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LITTLE RED RIVER
WATERSHED MANAGEMENT PLAN

MAY 23, 2023

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WATERSHED MANAGEMENT PLAN

Prepared for

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ACRONYMS

ARCDC	Arkansas Resource Conservation and Development Council
AGFC	Arkansas Game and Fish Commission
BMP	best management practice
BOD	biochemical oxygen demand
C	degrees Celsius
cfs	Cubic feet per second
col/100mL	Colonies per 100 milliliters
CPPE	Conservation Practice Physical Effects program of NRCS
CRP	Conservation Reserve Program of FSA
CSP	Conservation Stewardship Program of NRCS
DEQ	Arkansas Department of Energy and the Environment, Division of Environmental Quality
DO	dissolved oxygen
E. Coli	Escherichia coli
EPA	US Environmental Protection Agency
EQIP	Environmental Quality Incentives Program of NRCS
ERW	Extraordinary Resource Waters
ESM	Environmentally Sensitive Maintenance
FSA	US Department of Agriculture Farm Service Agency
HUC	Hydrologic Unit Code
IBI	index of biotic integrity
kg	kilograms
mg/L	milligrams per liter
MMI	Multimetric Index
NRCS	US Department of Agriculture Natural Resources Conservation Service
NRD	Arkansas Department of Agriculture Natural Resources Division
NTU	Nephelometric turbidity unit
NWQI	National Water Quality Initiative of NRCS
RCPP	Regional Conservation Partnership Program of NRCS
SSC	suspended sediment concentration
sq km	square kilometer
SU	standard units (of pH)
TDS	total dissolved solids
TKN	total Kjeldahl nitrogen
TMDL	Total Maximum Daily Load
TNC	The Nature Conservancy
TSS	total suspended solids
USACE	US Army Corps of Engineers
USDA	US Department of Agriculture
USFWS	US Fish and Wildlife Service
USGS	US Geological Survey
WRAS	Watershed restoration action strategy
WWTP	wastewater treatment plant
yr	year

1.0 INTRODUCTION

This management plan addresses the Little Red River Watershed. The primary focus of this plan is protection and improvement of surface water quality in the Little Red River and Greers Ferry Lake, and their tributaries, through management of unregulated nonpoint sources of pollution.

1.1 Plan Need and Mission

The Little Red River is one of the 12 Nonpoint Source Program priority watersheds designated by Arkansas Department of Agriculture Natural Resources Division (NRD) in 2022 (P. Massirer, FTN Associates, Ltd, personal communication, June 2022). There are stream reaches in the Little Red River watershed that are included on the most recent approved (2018) state impaired waters list (303(d) list) due in part to pollution from nonpoint sources. In addition, protection of the drinking water supply reservoir, Greers Ferry Lake, and populations of an endangered fish species and threatened and endangered mussels are a concern. Therefore, the Little Red River watershed was selected by NRD for development of a watershed management plan to address water quality impairments, protect a drinking water supply, protect threatened and endangered aquatic species, and meet the agency goal for development of watershed management plans.

The primary focus of this plan is the **protection** and **improvement** of surface water quality in Little Red River, Greers Ferry Lake, and its tributaries through management of unregulated nonpoint sources of pollution. The mission of the watershed management plan for the Little Red River watershed is to: Increase awareness of water quality issues through outreach and education and increase voluntary implementation of effective water quality management practices. There are agencies and interest groups with active outreach and education programs in the Little Red River watershed. These entities work to increase public awareness of water quality issues in the watershed and encourage practices that address those issues. This plan supports the efforts of these organizations.

1.2 Watershed Vision

The vision for the Little Red River watershed is: The desired and designated uses of Little Red River and its tributaries, including Greers Ferry Lake, are attained and sustained, resulting in healthy streams that enhance the socioeconomic, agricultural, and natural amenity benefits of the watershed, as visitors, landowners, and local communities work together to protect and improve both water resources and the quality of life throughout the watershed.

Each community, landowner, and producer has their own vision for their part of the watershed. In addition, there are a number of agricultural and natural resources agencies and other organizations that work within the Little Red River watershed to manage its natural resources. Some of them have developed plans that document their missions, visions and/or goals for the Little Red River watershed. Some of these are described in Appendix A. Overall, the vision above is compatible with, and supportive of, those of other programs and organizations active in the watershed.

1.3 Process

Development of the Little Red River watershed management plan followed the steps outlined by US Environmental Protection Agency (EPA) in the Handbook for Developing Watershed Plans (EPA 2008):

1. Building partnerships,
2. Characterizing the watershed,
3. Finalizing management goals and identifying solutions, and
4. Designing an implementation program.

NRD worked with consultants to develop this watershed management plan, utilizing the input of watershed stakeholders. Four public meetings were held as part of the process of developing the Little Red River watershed management plan. Three in person public meetings were held at different locations in the watershed and a fourth public meeting was held using Zoom. The purposes of these public meetings were to inform stakeholders of the plan and the process for developing it, and to request and obtain stakeholder input for the plan. Stakeholder input was sought specifically in identifying priority issues in the watershed and selecting management practices for addressing nonpoint source pollution in the watershed. Stakeholders who participated in development of this plan included local residents, representatives of federal and state legislatures, US Department of Agriculture Natural Resources Conservation Service (NRCS), US Fish and Wildlife Service (USFWS), Arkansas Department of Health, Arkansas natural resources agencies, University of Arkansas (UofA) Cooperative Extension Service, County Conservation Districts, and recreation and environmental interest groups. Attendance summaries from the meetings are included in Appendix B.

1.4 Document Overview

This document contains elements recommended by EPA for watershed management plans. Section 2 describes many of the features of the watershed. Section 3 summarizes conditions in the watershed, including water quality, hydrology, and ecology; and nonpoint pollutant sources in the Little Red River watershed. Section 4 identifies subwatersheds recommended for initial management of nonpoint pollutant sources, pollutant load reduction targets, and management strategies for controlling nonpoint source pollution in the recommended subwatersheds. Section 5 outlines the overall implementation plan, with schedule, list of management and outreach activities, and identification of indicators and monitoring to track progress and effects. Section 6 discusses costs and benefits of proposed management, and assistance that is available for implementation of nonpoint source pollution management practices. Watershed-based management plans developed to meet the requirements for Clean Water Act Section 319 funding must address nine planning elements required by EPA to manage and protect against nonpoint source pollution. Table 1.1 provides a roadmap for where the required planning elements are addressed in this plan.

Table 1.1. The required nine planning elements to manage and protect against nonpoint source pollution, and the location of the elements within this plan.

Element	Report Section(s)
Element A: Identification of Causes and Sources	
1. Sources identified, described, and mapped	3.4, 4.6
2. Subwatershed sources	4.6
3. Data Sources are accurate and verifiable	all
4. Data gaps	3.1.7, 3.2.6, 3.3.7
Element B: Expected Load Reductions	
1. Load reductions achieve environmental goal	4.8
2. Load reductions linked to sources	4.8, Appendix I
3. Model complexity appropriate	Appendix I
4. Basis of effectiveness estimates explained	4.7, 4.8, Appendix I
5. Methods and data cited and verifiable	Appendix I
Element C: Management Measures Identified	
1. Specific management measures are identified	4.7
2. Priority areas	4.3, Appendix H, 4.8, 4.9
3. Measure selection rationale documented	4.0
4. Technically sound	4.0
Element D: Technical and Financial Assistance	
1. Estimate of technical assistance	6.3
2.Estimate of financial assistance	6.1, 6.4, Appendix K
Element E: Education/Outreach	
1. Public education/information	5.1
2. All relevant stakeholders are identified in outreach process	1.0, Appendices A and B, 5.2
3. Stakeholder outreach	5.1, Appendix J
4. Public participation in plan development	Appendix B
5. Emphasis on achieving water quality standards	1.0, 4.4, 4.5, 4.8, 5.5, 5.6.3
6. Operation & maintenance of BMPs	5.3, 6.3.3
Element F: Implementation Schedule	
1. Includes completion dates	5.8
2. Schedule is appropriate	5.8
Element G: Milestones	
1. Milestones are measurable and attainable	5.8
2. Milestones include completion dates	5.8
3. Progress evaluation and course correction	5.5, 5.6, 5.8
4. Milestones linked to schedule	5.8

2.0 WATERSHED DESCRIPTION

2.1 Geography

The Little Red River watershed, identified by US Geological Survey (USGS) as 8-digit Hydrologic Unit Code [HUC] 11010014, encompasses 1,802 square miles (1,166,879 acres) within the White River Basin in Northern Arkansas (Figure 2.1). The headwaters of the Little Red River originate in Searcy and Van Buren Counties. From there the forks of the Little Red River flow east into Cleburne County, where the Little Red River is dammed to form Greers Ferry Lake. The Little Red River flows southwest out of the reservoir, into White County, where it joins the White River between Georgetown and Augusta. The watershed is wide and irregularly shaped, and includes parts of Searcy, Pope, Van Buren, Stone, Cleburne, White, Jackson, and Independence Counties (Table 2.1). A number of towns are located within the watershed, including Clinton, Fairfield Bay, Greers Ferry, Heber Springs, Searcy, Judsonia, and Bald Knob. US Highways that cross the watershed include 65, 67, and 167.

Table 2.1 County areas within the Little Red River watershed.

Counties	County area (square miles)	Area within watershed (square miles)	Percent of County within watershed	Percent of watershed within County
Cleburne	592.1	459.9	78%	26%
Conway	566.5	0.04	0.01%	0.002%
Independence	771.5	31.8	4.1%	1.8%
Jackson	641.5	1.4	0.2%	0.1%
Pope	830.6	10.8	1.3%	0.6%
Searcy	668.4	135.9	20%	7.5%
Stone	609.6	230.4	38%	13%
Van Buren	723.9	525.2	73%	29%
White	1,042.0	406.0	39%	23%

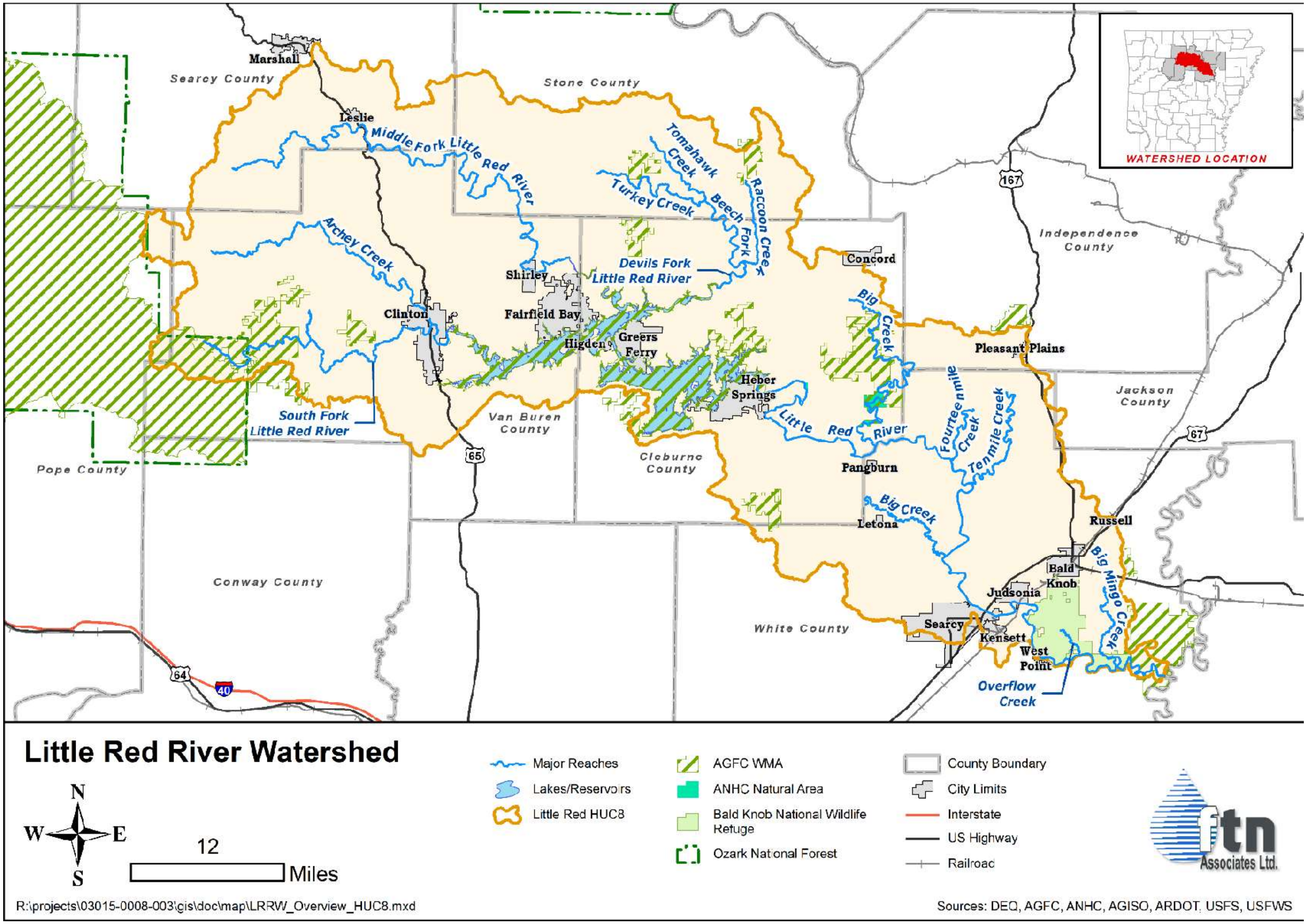


Figure 2.1. Map of Little Red River watershed.

2.2 Socioeconomics

This section summarizes demographic and economic information for the Little Red River watershed.

2.2.1 Population

Around 80,000 Arkansans live in the Little Red River watershed (NRD 2014, Arkansas Center for Advanced Spatial Technologies 2006). Numbers of people in counties with more than 50 square miles in the Little Red River watershed are presented in Table 2.2. The counties with significant areas within the Little Red River watershed all experienced population declines between 2010 and 2020. Population projections for 2035 suggest that population in Stone and White Counties is expected to increase. Population in the remaining counties is expected to continue to decline.

Table 2.2. Population information for selected counties associated with Little Red River watershed and Arkansas as a whole (Arkansas Economic Development Institute 2020).

Area	2010 Total Population	2010 Population Density (number/square mile)	2020 Total Population	2020 Population Density (number/square mile)	Percent Population Change 2010 – 2020	2035 Projection
Cleburne County	25,970	43.9	24,711	41.7	-4.8%	23,459
Searcy County	8,195	12.3	7,828	11.7	-4.5%	7,503
Stone County	12,394	20.3	12,359	20.3	-0.3%	15,275
Van Buren County	17,295	23.9	15,796	21.8	-8.7%	14,386
White County	77,076	74.0	76,822	73.7	-0.3%	77,653
State of Arkansas	2,915,919	56.1	3,011,524	57.9	3.3%	3,388,943

The US Census Bureau classifies the majority of the Little Red River watershed as rural. Within the watershed, Heber Springs, Searcy, and Bald Knob are classified by the US Census Bureau as urbanized areas (US Census Bureau 2016). White County is designated the Searcy Micropolitan Statistical Area (US Census Bureau 2021).

Additional demographic information for selected counties associated with the Little Red River watershed is listed in Table 2.3. This includes percentages of the population for characteristics of gender, age, race, education level, and household structure. The median age in most of the watershed counties is older than for the state as a whole. These counties have higher percentages of people aged 45 and over than the state. White County has a higher percentage of people 18 to 24 years old than the state, possibly due to the presence of Harding University. The majority of people in the watershed consider themselves white, non-Hispanic. These counties tend to have slightly higher percentages of High School graduates, but slightly lower percentages of people with college education than the state as a whole. Household structure distribution in these counties is similar to that for the state as a whole.

Table 2.3. Demographic information for selected counties associated with Little Red River watershed and Arkansas as a whole.

Information	Cleburne County	Searcy County	Stone County	Van Buren County	White County	State of Arkansas
Gender						
Female	50.1%	50.0%	50.6%	50.6%	51.1%	50.9%
Male	49.9%	50.0%	49.4%	49.4%	48.9%	49.1%
Age						
Median Age	49.5	48.4	50	48.6	37.1	38.3
Under 18	19.0%	19.7%	19.7%	19.3%	23.4%	23.3%
18 to 24 years	6.3%	8.0%	6.3%	6.9%	11.6%	9.4%
25 to 44 years	20.6%	18.8%	19.2%	19.2%	23.7%	25.4%
45 to 64 years	27.4%	27.8%	27.8%	28.8%	25.1%	24.9%
65 and older	26.8%	25.6%	27.1%	25.9%	16.3%	16.9%
Race						
White non-Hispanic	92.1%	90.6%	92.1%	90.6%	83.8%	68.5%
Black non-Hispanic	0.2%	0.1%	0.2%	0.4%	4.8%	14.9%
Native American	0.5%	0.8%	0.7%	0.7%	0.4%	0.7%
Asian	0.4%	0.3%	0.2%	0.4%	0.8%	1.7%
Other race	0.2%	0.3%	0.3%	0.1%	0.3%	0.7%

Table 2.3. Demographic information for selected counties associated with Little Red River watershed and Arkansas as a whole (continued).

