*

2.6.4 Antidegradation

As specified in EPA's regulation 40 CFR §130.7(b)(2), applicable water quality standards include antidegradation requirements. Arkansas' antidegradation policy is listed in Section 2.201 through 2.204 of Regulation No. 2. 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.

The numeric criteria above specific one value for primary contact recreation that applies between May 1 and September 30, and a different criterion for the remainder of the year. In this report, we will refer to the primary contact recreation time period from May 1 to September 30 as primary contact recreation-summer (PCR-S). The remainder of the year will be referred to as primary contact recreation-winter (PCR-W). The descriptors PCR-S and PCR-W do not appear in the State of Arkansas water quality standards. They are used to differentiate the numeric criterion that apply during the various seasons.

3.0 CHARACTERIZATION OF EXISTING WATER QUALITY

Eight reaches of the Strawberry River are included on the 2004 Arkansas 305(b) report as not supporting primary contact recreation designated use due to exceedences of numeric criteria for pathogens. ADEQ historical water quality data were analyzed

3.1 Comparison of Observed Data to Criteria

Fecal coliform and e.coli monitoring data for each listed reach were obtained from ADEQ. Data for most stations were available between 2001 and 2003. All of the available data for each of the stations were evaluated against the instantaneous fecal coliform and e.coli criterion. Based on this evaluation, most of the sampling locations had exceedances of the instantaneous fecal coliform and e.coli criterion (Table 7a and Table 7d).

Table 7a. Summary of Pathogen (E.Coli) Data –Primary Contact Recreation-Summer

HUC-Reach Number	Station Name	Sampling Station ID	Criterion (col./100mL)	N	Number of Exceedences (% exceedence)
11010012-015	Caney Creek*	WHI0143R	410	14	2/14 (14%)
11010009-902	Dota Creek+	WHI0165	410	10	0/10 (10%)
11010012-010	Little Strawberry River*	WH10143H	410	14	3/14 (21%)
11010012-016	Mill Creek*	WHI0143N	410	14	2/14 (14%)
11010012-014	Reed's Creek*	UWRDC01	410	14	3/14 (21%)
11010012-008	Strawberry River	UWSBR01	298	14	2/14 (14%)

Note: + Arkansas Bacteria Data, *TMDL Toolbox

Table 7b. Summary of Pathogen (E.Coli) Data –Primary Contact Recreation-Winter

HUC-Reach Number	Station Name	Sampling Station ID	Criterion (col./100mL)	N	Number of Exceedences (% exceedence)
11010012-015	Caney Creek	WHI0143R	2050	9	1/9 (11%)
11010009-902	Dota Creek+	WHI0165	2050	7	1/7 (15%)
11010012-010	Little Strawberry River*	WH10143H	2050	9	3/9 (33%)
11010012-016	Mill Creek*	WHI0143N	2050	9	0/9 (0%)
11010012-014	Reed's Creek*	UWRDC01	2050	9	1/9 (21%)
11010012-008	Strawberry River*	UWSBR01	1490	9	1/9 (11%)

Note: + Arkansas Bacteria Data, *TMDL Toolbox

Table 7c. Summary of Pathogen (Fecal) Data –Primary Contact Recreation-Summer

HUC-Reach Number	Station Name	Sampling Station ID	Criterion (col./100mL)	N	Number of Exceedences (% exceedence)
11010012-016	Cooper Creek	WH10143S	400	16	6/15 (40%)
11010009-902	Dota Creek+	WHI0165	400	10	3/10 (30%)
11010012-010	Little Strawberry River*	WH10143H	400	14	4/14 (36%)
11010012-016	Mill Creek*	WHI0143N	400	15	4/15 (27%)
11010012-014	Reed's Creek*	UWRDC01	400	20	7/20 (35%)

Note: + Arkansas Bacteria Data, *TMDL Toolbox

Table 7d. Summary of Pathogen (Fecal) Data –Primary Contact Recreation-Winter

HUC-Reach Number	Station Name	Sampling Station ID	Criterion (col./100mL)	N	Number of Exceedences (% exceedence)
11010012-016	Cooper Creek	WH10143S	2000	9	3/9 (33%)
11010009-902	Dota Creek+	WHI0165	2000	7	2/7 (29%)
11010012-010	Little Strawberry River*	WH10143H	2000	9	3/9 (33%)
11010012-016	Mill Creek*	WHI0143N	2000	9	0/9 (0%)
11010012-014	Reed's Creek*	UWRDC01	2000	14	3/14 (21%)

Note: + Arkansas Bacteria Data, *TMDL Toolbox

3.2 Trends and Patterns in Observed Data

The load duration curves for both fecal coliform and e.coli were used to determine the general trend in all of the observed data (Appendix B). For most watersheds, exceedences of the fecal and e.coli primary contact recreation criterion occurred during dry and low flow conditions. Exceedences of the secondary contact recreation criterion for both fecal coliform and e.coli occurred during dry and mid-range flow conditions.

In addition, precipitation and pathogen data (both fecal coliform and e.coli data) were evaluated to determine if a statistical association existed between the two variables. The data showed that some watershed showed a high positive association between bacteria (fecal coliform and e.coli) and rainfall. This high positive association may indicate that bacteria sources may be close to the stream and are only delivered in response to rainfall events. Some watersheds showed a low positive association between rainfall and bacteria. In these watersheds, most of the exceedence occurred during dry and low flow conditions. Therefore, there may be some indication that the exceedences of the water quality standard may be the result of direct inputs.

4.0 SOURCE ASSESSMENT

An important part of the TMDL analysis is the identification of potential source categories. Sources are broadly classified as either point or nonpoint sources. A point source is defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. Nonpoint sources are diffuse, and generally, but not always, involve accumulation of fecal coliform bacteria on land surfaces that wash off as a result of storm events.

4.1 Point Source Assessment

Title IV of the Clean Water Act establishes the National Pollutant Discharge Elimination System (NPDES) permit program. Basically, there are three categories of NPDES permits: 1) municipal and industrial wastewater treatment facilities, 2) regulated storm water discharges, and combined animal feeding operations (CAFO). The location of all point sources can be found in Appendix A (Figure A-7).

4.1.1 Wastewater Treatment Facilities

In general, industrial and municipal wastewater treatment facilities have NPDES permits with effluent limits. These permit limits are either based on federal and state effluent guidelines (technology-based limits) or on water quality standards (water quality-based limits).

The EPA has developed technology-based guidelines, which establish a minimum standard of pollution control for municipal and industrial discharges without regard for the quality of the receiving waters. These are based on Best Practical Control Technology Currently Available (BPT), Best Conventional Control Technology (BCT), and Best Available Technology Economically Achievable (BAT). The level of control required by each facility depends on the type of discharge and the pollutant.

Municipal and industrial wastewater treatment facilities' discharges may contribute fecal coliform to receiving waters. There are three NPDES permitted discharges with flows greater than 0.1 MGD identified in the Strawberry River Basin that discharge treated municipal wastewater to the impaired stream segments. Table 8 provides the monthly average discharge flows and fecal coliform concentrations for the municipal and industrial treatment facilities, obtained from calendar year 2005 Discharge Monitoring Report (DMR) data. The permitted flow and fecal coliform concentrations for these facilities are also included in this table.

Table 8- Point Source Discharges in Planning Unit 4G

Facility Name	NPDES Permit No.	Receiving Stream	NPDES Permit Limits		Number of Violations
			Average Design Flow (MGD)	Average Monthly FC (No./ 100mL)	
City of Horseshoe Bend (Paradise)	AR0039608	Hubble Branch / Little Strawberry River	0.06	87	0
City of Horseshoe Bend (White)	AR0035254	Little Strawberry River / Strawberry River	0.2	43	0
City of Oxford	AR0049701	Little Strawberry River	0.09	2	0

Combined sewer systems convey a mixture of raw sewage and storm water in the same conveyance structure to the wastewater treatment plant. These are considered a component of municipal wastewater treatment facilities. When the combined sewage exceeds the capacity of the wastewater treatment plant, the excess is diverted to a combined sewage overflow (CSO) discharge point. There are no permitted CSO outfalls in the Strawberry River Basin.

4.1.2 Regulated Storm Water Discharges

Some storm water runoff is covered under the NPDES Permit Program. It is considered a diffuse source of pollution. Unlike other NPDES permits that establish end-of-pipe limits, storm water NPDES permits establish controls "to the maximum extent practicable" (MEP). Regulated storm water discharges that may contain fecal coliform bacteria consist of those associated with industrial activities including construction sites disturbing one acre or greater, and large, medium, and small municipal separate storm sewer systems (MS4s) that serve populations of 50,000 or more.

Storm water discharges associated with industrial activities are currently covered under a General Storm Water NPDES Permit. This permit requires visual monitoring of storm water discharges, site inspections, implementation of Best Management Practices (BMPs), and record keeping.

As of March 10, 2003, small MS4s serving urbanized areas are required to obtain a storm water permit under the Phase II storm water regulations. An urbanized area is defined as an entity with a residential population of at least 50,000 people and an overall population density of at least 1,000 people per square mile. There are no Phase I or Phase II cities in this planning segment.

4.1.3 Confined Animal Feeding Operations

Confined livestock and confined animal feeding operations (CAFOs) are characterized by high animal densities. This results in large quantities of fecal material being contained in a limited area. Processed agricultural manure from confined hog, dairy cattle, and select poultry operations is generally collected in lagoons. It is then applied to pastureland and cropland as a fertilizer during the growing season, at rates that often vary monthly.

In 1990, the State of Arkansas began registering CAFOs. Many of the CAFOs were issued land application or NPDES permits for treatment of wastewaters generated from their operations. The type of permit issued depends on the operation size (i.e., number of animal units. There are no registered CAFOs in this planning segment.

4.2 Nonpoint Sources

In general, nonpoint sources cannot be identified as entering a waterbody through a discrete conveyance at a single location. Typical nonpoint sources of fecal coliform bacteria include:

- Wildlife
- Agricultural Livestock
  - Animal grazing
  - Animal access to streams
  - Application of manure to pastureland and cropland
- Urban Development
  - Leaking sanitary sewer lines
  - Septic systems
  - Land Application Systems
  - Landfills

4.2.1 Wildlife

The importance of wildlife as a source of fecal coliform bacteria in streams varies considerably, depending on the animal species present in the subwatersheds. Wildlife resource studies show that animals that spend a large portion of their time in or around aquatic habitats are the most important wildlife sources of fecal coliform. Waterfowl, most notably ducks and geese, are considered to potentially be the greatest contributors of fecal coliform. This is because they are typically found on the water surface, often in large numbers, and deposit their feces directly into the water. Other potentially important animals regularly found around aquatic environments include racoons, beavers, muskrats, and to a lesser extent, river otters and minks. Population estimates of these animal species in Arkansas are currently not available.

White-tailed deer have a significant presence throughout the Strawberry River Basin. The number of deer camps for hunters provides a relative estimate of area that may have higher deer populations. Based on 1999 deer camp densities for Fulton, Independence, Izard, Lawrence, and Sharp counties have deer densities ranging from 11 – 100 deer per square mile.

Fecal coliform bacteria contributions from deer to water bodies are generally considered less significant than that of waterfowl, racoons, and beavers. This is because a greater portion of their time is spent in terrestrial habitats. Feces deposited on the land surface can result in the introduction of fecal coliform to streams during runoff events. It should be noted that between storm events, considerable decomposition of the fecal matter might occur, resulting in a decrease in the associated fecal coliform numbers.

3.2.2 Agricultural Livestock

Agricultural livestock are a potential source of fecal coliform to streams in the Strawberry River Basin. The animals grazing on pastureland deposit their feces onto land surfaces, where it can be transported during storm events to nearby streams. Animal access to pastureland varies monthly, resulting in varying fecal coliform loading rates throughout the year. Beef cattle spend all of their time in pastures, while dairy cattle and hogs are periodically confined. Agricultural livestock will often have direct access to streams that pass through their pastures, and can thus impact water quality in a more direct manner (USDA, 2002).

Table 9 provides the estimated number of beef cattle, dairy cattle, goats, horse, swine, sheep, and chickens by category reported by county. These data were provided by the Natural Resources Conservation Service (NRCS) and are based on 2006 data (NRCS, 2006).

Table 9. Estimated Agricultural Livestock Populations in the Strawberry River Basin

County	Livestock (head of animals)				
	Beef Cattle	Dairy Cattle	Chickens-Broilers Farms	Chickens-Broilers Sold	Hog and Pig Inventory
Fulton	24,057	755	1	(D)	160
Independence	25,284	140	54	20,880,219	261
Izard	18,101	255	24	8,528,054	(D)
Lawrence	10,467	0	24	8,469,646	363
Sharp	17,000	(D)	34	13,755,996	214

Source: USDA, National Agricultural Statistics Service, Arkansas Field Office, 2002
(D) Withheld to avoid disclosing data for individual farms.

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.

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. In addition, the TMDL must include an implicit or explicit margin of safety (MOS) to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. This TMDL also includes a future growth (FG) component to account for loadings from the continued growth in the TMDL area. The TMDL components are illustrated using the following equation:

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

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

4.1 TMDL Analytical Approach

The methodology used for the TMDLs in the report is the load duration curve. 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:

1. Develop a flow duration curve.
2. Convert the flow duration curve to load duration curves for bacteria
3. Plot observed loads with load duration curves.
4. Calculate TMDL, MOS, FG, WLA, and LA (see also Section 4.2).

4.1.1 Flow Duration Curve

For this TMDL, a flow duration curve was developed based on one active USGS gage in the drainage basin (Table 10). Daily streamflow measurements from the USGS gage was sorted in increasing order, and the percentile ranking of each flow was calculated (Appendix C).

Figure 1 below is an example of a flow duration curve. The X-axis shows the percentage of days on which the plotted flow is exceeded. Points at the lower 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. Conversely, points on the high end of the plot (90 to 100 percent) represent low-flow

conditions.

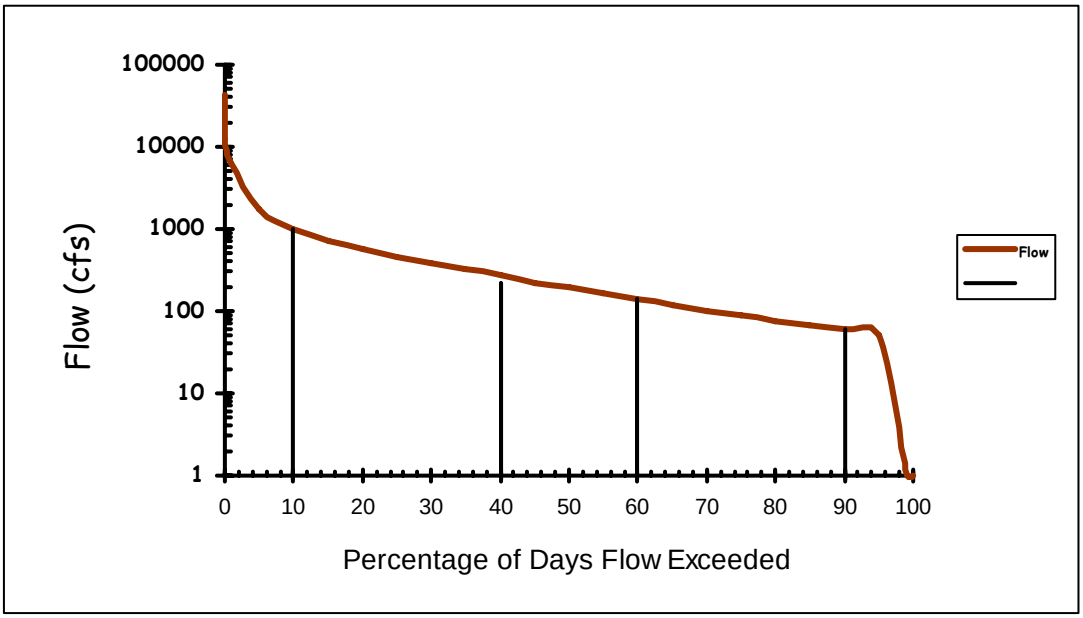


Figure 1. Example of Flow Duration Curve.

Table 10. USGS Streamflow Gage Used for Load Duration Curve

Watershed	Stream Gage Name	Stream Gage Number	Gage Type		Period of Record
			C	P	
Strawberry River	Strawberry River Near Poughkeepsie	07074000	C	P	1939-Present

4.1.2 Load Duration Curve

In developing the load duration curve, the methodology requires that the same flow period be used for both developing the flow duration and calculating load curves from sampling data.

The load duration curve is beneficial when analyzing monitoring data 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. 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. Appendix B contains the load duration curve calculations.

4.1.3 Observed Loads

For each sampling station and season, observed loads were calculated by multiplying the observed bacterial concentration by the flow on the sampling day. These observed loads were then plotted versus the percent flow exceedance of the flow curve on the sampling day and placed on the same plot as the load duration curve. TMDL allocations were set at the 50th percentile water quality criteria to obtain a TMDL for each reach. These plots are shown in Appendix B of this report.

These plots provide visual comparisons between observed and allowable loads under different flow conditions. Observed loads that are plotted above the load duration curve represent conditions where observed water quality concentrations exceed the target concentrations. Observed loads plotted below the load duration curve represent conditions where observed water quality concentrations were less than target concentrations (i.e., not exceeding water quality standards).

4.2 TMDL Development

Each TMDL was calculated as the area under the load duration curve. Because the load duration curves were expressed in mass per unit drainage area, the area under the curve was multiplied by the drainage area for each reach. Tables 11a through 11d present the TMDLs and allocations for the sub-segments in this report.

Table 11a Summary of Fecal Coliform TMDLs, (Primary Contact Recreation-Summer)

Arkansas Reach ID	Stream Name	Explicit MOS*	WLA*	LA*	TMDL*
11010009-902	Dota Creek*	2.51E+10	0	2.26E+11	2.51E+11
11010012-015	Caney Creek	5.67E+09	0	5.10E+10	5.67E+10
11010012-016	Mill Creek	4.18E+09	0	3.76E+10	4.18E+10
11010012-014	Reeds' Creek	1.57E+10	0	1.41E+11	1.57E+11
11010012-011	Strawberry River	3.86E+10	0	3.47E+11	3.86E+11
11010012-010	Little Strawberry River	1.62E+10	5.31E+09	1.40E+11	1.62E+11
11010012-008	Strawberry River	1.43E+10	0	1.28E+11	1.43E+11
11010012-003	Cooper Creek	2.09E+10	0	1.88E+11	2.09E+11

***Note: cfu/day = colony forming units per day**

Table 11b Summary of Fecal Coliform TMDLs, (Primary Contact Recreation-Winter)

Arkansas Reach ID	Stream Name	Explicit MOS*	WLA*	LA*	TMDL*
11010009-902	Dota Creek	1.26E+11	0	1.13E+12	1.26E+12
11010012-015	Caney Creek	2.84E+10	0	2.55E+11	2.84E+11
11010012-016	Mill Creek	2.09E+10	0	1.88E+11	2.09E+11
11010012-014	Reed's Creek	7.84E+10	0	7.06E+11	7.84E+11
11010012-011	Strawberry River	1.93E+11	0	1.74E+12	1.93E+12
11010012-010	Little Strawberry River	8.10E+10	2.65E+10	7.02E+11	8.10E+11
11010012-008	Strawberry River	7.13E+10	0	6.42E+11	7.13E+11
11010012-003	Cooper Creek	1.05E+11	0	9.42E+11	1.05E+12

***Note: cfu/day = colony forming units per day**

Table 11c Summary of E. Coli TMDLs (Primary Contact Recreation-Summer)

Arkansas Reach ID	Stream Name	Explicit MOS*	WLA*	LA*	TMDL*
11010009-902	Dota Creek	2.57E+10	0	2.32E+11	2.57E+11
11010012-015	Caney Creek	5.81E+09	0	5.23E+10	5.81E+10
11010012-016	Mill Creek	4.28E+09	0	3.85E+10	4.28E+10
11010012-014	Reed's Creek	1.61E+10	0	1.45E+11	1.61E+11
11010012-011	Strawberry River	3.97E+10	0	3.57E+11	3.97E+11
11010012-010	Little Strawberry River	1.66E+10	5.44E+09	1.44E+11	1.66E+11
11010012-008	Strawberry River	1.46E+10	0	1.32E+11	1.46E+11
11010012-003	Cooper Creek	2.15E+10	0	1.93E+11	2.15E+11

***Note: cfu/day = colony forming units per day**

Table 11d Summary of E. Coli TMDLs (Primary Contact Recreation-Winter)

Arkansas Reach ID	Stream Name	Explicit MOS*	WLA*	LA*	TMDL*
11010009-902	Dota Creek	1.29E+11	0	1.16E+12	1.29E+12
11010012-015	Caney Creek	2.91E+10	0	2.62E+11	2.91E+11
11010012-016	Mill Creek	2.14E+10	0	1.93E+11	2.14E+11
11010012-014	Reed's Creek	8.04E+10	0	7.24E+11	8.04E+11
11010012-011	Strawberry River	1.98E+11	0	1.78E+12	1.98E+12
11010012-010	Little Strawberry River	8.30E+10	2.72E+10	7.20E+11	8.30E+11
11010012-008	Strawberry River	7.31E+10	0	6.58E+11	7.31E+11
11010012-003	Cooper Creek	1.07E+11	0	9.66E+11	1.07E+12

***Note: cfu/day = colony forming units per day**

4.2.1 Wasteload Allocation

The WLA portion of the TMDL equation is the total loading of a pollutant that is assigned to point sources. There are three permitted facilities discharging sanitary wastewater into Little Strawberry River reach 11010012-010 (Table 12).