Information	Cleburne County	Searcy County	Stone County	Van Buren County	White County	State of Arkansas
Education						
Less than High School Graduate	13.8%	18.9%	20.6%	15.5%	13.3%	12.8%
High School Graduate (or Equivalency)	42.0%	42.0%	34.1%	42.2%	38.6%	34.0%
Some College or Associate's Degree	28.6%	28.9%	33.4%	27.3%	29.3%	31.2%
Bachelor's Degree	9.8%	7.5%	8.9%	9.0%	11.6%	14.4%
Graduate Degree	6.1%	3.1%	3.3%	6.4%	8.4%	8.6%
Household Structure						
Family households	98.8%	99.0%	98.9%	98.9%	95.3%	97.2%
Two parent families	24.4%	24.5%	21.3%	24.2%	20.4%	20.9%
Single parent families	24.1%	24.2%	21.0%	23.9%	20.1%	20.6%
Single person household	13.3%	11.1%	11.5%	12.8%	10.1%	11.2%
Other non-family household	1.2%	1.0%	1.1%	1.1%	4.7%	2.8%

2.2.2 Economics

County economic information from the US Census Bureau American Community Survey is summarized in Table 2.4. Per capita income in counties with more than 50 square miles in the Little Red River watershed, shown in Table 2.4, is lower than for the state as a whole. However, this does not necessarily translate to higher percentages of people living below the poverty level. In the counties of the Little Red River watershed listed in Table 2.4, higher percentages of people are self-employed, and work in service, natural resources, construction, maintenance, production, transportation, and material moving industries than at the state level.

Table 2.4. US Census Bureau American Community Survey economic information for selected counties of the Little Red River watershed (US Census Bureau 2022).

Information	Cleburne County	Searcy County	Stone County	Van Buren County	White County	State of Arkansas
Per Capita Income	$27,490	$19,761	$20,462	$23,244	$23,801	$27,724
Families below poverty level	10.1%	18.5%	12.1%	11.5%	11.2%	11.8%
People below poverty level	14.3%	25.9%	20.4%	16.3%	14.4%	16.1%
Unemployment rate	5.1%	3.7%	8.2%	7.1%	4.9%	5.2%
Mgmt, business, science, arts	27.5%	25.0%	30.7%	27.8%	32.9%	34.9%
Service	19.9%	17.6%	19.5%	18.7%	18.7%	16.6%
Sales, office	19.7%	22.6%	15.3%	18.6%	19.1%	21.2%
Natural resources, construction, maintenance	15.1%	11.6%	23.2%	13.0%	12.0%	10.1%
Production, transportation, material moving	17.8%	23.1%	11.3%	21.9%	17.2%	17.3%
Self-employed	10.7%	9.8%	19.0%	10.1%	5.3%	6.0%

Drivers of the economy in the Little Red River watershed include agriculture, outdoor recreation, and natural resources extraction. The values of sales and receipts reported for selected economic sectors in selected counties of the Little Red River watershed, in the 2017 economic census, are summarized in Table 2.5. Manufacturing and retail trade reported the highest revenues in these counties.

Table 2.5. Value of county sales, shipments, receipts, revenue, or business done ($1,000) reported in the 2017 Economic Census of the US (US Census Bureau 2017).

Industry	Cleburne County	Searcy County	Stone County	Van Buren County	White County	Sum
Manufacturing	$256,291	$23,586	$18,295	$11,947	$761,143	$2,800,216
Wholesale trade	$35,670	D	$30,267	$36,275	$350,773	$844,980
Retail trade	$412,542	$51,315	$126,398	$159,558	$1,051,907	$2,696,958
Transportation and warehousing	D	NA	D	$32,517	$156,231	$276,029
Real estate and rental and leasing	$8,550	$1,762	$877	$1,510	$33,124	$92,358
Professional, scientific, and technical services	$9,330	$1,123	$2,368	$5,621	$54,244	$161,822
Administrative and support and waste management and remediation services	$14,604	NA	NA	$5,695	$36,197	$174,793
Educational Services	NA	NA	NA	NA	$1,476	$1,476
Health care and social assistance	$60,778	$13,827	$39,470	$55,491	$425,000	$594,566
Arts, entertainment, and recreation	$9,012	NA	NA	D	$9,774	$22,144
Accommodation and food services	$35,689	D	$19,661	$14,461	$126,172	$332,783
Other services (except public administration)	$11,092	NA	$4,433	D	$53,512	$107,844

D - Withheld to avoid disclosing data for individual companies; data are included in higher level totals
NA- data not available

Agriculture is not an economic sector reported in the economic census. However, agriculture contributes value to manufacturing, real estate, wholesale trade, and transportation and warehousing economic sectors (English and Popp 2022). Table 2.6 lists the value of sales of agricultural products reported for five counties of the Little Red River watershed in the 2017 census of agriculture. Cattle and poultry production are important in most of the Little Red River watershed. Row crops dominate in the farthest downstream areas of the watershed, located in the

Delta region. Poultry and eggs account for the greatest sales in four of the counties, and cattle account for the greatest sales in the other two counties.

Table 2.6. Value of county sales of agricultural commodities in thousands of dollars (USDA National Agricultural Statistics Service 2017).

Commodity	Cleburne County	Searcy County	Stone County	Van Buren County	White County	State of Arkansas
All agricultural products	$57,552	$18,024	$60,192	$16,347	$124,715	$9,651,160
All crops	$1,490	$1,331	$959	$1,074	$34,182	$3,624,930
Rice	-	-	-	-	$8,359	$922,214
Soybeans	-	-	-	-	$14,638	$1,717,830
Cotton	-	-	-	-	-	$342,825
Corn	-	-	-	-	$3,089	$386,041
Wheat	-	-	-	-	D	$29,023
Other crops and hay	$1,417	$1,254	$740	$1,009	$3,296	$110,864
Fruit & tree nut	$58	$67	$198	D	$1,344	$19,535
Vegetable (including seeds, transplants)	D	$9	D	$36	D	$45,129
All livestock	$56,063	$16,693	$59,234	$15,273	$90,533	$6,026,230
Cattle & calves	$14,998	$14,174	$21,761	$10,463	$14,082	$737,961
Poultry & eggs	$40,504	$2,303	$37,224	$4,594	$74,822	$5,112,242
Hogs & pigs	D	D	D	D	D	$69,438
Horses, etc.	$174	D	$37	$177	$183	$10,525
Sheep, goats products	$33	$22	$54	D	$246	$4,190
Aquaculture	D	-	-	-	-	$71,121

D - Withheld to avoid disclosing data for individual companies; data are included in higher level totals

Tourism in Arkansas rebounded in 2021 after declining in 2020. From 2020 to 2021 visitor spending increased 33%, returning to 2019 levels. Tourism related jobs increased 24% between 2020 and 2021 but were still 5% lower than in 2019 (Arkansas Department of Parks, Heritage and Tourism 2022). County-level data from 2021 have not yet been released, so a summary of 2020 travel-related revenue for selected counties of the Little Red River watershed is provided in Table 2.7.

Table 2.7. Travel impact data for selected counties of the Little Red River watershed (Arkansas Department of Parks, Heritage and Tourism 2021).

Industry	Cleburne County	Searcy County	Stone County	Van Buren County	White County	**Sum**
Total County Expenditures (Millions)	110.1	16.2	44.5	48.1	88.5	406.2
Travel-Generated Payroll (Millions)	22.6	3.3	10.7	9.9	18.4	84.5
Travel-Generated Employment (Jobs, Thousands)	853.0	118.0	398.0	381.0	753.0	3249.0
Travel-Generated State Tax (Millions)	7.2	1.1	2.9	3.3	5.8	25.1
Travel-Generated Local Tax (Millions)	3.4	0.4	1.0	1.5	1.7	9.7
2% Tax (Thousands)	200.5	68.6	105.9	68.1	200.3	803.5

The US Army Corps of Engineers (USACE) has estimated the regional economic impact of recreation at Greers Ferry Lake reservoir. Impacts for fiscal year 2021 to areas within 30 miles of the reservoir are listed in Table 2.8.

Table 2.8 Fiscal year 2021 economic impacts of recreation at Greers Ferry Lake, within 30 miles of the reservoir (USACE 2022).

Commodity	**Greers Ferry Lake Economic Data**	**Greers Ferry Lake Economic Data with Multiplier Effect**
Visitor spending ($1,000)	$104,929,162	Not available
Sales ($1,000)	$75,729,038	$116,199,748
Jobs supported/created	723	1,041
Labor income ($1,000)	$21,011,326	$32,009,427
Value added ($1,000)	$35,296,646	$54,344,631

The USFWS National Wildlife Refuges act as economic engines for the areas where they are located. The USFWS estimated the local economic impact of selected National Wildlife Refuges for fiscal year 2017 in the Banking on Nature 2017 report. According to this report, the Bald Knob NWR experienced 19,344 recreation visits during the 2017 fiscal year, generating

$7,768,000 of economic output, $2,466,000 in employment income, and 9 jobs (Caudill and Carver 2019).

2.3 Ecoregions

Four Level III, and five Level IV ecoregions occur in the Little Red River watershed (Figure 2.2). Table 2.9 summarizes the characteristics of these ecoregions. These characteristics are described in greater detail in the following subsections.

2.3.1 Climate

Climate normals are 30-year averages of climate data, calculated at individual recording stations for the United States by the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information. For the Little Red River watershed, the 1991-2020 climate normals are estimated by averaging normal from weather stations at Marshall, Greers Ferry Dam, and Searcy Arkansas. The average annual precipitation is approximately 51 inches. The lowest average monthly precipitation occurs in August and June, with the highest occurring in April and May. The warmest average monthly temperatures occur in July and August, while the coldest occur in January. The average monthly precipitation and the average monthly minimum and maximum temperatures are shown on Figure 2.3 (NOAA 2021).

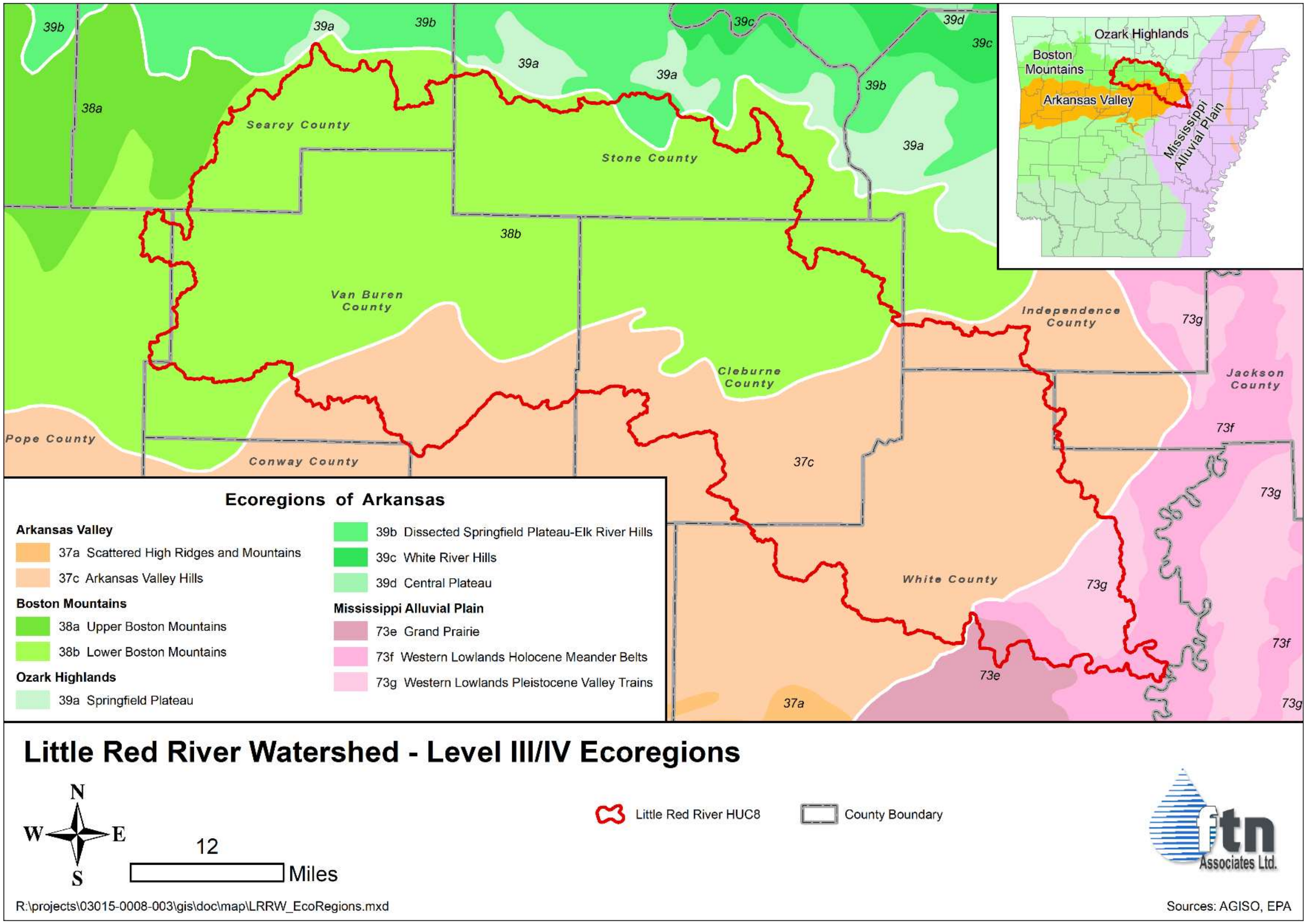


Figure 2.2. Ecoregions map of the Little Red River watershed (US EPA 2014).

Table 2.9. Characteristics of Level IV ecoregions of the Little Red River watershed (from Woods et al. 2004).