Table 12 Summary of WLA for Fecal Coliform and E.coli

Facility Name	NPDES Permit No.	Receiving Stream	Contact Recreation Season	Fecal Coliform WLA (cfu/day)	E.coli WLA (cfu/day)
City of Horseshoe Bend (Paradise)	AR0039608	Hubble Branch / Little Strawberry River	PCR-S	9.53E+08	9.32E+08
City of Horseshoe Bend (White)	AR0035254	Little Strawberry River / Strawberry River	PCR-S	3.18E+09	3.11E+09
City of Oxford	AR0049701	Little Strawberry River	PCR-S	1.43E+09	1.40E+09
City of Horseshoe Bend (Paradise)	AR0039608	Hubble Branch / Little Strawberry River	PCR-W	4.76E+09	2.38E+09
City of Horseshoe Bend (White)	AR0035254	Little Strawberry River / Strawberry River	PCR-W	1.59E+10	7.94E+09
City of Oxford	AR0049701	Little Strawberry River	PCR-W	7.15E+09	3.57E+09

4.2.2 Load Allocation

The load allocation is the portion of the TMDL assigned to natural background loadings as well as nonpoint sources such as septic tank leakage, wildlife, and agricultural practices. For this TMDL, that LA was calculated by subtracting the WLA, MOS, and FG 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 4-2.

Both section 303(d) of the Clean Water Act and the regulations at 40 CFR 130.7 require that TMDLs include an MOS to account for uncertainty in available data or in the actual effect that controls will have on the loading reductions and receiving water quality.

4.2.3 Seasonality and Critical Conditions

The federal regulations at 40 CFR 130.7 require that TMDLs include seasonal variations and take into account critical conditions for streamflow, loading, and water quality parameters. Fecal coliform and e.coli loadings for subsegments 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. The sampling results for fecal coliform bacteria were plotted over time and reviewed for any seasonal patterns (see Section 3.2).

By accounting for critical conditions, the TMDL makes sure that water quality standards are maintained for infrequent occurrences and not only for average conditions. For fecal coliform bacteria, the water quality criteria include values that must not be exceeded more than 25 percent of the time (primary and secondary contact recreation).

Because of the way the criteria are written (i.e., including critical and noncritical conditions), the TMDL for the pollutant of concern can be developed by reviewing pollutant loads at all flow conditions within applicable periods of the year and evaluating the percentage of values exceeding the criteria. The load duration curve, which determines the allowable loading at a wide range of flows, was chosen as the approach for these TMDLs (see Section 4.1). Therefore, the TMDLs were calculated at all flows rather than at a single critical flow.

4.2.4 Margin of Safety

The margin of safety (MOS) is the portion of the pollutant loading reserved to account for any lack of knowledge concerning the relationship between effluent limitations as stated in 40 CFR §130.7. 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. The MOS is an explicit 10 percent was set aside for each impaired segment. Using 10 percent of the TMDL load provides an additional level of protection to the designated uses of the waterbodies of concern.

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.

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.

7.0 REFERENCES

ADEQ. 2002. 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. 2004. 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.

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

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

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. 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. 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.

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. 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.