Level III ecoregion code and name	Level IV ecoregion code and name	Topography	Hydrology	Elevation/local relief (feet)	Geology	Common soil series	Mean annual precipitation (inches)	Natural vegetation
37	37c. Arkansas Valley Hills	Mostly hills, valleys, and cuestas; also scattered low mountains that are too small and discontinuous to map as part of Ecoregion 37a.	N/A	250-1000; uplands are lowest in the east/ 50-600	Quaternary colluvium and alluvium. Mostly Pennsylvanian sandstone and shale. Easternmost areas: shale, limy sandstone, sandy limestone, siltstone, and fine-grained sandstone.	Mostly Linker, Mountainburg; also Leadvale, Steprock, Enders, Sidon. On terraces and floodplains: Spadra, Ouachita.	43-51	Potential natural vegetation: oak–hickory forest and oak–hickory-pine forest. Common native trees include blackjack oak, post oak, red oak, white oak, hickories, and shortleaf pine. Today, upland oaks, loblolly pine, shortleaf pine, and hickory occur.
38	38a. Upper Boston Mountains	Dissected, rugged mountains with steep slopes, sharp ridges, and narrow valleys. Benches on the mountainsides occur and are characteristic.	Summer flow in many streams is zero or near zero but enduring pools fed by interstitial flow occur.	Mostly 1900-2800/ 300-900	Quaternary colluvium and alluvium. Pennsylvanian sandstone, shale, limy sandstone, sandy limestone, and siltstone. Mountaintops: generally capped by resistant sandstone. Sideslopes: interbedded sandstone, siltstone, and shale.	Uplands: Enders, Nella, Steprock, Mountainburg, Leesburg, Sidon, Nauvoo; upland soils have low natural fertility. Terraces and floodplains: Spadra, Ceda.	52-54	Potential natural vegetation: oak–hickory forest. Mixed deciduous forest and oak woodlands are native. Today, on upland areas: northern red oak, white oak, pignut hickory, and mockernut hickory. Today, on narrow floodplains and low terraces: sweetgum, willows, birch, American sycamore, hickories, southern red oak, and white oak.
38	38b. Lower Boston Mountains	Low mountains, rounded high hills, and undulating plateaus.	Summer flow in many streams is zero or near zero but enduring pools fed by interstitial flow occur	Mostly 200-1900; up to 2300/ 150-800	Quaternary colluvium and alluvium. Pennsylvanian sandstone, shale, limy sandstone, sandy limestone, and siltstone. Mountaintops are usually capped by resistant sandstone. Sideslopes are often underlain by interbedded sandstone, siltstone, and shale.	Uplands: Enders, Nella, Mountainburg, Steprock, Nella, Linker, Sidon; in east, Steprock and Linker are more widespread than in west. On floodplains and terraces: Ceda, Cleora, Razort, Spadra. Upland soils have low natural fertility.	46-52. The east is moister than the west.	Potential natural vegetation: oak–hickory–pine forest and oak–hickory forest. Mixed oak and oak–pine forests, woodland, or savanna occur on uplands; northern red oak, white oak, post, scarlet, black, blackjack oak, pignut hickory, shagbark hickory, mockernut hickory, and shortleaf pine are native. On lower, drier south- and west-facing sites: shortleaf pine. On narrow floodplains and low terraces: sweetgum, willows, birch, American sycamore, hickories, southern red oak, and white oak.
39	39b. Dissected Springfield Plateau-Elk River Hills	Moderately to highly dissected, hilly part of the Springfield Plateau. Gently sloping, narrow ridge tops are separated by steep V-shaped valleys. Karst features occur.	Springs are common and contribute to streamflow in the summer and fall. Streams are usually perennial but some dry valleys occur.	300-1850/ 50-800	Quaternary cherty clay solution residuum, colluvium, and alluvium. On uplands: limestone and interbedded chert of the Mississippian Boone Formation. Along deeply entrenched rivers: early-Mississippian or Devonian Chattanooga Shale and Ordovician Cotter Dolomite. Rock outcrops.	Clarksville, Nixa, Noark, Arkana, Moko, Portia, Estate	44-48. Parts are in the rainshadow of the Boston Mountains.	Potential natural vegetation: oak–hickory–pine forest and oak–hickory forest. Native on uplands: oak–woodland, mixed deciduous forest, or mixed deciduous–pine forest containing black oak, white oak, blackjack oak, post oak, hickories, and shortleaf pine. Native on north-facing slopes and in ravines: mesic forest containing sugar maple, white oak, northern red oak, and beech.
73	73e. Grand Prairie	Broad, nearly level terrace with incised streams. A narrow belt of hills occurs in the east.	Perennial and intermittent streams occur.	150-320/ 10-50	Quaternary windblown silt (i.e., loess) veneers Pleistocene terrace deposits (composed of alluvial sand, silt, and clay).	Loring, Crowley, Stuttgart, Calloway, Calhoun, Hillemann, McKamie	48-52	Potential natural vegetation: oak–hickory forest. Native vegetation is mostly tall grass prairie dominated by big bluestem, Indiangrass, and switchgrass. In addition, open woodland and savanna dominated by upland oaks, hickory, elm, maple, and locust.
73	73f. Western Lowlands Holocene Meander Belts	Flat to nearly flat floodplain containing the meander belts of the present and past courses of the White, Black, and Cache rivers. Point bars, natural levees, swales, meander scars.	Oxbow lakes, and low gradient rivers occur.	130-300/ 5-20	Holocene sandy, silty, clayey, and gravelly alluvium.	Kobel, Commerce, Sharkey, Foley, Egam, Staser, Dundee, Forestdale, Rexor, Tichnor, Mhoon	46-52	Potential natural vegetation: southern floodplain forest. Native vegetation is bottomland hardwood forest and woodland dominated by oak communities. Eastern cottonwood, green ash, cherrybark oak, Nuttall oak, water oak, willow oak, and sweetgum are common.
73	73g. Western Lowlands Pleistocene Valley Trains	Wide, flat to irregular terraces with relict patterns of branching channels, irregular braided bars, dunes, interdunal depressions, and interfluves.	Includes low gradient, extensively channelized rivers, and creeks that have silty substrates. Drainage ditches occur.	150-320/ 5-20	Quaternary windblown silt (i.e., loess) veneers Quaternary sand sheets, Quaternary sand dunes, Pleistocene terrace deposits (composed of unconsolidated alluvial sand, silt, and gravel), and Pleistocene glacial outwash deposits.	Calloway, Henry, Loring, Memphis, Grenada, Calhoun, Jackport, Foley, Hillemann	46-52	Potential natural vegetation: southern floodplain forest. Native vegetation is bottomland hardwood forest with an abundance of green ash, bottomland oaks, American elm, cottonwood, sugarberry, sweetgum, water tupelo, and bald cypress; in limited areas, loblolly pine also occurred. Native on Pleistocene dunes: white oak–black oak–southern red oak forest or post oak woodland. In dune depressions or sandponds: forests dominated by overcup oak, water hickory, and pin oak with the federally-endangered shrub, pondberry, in the understory.

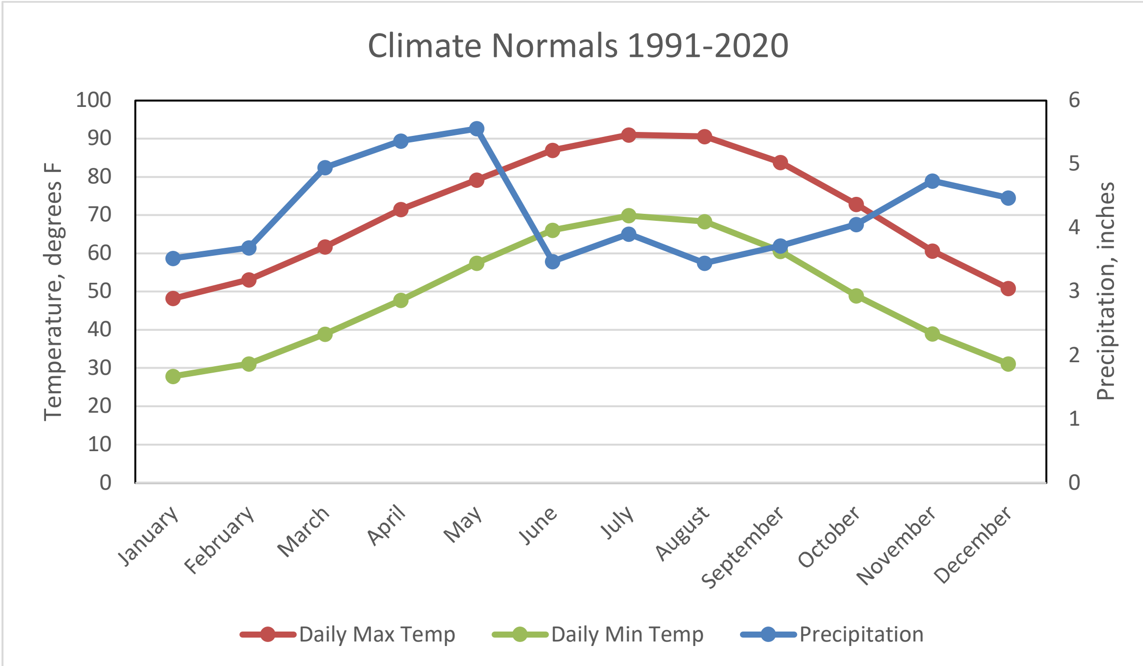


Figure 2.3. Estimated 1991-2020 climate normal for Little Red River watershed.

Climate change projections for Arkansas indicate small increases in temperature and increasing incidence of both drought and flood events. The 2014 National Climate Assessment predicts that climate change may result in a decline in water availability in the future in Arkansas (Northwest Arkansas Land Trust 2019?, US Global Change Research Program 2014, Passe-Smith 2023).

2.3.2 Geology

The majority of the Little Red River watershed is located in the Boston Mountains section of the Ozark Plateaus physiographic province and the Arkansas Valley section of the Ouachita physiographic province (Figure 2.4). The Ozark Plateaus are underlain by fairly level layers of primarily sandstone and shale (including the Fayetteville shale), with some chert, dolostone, and limestone. The Arkansas Valley is underlain by folded layers of primarily sandstone and shale, including the Fayetteville shale. The Fayetteville shale natural gas play is located under most of the southern half of the watershed. The mouth of the Little Red River is in the Mississippi Alluvial Plain section of the Coastal Plain physiographic province, with flat topography underlain by unconsolidated sediments of sizes ranging from gravel to silt (Chandler 2014, USACE 2019). A surface geology map of the Little Red River watershed is shown in Figure 2.5. Table 2.10 shows the stratigraphy of the geology underlying the watershed.

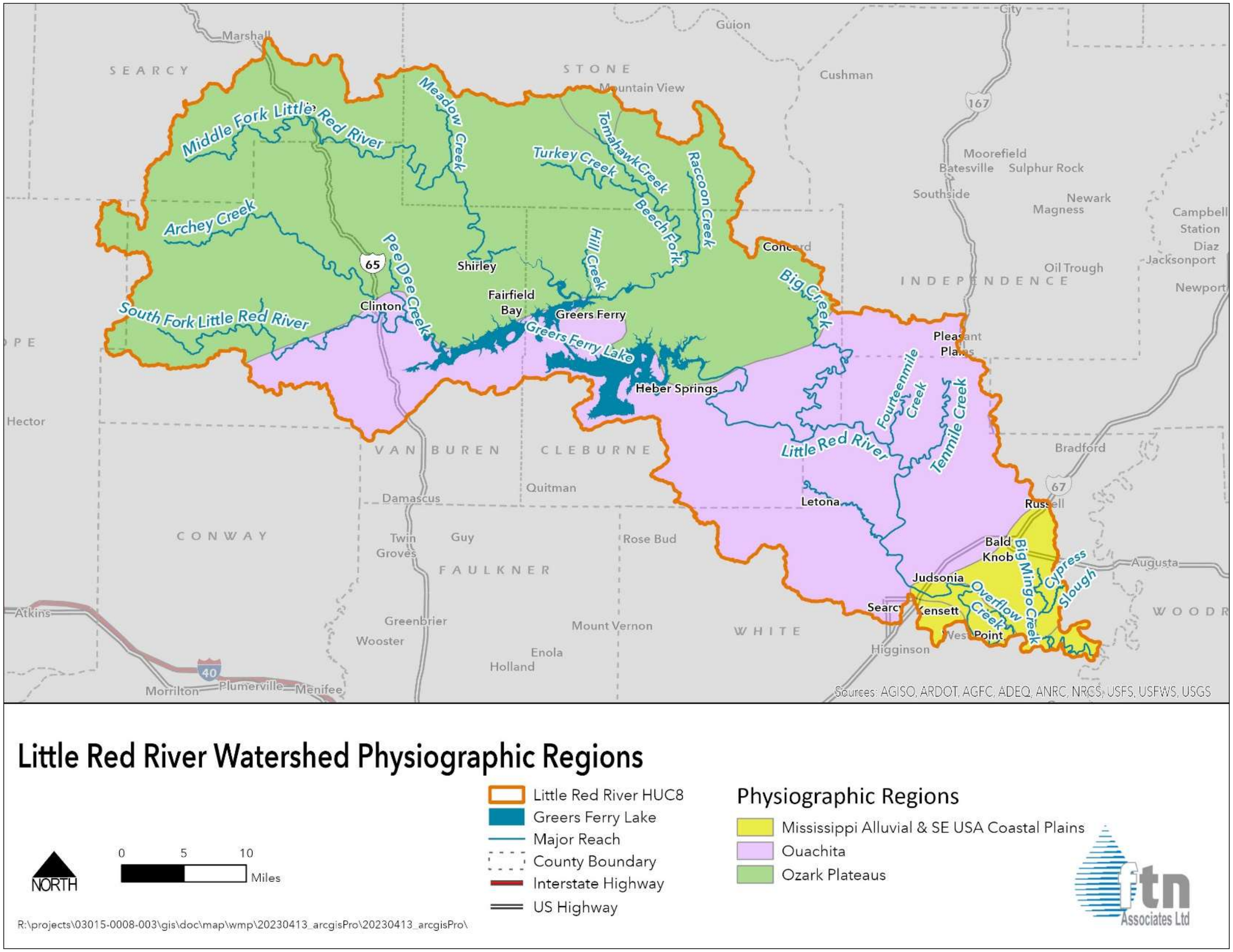


Figure 2.4. Physiographic regions within the Little Red River watershed (Fenman and Johnson 1946).

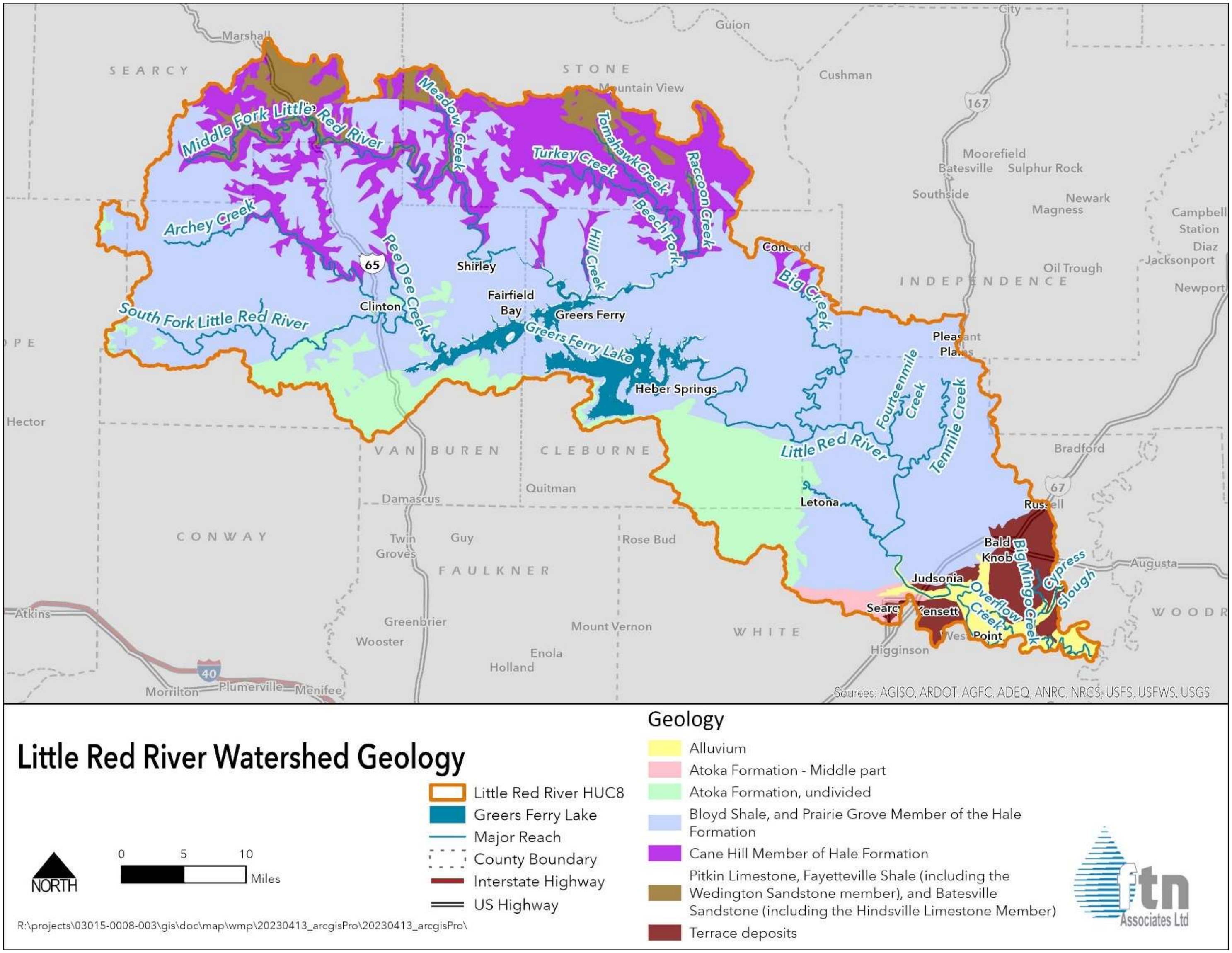


Figure 2.5. Surface geology of the Little Red River watershed (Stoeser, et al. 2005).

Table 2.10. Stratigraphy of geology underlying Little Red River watershed (oldest formations at the top, youngest at the bottom) (Arkansas Geological Survey 2020).

Age	Formation	General Geology
Mississippian	Batesville sandstone	sandstone
Mississippian	Fayetteville shale	shale
Mississippian	Pitkin	limestone
Pennsylvanian	Atoka	Sandstone and shale
Pennsylvanian	Bloyd	Shale and limestone
Pennsylvanian	Hale (Prairie Grove member)	Sandstone and limestone
Pennsylvanian	Hale (Cane Hill member)	Shale and sandstone
Quaternary	Terrace deposits	Unconsolidated gravel, sand, silt, and clay
Quaternary	Alluvial deposits	Unconsolidated gravel, sand, silt, and clay

2.3.3 Topography

Elevations within the Little Red River watershed range from 2,053 feet above sea level in the Boston Mountains of the upper watershed, to 171 feet above sea level in the lower end of the watershed where Little Red River joins the White River (Arkansas Center for Advanced Spatial Technologies 2006). The gradient of Little Red River from the upstream end of the watershed to the confluence with the White River, 194 miles, is approximately 9 feet/mile, with an average gradient of around 5 feet/mile (USGS 2023). Overall, the watershed slopes generally to the southeast.

Land slopes in the Little Red River watershed range from zero degrees in the Mississippi Alluvial Plain, to around 86 degrees (1,463% grade) on cliff faces and hill sides in the Boston Mountains. Slopes of 14% or more are considered steep, while areas with slopes of 7% or less are considered flat lands. Geographic Information System (GIS) analysis indicates that approximately 40% of the watershed has slopes flatter than 7%. Table 2.11 lists the proportion of the Little Red River watershed considered flat lands, steep, and in between. Figure 2.6 shows a map of the locations of areas within the three slope ranges. Slopes <7% are most prevalent in the lower watershed and slopes >14% are most common in the upper watershed.

Table 2.11. Slope areas in the Little Red River watershed.

Slope ranges, degrees	Area within the watershed, acres	Percent of watershed
<7%	461,058	40%
7-14%	269,445	23%
>14%	421,779	37%
Total	1,152,282	100%

2.3.4 Soils

Table 2.12 lists the soil associations present in the Little Red River watershed with selected characteristics. Figure 2.7 shows a map of these soil associations in the watershed. Soils in the Boston Mountains portion of the watershed are primarily loamy and stoney (skeletal), deep to moderately deep, and well drained. Soils in the Arkansas River Valley area of the watershed are primarily fine (fine-silty, fine-loamy, fine-skeletal), deep to moderately deep, and well drained. Upland soils tend to have low natural fertility and may be stony. Soils in the Mississippi Alluvial Plain area of the watershed are primarily fine, often have a shallow hard pan, and are poorly drained.

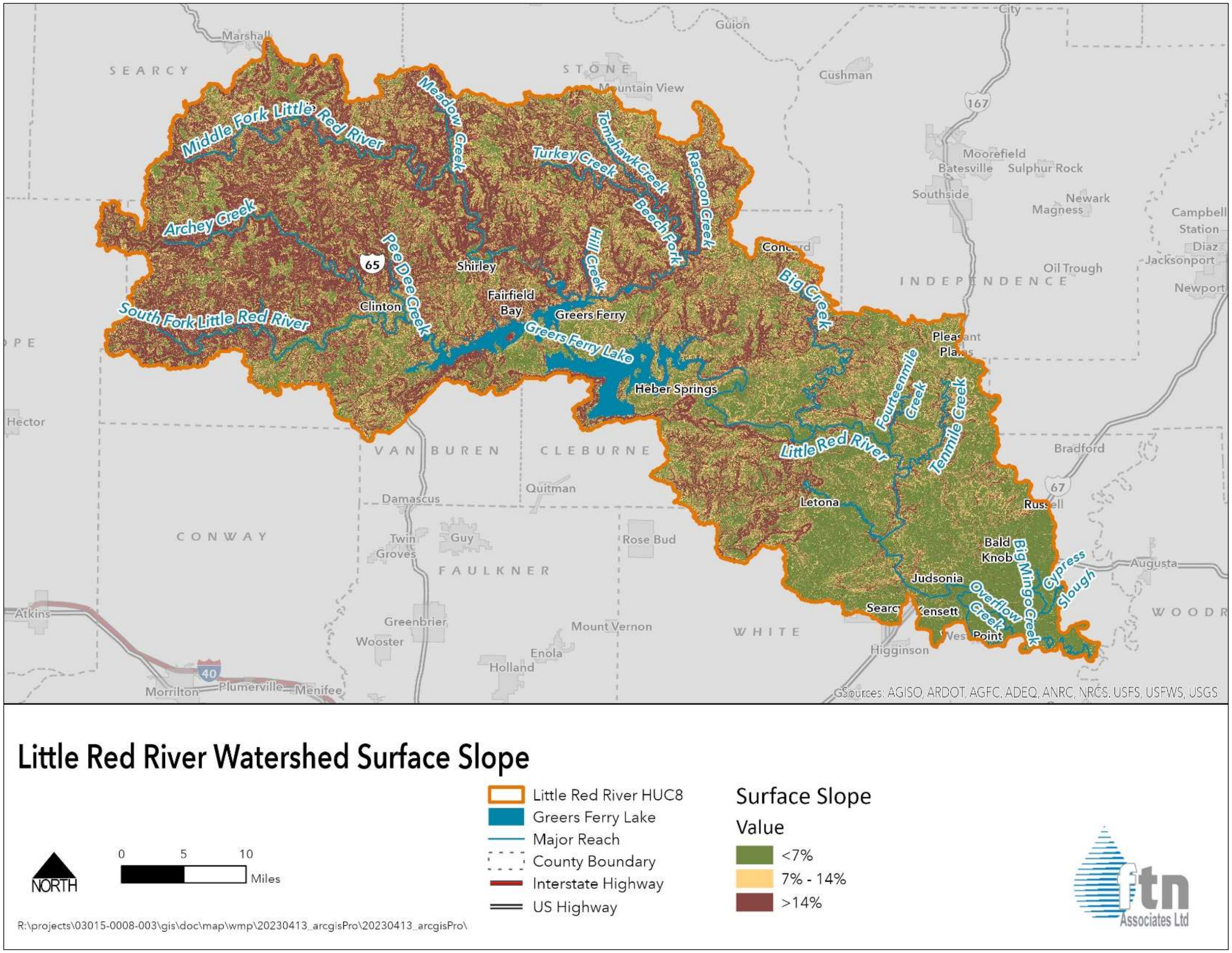


Figure 2.6. Slope map of the Little Red River watershed.

Table 2.12. Soil associations present in the Little Red River watershed.

Soil Association	Drainage	Character	Depth
Crowley-Calhoun-Amagon (s245)	Poorly drained	fine	Shallow-Impervious
Henry-Grenada-Calloway-Calhoun (s266)	Poorly drained	fine-silty	Moderately deep
Kobel-Commerce (s246)	Poorly drained	fine	Shallow-Impervious
Mountainburg-Linker-Enders (s240)	Well drained	fine-silty	Deep-Moderately deep
Spadra-Guthrie-Barling (s239)	Well drained	fine	Deep-Moderately deep
Steprock-Nella-Mountainburg-Linker-Enders (s235)	Well drained	Fine to loamy-skeletal	Deep-Moderately deep
Steprock-Sidon-Mountainburg-Linker-Enders (s234)	Well drained	loamy-skeletal	Deep-Moderately deep
Summit-Newnata-Moko-Eden (s231)	Well drained	loamy-skeletal	Moderately deep
Taft-Leadvale (s237)	Moderately well drained	fine-loamy	Moderately deep

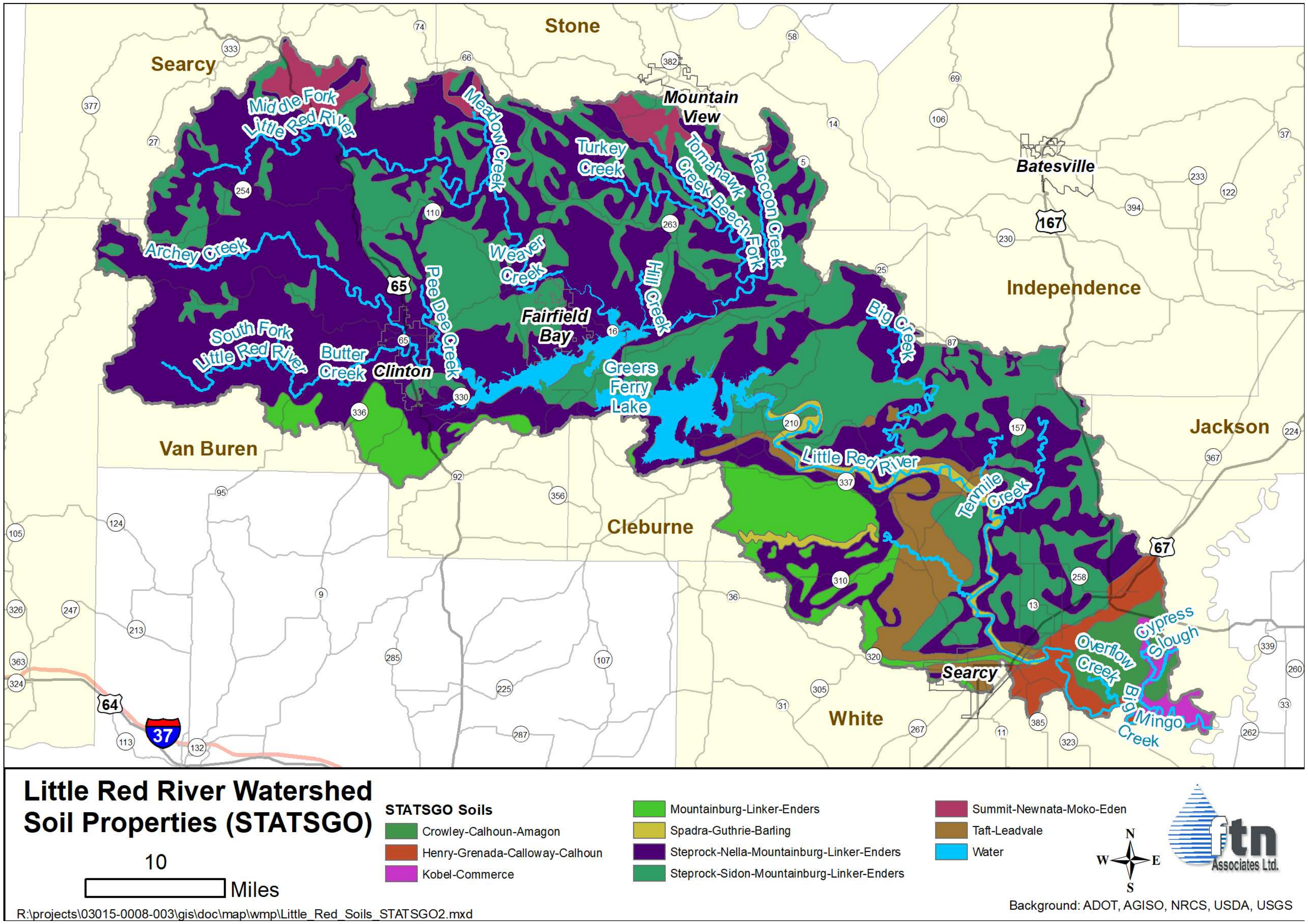


Figure 2.7. Soils map of the Little Red River watershed.

2.3.5 Land Use/Land Cover

Forest is the predominant land use in the Little Red River watershed. Around 50 percent of the watershed's land area is forested (Figure 2.8). The majority of forest is upstream of Greers Ferry Lake (Figure 2.9). Around 30 percent of the land is pasture and herbaceous cover, which is scattered throughout the watershed but accounts for a significant portion of the watershed downstream of the reservoir. Seven percent of the watershed is urban and suburban, with the largest developed areas downstream of the reservoir. Eight percent of the watershed is in crops and 4% is wetlands, the majority of which are located in the lower watershed, in the Mississippi Alluvial Plain. The remaining area is covered by water, the majority of which is Greers Ferry Lake.

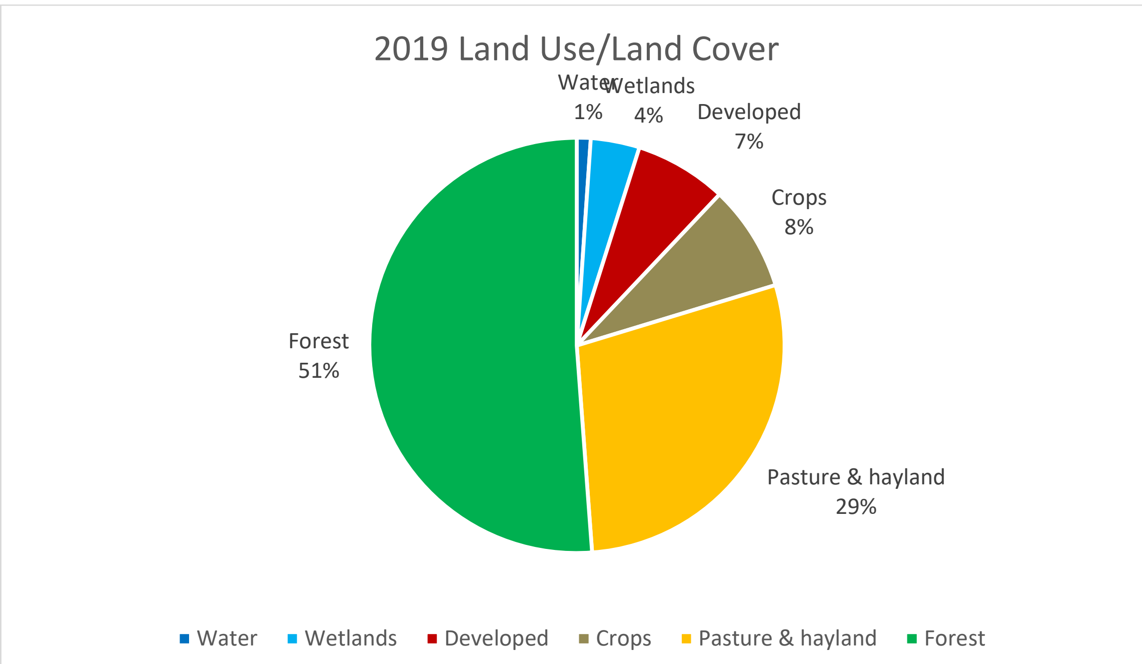


Figure 2.8. Land cover proportions for the Little Red River watershed.

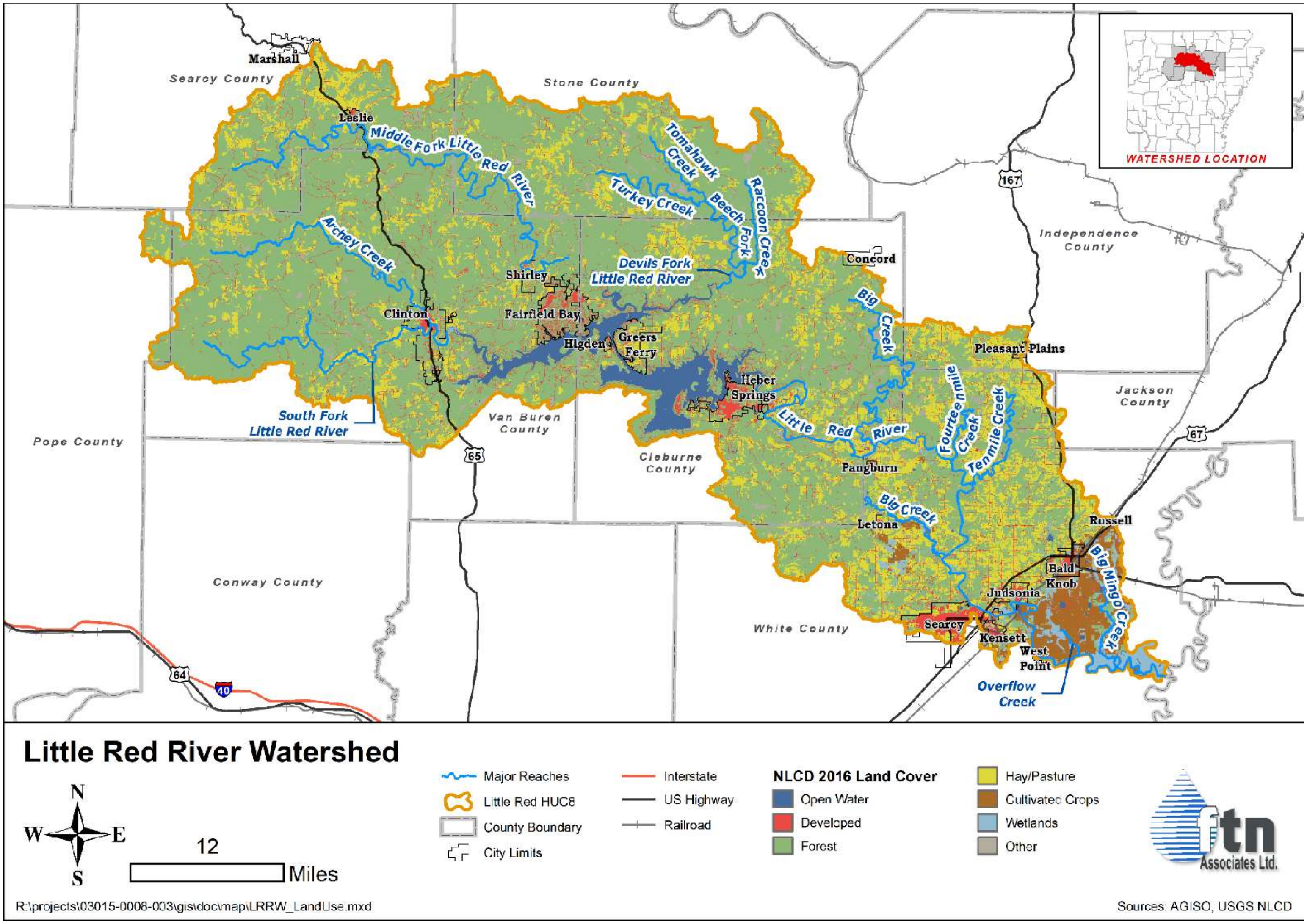


Figure 2.9. Land cover map of the Little Red River watershed (Dewitz and USGS 2021).