Appendix A

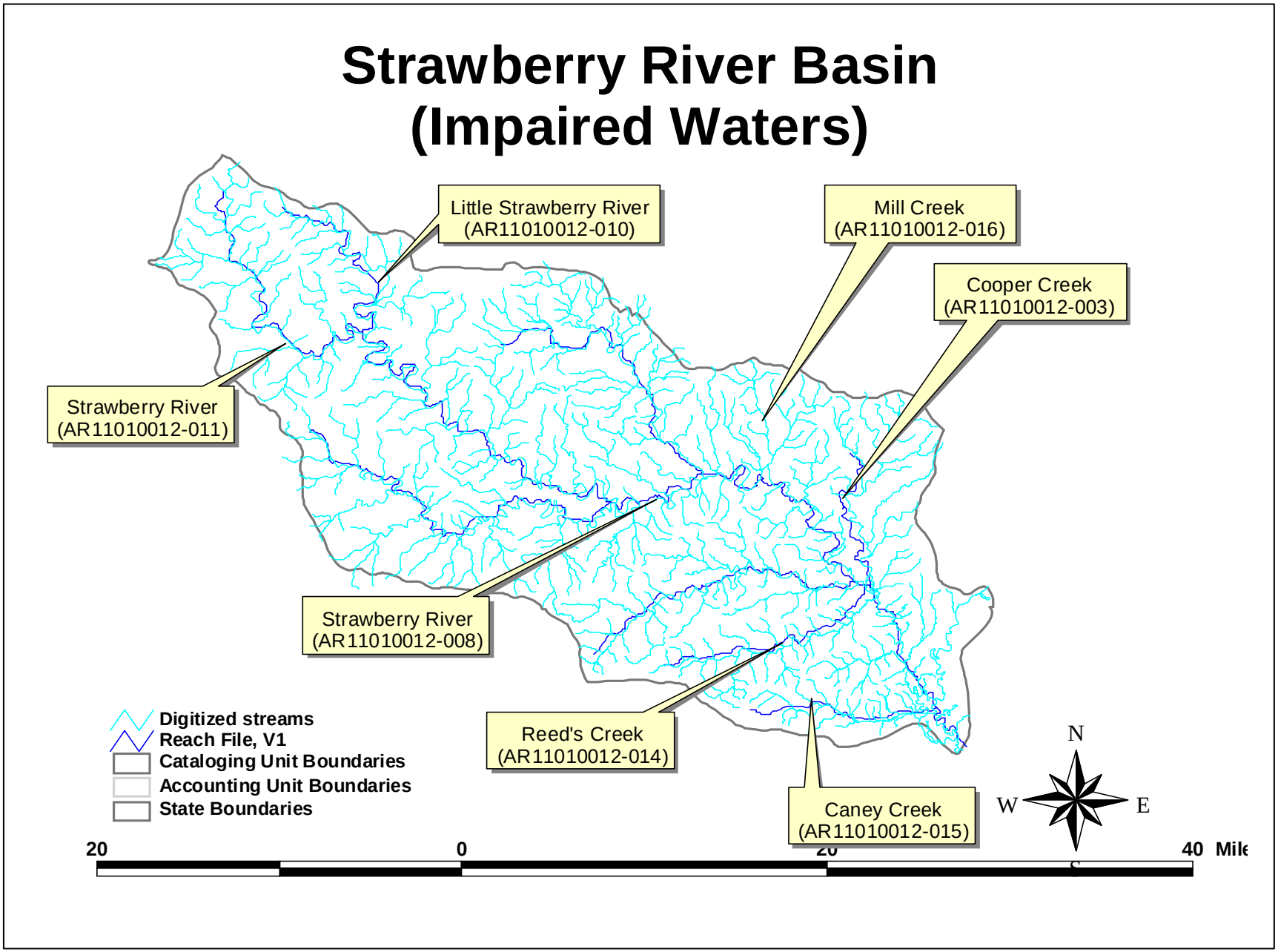


Figure A-1 Study area for Planning Segments in 4G

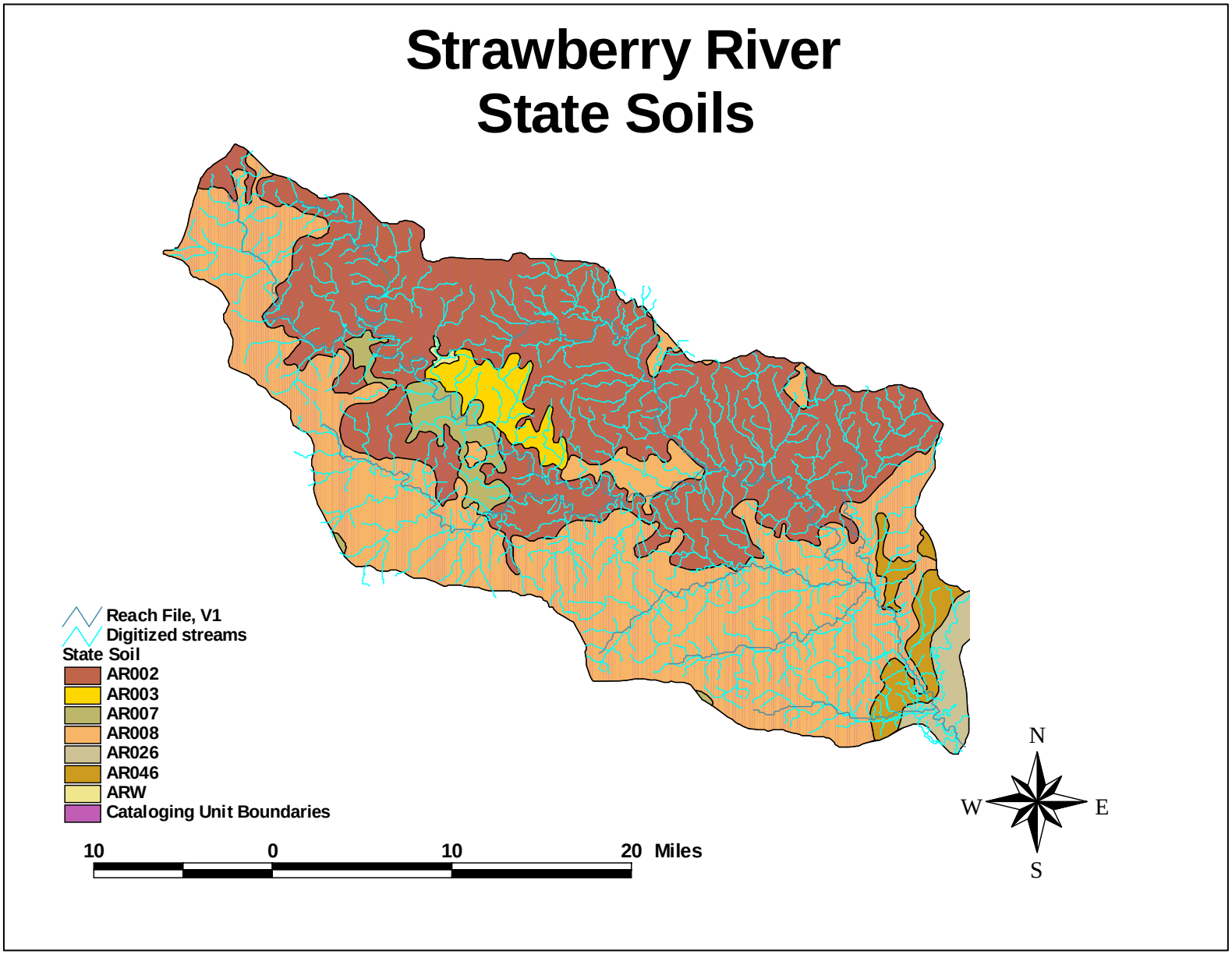


Figure A-2 Soil Types in Planning Segments 4G

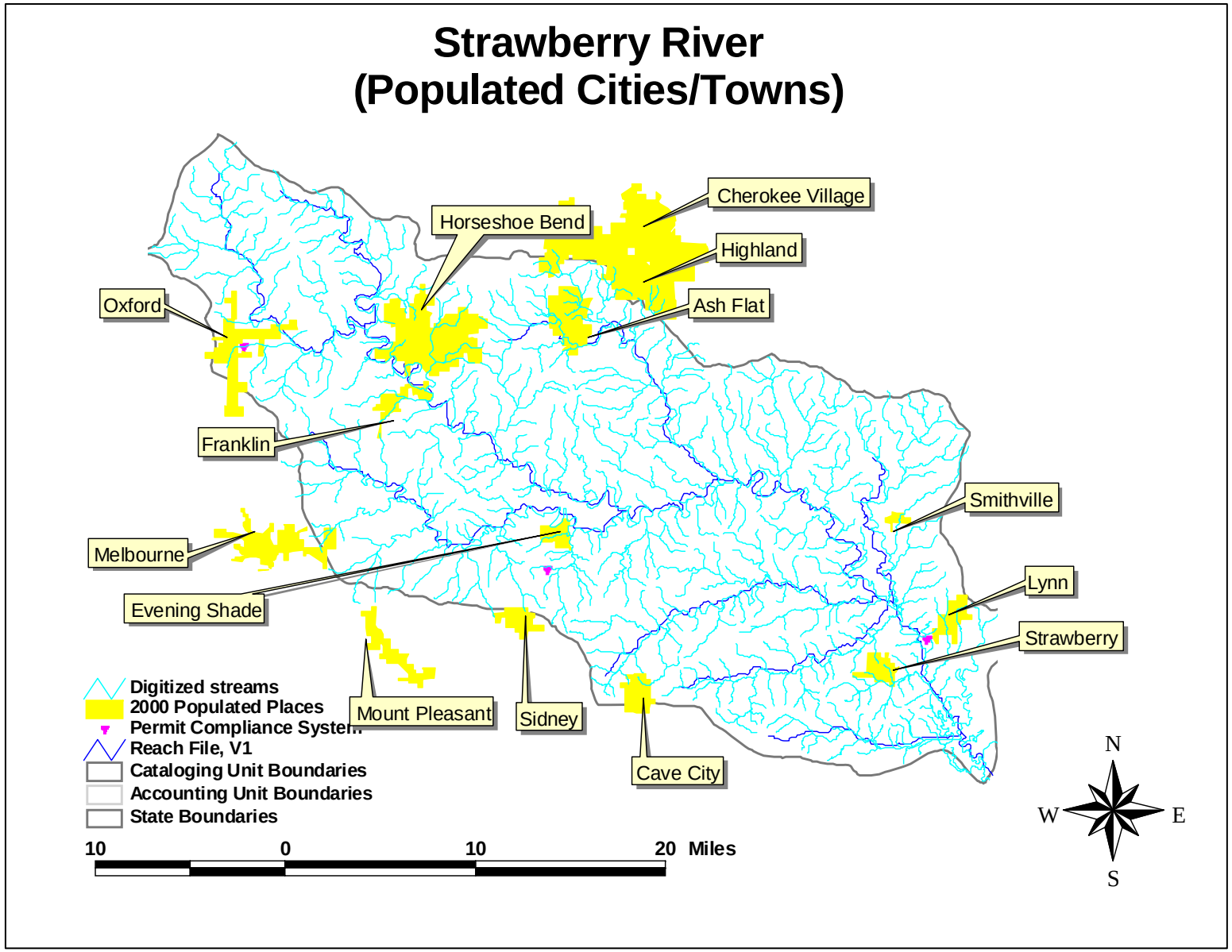


Figure A-3 Populated Cities/Towns in Planning Segments 4G

Strawberry River Basin Landuse

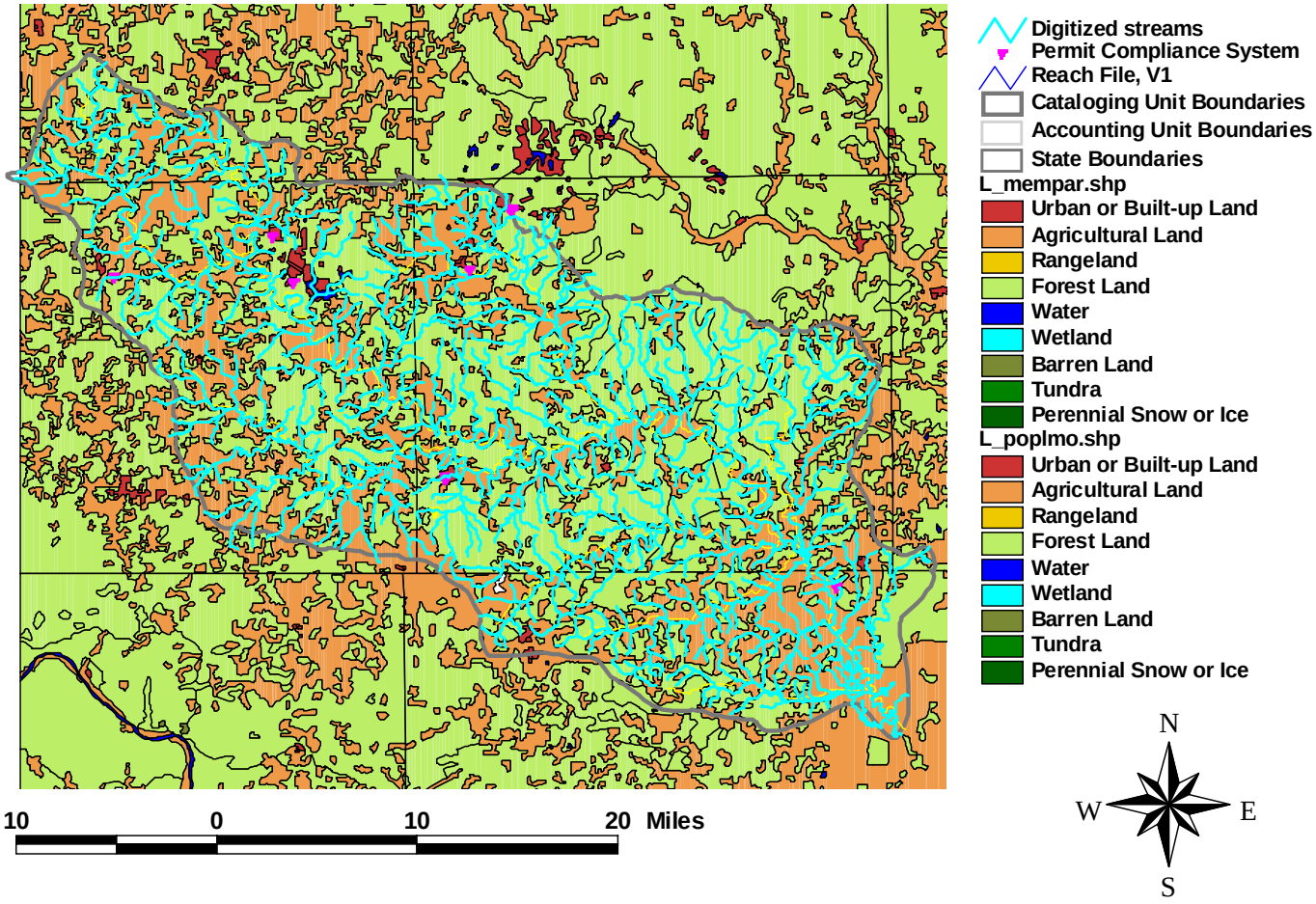


Figure A-4 Landuse in Planning Segments 4G

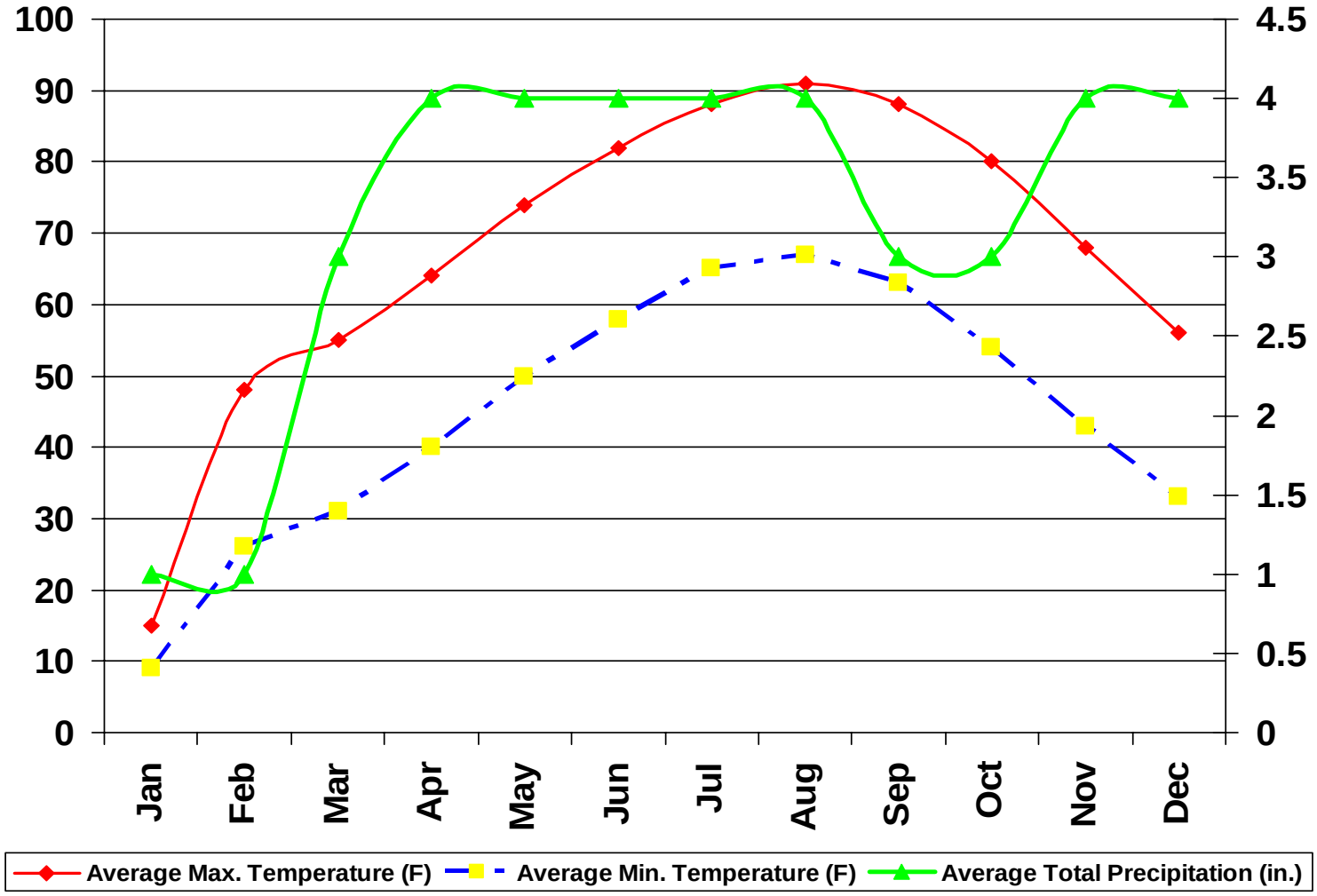


Figure A-5 Climate Conditions in Planning Segments 4G

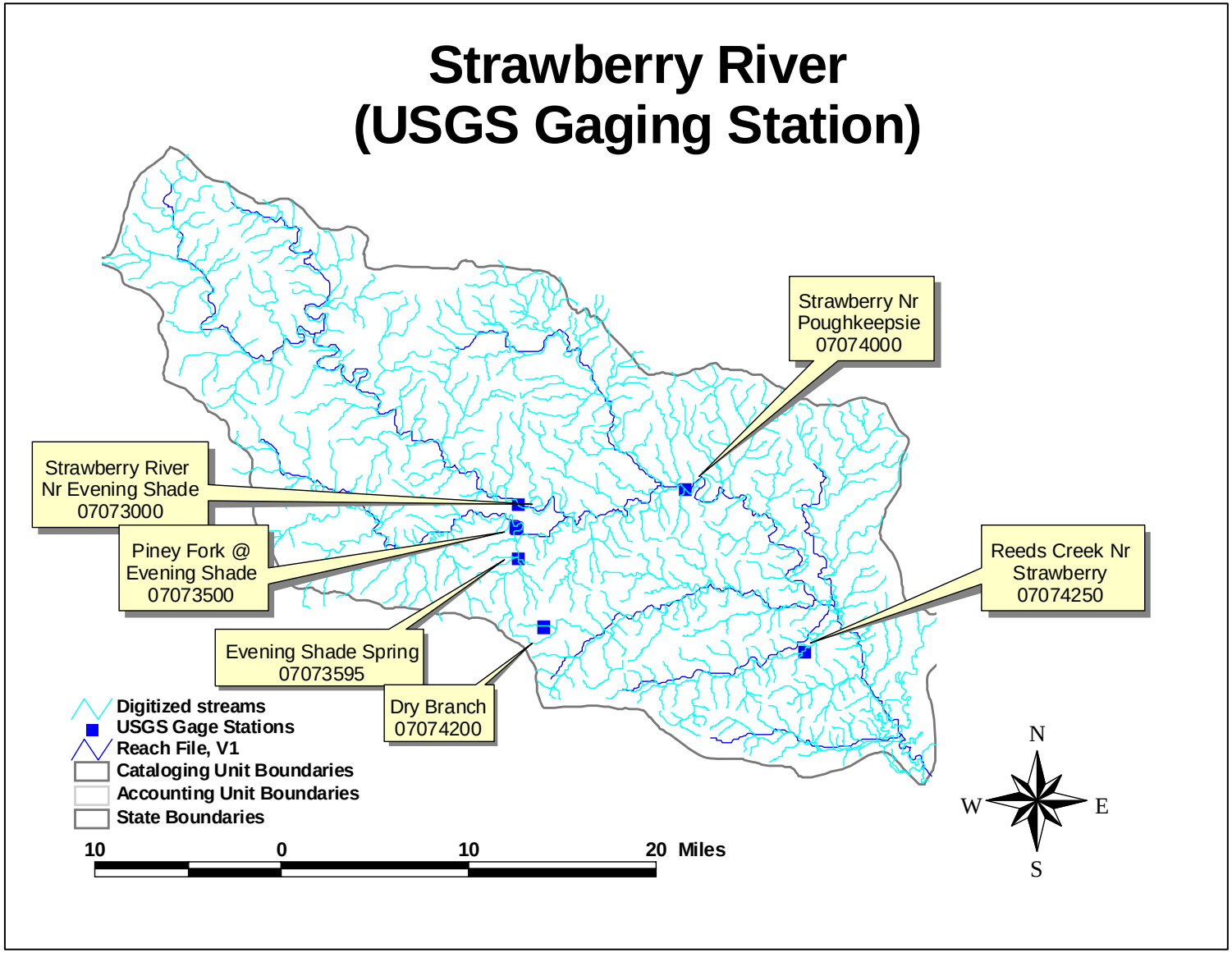


Figure A-6 USGS Streamflow Gages in Planning Segments 4G

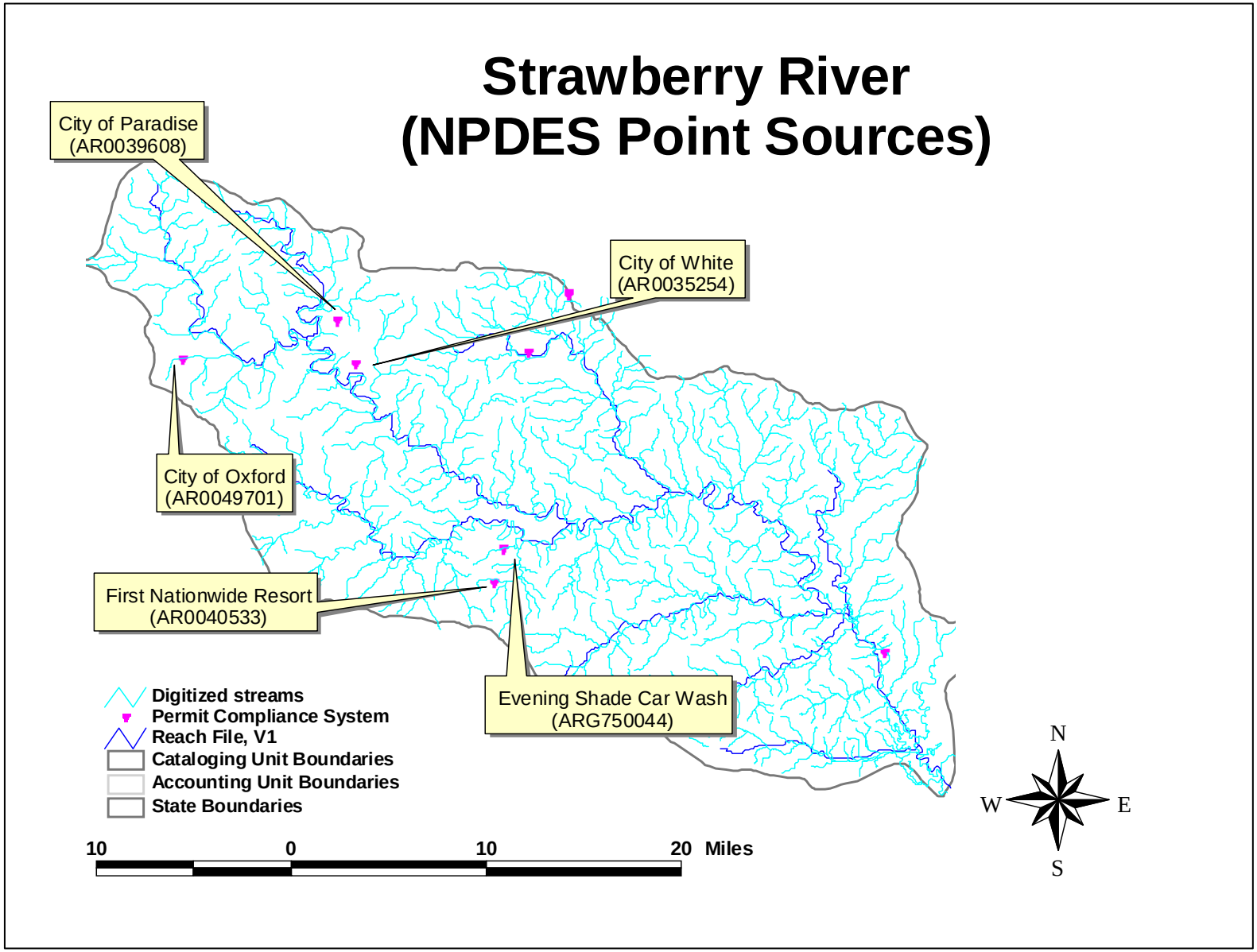


Figure A-7 Point Source Dischargers in Planning Segment 4G

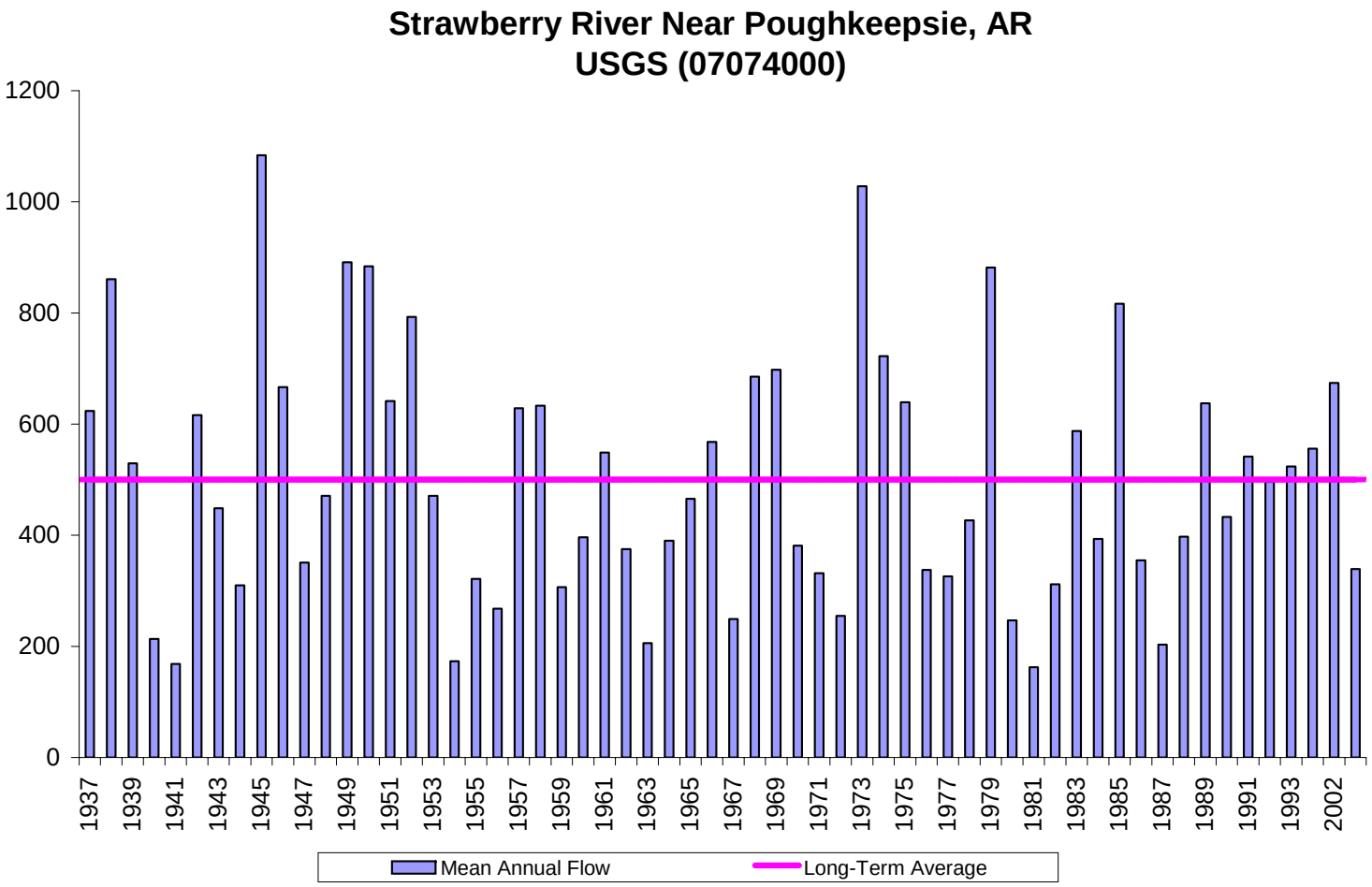


Figure A-8 Streamflow Estimation for Strawberry River Stations

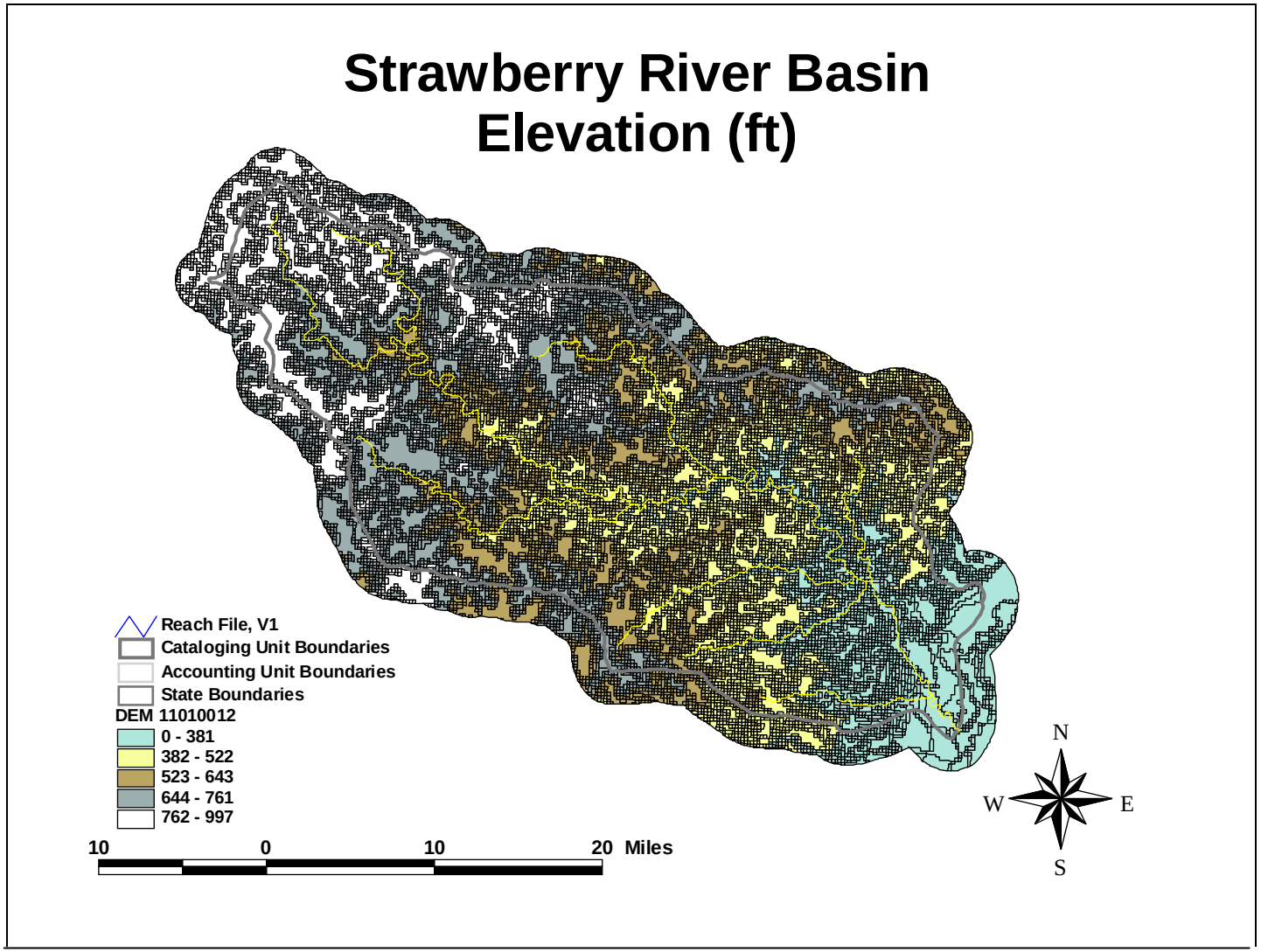
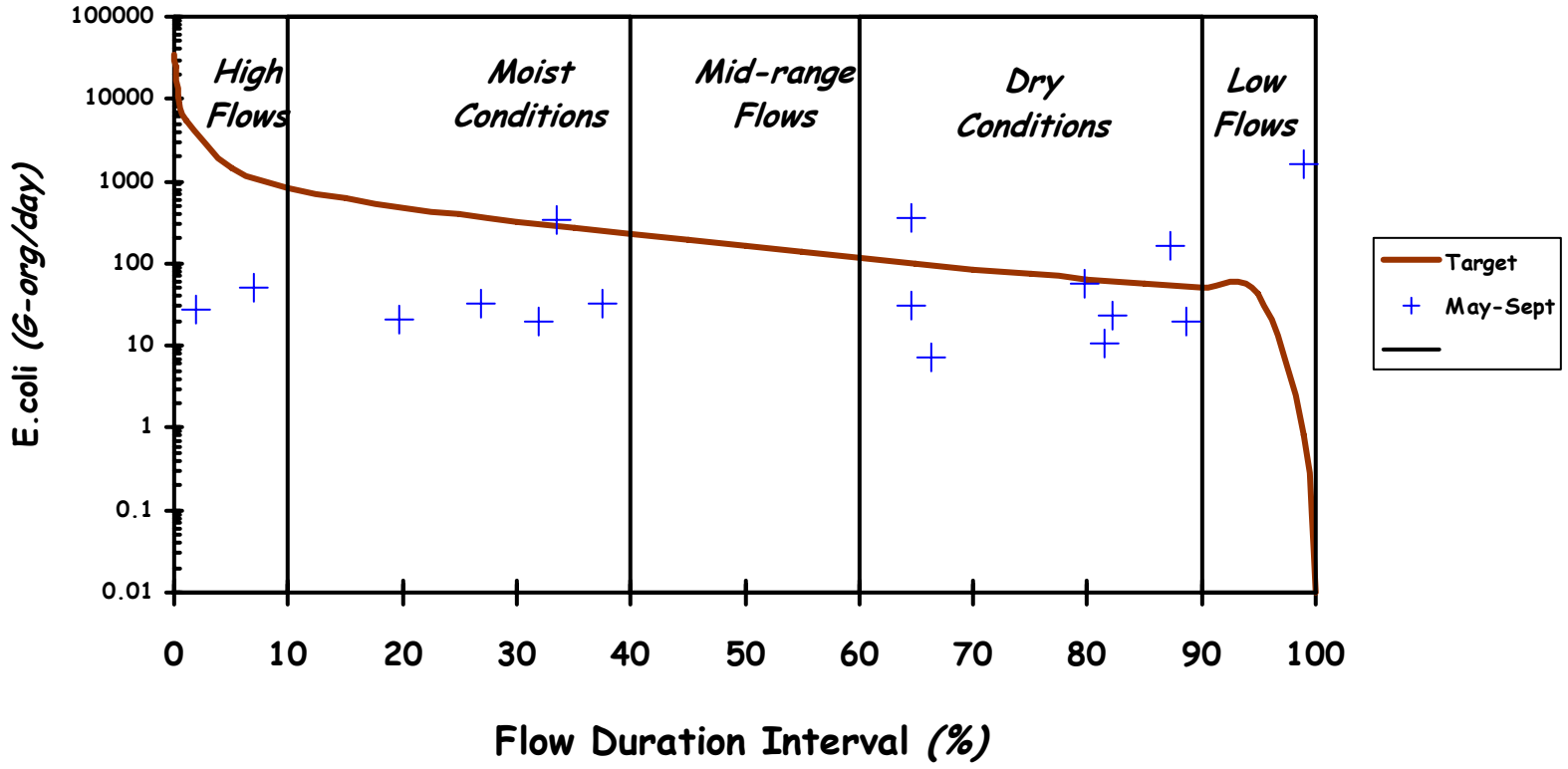


Figure A-9 Strawberry River Basin Elevation (ft)

Appendix B

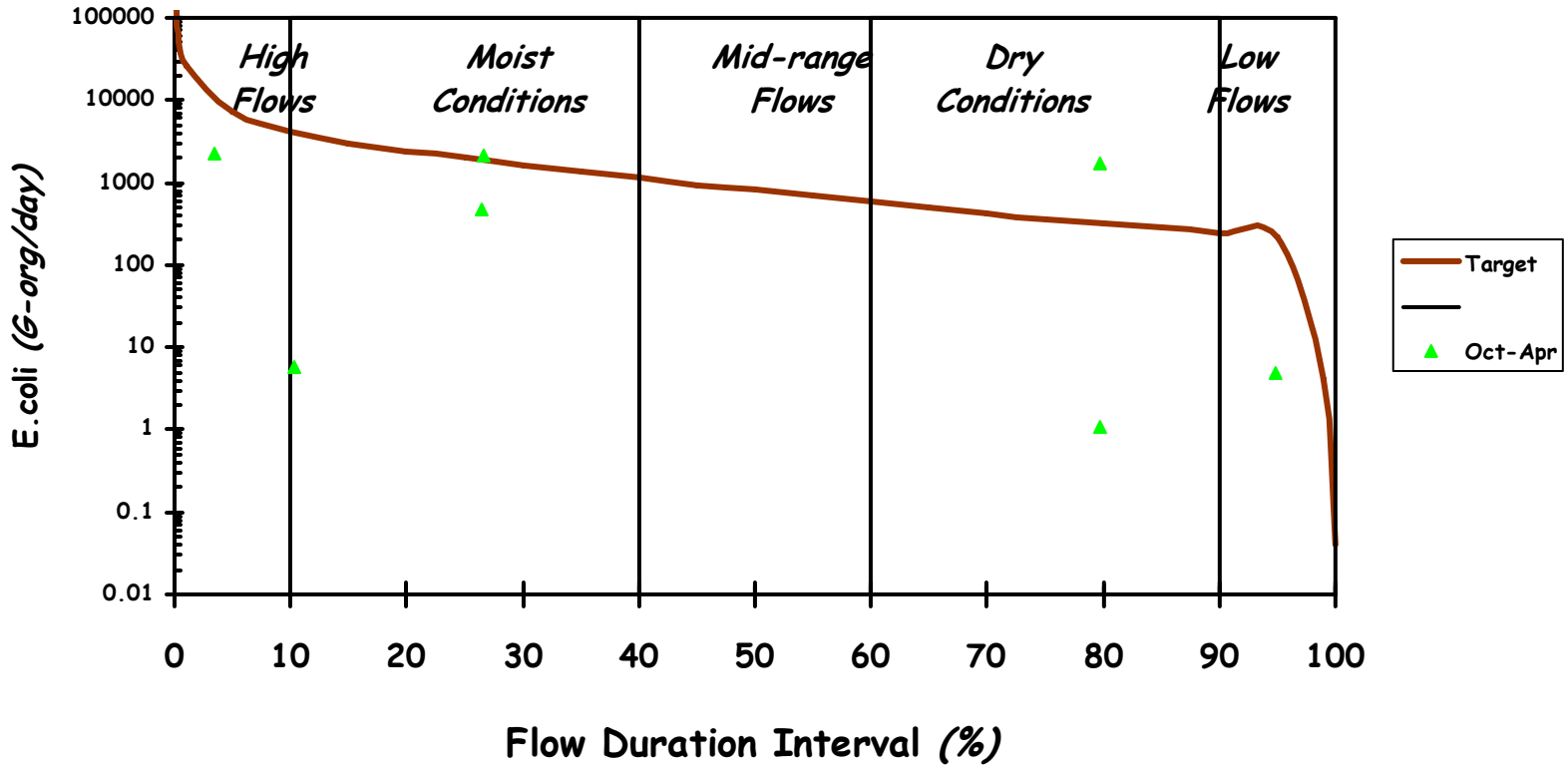
Reed's Creek, AR
Load Duration Curve
(2001 - 2002 E.coli Monitoring Data (PCR-Summer))
Site:UWRDC01



ADEQ Data & USGS Gage Duration Interval

39.7 square miles

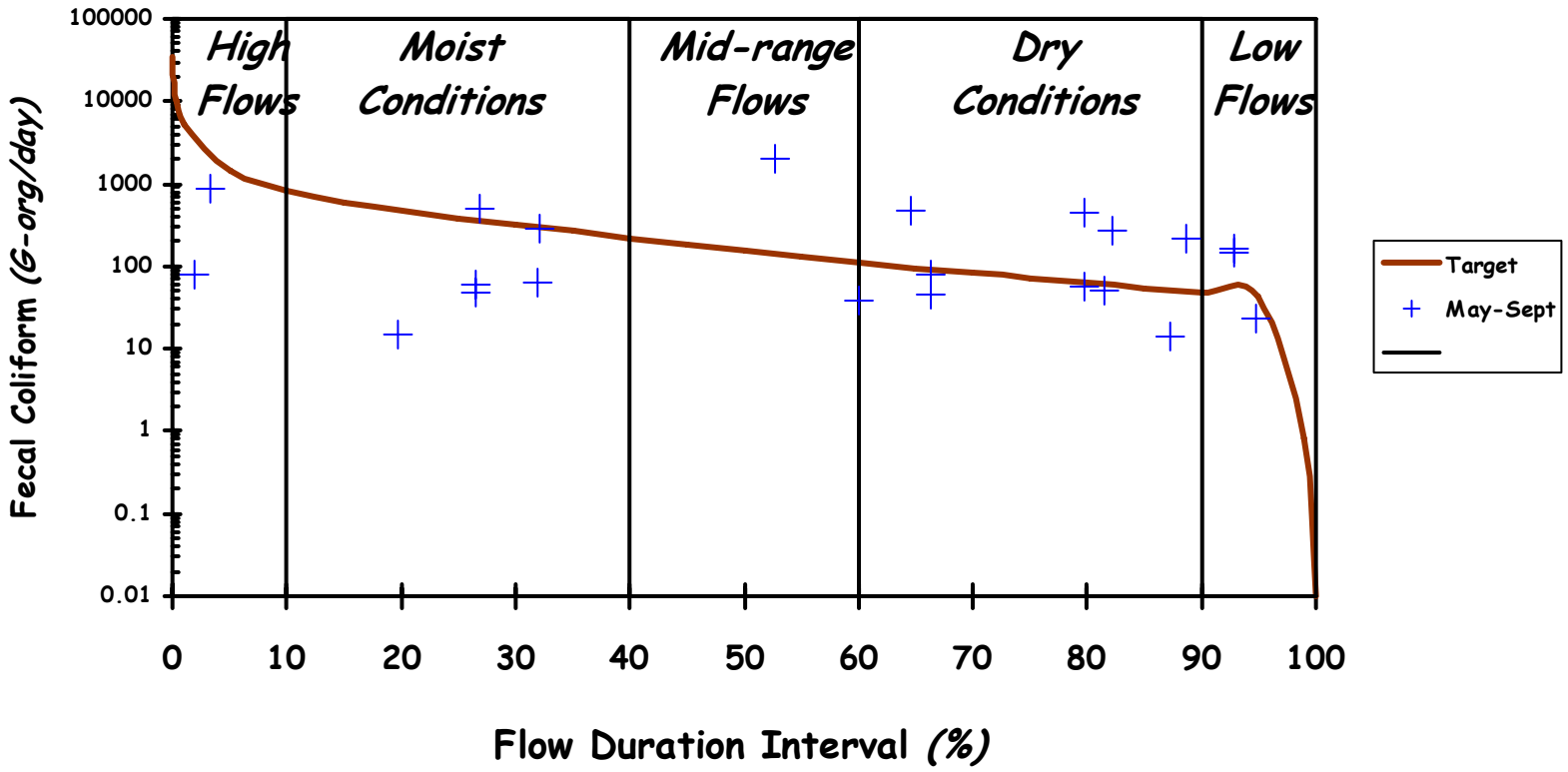
Reed's Creek, AR
Load Duration Curve
(2001 - 2002 E.coli Monitoring Data (PCR-Winter))
Site:UWRDC01



ADEQ Data & USGS Gage Duration Interval

39.7 square miles

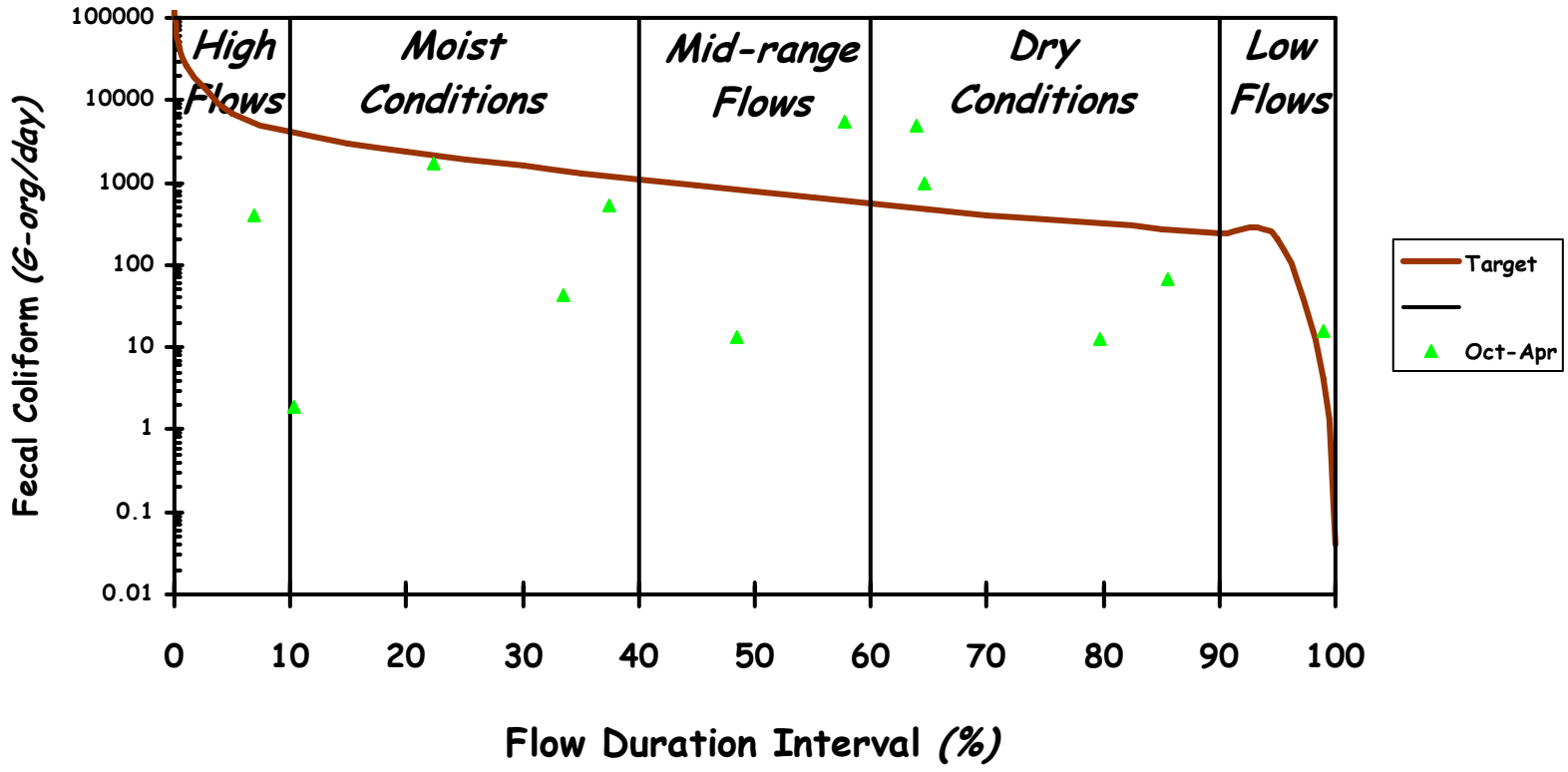
Reed's Creek, AR
Load Duration Curve
(1994 - 2002 Fecal Coliform Monitoring Data (PCR-Summer))
Site:UWRDC01



ADEQ Data & USGS Gage Duration Interval

39.7 square miles

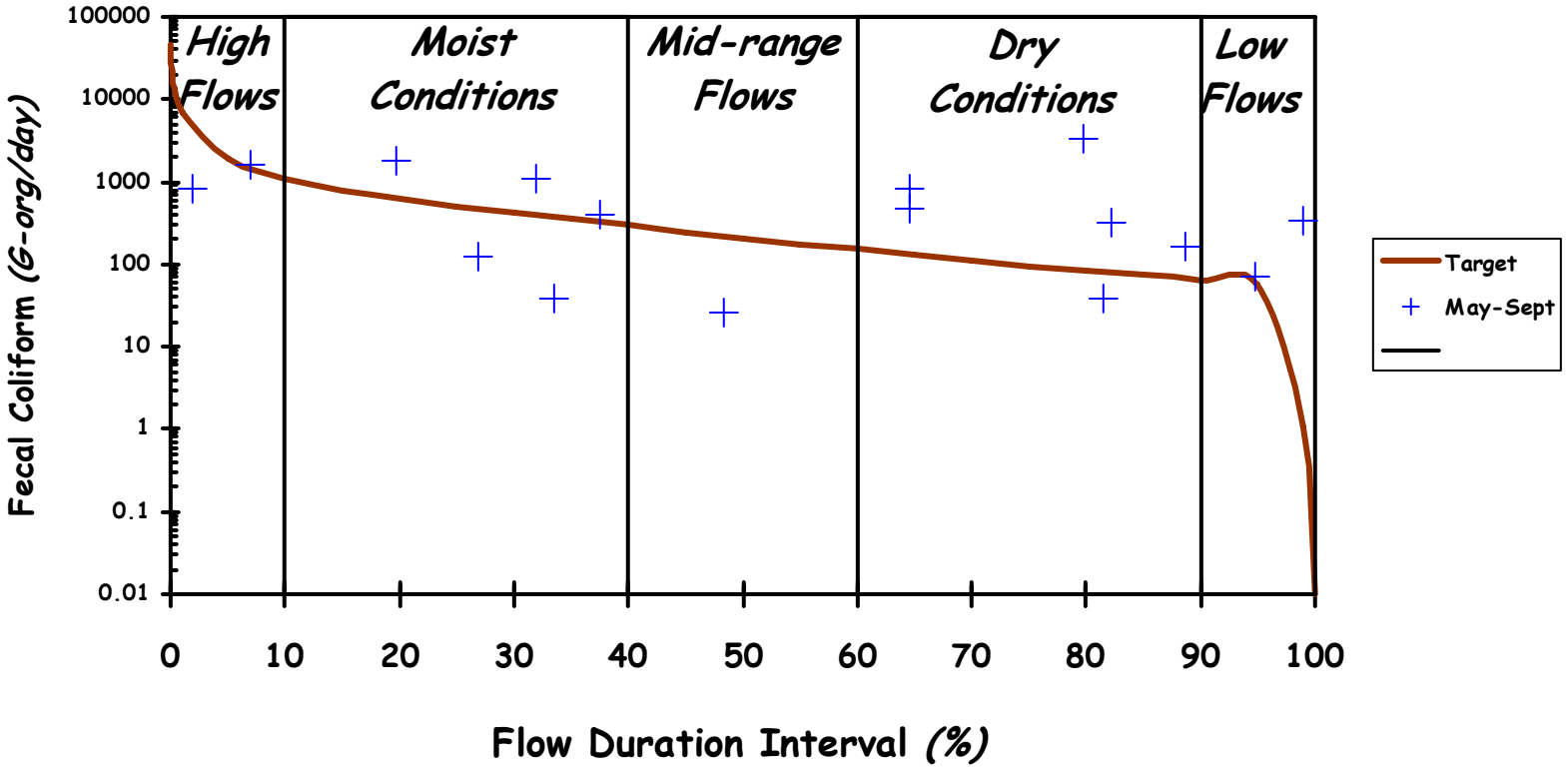
Reed's Creek, AR
Load Duration Curve
(1994 - 2002 Fecal Coliform Monitoring Data (PCR-Winter))
Site:UWRDC01



ADEQ Data & USGS Gage Duration Interval

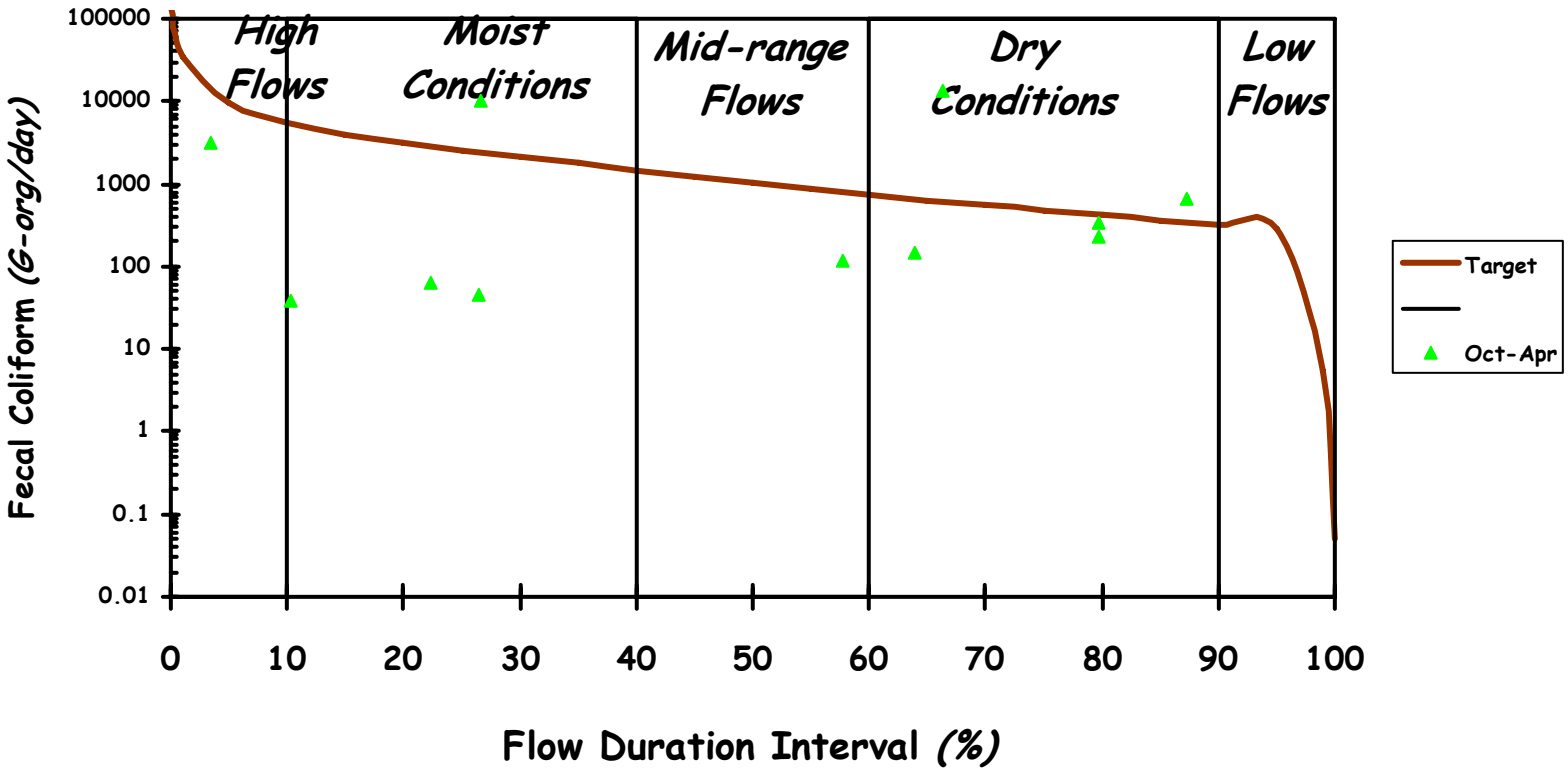
39.7 square miles

Cooper Creek near Smithsville, AR
Load Duration Curve
(2001 - 2002 Fecal Coliform Monitoring Data (PCR-Summer))
Site:WHI0143S