2.4 Water Resources

Surface water and groundwater resources of the Little Red River watershed are described below.

2.4.1 Surface Water

There are over 2,700 miles of streams in the Little Red River watershed, and over 50 square miles of impounded water. The longest streamline is 194 miles, from the headwaters of the Archey Fork to the confluence of the Little Red River with the White River. The Little Red River serves as a water supply for Searcy, Bald Knob, Judsonia, and Kennsett (Arkansas Department of Health 2017).

The Little Red River is impounded by the Greers Ferry Dam approximately 79 miles upstream from the White River. Greers Ferry Lake is a multipurpose reservoir built and managed by the US Army Corps of Engineers (USACE). The purposes for which USACE manages the reservoir are primarily flood control and hydropower generation, with secondary purposes of water supply and recreation (USACE Little Rock District 2022). Greers Ferry Lake serves as water supply for six water utilities and the Mid-Arkansas Water Alliance, an alliance of nine water utilities in Central Arkansas (USACE Little Rock District 2015). Releases from Greers Ferry Lake are set to meet demands for power generation, and to achieve downstream temperature and dissolved oxygen targets (https://www.swl.usace.army.mil/Missions/Water-Management/Water-Management-FAQ/#_Toc38481912).

2.4.2 Groundwater

The majority of the Little Red River watershed is underlain by the Western Interior Plains Confining Unit, which is made up of rock formations characterized by low porosity, permeability and yields (Figure 2.10). As a result, there are no formally designated aquifers in the watershed. However, there are scattered shallow, undifferentiated, saturated rock formations that are used as water supply for households or small communities. In these aquifers, water is stored primarily in fractures and faults and wells in these aquifers can yield up to 10 gallons per minute (Kresse, et al. 2014).

Where the Little Red River flows into the Mississippi Alluvial Plain, it is underlain by the Mississippi River Valley alluvial aquifer. This is a highly productive unconfined aquifer system comprised of unconsolidated, saturated mixed sediments (gravel, sand, silt, and clay). Well yields of 2,000 gallons per minute are common for this aquifer. This aquifer is recharged by infiltration from the surface. The largest use of water from this aquifer is crop irrigation (Kresse, et al. 2014).

2.4.3 Surface-Groundwater Interactions

In the Little Red River watershed, water primarily moves from the surface into the ground. Few streams in the watershed are classified as perennial or receive sustaining flow from groundwater. Most springs in the watershed are wet weather springs. There are several perennial springs in the watershed, including the seven springs in Spring Park within the town of Heber Springs. Groundwater vulnerability modeling of the Ozark Plateaus region of Arkansas by The Nature Conservancy indicates that groundwater quality within the Little Red River watershed is at greatest risk in streambeds and floodplains (Figure 2.11).

2.5 Wildlife Resources

Several species present in the Little Red River watershed are found only in Arkansas. A number of native species present in the watershed are listed as threatened or endangered by the state or federal government. There are also a number of native species present that the state has identified as species of greatest conservation need. In addition, there are plants and animals present in the watershed that are not native and that are believed to pose a threat to native species.

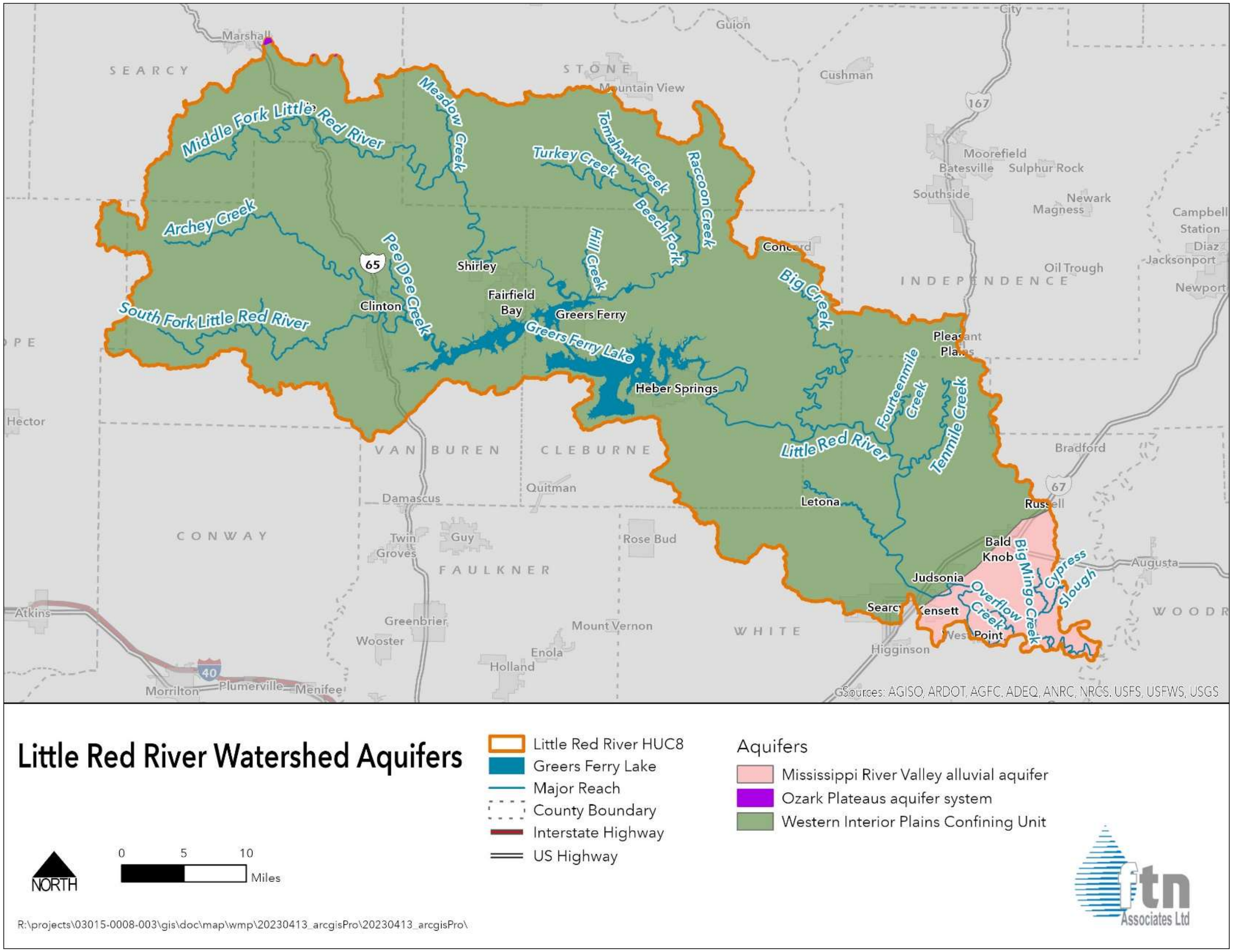


Figure 2.10. Principle aquifers associated with the Little Red River watershed.

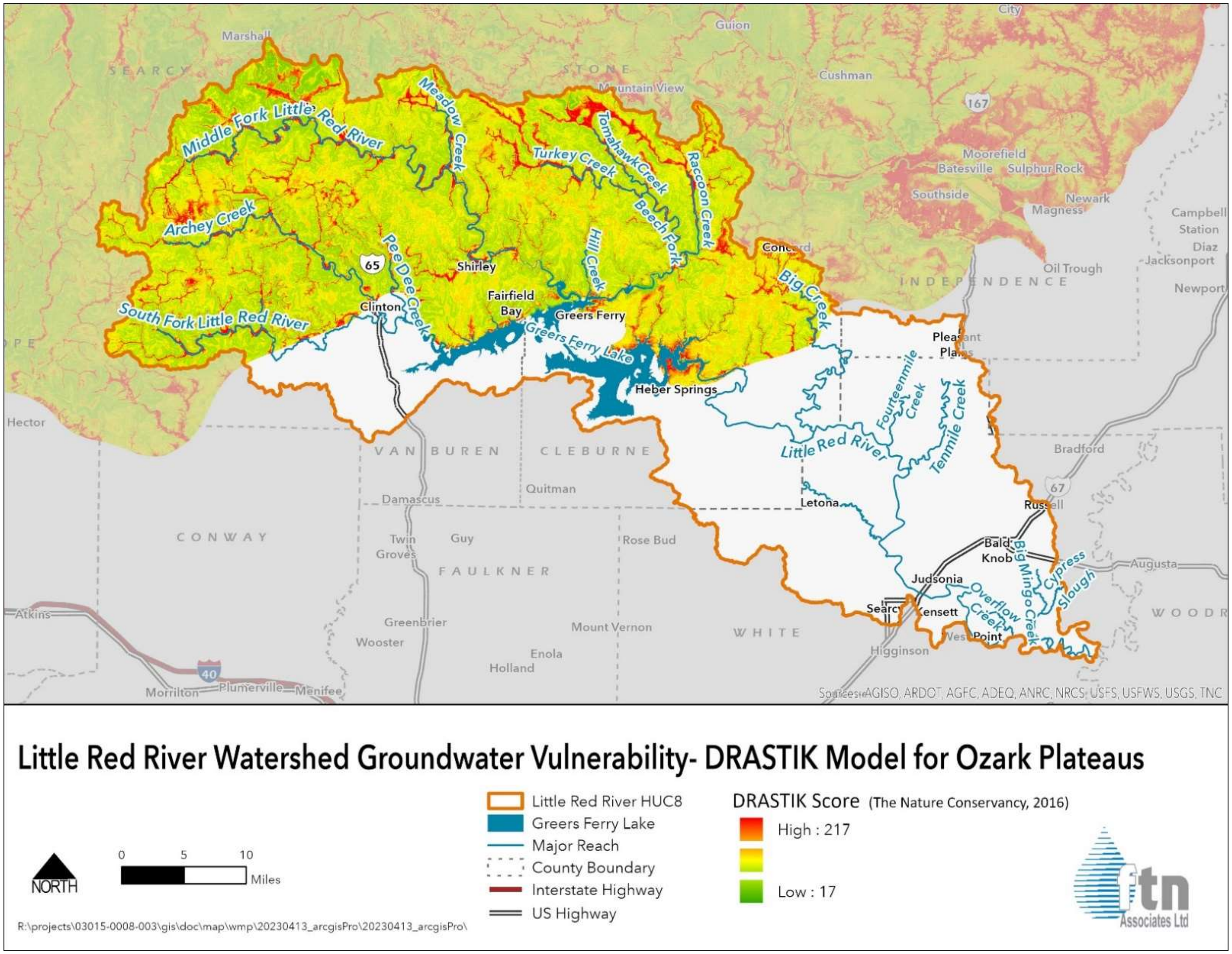


Figure 2.11. Map of modeled groundwater vulnerability in the Ozark Plateaus region of the Little Red River watershed (Inlander, Gallipeau and Slay 2011).

2.5.1 Protected Species

There are 16 species that may be found in the Little Red River watershed that are listed as threatened or endangered by the state and/or federal government (Table 2.13). Seven of these are endangered aquatic species, and there is one threatened mussel species. The Yellowcheek Darter is found only in the Little Red River watershed upstream of Greers Ferry Lake. The Little Red River watershed is the site of a stocking program for Speckled Pocketbook mussels (Fischer 2022).

2.5.2 Species of Greatest Conservation Need

There are an additional 30 or so aquatic species of greatest conservation need identified by Arkansas Game and Fish Commission in the Arkansas Wildlife Action Plan for the ecobasins[1] of the Little Red River (Fowler and Anderson 2015). Although there is little karst terrain in the Little Red River watershed, one aquatic karst species of greatest conservation need identified in the Arkansas Wildlife Action Plan is present in the watershed (Inlander, Gallipeau and Slay 2011).

2.5.3 Nuisance Species

There are a number of non-native species of plants and animals present in the Little Red River watershed. Non-native aquatic invasive species that have been reported in the Little Red River watershed are listed in Table 2.14. This list includes several species of sport fish that are stocked in Greers Ferry Lake or the Little Red River coldwater fishery downstream of Greers Ferry Dam. The exotic fish species present in the watershed pose the greatest threat to native aquatic species. None of the species listed in Table 2.14 have been identified specifically as being a threat to the Yellowcheek Darter or populations of endangered or threatened mussel species present in the watershed.

[1] Ecobasins are the seven Arkansas Level III ecoregions subdivided by the six major river basins in Arkansas. There are a total of 18 ecobasins defined in the Arkansas Wildlife Action Plan.

Table 2.13. Listed species of the Little Red River watershed (USFWS 2021b).

Common Name	Scientific Name	Category	Federal Status	State Status	Counties
gray bat	*Myotis Grisecens*	Mammal	Endangered	S2S3-Imperiled	Cleburne, Independence, Jackson, Pope, Searcy, Stone, Van Buren, White
Indiana bat	*Myotis sodalis*	Mammal	Endangered	S1-Critically Imperiled	Cleburne, Independence, Pope, Searcy, Stone, Van Buren,
northern long-eared bat	*Myotis septentrionalis*	Mammal	Threatened	S1S2-Critically Imperiled	Cleburne, Independence, Jackson, Pope, Searcy, Stone, Van Buren, White
Ozark big-eared bat	*Corynorhinus townsendii ingens*	Mammal	Endangered	S1- Critically Imperiled	Searcy and Pope
Piping Plover	*Charadrius melodus*	Bird	Threatened	S1N- Critically Imperiled Nonbreeding Species	Cleburne, Independence, Pope, Jackson, Searcy, Stone, Van Buren, White
Red Knot	*Calidris canutus rufa*	Bird	Threatened	No Data	White
Yellowcheek Darter	*Etheostoma moorei*	Fish	Endangered	S1-Critically Imperiled	Cleburne, Pope, Searcy, Stone, Van Buren
pink mucket (pearlymussel)	*Lampsilis abrupta*	Clam	Endangered	S2-Imperiled	White
rabbitsfoot	*Quadrula cylindrica cylindrica*	Clam	Threatened	S3-Vulnerable	Independence, Jackson, Searcy, Van Buren, White
scaleshell mussel	*Leptodea leptodon*	Clam	Endangered	S2-Imperiled	Jackson, White
snuffbox mussel	*Epioblasma triquetra*	Clam	Endangered	S1-Critically Imperiled	Searcy
speckled pocketbook	*Lampsilis streckeri*	Clam	Endangered	S1-Critically Imperiled	Cleburne, Independence, Pope, Searcy, Stone, Van Buren, White
monarch butterfly	*Danaus plexippus*	Insect	Candidate	S4-Apparently Secure	Cleburne, Independence, Jackson, Pope, Searcy, Stone, Van Buren, White
Hell Creek Cave Crayfish	*Cambarus zophonastes*	Crustacean	Endangered	S1-Critically Imperiled	Stone
pondberry	*Lindera melissifolia*	Flowering Plant	Endangered	No Data	Jackson

Table 2.14. Non-native aquatic invasive species reported in the Little Red River watershed (USGS 2022a).

Common Name	Scientific Name	Category	Source	Location	Status
Nutria	*Myocastor coypus*	Mammal	Exotic	Bald Knob NWR	Established
Rock Bass	*Ambloplites rupestris*	Fish	Native Transplant	Greers Ferry Lake, S. Fork Little Red	Established
Goldfish	*Carassius auratus*	Fish	Exotic	Greers Ferry Lake	Unknown
Knobfin Sculpin	*Cottus immaculatus*	Fish	Native Transplant	Little Red at dam	Unknown
Common Carp	*Cyprinus carpio*	Fish	Exotic	Greers Ferry Lake, S. Fork Little Red, Archey Cr, Little Red d/s dam	Established
Threadfin Shad	*Dorosoma petenense*	Fish	Native Transplant	Greers Ferry Lake	Established
Western Mosquitofish	*Gambusia affinis*	Fish	Native Transplant	Unknown	Established
Silver Carp	*Hypophthalmichthys molitrix*	Fish	Exotic	Little Red near confluence with White	Established
Redbreast Sunfish	*Lepomis auritus*	Fish	Native Transplant	Devils Fork	Established
Wiper	*Morone chrysops* × *saxatilis*	Fish	Native Hybrid Transplant	Greers ferry Lake, Little Red d/s dam	Stocked
Striped Bass	*Morone saxatilis*	Fish	Native Transplant	Greers Ferry Lake	Established (stocked)
Cutthroat Trout	*Oncorhynchus clarkii*	Fish	Native Transplant	Little Red d/s dam	Established (stocked)
Rainbow Trout	*Oncorhynchus mykiss*	Fish	Native Transplant	Greers Ferry Lake, Little Red d/s dam	Established, stocked
Yellow Perch	*Perca flavescens*	Fish	Native Transplant	Private pond Archey Cr watershed	Established (stocked)
Flathead Minnow	*Pimephales promelas*	Fish	Native Transplant	Greers Ferry Lake, Little Red d/s dam	Established (escaped?)
Brown Trout	*Salmo trutta*	Fish	Exotic	Little Red d/s dam	Stocked
Tiger trout	*Salmo trutta X Salvelinus fontinalis*	Fish	Exotic Hybrid	Little Red R d/s dam	Stocked

Table 2.14. Non-native aquatic invasive species reported in the Little Red River watershed (continued).