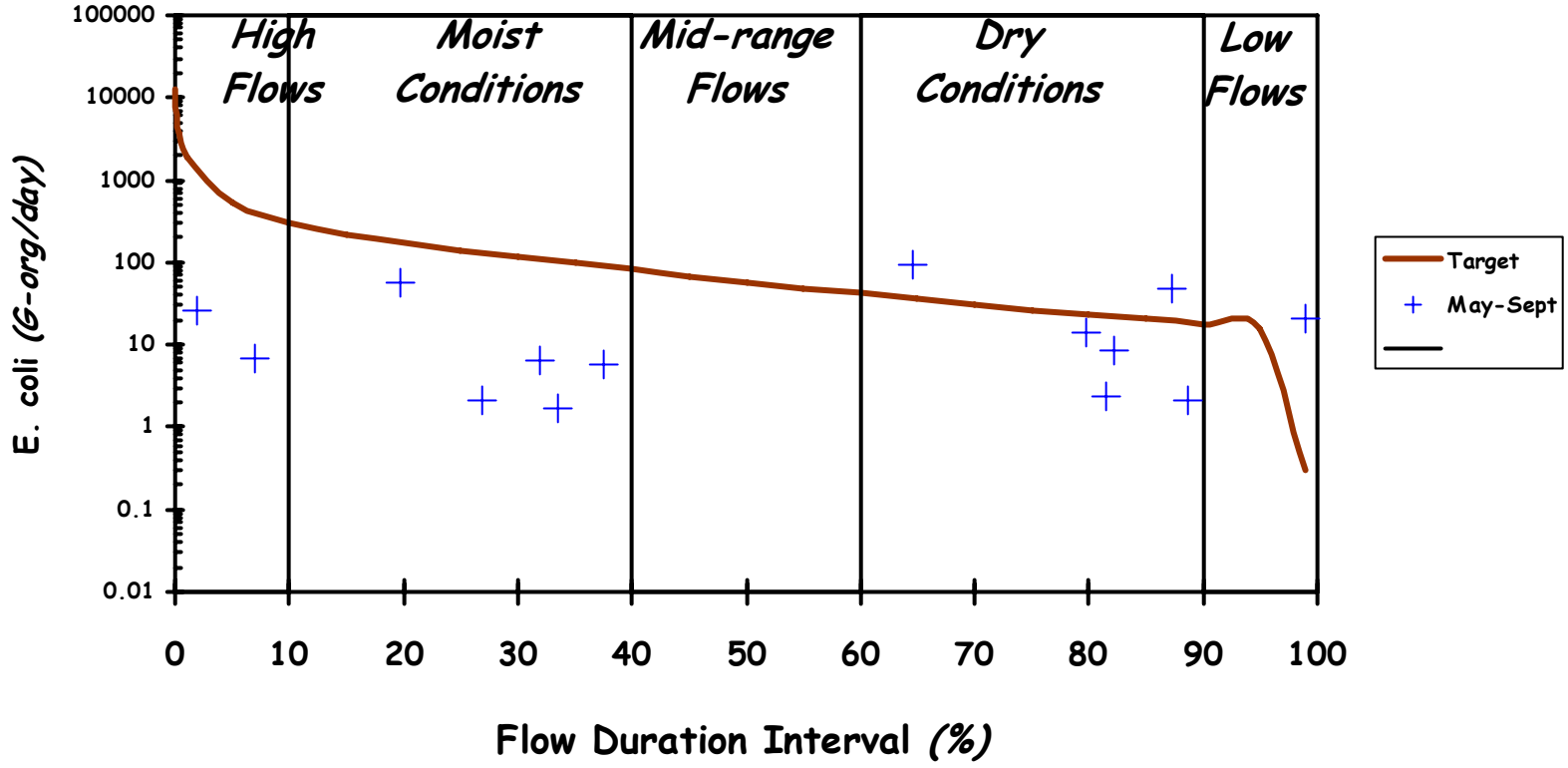
ADEQ Data & USGS Gage Duration Interval *53 square miles*

Cooper Creek near Smithsville, AR
Load Duration Curve
(2001 - 2002 Fecal Coliform Monitoring Data (PCR-Winter))
Site:WHI0143S



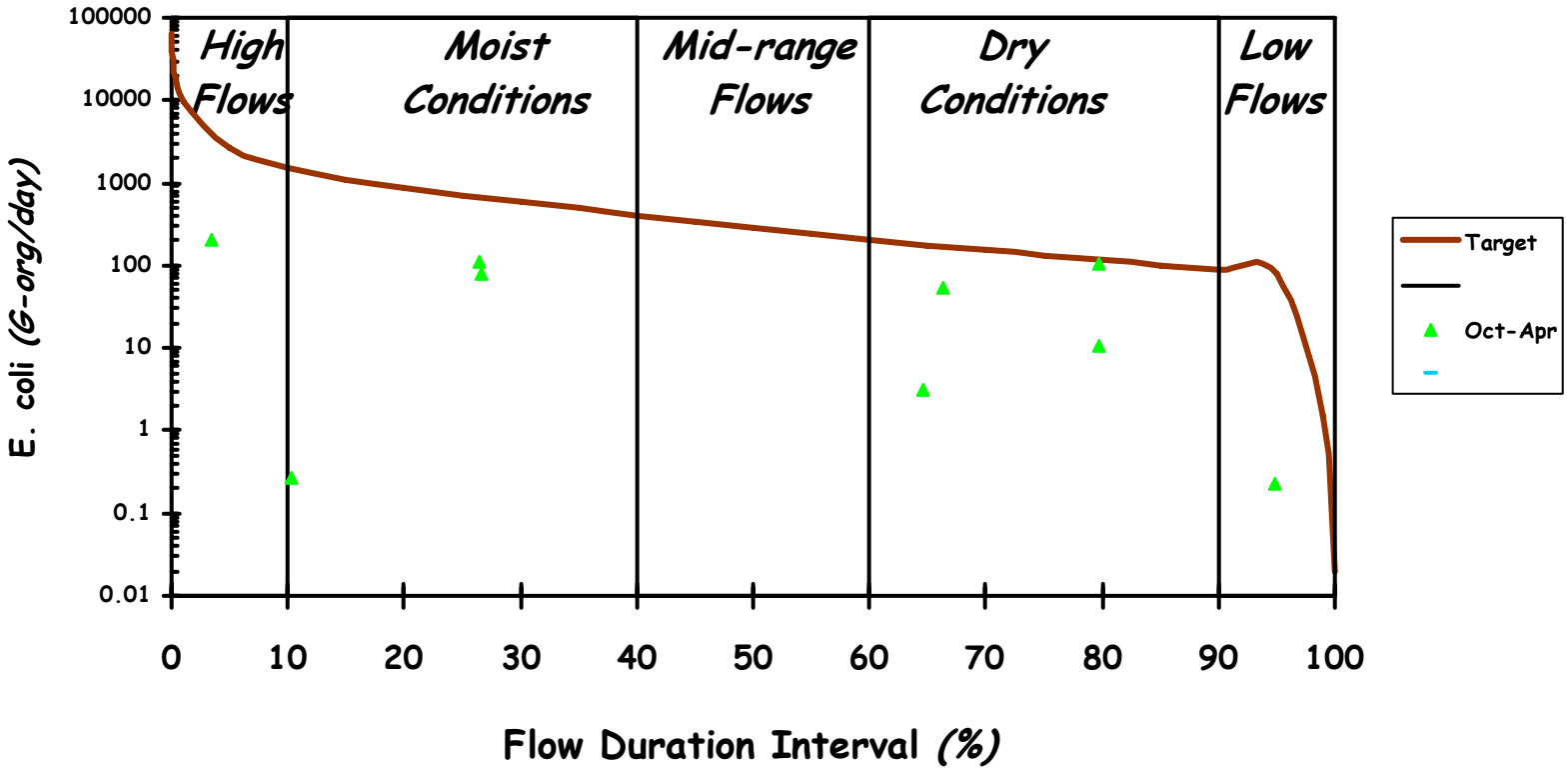
ADEQ Data & USGS Gage Duration Interval *53 square miles*

Caney Creek east of Saffell, AR
Load Duration Curve
(2001 - 2002 E.coli Monitoring Data (PCR-Summer))
Site:WHI0143R



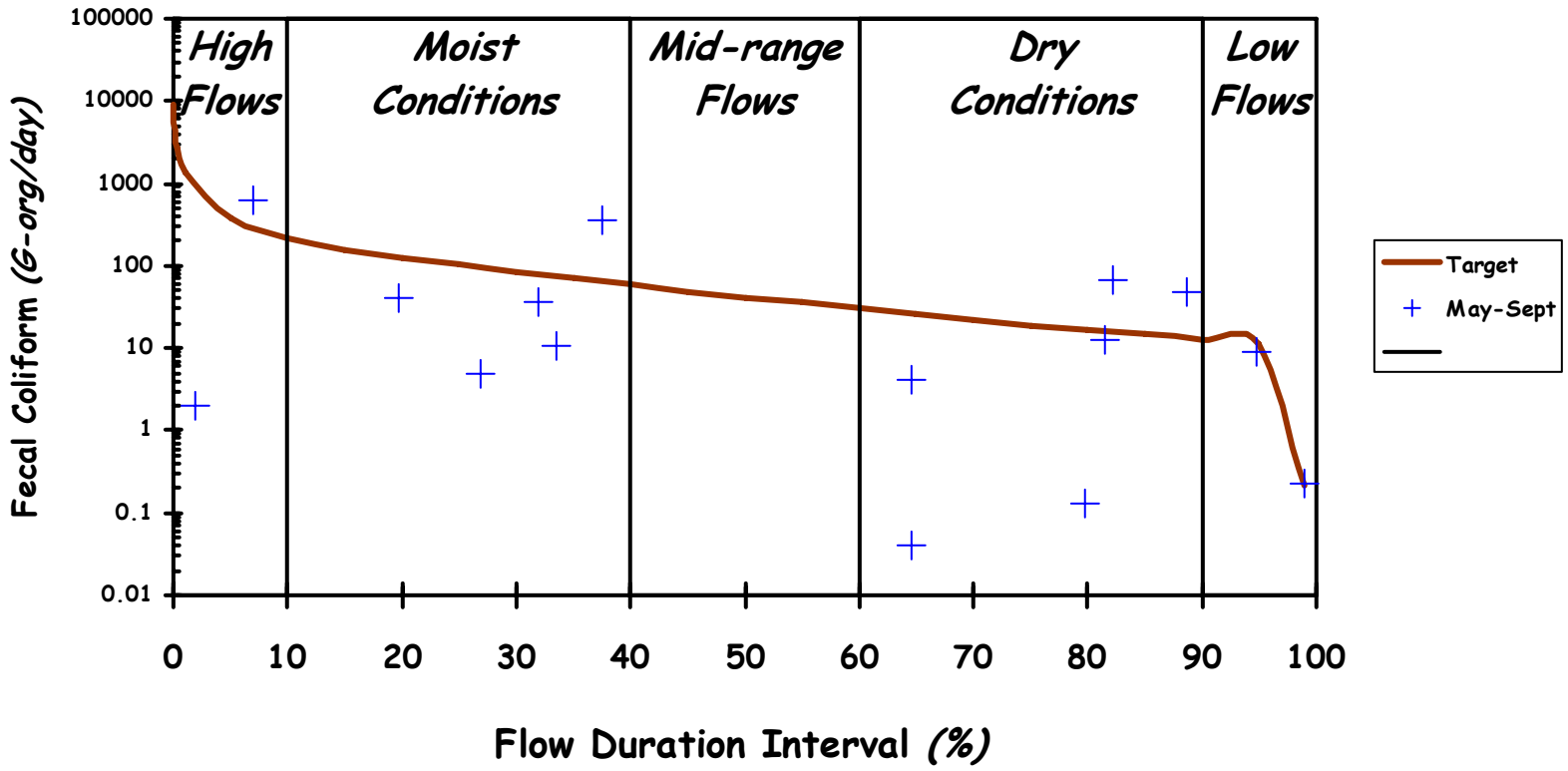
ADEQ Data & USGS Gage Duration Interval *14.4 square miles*

Caney Creek east of Saffell, AR
Load Duration Curve
(2001 - 2002 E. Coli Monitoring Data (PCR-Winter))
Site:WHI0143R



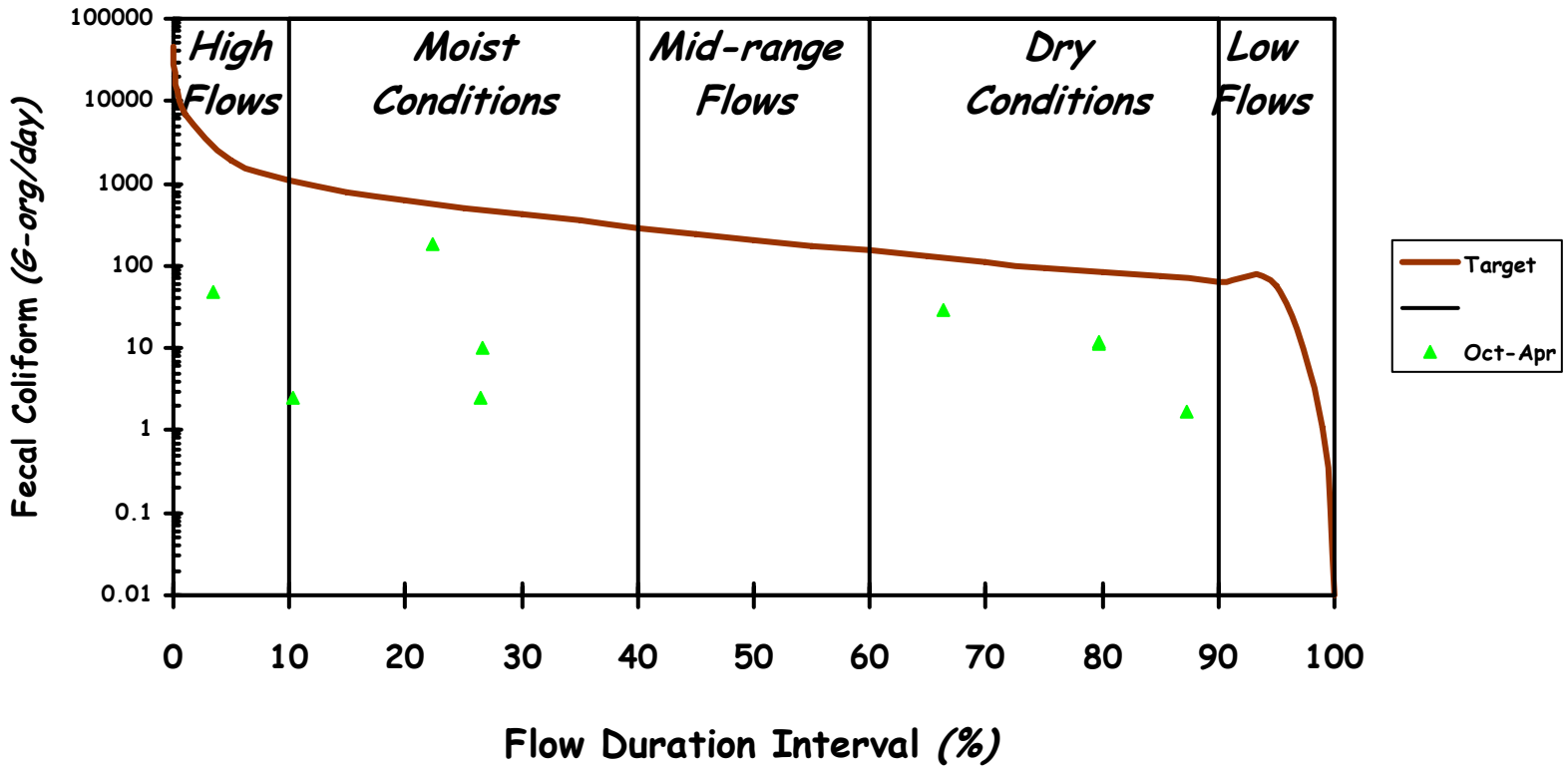
ADEQ Data & USGS Gage Duration Interval *14.4 square miles*

Mill Creek, South of Sitka, AR
Load Duration Curve
(Fecal Coliform 2001 - 2002 Monitoring Data (PCR-Summer))
Site:WHI0143N



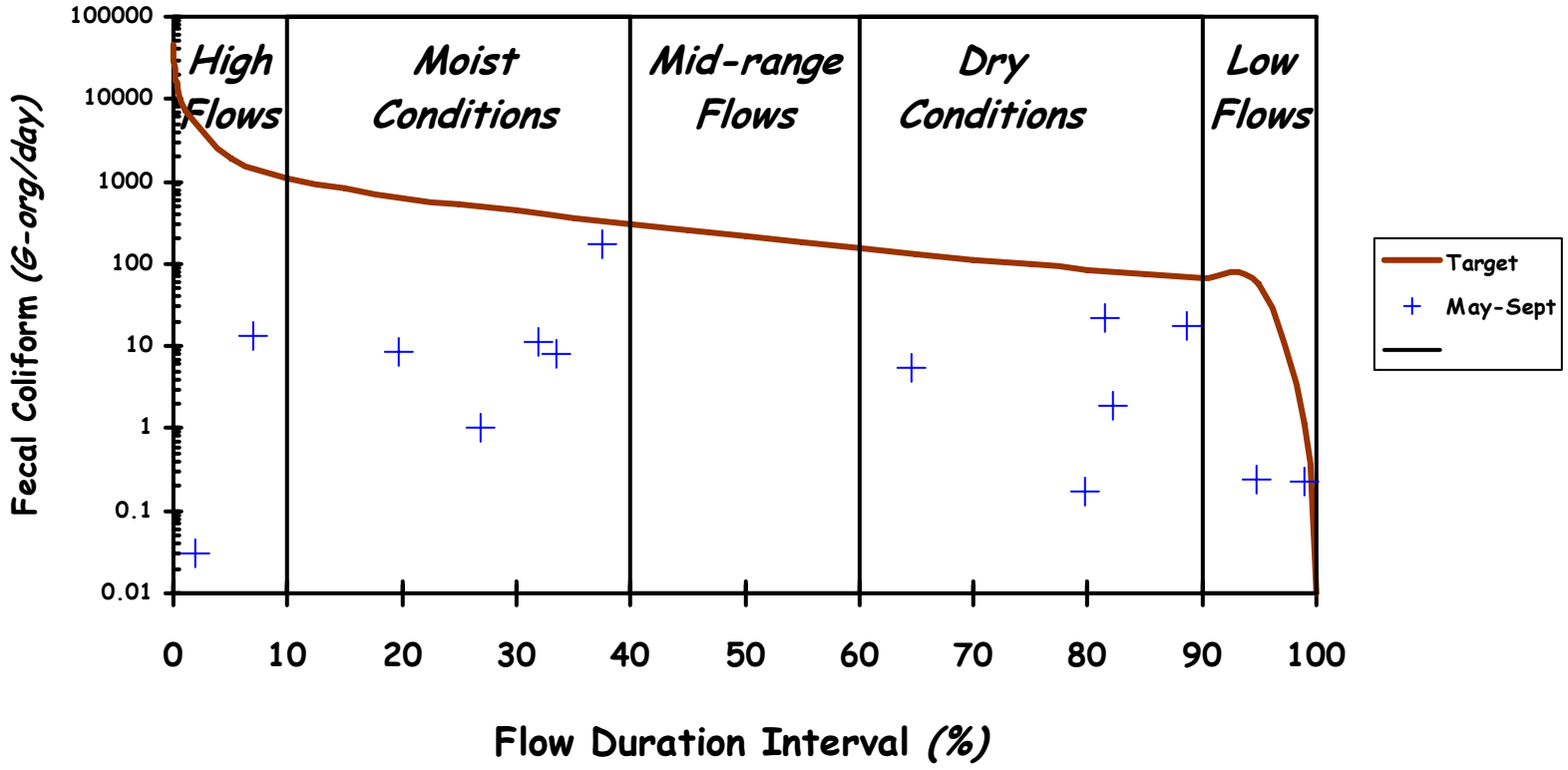
ADEQ Data & USGS Gage Duration Interval *10 square miles*