Common Name	Scientific Name	Category	Source	Location	Status
Lake Trout	*Salvelinus namaycush*	Fish	Native Transplant	Greers Ferry Lake, Little Red @ dam	Stocked
Sauger	*Sander canadensis*	Fish	Native Transplant	Greers Ferry Lake	Established (stocked?)
White River Crayfish	*Procambarus acutus acutus*	Crustaceans-Crayfish	Native Transplant	Little Red and watershed or tributaries d/s of dam	Established
Freshwater jellyfish	*Craspedacusta sowerbyi*	Coelenterates-Hydrozoans	Exotic	Greers Ferry Lake	Unknown or established
Asian clam	*Corbicula fluminea*	Mollusks-Bivalves	Exotic	Greers Ferry Lake, S. Fork Little Red, M. Fork Little Red, Gin Cr (Searcy)	Established
Zebra mussel	*Dreissena polymorpha*	Mollusks-Bivalves	Exotic	Greers Ferry Lake	Established
Yellow iris	*Iris pseudacorus*	Plant	Exotic	S. Fork Little Red	Established
Parrot feather	*Myriophyllum aquaticum*	Plant	Exotic	unknown	Established
Curly-leaf pondweed	*Potamogeton crispus*	Plant	Exotic	Little Red d/s dam	Unknown

Zebra mussels and nutria are two well-known nuisance non-native species that are present and established in the Little Red River watershed. The algae Didymo (*Didymosphenia geminate*) has also been reported in the Little Red River downstream of Greers Ferry Dam (Shelby 2006).

2.5.4 Sensitive Areas

Sensitive areas within the Little Red River watershed include federally designated critical habitat for endangered species, a national wildlife refuge, national forest, state wildlife management areas, state natural areas, a habitat preserve, and state designated Trout Waters, Extraordinary Resource Waters, and Ecologically Sensitive Waterbodies. Figure 2.12 shows the locations of these sensitive areas within the watershed. Federally designated critical habitat for two endangered species, Yellowcheek Darter and Rabbitsfoot mussel, is located within the Little Red River watershed, upstream of Greers Ferry Lake. The Little Red River forks, upstream of Greers Ferry Lake, are also subject to a Safe Harbor Agreement and Candidate Conservation Agreement with Assurances created and implemented by the US Fish and Wildlife Service (USFWS), Arkansas Game and Fish Commission (AGFC), The Nature Conservancy, and US Natural Resources Conservation Service (NRCS). Table 2.15 Lists designated management areas within the watershed with some descriptive information about these areas.

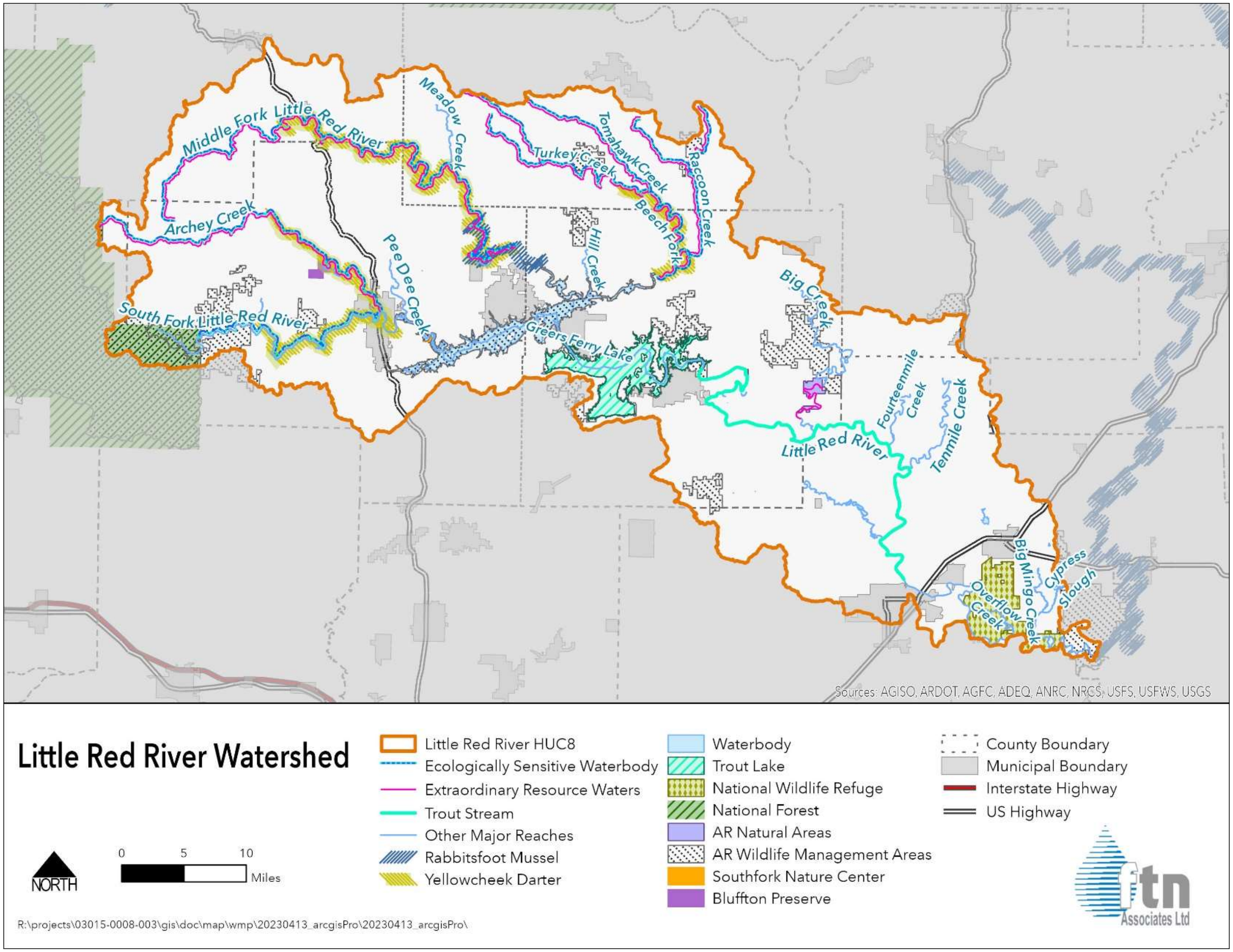


Figure 2.12. Designated sensitive areas within the Little Red River watershed.

Table 2.15. Designated conservation and protected areas in the Little Red River watershed.

Name	County	Area	Focus habitat	Owned By
Bald Knob National Wildlife Refuge	White	15,000+ acres	Wetlands	USFWS
Ozark National Forest, Big Piney Ranger District	Van Buren, Conway, Searcy, Newton, Johnson, Madison, and Pope	496,000+ acres	Forest	US Forest Service
Cherokee Wildlife Management Area	Cleburne, Conway, Independence, Logan, Pope, Scott, Stone, Van Buren, White	--	Forest	Green Bay Packaging, Inc.
Greers Ferry Lake Wildlife Management Area	Cleburne, Van Buren	--	Lake and forest	US Army Corps of Engineers
Piney Creeks Wildlife Management Area	Conway, Johnson, Newton, Pope, Searcy, Van Buren	504,643 acres	Forest	US Forest Service
Scott Henderson Gulf Mountain Wildlife Management Area	Van Buren	14,000 acres	Forest	AGFC, Green Bay Packaging, Inc.
Jim Kress Wildlife Management Area	Cleburne, White	--	Forest	Green Bay Packaging, Arkansas Natural Heritage Commission
Henry Gray Hurricane Lake Wildlife Management Area	White, Woodruff	17,000 acres	Wetlands	AGFC
Cow Shoals Riverfront Natural Area	Cleburne	63.3 acres	Floodplain	AGFC
Big Creek Natural Area	Cleburne	1,508 acres	Forest, creek	Arkansas Natural Heritage Commission
Bluffton Preserve	Van Buren	989 acres	Forest, creek	The Nature Conservancy
South Fork Nature Center	Van Buren	125 acres	Forest	Gates Rogers Foundation

3.0 WATERSHED ASSESSMENT

This section describes the water quality and ecological condition of the Little Red River watershed and nonpoint sources of pollution that are present.

3.1 Surface Water Quality

This subsection describes surface water quality in the Little Red River watershed in terms of measured concentrations of selected parameters. This includes a summary of the water quality standards that apply in the watershed and the water quality monitoring programs active in the watershed. Recent surface water quality data are summarized and discussed, trends in long-term water quality data are evaluated, and surface water quality data gaps are identified.

3.1.1 Water Quality Standards

Arkansas state water quality standards consist of designated uses for waterbodies, numeric criteria for selected water pollutants or water quality indicators, narrative criteria for pollutants or indicators without numeric standards, and an antidegradation statement. State water quality standards that apply to surface waters in Little Red River watershed are described below (Arkansas Pollution Control and Ecology Commission 2020).

3.1.1.1 Designated Uses

Designated uses of all the streams in the watershed are Primary Contact Recreation (streams with watersheds larger than 10 square miles), , Seasonal Aquatic Life (streams with watersheds smaller than 10 square miles), and Perennial Aquatic Life (streams with watersheds 10 square miles or larger and waters where discharges equal or exceed 1 cubic foot per second (cfs)). Additionally, all streams have Secondary Contact Recreation, and Domestic, Industrial and Agricultural Water Supply as designated uses. Designated uses of lakes and reservoirs in the watershed are Primary Contact Recreation, Secondary Contact Recreation, Perennial Aquatic Life, and Domestic, Industrial and Agricultural Water Supply. Greers Ferry Lake below the narrows and the Little Red River below Greers Ferry dam to Searcy are designated as Trout

Waters. There are several stream reaches in this watershed that are designated Extraordinary Resource Waters and/or Ecologically Sensitive Waterbodies (see Figure 3.1) (Arkansas Pollution Control and Ecology Commission 2020).

3.1.1.2 Numeric Criteria

Numeric water quality criteria for selected parameters that apply in the Little Red River watershed are listed in Table 3.1. Separate turbidity criteria are specified for baseflow conditions. The baseflow criteria should not be exceeded in more than 20% of samples collected June to October. The "all flow" criteria should not be exceeded in more than 25% of all samples collected over an entire year. Numeric water quality criteria for toxic substances and metals can be found in Regulation 2 of the Arkansas Pollution Control and Ecology Commission (Arkansas Pollution Control and Ecology Commission 2020).

3.1.1.3 Narrative Criteria

In addition to numeric water quality criteria, state narrative criteria have been developed for the following: nuisance species; color; taste and odor; solids, floating material, and deposits; toxic substances; oil and grease; and nutrients (Arkansas Pollution Control and Ecology Commission 2020).

3.1.2 Surface Water Quality Monitoring

Arkansas Department of Energy and Environment Division of Environmental Quality (DEQ), US Geological Survey (USGS), Arkansas Stream Teams, US Army Corps of Engineers (USACE) and the US Environmental Protection Agency (EPA) have collected surface water quality data in the Little Red River watershed. An inventory of historical surface water quality monitoring locations is included as Appendix C. Table 3.2 lists water quality monitoring locations active during the period 2016-2020, which are mapped in Figure 3.2. Data collected from 2016 through 2020 reflect current water quality conditions in the watershed. Table 3.3 summarizes the water quality parameters that were monitored at water quality stations active during 2016-2020. Archey Fork of the Little Red River and Ten Mile Creek were used by DEQ as ecoregion reference streams in development of ecoregion ambient water quality standards in the 1980s (Giese, et al. 1987).

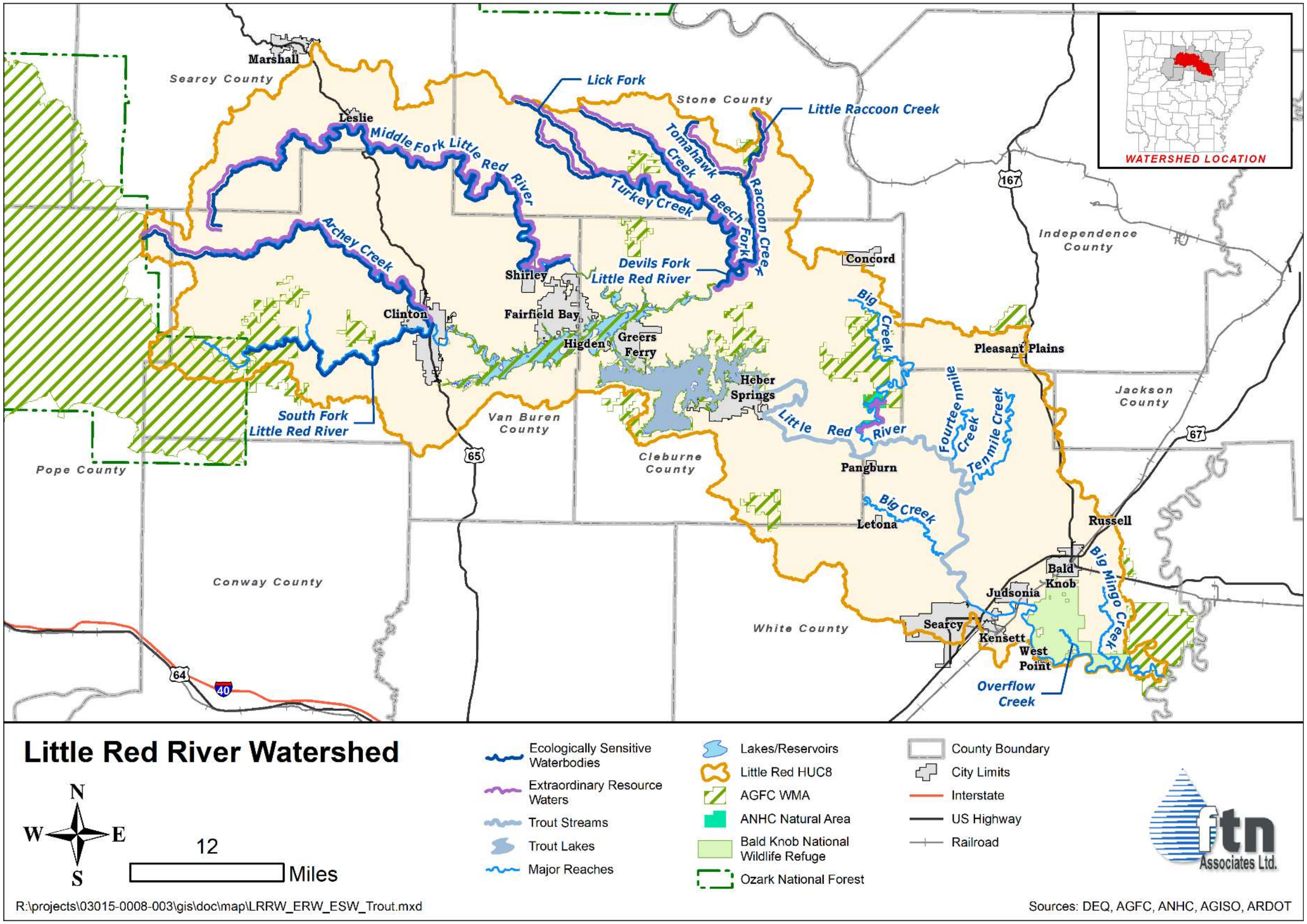


Figure 3.1. Designated outstanding water resources in Little Red River watershed.

Table 3.1. Numeric water quality criteria for surface waters in the Little Red River watershed (Arkansas Pollution Control and Ecology Commission 2020).

Parameter	Season	Location	Conditions	Criteria
Water Temperature	All	Non-trout streams/reaches	All	31°C (87.8°F)
		Trout streams/reaches	All	20°C (68°F)
		Lakes and Reservoirs	1-meter depth	32°C (89.6°F)
Turbidity	Baseflow[a]	Boston Mountains	All	10 NTU
		Arkansas River Valley	All	21 NTU
		Delta	Channel-altered	75 NTU
		Lakes and Reservoirs	1-meter depth	25 NTU
	Storm Flows[b]	Boston Mountains	All	19 NTU
		Arkansas River Valley	All	40 NTU
		Delta	Channel-altered	250 NTU
		Lakes and Reservoirs	1-meter depth	45 NTU
pH	All	All	All	6 – 9 SU
		Lakes and Reservoirs	1-meter depth	
Dissolved Oxygen	Primary Season[c]	Boston Mountains	All	6 mg/L
		Arkansas River Valley	Non-trout streams/reaches	5 mg/L
			Trout streams/reaches	6 mg/L
		Delta	All	5 mg/L
	Critical Season[d]	All	Trout streams/reaches	6 mg/L
			<10 mi^2 watershed	2 mg/L
		Boston Mountains	10 mi^2 and greater	6 mg/L
		Arkansas River Valley	10 mi^2 to 150 mi^2	3 mg/L
			151 mi^2 to 400 mi^2	4 mg/L
			>400 mi^2	5 mg/L
		Delta	10 mi^2 to 100 mi^2	3 mg/L
	All	Lakes and Reservoirs	1-meter depth	5 mg/L

Table 3.1. Numeric water quality criteria for surface waters in the Little Red River watershed (Arkansas Pollution Control and Ecology Commission 2020) (continued).

<table>
<tr><th>Parameter</th><th>Season</th><th>Location</th><th>Conditions</th><th>Criteria</th></tr>
<tr><td rowspan="4">Fecal Coliforms</td><td rowspan="2">Primary Contact</td><td rowspan="2">All</td><td>Individual sample criterion</td><td>400 col/100mL</td></tr>
<tr><td>Geometric mean</td><td>200 col/100mL</td></tr>
<tr><td rowspan="2">Secondary Contact</td><td rowspan="2">All</td><td>Individual sample criterion</td><td>2,000 col/100mL</td></tr>
<tr><td>Geometric mean</td><td>1,000 col/100mL</td></tr>
<tr><td rowspan="6">Escherichia coli</td><td rowspan="3">Primary Contact[e]</td><td rowspan="2">Extraordinary Resource Waters
Ecologically Sensitive Waterbodies
Reservoirs</td><td>Individual sample criterion</td><td>298 col/100mL</td></tr>
<tr><td>Geometric mean</td><td>126 col/100mL</td></tr>
<tr><td>All other waters</td><td>Individual sample criterion</td><td>410 col/100mL</td></tr>
<tr><td rowspan="3">Secondary Contact[f]</td><td rowspan="2">Extraordinary Resource Waters
Ecologically Sensitive Waterbodies
Reservoirs</td><td>Individual sample criterion</td><td>1,490 col/100mL</td></tr>
<tr><td>Geometric mean</td><td>630 col/100mL</td></tr>
<tr><td>All other waters</td><td>Individual sample criterion</td><td>2,050 col/100mL</td></tr>
</table>

[a]Baseflow = June – October
[b]Storm Flows = Entire Year
[c]Primary Season = when water temperature is 22°C or less, usually mid-September to mid-May
[d]Critical Season = when water temperature is > 22°C, usually mid-May to mid-September
[e]Primary Contact = May 1 to September 31
[f]Secondary Contact = October 1 to April 30

Table 3.2. Surface water quality monitoring stations active in the Little Red River watershed during 2016-2020 (AGFC 2021a, DEQ 2021a, DEQ 2018a, EPA 2020a, USACE 2023a, USGS 2021).

Entity	Program	Station ID	Stream	County	Location	Ecoregion	Start year (earliest year during target period)	End year	Number of sample dates 2016-2020
DEQ	Nutrient ERW Boston Mts Project	UWBHC01	Beech Fork	Cleburne	co. rd. 2.5 mi. SE Hwy. 263 near Woodrow (DEQ reach 023)	Boston Mountains	1994 (2016)	2016	2
DEQ	Lakes	LWHI010A	Greers Ferry Lake	Cleburne	near Dam	Arkansas River Valley	1999 (2016)	2019	15
USGS	Lakes	07075900	Greers Ferry Lake	Cleburne	near Heber Springs	Arkansas River Valley	1973 (2016)	2020	15
DEQ	Lakes	LWHI010B	Greers Ferry Lake	Cleburne	above Narrows near Higden	Arkansas River Valley	1999 (2016)	2019	14
USGS	-	07076000	Little Red River	Cleburne	near Heber Springs (DEQ reach 014?)	Arkansas River Valley	1945 (2016)	2020	15
DEQ	Roving	UWMFK01	Middle Fork Little Red River	Searcy	Hwy. 65 near Leslie (DEQ reach 932)	Boston Mountains	1994 (2016)	2016	3
DEQ	Nutrient ERW Boston Mts Project	WHI0177	Middle Fork Little Red River	Searcy	Hwy 65 S of Leslie (DEQ reach 030)	Boston Mountains	2004 (2016)	2016	2
DEQ	Nutrient ERW Boston Mts Project	WHI0187	Turkey Creek	Stone	CR21/Hanover Rd N of Prim (DEQ reach 925)	Boston Mountains	2005 (2016)	2016	2
DEQ	Roving	UWAFK01	Archey Fork Little Red River	Van Buren	in Clinton on Hwy. 65 (DEQ reach 037)	Boston Mountains	1994 (2016)	2016	3
DEQ	Nutrient ERW Boston Mts Project	WHI0195	Archey Fork Little Red River	Van Buren	CR166 SW of Dennard (DEQ reach 037)	Boston Mountains	2008 (2016)	2016	1
DEQ	Ambient	WHI0043	Middle Fork Little Red River	Van Buren	SR9/Guffy Ln near Shirley (DEQ reach 028)	Boston Mountains	1990 (2016)	2020	74
DEQ	Ambient	ARK0170	South Fork Little Red River	Van Buren	County Road 23 (DEQ reach 036)	Boston Mountains	2011 (2016)	2020	50
DEQ	Roving	UWSRR01	South Fork Little Red River	Van Buren	Hwy. 95 near Scotland (DEQ reach 938)	Boston Mountains	1994 (2018)	2019	15
DEQ	Roving	UWSRR02	South Fork Little Red River	Van Buren	Hwy. 65 at Clinton (DEQ reach 038)	Boston Mountains	1994 (2016)	2019	18
USGS	-	07075270	South Fork of Little Red River	Van Buren	near Scotland (DEQ reach 940)	Boston Mountains	2011 (2016)	2020	41
USGS	-	07075250	South Fork of Little Red River	Van Buren	u/s of Gulf Mt WMA nr Scotland (DEQ reach 040)	Boston Mountains	2011 (2016)	2017	14
DEQ	Ambient	WHI0059	Little Red River	White	SR367/Lakeshore Dr S of Searcy (DEQ reach 007)	Arkansas River Valley	1990 (2016)	2020	68
DEQ	Roving	UWOFC01	Overflow Creek	White	Huntsman Rd 1 ½ mi. SE of Judsonia (DEQ reach 006)	Delta	1993 (2018)	2018	11
DEQ	Roving	UWTMC01	Tenmile Creek	White	CR157/Sunny Dale Rd. 3 mi. N of Providence (DEQ reach 009)	Arkansas River Valley	1993 (2018)	2019	16
USACE	Ambient	--	Little Red River	Cleburne	At Greers Ferry Dam	Arkansas River Valley	2005 (2018)	2020	1,825?

Table 3.2. Surface water quality monitoring stations active in the Little Red River watershed during 2016-2020 (AGFC 2021a, DEQ 2021a, DEQ 2018a, EPA 2020a, USACE 2023a, USGS 2021) (continued).

Entity	Program	Station ID	Stream	County	Location	Ecoregion	Start year (earliest year during target period)	End year	Number of sample dates 2016-2020
Arkansas Master Naturalists	Stream Team	Not available	Archey Fork Little Red River	Van Buren	At Highway 65	Boston Mountains	2017	2019	4
Arkansas Master Naturalists	Stream Team	Not available	South Fork Little Red River		At Highway 65	Boston Mountains	2017	2019	6
White County 4-H	Stream Team	Not available	Gin Creek	White	Berryhill Park in Searcy	Arkansas River Valley	2004 (2017)	2017	1
EPA	National Water Resource Survey	NRS18_AR_10016	Little Red River	Cleburne	East of Heber Springs	Arkansas River Valley	2018	2018	1

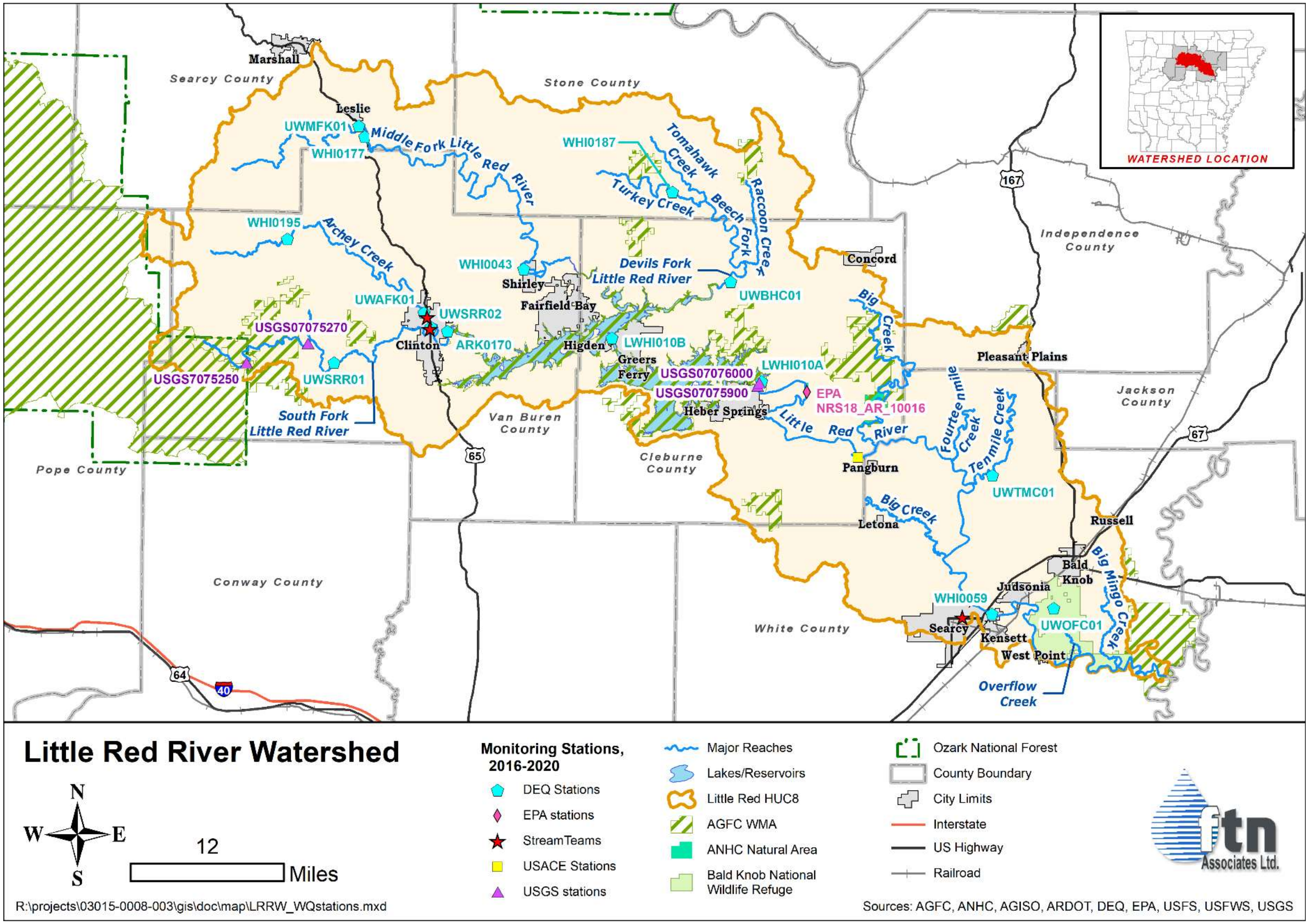


Figure 3.2. Water quality monitoring stations in the Little Red River watershed sampled during 2016-2020.

Table 3.3 Water quality parameters and sampling frequency for monitoring programs active in the Little Red River watershed 2016-2020 (AGFC 2021a, DEQ 2021a, EPA 2020a, USACE 2023a, USGS 2021).

Parameter	DEQ Ambient	DEQ Roving	DEQ Special Study	DEQ Lake	USGS Streams	USGS lake	EPA	USACE	Stream Teams
Mercury	-	-	-	-	-	-	-	-	-
Other metals	4-6/yr	2-3/yr	B	Q	S	-	X	-	-
DO	M	M	B	Q	X	X	-	D, S	X
Turbidity	M	2-3/yr	B	Q	S	-	X	-	X
transparency	-	-	-	Q	-	X	-	-	-
Nutrients	M	2-3/yr	B	Q	S	-	X	-	X
TSS	M	2-3/yr	B	Q	-	-	X	-	-
Suspended sediment	-	-	-	-	S	-	-	-	-
Pathogens	X	15-16/yr	-	-	S	-	-	-	-
Alkalinity	M	2-3/yr	B	Q	-	-	-	-	X
Minerals	M	2-3/yr	B	Q	S	-	X	-	X
Temperature	M	M	B	Q	X	X	-	D, S	X
Specific conductance	M	M	X	Q	X	-	X	-	-
pH	M	M	B	Q	X	X	X	-	X
Hardness	3-6/yr	2-3/yr	B	Q	S	-	-	-	X
Total organic carbon	M	2-3/yr	H	Q	-	-	-	-	-
Organics	H	-	-	-	-	-	-	-	-
Biochemical oxygen demand	9-11/yr+	H	-	-	-	-	-	-	-

D=daily, M=monthly; B=every two months; H=historically, but not in the last five years; Q=quarterly, X=varies; S=some stations

+ one station only, WHI0059

DEQ monitors surface water quality in the Little Red River watershed through several programs. There are three DEQ ambient water quality monitoring network sites in the watershed that are sampled monthly. There are also six roving stream water quality monitoring network sites in the watershed. Roving sites are sampled for chemical and bacterial analysis on a rotating basis, bimonthly over a 2-year period. Historically roving stations were usually sampled every 6 years (DEQ 2016). DEQ roving surface water quality sampling is currently on hold while the agency conducts ecoregion studies (J. Martin, DEQ, personal communication 11/24/2021). In addition to the ambient and roving stations, there are stream sites in the watershed where DEQ has collected, or is collecting, water quality data as part of special studies (DEQ 2018a). Several locations in the Little Red River watershed were recently sampled as part of a project to develop nutrient criteria for the Boston Mountains ecoregion. DEQ has classified Greers Ferry Lake as a Significant Publicly-Owned Lake. DEQ occasionally collects water quality data from these lakes. Greers Ferry Lake was sampled quarterly from 2011 through 2018.

The USGS has collected water quality data from upstream and downstream of Greers Ferry dam for decades. USGS also recently conducted a short-term water quality monitoring project on the South Fork Little Red River.

EPA has collected water quality samples in the watershed as part of the National Aquatic Resource Surveys. The most recent survey, conducted in 2018, included a location on the Little Red River. One sample was collected at this location.

There have been active Arkansas Game and Fish Commission (AGFC) Stream Teams in the Little Red River watershed that conducted water quality sampling. Arkansas Master Naturalists Stream Teams have collected water quality data from the Archey Fork and South Fork Little Red River within the last five years. White County 4H Stream Team collected water quality data from Gin Creek, a Little Red River tributary located in Searcy, in 2017 (AGFC 2021a).

3.1.3 Summary of Current Surface Water Quality

Water quality data collected by DEQ and USGS from 2016 through 2020 were evaluated to characterize current water quality in the Little Red River watershed. Parameters evaluated were bacteria, pH, alkalinity, turbidity, total suspended solids (TSS), suspended sediment, water temperature, dissolved oxygen (DO), DO saturation, biochemical oxygen demand (BOD), phosphorus, ammonia nitrogen, nitrate + nitrite nitrogen, and total nitrogen. Below is a summary of key findings from this evaluation. A detailed analysis and discussion of these water quality data is provided in Appendix D.

Recent (2018) *E. Coli* measurements collected by DEQ from the pathogen impaired stream reaches appear to indicate the *E. Coli* criterion is being met at some sampled locations, but not at others.

Low pH values in the Little Red River watershed appear to be largely a result of low buffering capacity (i.e., alkalinity) in the streams. This is a function of the underlying geology of the areas of the watershed within the Boston Mountains physiographic region, which has little carbonate rock. The Middle Fork Little Red River stations have the highest alkalinity measurements in the watershed, and the highest pH measurements.

For the most part, sediment parameters data from monitored stream locations appear relatively consistent across the watershed. Values in Greers Ferry Lake epilimnion are statistically significantly lower than values in the streams, due to the settling that occurs. Turbidity and TSS values at the downstream Little Red River station, WHI0059, tend to be higher than values from the tributaries upstream of Greers Ferry Lake, suggesting that sediment and erosion may be more of an issue downstream of the reservoir.

For the most part, DO levels at monitored locations in the Little Red River watershed are supportive of aquatic life, especially during the Primary Season. DO concentrations and DO saturation values at the monitoring location just downstream of Greers Ferry Lake dam (07076000) reflect DO levels in reservoir releases, which tend to be a bit lower than stream values. Water temperatures at station WHI0059 are so cool that only six out of the 68 DO measurements from this station are classified as Critical Season. BOD values at this location are low, less than 5 mg/L.