Mill Creek, South of Sitka, AR
Load Duration Curve
(Fecal Coliform 2001 - 2002 Monitoring Data (PCR-Winter))
Site:WHI0143N



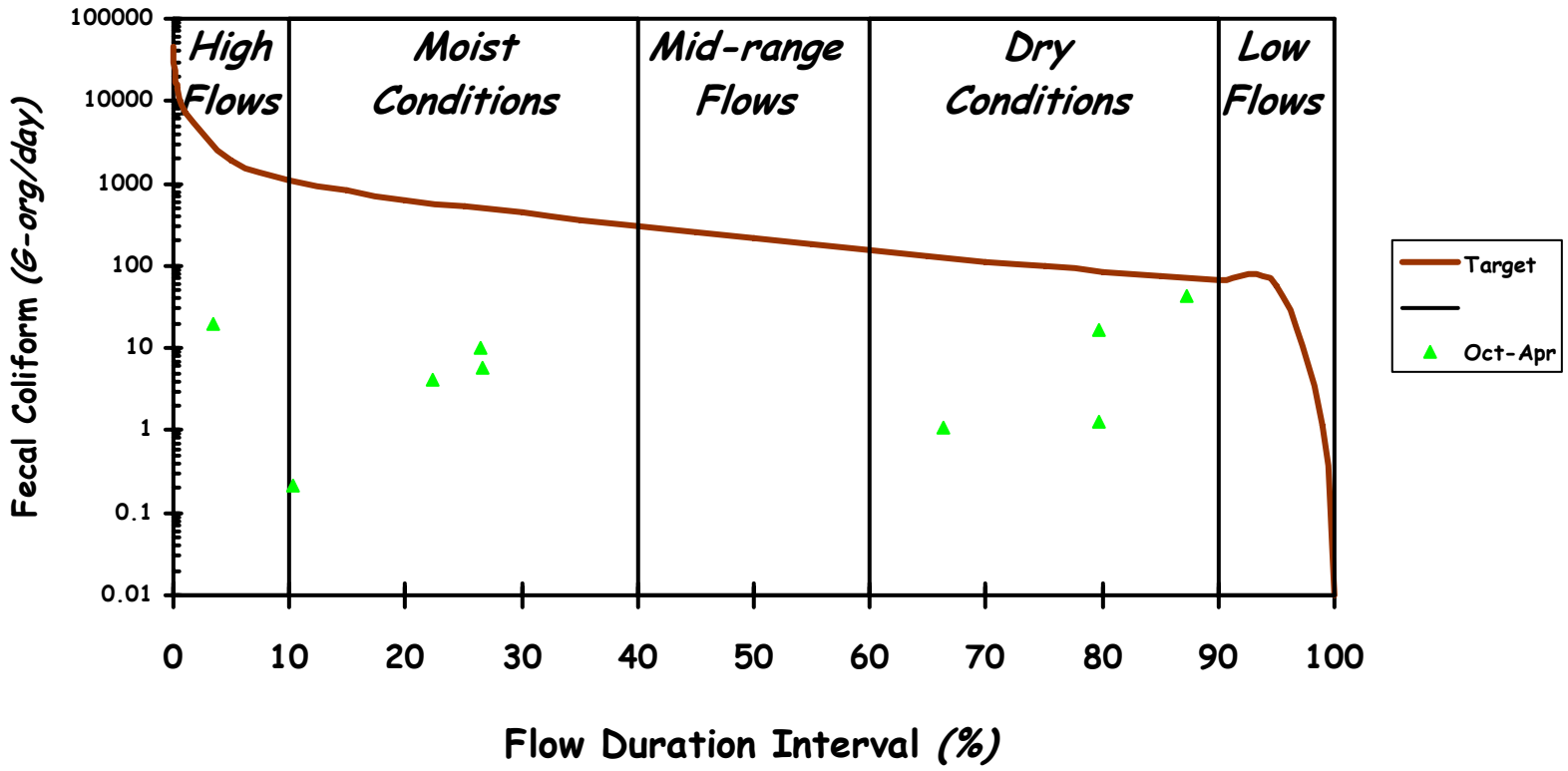
ADEQ Data & USGS Gage Duration Interval *10 square miles*

Mill Creek, South of Sitka, AR
Load Duration Curve
(2001 - 2002 E.coli Monitoring Data (PCR-Summer))



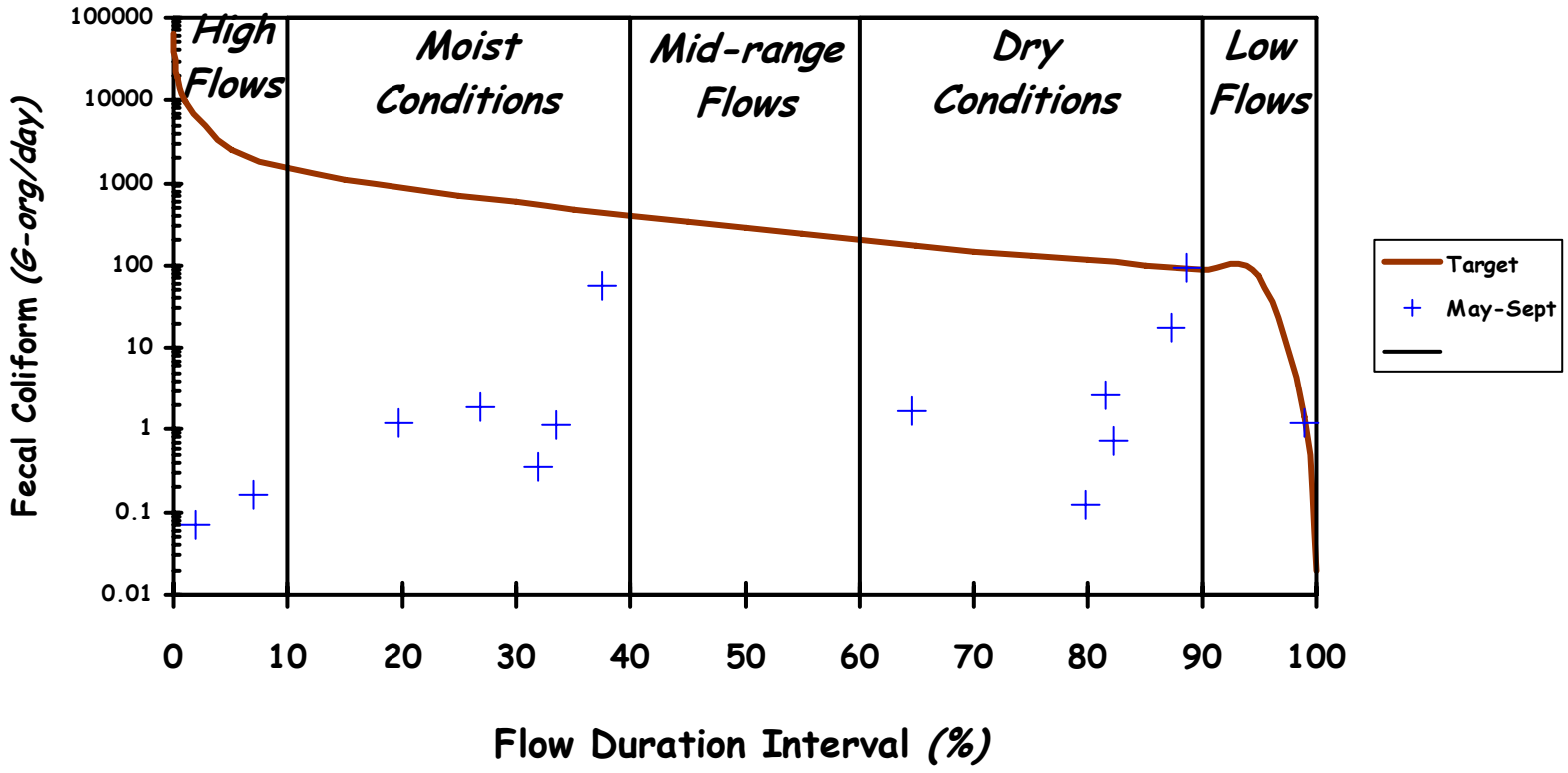
ADEQ Data & USGS Gage Duration Interval *10 square miles*

Mill Creek, South of Sitka,AR
Load Duration Curve
(2001 - 2002 E.coli Monitoring Data (PCR-Winter))
Site:WHI0143N



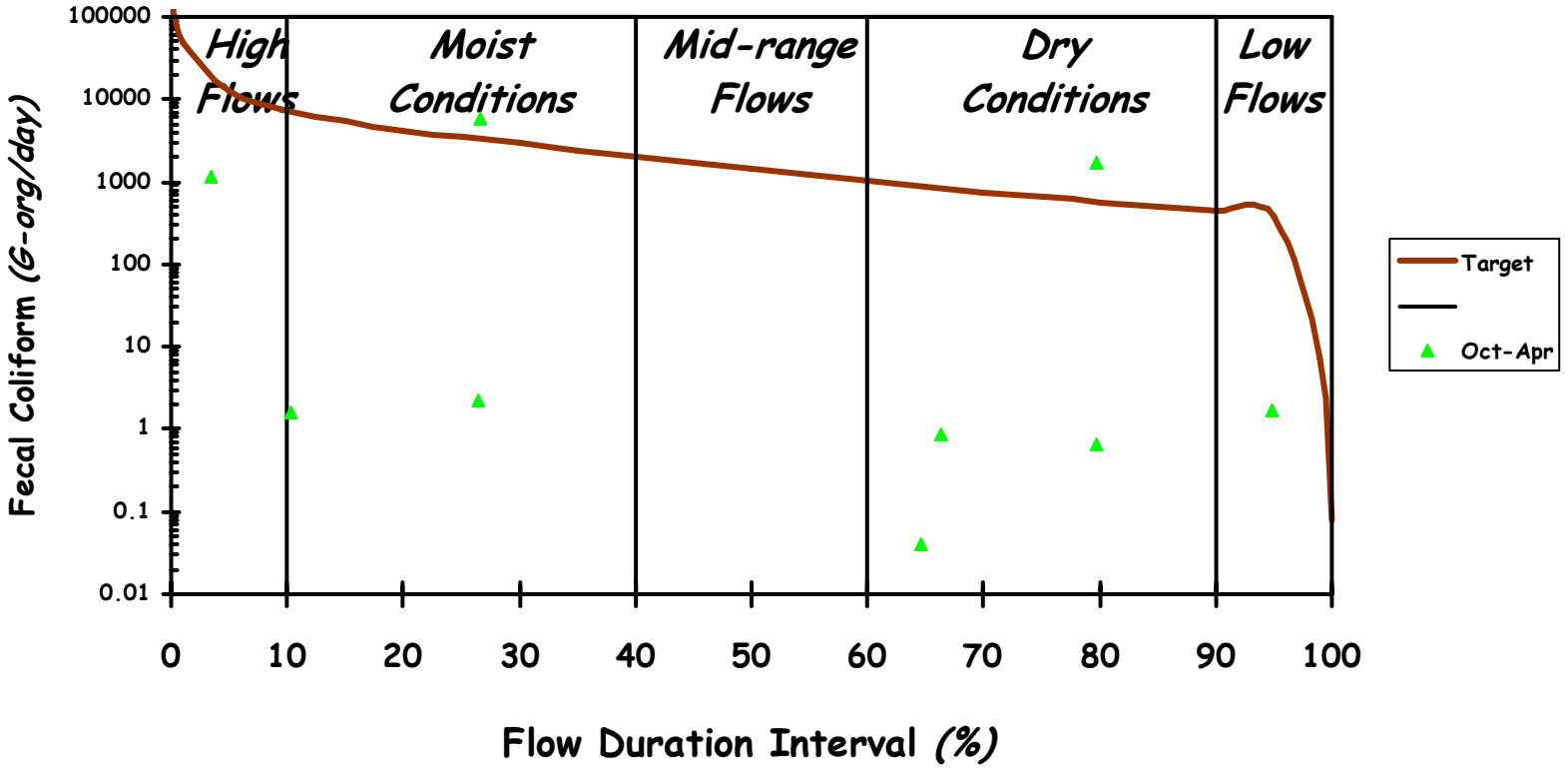
ADEQ Data & USGS Gage Duration Interval *10 square miles*

Strawberry River near Wiseman, AR
Load Duration Curve
(2001 - 2002 E.coli Monitoring Data (PCR-Summer))
Site: UWSBR01 (ERW)



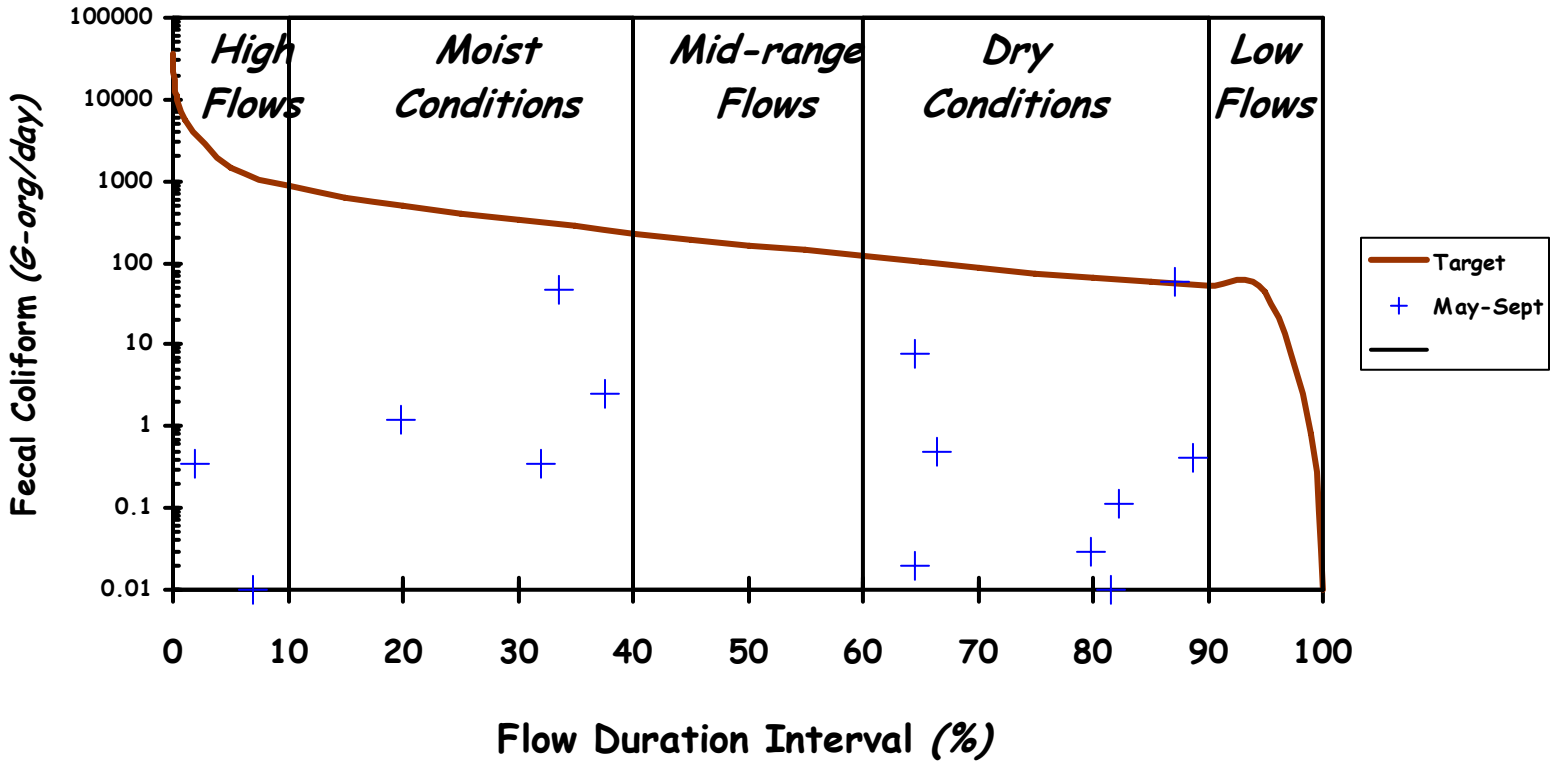
ADEQ Data & USGS Gage Duration Interval *36.6 square miles*

Strawberry River near Wiseman, AR
Load Duration Curve
(2001 - 2002 E.coli Monitoring Data (PCR-Winter))
Site: UWSBR01 (ERW)



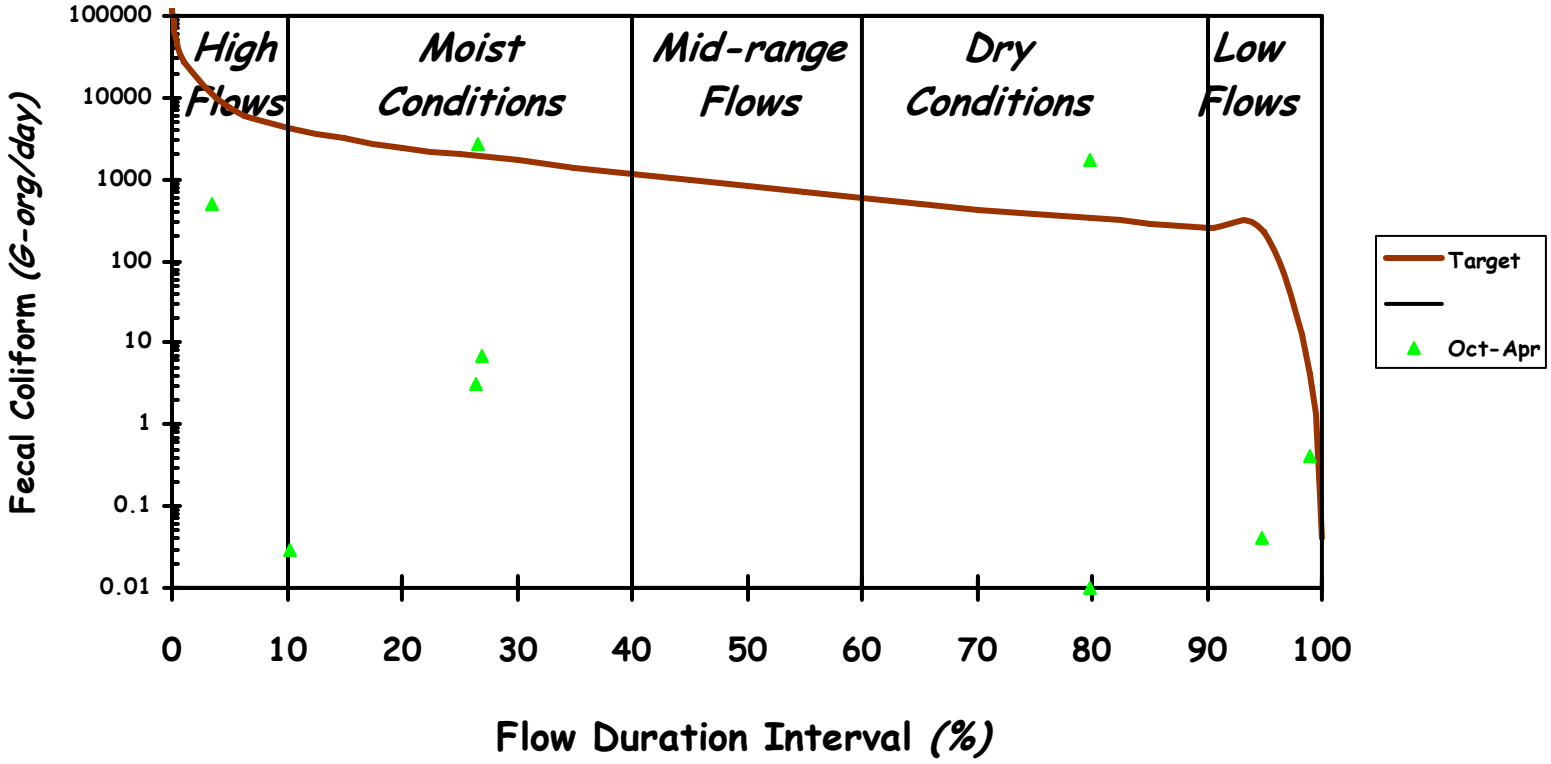
ADEQ Data & USGS Gage Duration Interval *36.6 square miles*

Little Strawberry River near Wiseman, AR
Load Duration Curve
(2001 - 2002 E.coli Monitoring Data (PCR-Summer))
Site: WHI0143H



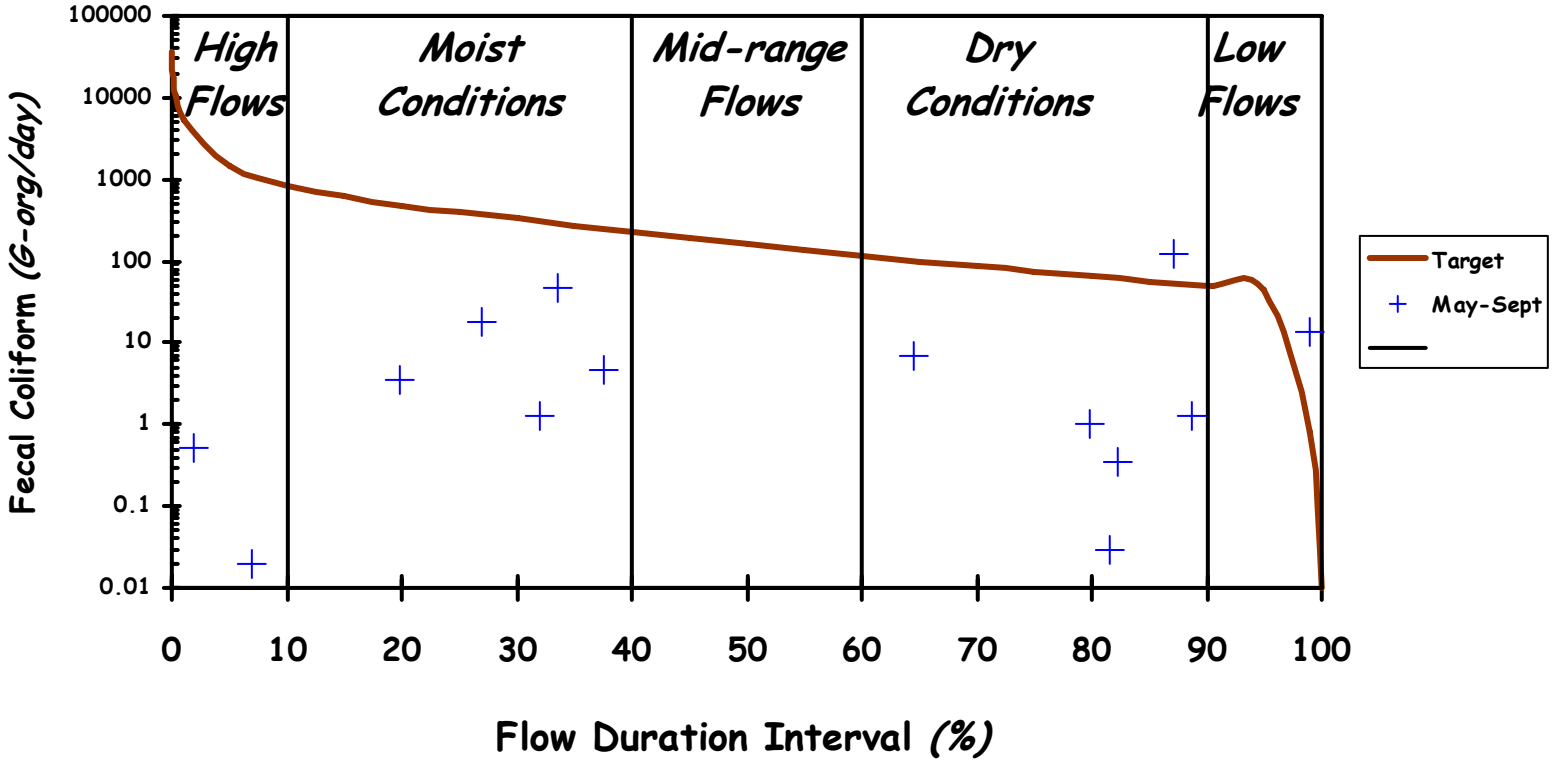
ADEQ Data & USGS Gage Duration Interval *42.2 square miles*

Little Strawberry River near Wiseman, AR
Load Duration Curve
(2001 - 2002 E.coli Monitoring Data (PCR-Winter))
Site: WHI0143H



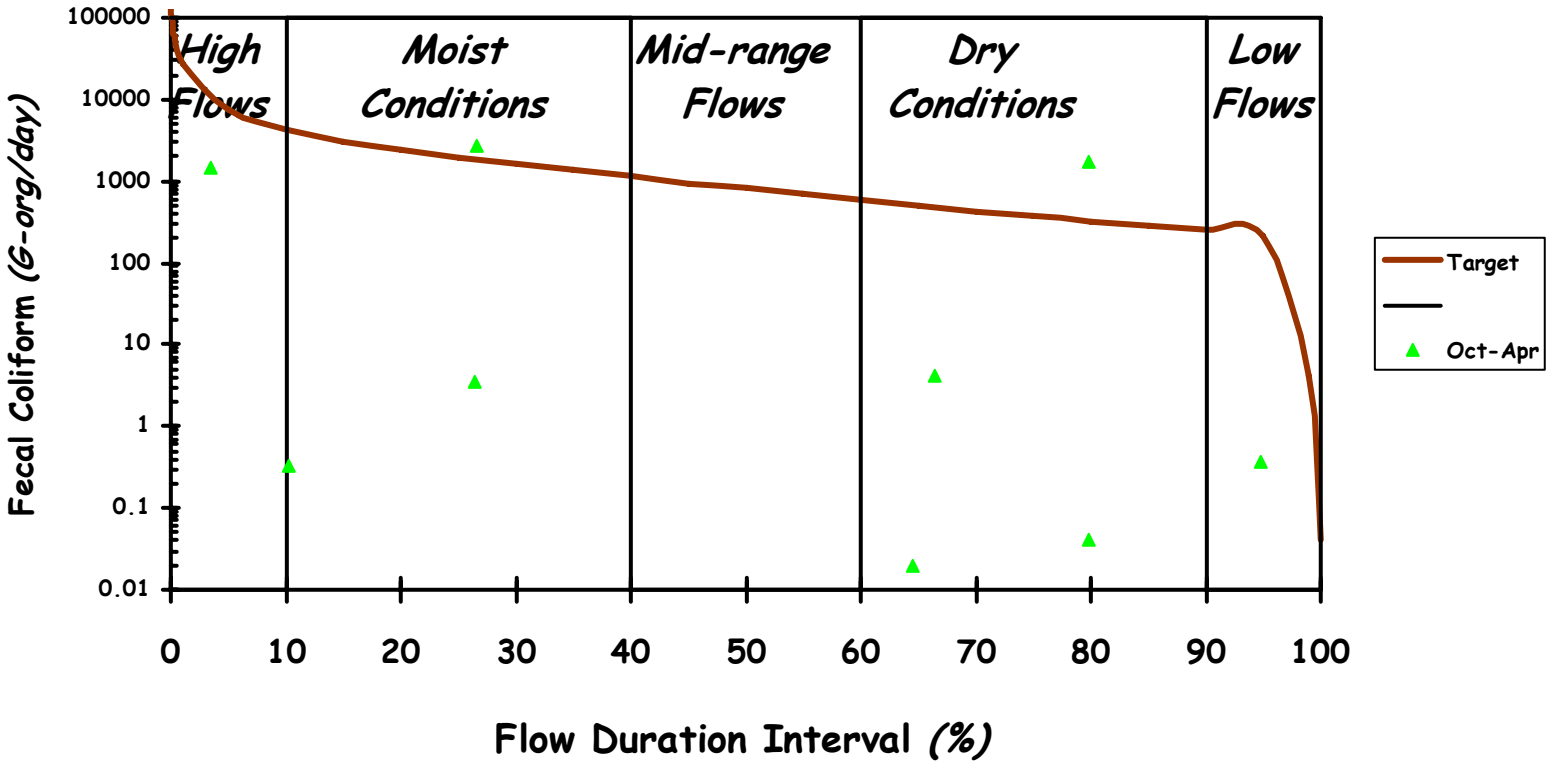
ADEQ Data & USGS Gage Duration Interval *42.2 square miles*

Little Strawberry River near Wiseman, AR
Load Duration Curve
(2001 - 2002 Fecal Coliform Monitoring Data (PCR-Summer))
Site: WHI0143H



ADEQ Data & USGS Gage Duration Interval *42.2 square miles*

Little Strawberry River near Wiseman, AR
Load Duration Curve
(2001 - 2002 Fecal Coliform Monitoring Data (PCR-Winter))
Site: WHI0143H



ADEQ Data & USGS Gage Duration Interval *42.2 square miles*

Appendix C

Figure 1 –Flow Duration Curve for Strawberry River at Poughkeepsie, AR

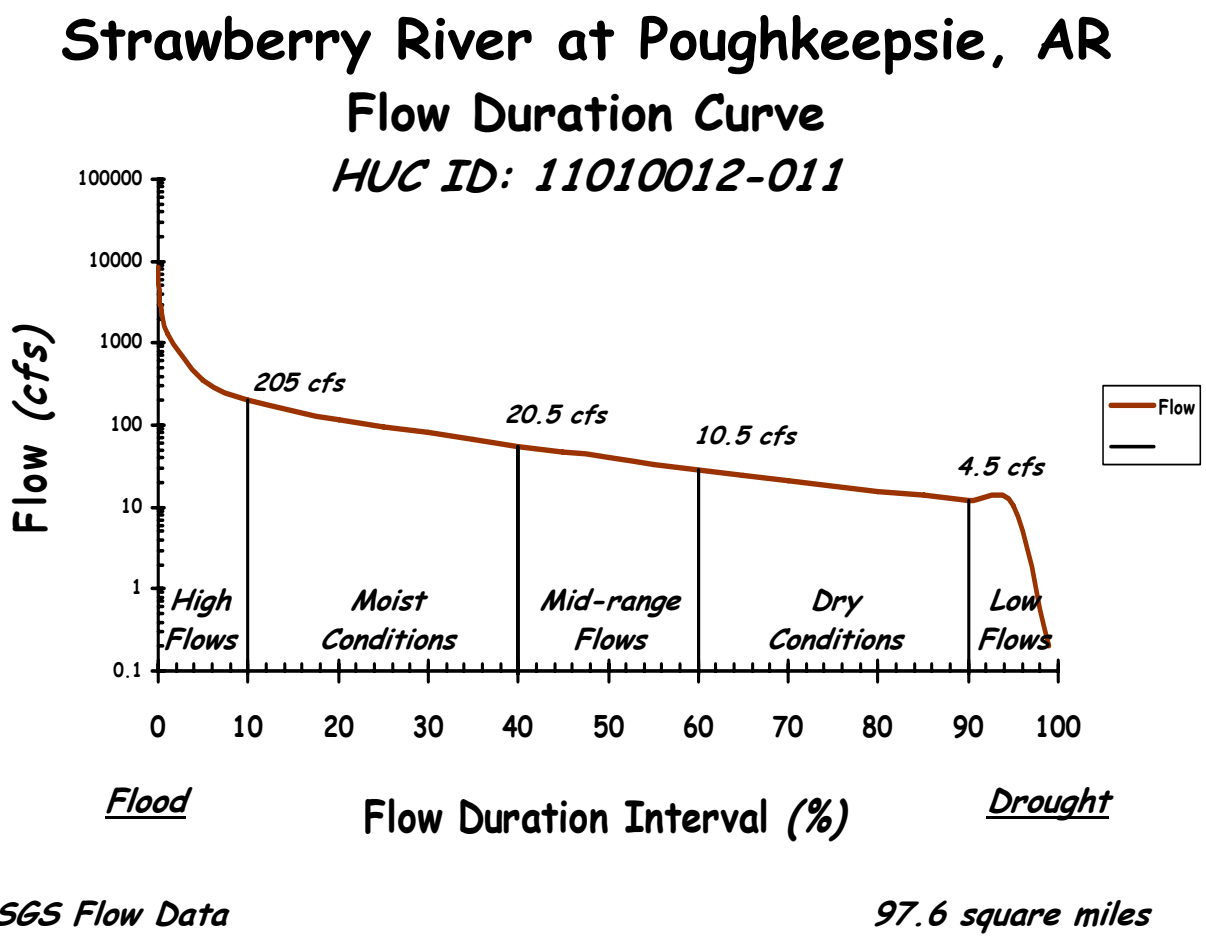


Table 1 –Flow Duration Curve for Strawberry River @ Poughkeepsie, AR

% > Flow	Flow (cfs)
0.005	42000
0.01	30155
0.1	12460
1	6405
5	1720
10	994
15	726
20	569
25	468
30	390
35	323
40	269
45	225
50	191
55	162
60	138
65	117
70	100
75	87
80	76
85	67
90	59
95	51
99	1
100	0.99

Figure 2 –Flow Duration Curve for Reed's Creek

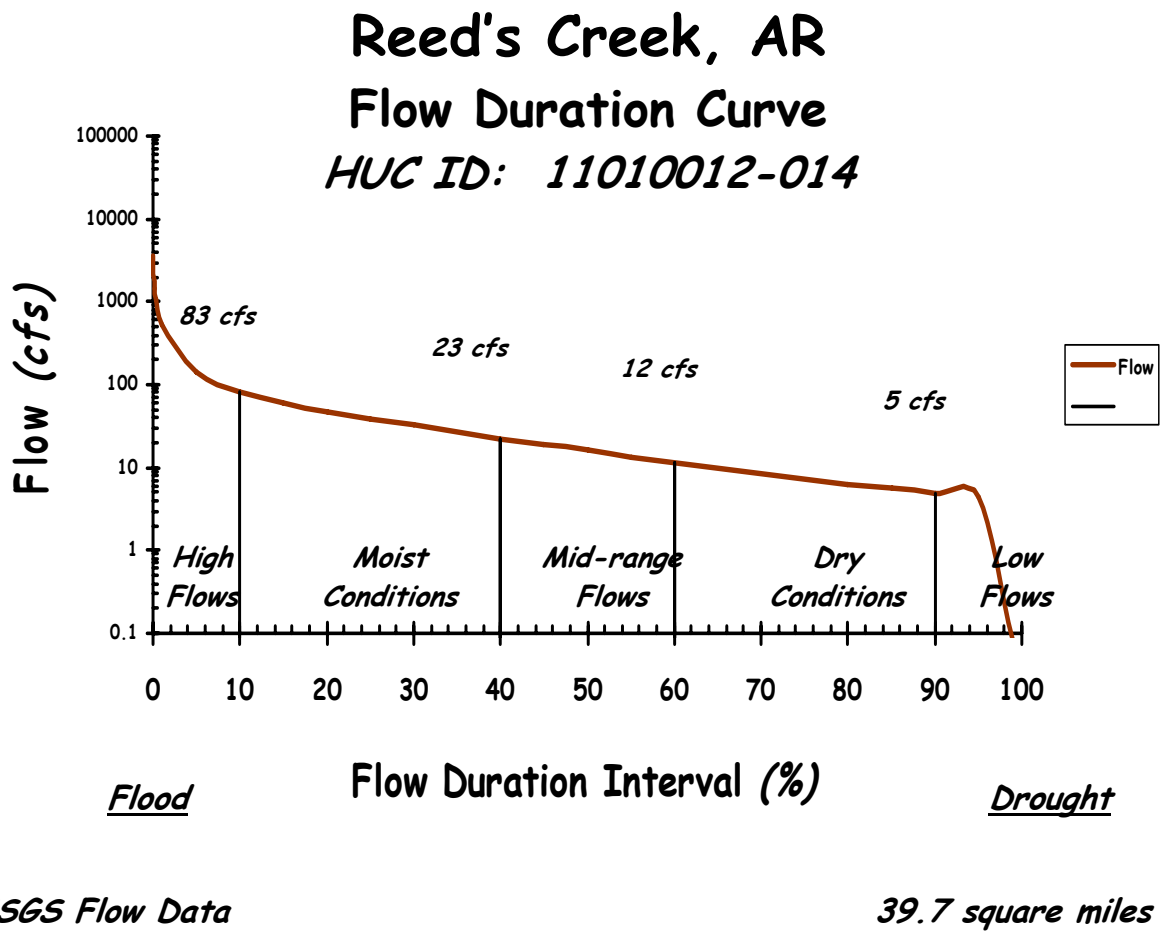


Table 2 –Flow Duration Curve for Reeds Creek

% > Flow	Flow (cfs)
0.005	3520.72
0.01	1452.09
0.1	1044.5
1	536.91
5	144.18
10	83.32
15	60.82
20	47.7
25	39.23
30	32.69
35	27.08
40	22.55
45	18.86
50	16.01
55	13.58
60	11.57
65	9.81
70	8.38
75	7.29
80	6.37
85	5.62
90	4.95
95	4.28
99	0.08
100	0

Figure 3 –Flow Duration Curve for Caney Creek

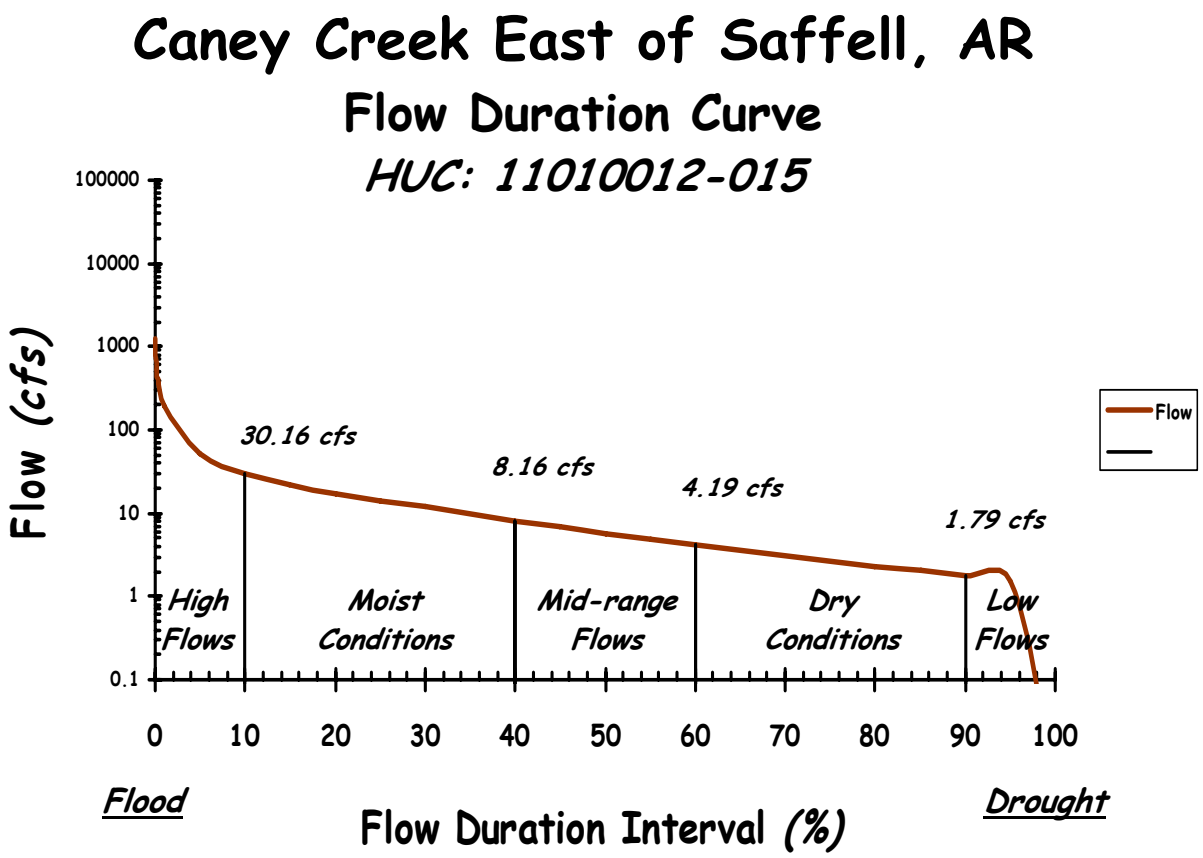


Table 3 –Flow Duration Curve for Caney Creek

% > Flow	Flow (cfs)
0.005	1274.21
0.01	525.53
0.1	378.02
1	194.32
5	52.18
10	30.16
15	22.01
20	17.26
25	14.2
30	11.83
35	9.8
40	8.16
45	6.83
50	5.79
55	4.91
60	4.19
65	3.55
70	3.03
75	2.64
80	2.31
85	2.03
90	1.79
95	1.55
99	0.03
100	0

Figure 3 –Flow Duration Curve for Cooper Creek

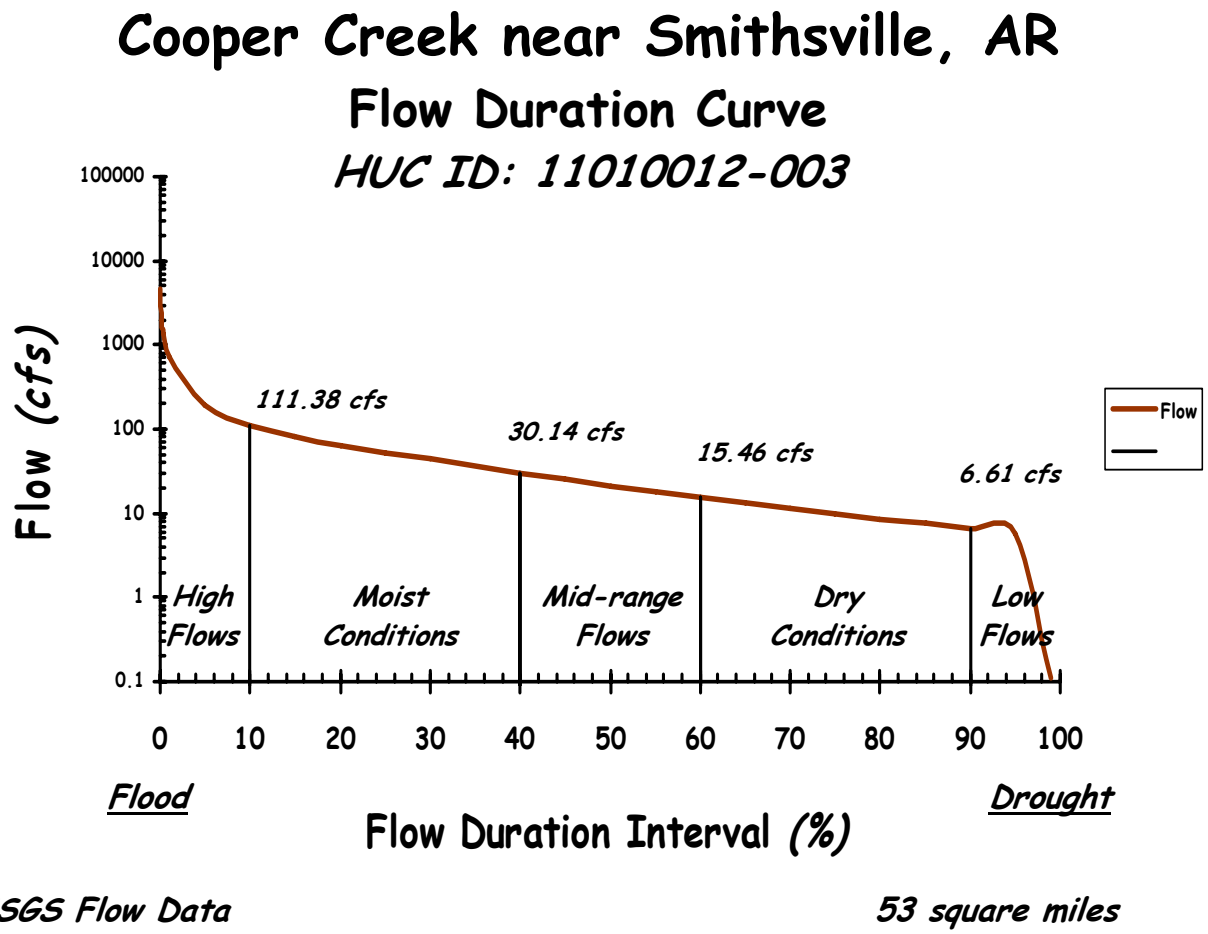


Table 4 –Flow Duration Curve for Cooper Creek

% > Flow	Flow (cfs)
0.005	4706.13
0.01	1941
0.1	1396.18
1	717.68
5	192.73
10	111.38
15	81.29
20	63.76
25	52.44
30	43.7
35	36.19
40	30.14
45	25.21
50	21.4
55	18.15
60	15.46
65	13.11
70	11.21
75	9.75
80	8.52
85	7.51
90	6.61
95	5.71
99	0.11
100	0

Figure 5 –Flow Duration Curve for Little Strawberry River

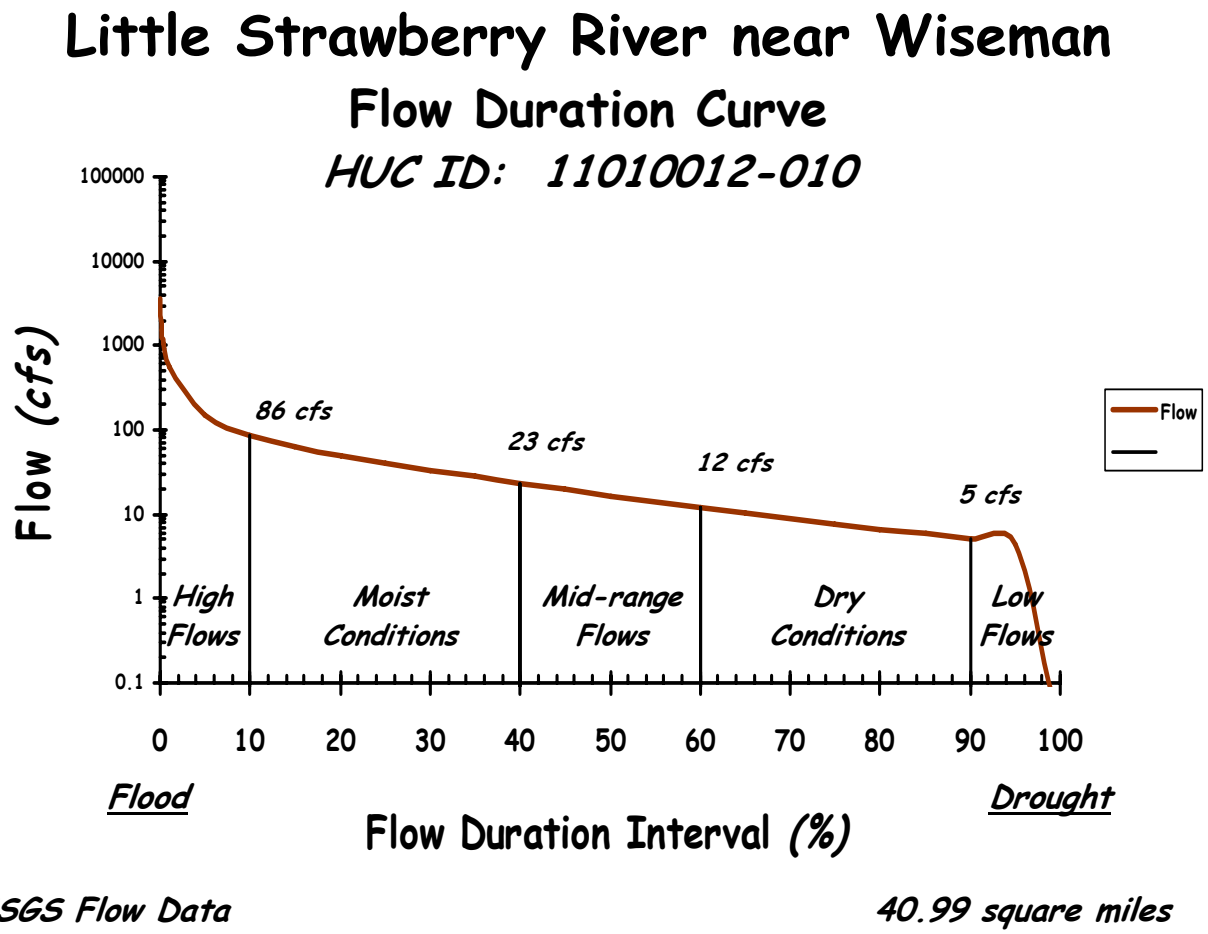


Table 5 –Flow Duration Curve for the Little Strawberry River

% > Flow	Flow (cfs)
0.005	4706.13
0.01	1941
0.1	1396.18
1	717.68
5	192.73
10	111.38
15	81.29
20	63.76
25	52.44
30	43.7
35	36.19
40	30.14
45	25.21
50	21.4
55	18.15
60	15.46
65	13.11
70	11.21
75	9.75
80	8.52
85	7.51
90	6.61
95	5.71
99	0.11
100	0

Figure 6 –Flow Duration Curve for Mill Creek

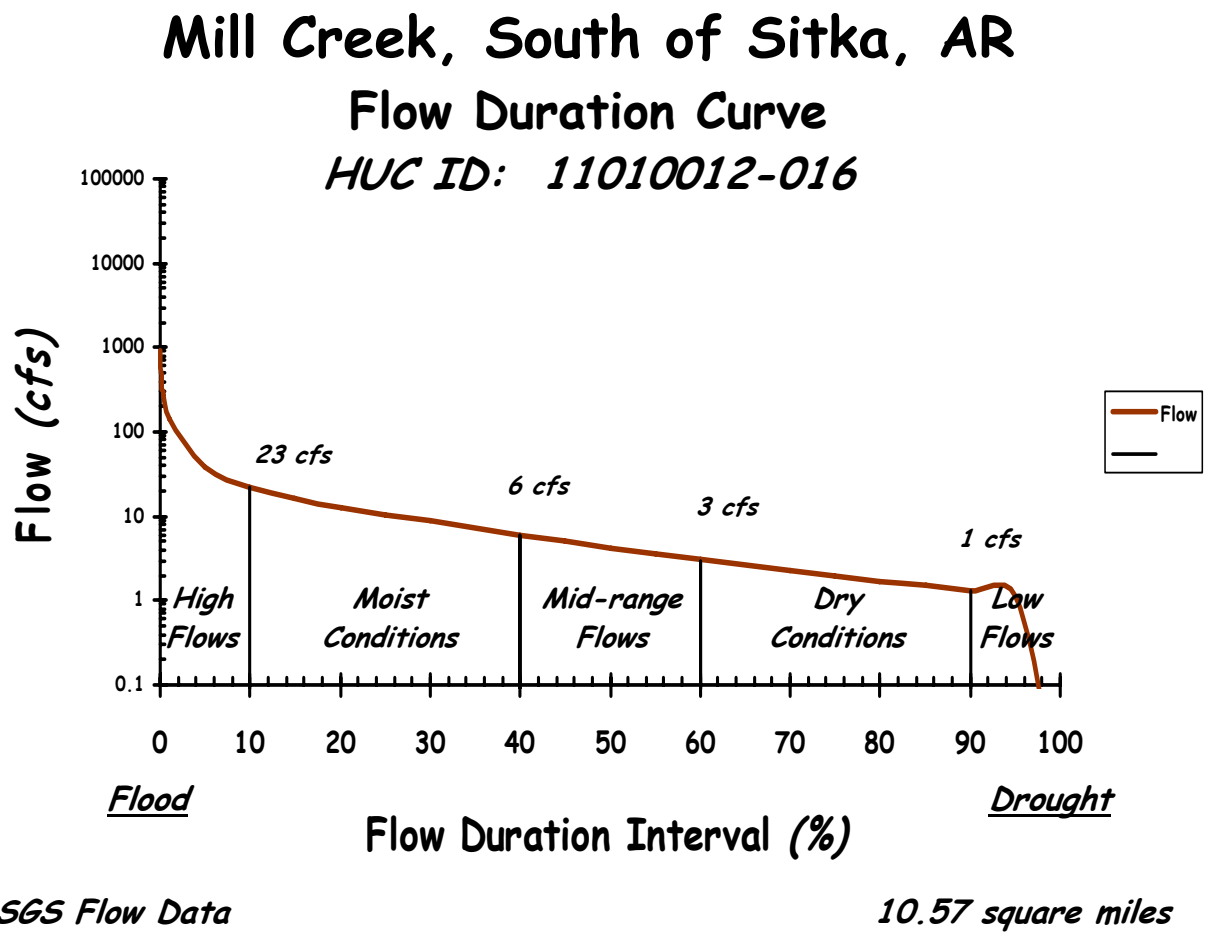


Table 6 –Flow Duration Curve for Mill Creek

% > Flow	Flow (cfs)
0.005	938.56
0.01	387.1
0.1	278.45
1	143.13
5	38.44
10	22.21
15	16.21
20	12.72
25	10.46
30	8.72
35	7.22
40	6.01
45	5.03
50	4.27
55	3.62
60	3.08
65	2.61
70	2.23
75	1.94
80	1.7
85	1.5
90	1.32
95	1.14
99	0.02
100	0

Figure 7 –Flow Duration Curve for Strawberry River (Segment 11010012-008)

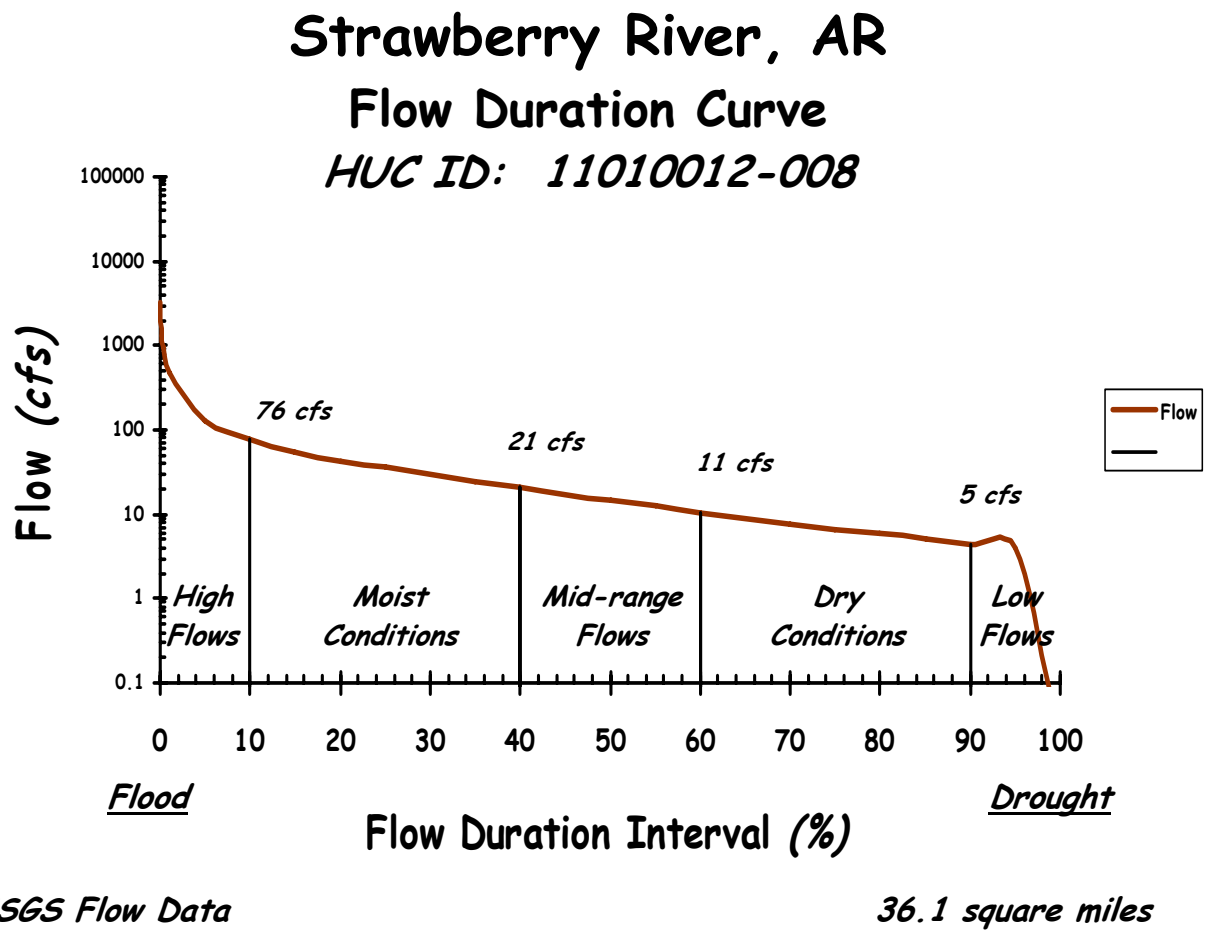


Table 7 – Flow Duration Curve for the Strawberry River (Segment 11010012-008)

% > Flow	Flow (cfs)
0.005	3204.61
0.01	1321.71
0.1	950.72
1	488.7
5	131.24
10	75.84
15	55.36
20	43.41
25	35.71
30	29.76
35	24.64
40	20.52
45	17.17
50	14.57
55	12.36
60	10.53
65	8.93
70	7.63
75	6.64
80	5.8
85	5.11
90	4.5
95	3.89
99	0.07
100	0

Figure 8 –Flow Duration Curve for Dota Creek

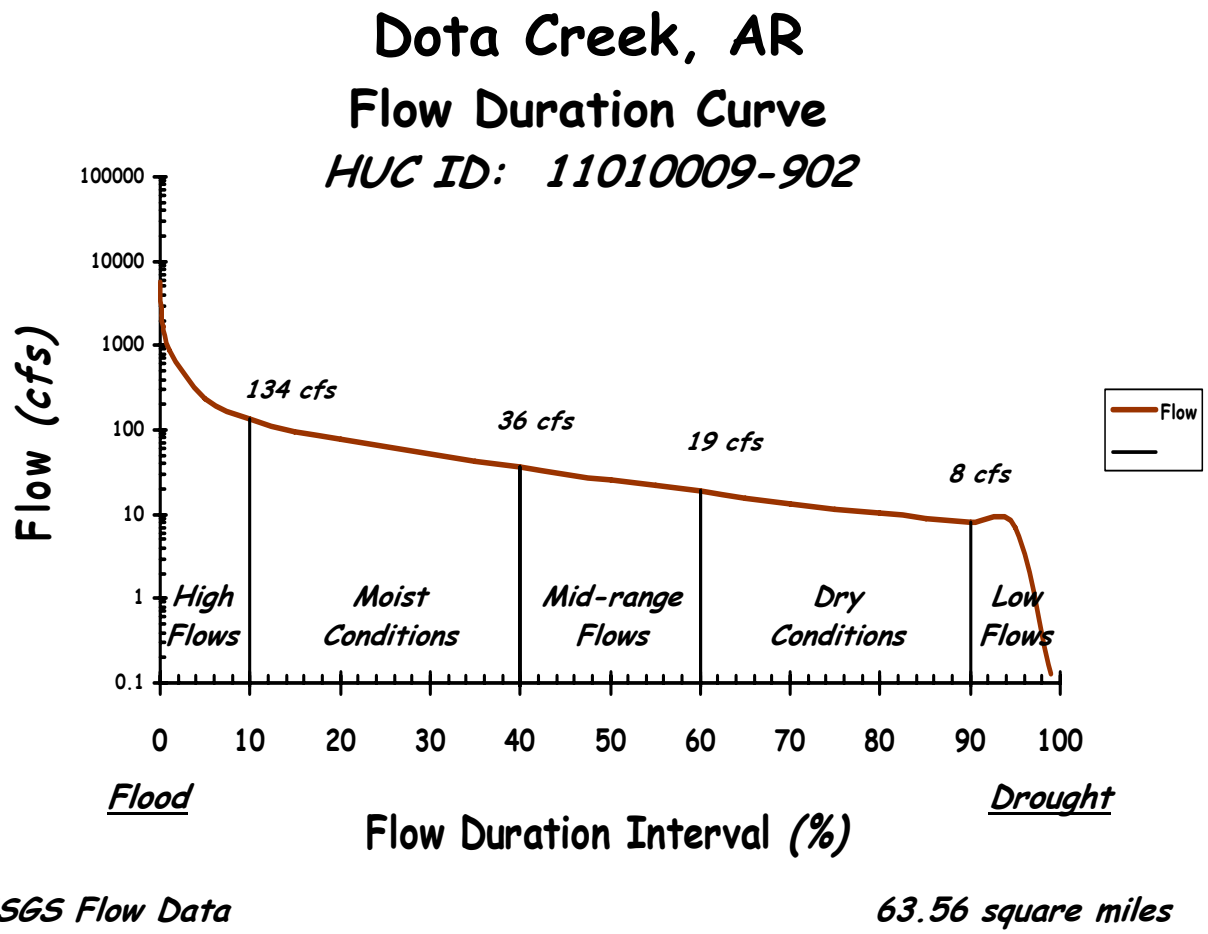


Table 8 – Flow Duration Curve for Dota Creek (11010009-902)

% > Flow	Flow (cfs)
0.005	5643.81
0.01	2327.73
0.1	1674.37
1	860.68
5	231.13
10	133.57
15	97.49
20	76.46
25	62.89
30	52.41
35	43.4
40	36.15
45	30.23
50	25.67
55	21.77
60	18.54
65	15.72
70	13.44
75	11.69
80	10.21
85	9
90	7.93
95	6.85
99	0.13
100	0