3.1.4 Assessed Water Quality Impairments

At the time of this writing, the most recent EPA approved state impaired waters list (i.e., 303(d) list) for Arkansas is from 2018. The 2020 303(d) list is currently under review. Impaired waters in the Little Red River watershed from the final 2018 list are given in Table 3.4 and mapped on Figure 3.3. On the 2018 303(d) list, over 130 miles of streams in the watershed are classified as impaired. Table 3.5 lists impaired waters in the Little Red River watershed from the draft 2020 list. New impairments from this list are also indicated on Figure 3.3.

There is an active fish consumption advisory in the watershed for Johnson Hole on the South Fork Little Red River (Figure 3.3). Due to high mercury levels in fish tissue, the public is advised not to eat largemouth bass 16 inches or larger from this area of the river. The majority of the mercury in these fish appears to come from natural mineral sources. Water quality conditions in this section of the South Fork Little Red River are conducive to the uptake and methylation of mercury by bacteria. The methylmercury becomes more concentrated in animal tissues as it moves up the food chain. Reducing erosion might help reduce the mercury available for bioaccumulation (FTN Associates, Ltd. 2002).

Table 3.4. Water quality impairments in the Little Red River watershed identified in the 2018 final 303(d) list (DEQ 2020, DEQ 2016).

Reach number	Reach description	Category*	Designated use not supported	Pollutant(s) causing impairment	Monitoring Station	Suspected source(s) of pollutants
11010014-940	South Fork Little Red River (13.8 miles long)	5	Not specified	pH	USGS (07075250)	Unknown
11010014-040	South Fork Little Red River (7.7 miles long)	5	Aquatic life	DO	USGS (07075270), WHI0189	Unknown
11010014-038	South Fork Little Red River (9.7 miles long)	5	Not specified	pH	UWSRR01, UWSRR02, WHI0190	Unknown
		4a	Primary contact recreation	Pathogen indicator bacteria		Unknown
11010014-036	South Fork Little Red River (4.0 miles long)	5	Not specified	pH	ARK0170	Unknown
		4a	Aquatic Life	Mercury		Unknown
11010014-028, -027	Middle Fork Little Red River (17.5 miles long)	4a	Primary contact recreation	Pathogen indicator bacteria	WHI0043	Unknown
11010014-009	Ten Mile Creek (23.5 miles long)	4a	Primary contact recreation	Pathogen indicator bacteria, turbidity	UWTMC01	Unknown (bacteria), erosion (turbidity)
11010014-012, -010, -008, -007	Little Red River (42.5 miles long)	4a	Primary contact recreation	Pathogen indicator bacteria	WHI0059	Unknown
11010014-006, -004	Overflow Creek (12.9 miles long)	4a	Primary contact recreation	Pathogen indicator bacteria	UWOFC01	Unknown

* Category 5 = impaired waterbodies that need a TMDL; Category 4a = impaired waterbodies for which a TMDL has already been developed

Table 3.5. Water quality impairments in the Little Red River watershed identified in the 2020 draft 303(d) list (DEQ 2021b).

Reach number	Reach description	Category*	Designated use not supported	Pollutant(s) causing impairment	Suspected source(s) of pollutants
11010014-940	South Fork Little Red River (13.0 miles long)	5	Not specified	pH	Unknown
11010014-040	South Fork Little Red River (7.0 miles long)	5	Aquatic life	DO (Critical Season)	Unknown
11010014-038	South Fork Little Red River (9.7 miles long)	5	Not specified	pH	Unknown
		4a	Primary contact recreation	Pathogen indicator bacteria	Unknown
11010014-036	South Fork Little Red River (4.0 miles long)	5	Not specified	pH	Unknown
		4a	Aquatic Life	Mercury	Unknown
11010014-028, -027	Middle Fork Little Red River (17.5 miles long)	4a	Primary contact recreation	Pathogen indicator bacteria	Unknown
11010014-009	Ten Mile Creek (23.5 miles long)	4a	Primary contact recreation	Pathogen indicator bacteria, turbidity	Unknown (bacteria), erosion (turbidity)
11010014-012, -010, -008	Little Red River (20.5 miles long)	4a	Primary contact recreation	Pathogen indicator bacteria	Unknown
11010014-007	Little Red River (22 miles long)	5	Not specified	pH	Unknown
		4a	Primary contact recreation	Pathogen indicator bacteria	Unknown
11010014-006, -004	Overflow Creek (12.9 miles long)	4a	Primary contact recreation	Pathogen indicator bacteria	Unknown
11010014-037	Archey Fork Little Red River (18 miles long)	5	Not specified, Outstanding Resource Waterbody	pH	Unknown

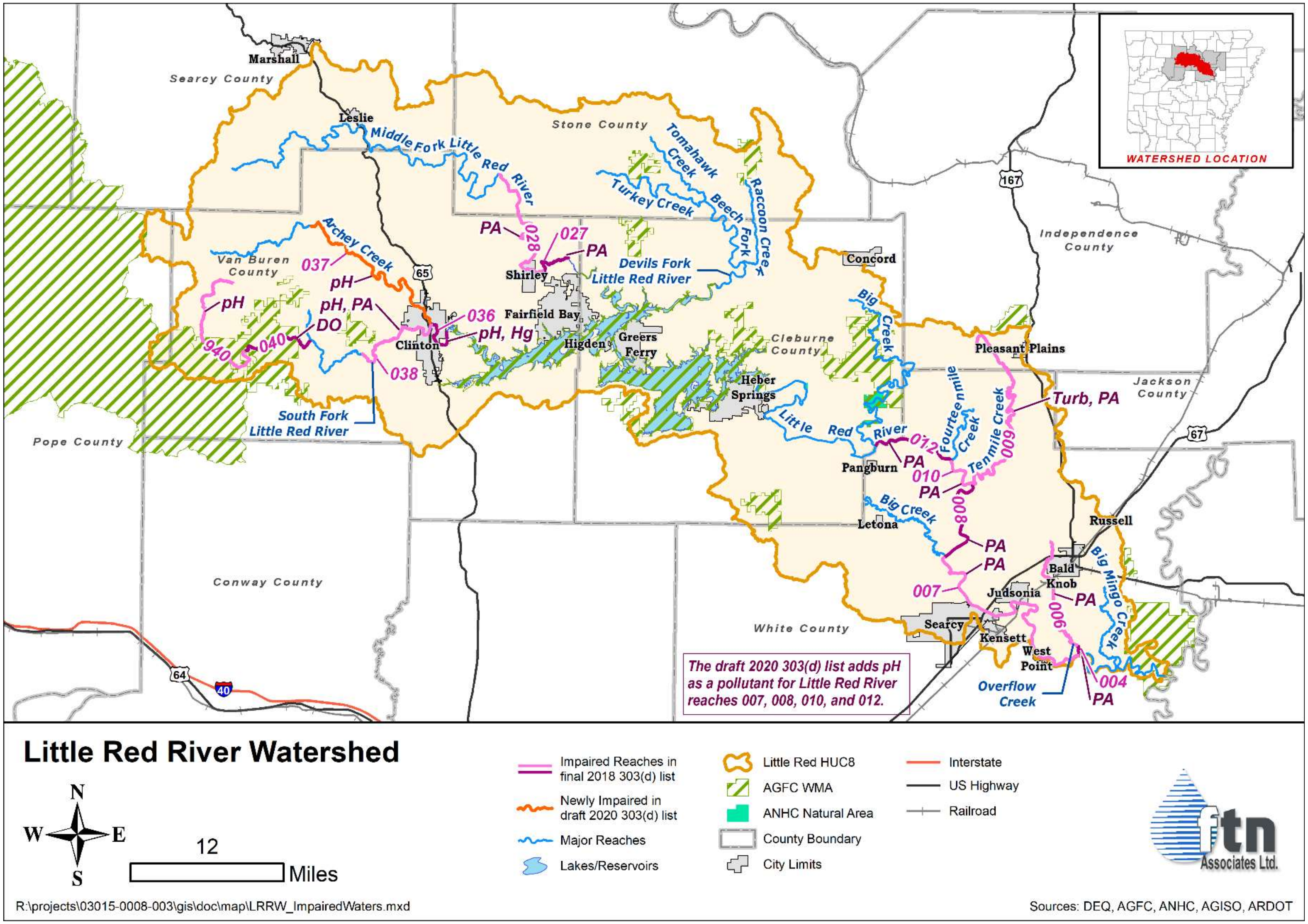


Figure 3.3. Waterbodies of the Little Red River watershed classified as impaired in the 2018 303(d) list. Impairment abbreviations are PA for pathogen indicator bacteria, Hg for mercury, Turb for turbidity, and DO for dissolved oxygen.

3.1.5 Long Term Trends/Changes in Water Quality

While it is important to look at current water quality conditions in the watershed, it is also important to determine if water quality is changing over time. Of particular interest for nonpoint source management are locations where water quality still meets water quality standards, but long-term trends suggest that water quality standards may not be met in the future if no action is taken. Pollutant concentrations that are decreasing over time suggest that water quality is improving and that upstream pollution management practices are providing benefits.

Adequate data for trend analysis were available from 11 stream water quality stations in the Little Red River watershed. Analysis of these data is described in detail in Appendix E. In most of the data sets evaluated, no trend was apparent. The results where trends were indicated are discussed below.

In the Little Red River downstream of Greers Ferry Lake, at Station WHI0059 near Searcy, water temperatures exhibit a statistically significant decreasing trend. Decreasing water temperatures may make this stream reach unsuitable for some aquatic organisms that currently occur here. They are also affecting evaluation of DO water quality criteria at this location (see Appendix D). The cause behind the declining temperatures is unknown. Also at station WHI0059, turbidity exhibits an increasing trend while TSS shows a decreasing trend. Turbidity levels that exceed the criteria already occur at this station. The increasing trend in turbidity suggests that exceedances of the turbidity criteria could increase in the future, with the potential for this stream reach eventually being classified as impaired due to high turbidity levels.

Measurements of pH exhibit a decreasing trend in Ten Mile Creek (UWTMC01). Ten Mile Creek is not currently listed as impaired due to low pH. The decreasing trend in pH suggests there is the potential for this stream reach to be listed as impaired due to low pH in the future.

Measurements of pH exhibit a decreasing trend in Middle Fork Little Red River (UWMFK01). Middle Fork Little Red River is not currently listed as impaired due to low pH. The decreasing trend in pH suggests there is the potential for the stream reach at UWMFK01 to be listed as impaired due to low pH in the future. Note that this reach of the Middle Fork Little Red River is designated as Critical Habitat for the Yellowcheek Darter.

Measurements of pH exhibit an increasing trend in lower Middle Fork Little Red River (WHI0043). Compared to other stations in the Little Red River watershed, pH values at WHI0043 are unusually high, and the maximum value from 2016-2020 is close to the upper pH criterion of 9. High levels of algal activity, such as occur with excessive nutrients, can cause high pH values. Thus, increasing pH levels at this location may indicate excessive productivity. Relatively high maximum DO from 2016-2020 could also indicate excessive productivity (see Appendix D). The lack of a declining trend in DO at this location is encouraging, but this location bears watching.

Turbidity in the upper Middle Fork Little Red River (WHI0177) exhibits a decreasing trend, while in the lower Middle Fork Little Red River (WHI0043) turbidity exhibits an increasing trend and TSS shows a decreasing trend. The Middle Fork Little Red River is not currently listed as impaired due to high turbidity. The decreasing turbidity trend at station WHI0177 suggests that the turbidity criteria will continue to be met at this location.

The increasing trend in turbidity at WHI0043 suggests that exceedances of the turbidity criteria could increase in the future, with the potential for this stream reach eventually being classified as impaired due to high turbidity levels. Given the pH and DO conditions at this location, it is possible that higher turbidity levels may be caused by higher algal populations, especially as all the turbidity criterion exceedances occur during the Baseflow period, i.e., summer. A further indication that water quality at this location may be declining. Note that decreasing TSS, suggesting increasing water clarity, could mean an increase in light available for algal growth.

Measurements of pH exhibit a decreasing trend in South Fork Little Red River (UWSRR01, UWSRR02, and ARK0170). The South Fork Little Red River is classified as impaired due to low pH. However, pH values at station ARK0170 increased to within the criteria range in 2020. If pH values at this station continue to remain within the criteria range, this stream reach may be removed from the impaired waters list. The pH values from UWSRR01 and UWSRR02 from the two most recent sampling periods appear stable (i.e., no statistically significant change), but are below the criteria range.

Turbidity exhibits an increasing trend at one station on the South Fork Little Red River, ARK0170. South Fork Little Red River is not currently listed as impaired due to high turbidity. The increasing trend in turbidity suggests that exceedances of the turbidity criteria could increase in the future, with the potential for this stream reach eventually being classified as impaired due to high turbidity levels.

3.1.6 Pollutant Loads

Pollutant loads are the product of concentration and stream flow. As a result, streams with low concentrations can contribute large loads if they have very large flow. Vice versa, a stream with a high concentration but a low flow, may have a relatively small load. Yield is the load for a stream divided by the drainage area of the stream. This section discusses and compares estimates of loads and yields for the Little Red River and some of its tributaries. The parameters for which loads are discussed are TSS, total phosphorus, and total nitrogen. Loads and yields calculated using flow and water quality measurements are discussed, as well as loads and yields estimated using water quality models.

3.1.6.1 Loads From Measurements

There are several active daily flow gages in the Little Red River watershed that are located near to water quality monitoring locations (Table 3.6). We selected water quality monitoring locations where samples were collected monthly during the period 2016-2020 to calculate load estimates, ARK0170, WHI0043, and WHI0059. Annual loads of TSS, total phosphorus, total nitrogen, and nitrate + nitrite nitrogen were calculated for these locations. Annual load estimates were calculated by multiplying the harmonic mean[2] flow by the harmonic mean concentration, both calculated from measurements collected during 2016-2020.

[2] Harmonic mean is the reciprocal of arithmetic mean. It is considered the most appropriate mean for rates, such as flow. It also is less influenced by occasional large values, which occur in some of the water quality records.

Table 3.6. Active daily flow gages located at or near selected water quality stations in Little Red River watershed.

Water Quality Station ID	Stream	Water Quality Station Location	Flow Gage ID	Flow Gage Location
WHI0043	Middle Fork Little Red River	Highway 9	07075000	Highway 9
ARK0170	South Fork Little Red River	County Road 23	07075300	Highway 65
WHI0059	Little Red River	State Rd 367, near Searcy	07076517	Near Dewey

For the water quality data, to improve comparability of the estimated loads, the same number of measurements were used to calculate the harmonic mean for each of the water quality stations. As can be seen in the tables in Appendix D, different numbers of measurements were collected at the three water quality monitoring stations during the period 2016-2020. In most cases samples were not collected on the same date of the month at all three stations. Therefore, measurements were used only from the months when all three stations were sampled. This approach resulted in 44 measurements being used to calculate the harmonic mean concentrations.

Load calculations for TSS, total phosphorus, nitrate + nitrite nitrogen, and total nitrogen are summarized in Tables 3.7 through 3.10. Upstream of Greers Ferry Lake, the estimated loads from the Middle Fork Little Red River tend to be greater than those from the South Fork Little Red River, even though concentrations are lower, because flow (and drainage area) is higher. Yields (load divided by drainage area) from the South Fork Little Red River are higher than those from the Middle Fork Little Red River, around double for nitrogen and TSS. The estimated loads downstream of Greers Ferry Lake are at least an order of magnitude greater than those estimated for the stations upstream of Greers Ferry Lake. It is reasonable to assume that TSS from upstream of Greers Ferry Lake is trapped in the reservoir, rather than being transported downstream. If we calculate TSS yield for station WHI0059 using just the drainage area downstream of Greers Ferry Lake dam, it increases by an order of magnitude (Table 3.7).

Table 3.7. TSS loads estimated using measurements.

Stream	Water Quality Station	Harmonic Mean TSS, mg/L	Harmonic mean flow, cfs	Estimated Load, kg/year	Drainage area, sq km	Estimated Yield, kg/sq km
Middle Fork Little Red River	WHI0043	1.68	21.75	544	782	0.7
South Fork Little Red River	ARK0170	2.18	15.81	514	383	1.3
Little Red River	WHI0059	2.74	783.20	31,922	3,469 (492)*	9.2 (65)+

* drainage area between Greers Ferry dam and WHI0059
\+ yield calculated using drainage area between Greers Ferry dam and WHI0059

Table 3.8. Total phosphorus loads estimated using measurements.

Stream	Water Quality Station	Harmonic Mean Total Phosphorus, mg/L	Harmonic mean flow, cfs	Estimated Load, kg/year	Drainage area, sq km	Estimated Yield, kg/sq km
Middle Fork Little Red River	WHI0043	0.015	21.75	4.8	782	0.006
South Fork Little Red River	ARK0170	0.015	15.81	3.6	383	0.009
Little Red River	WHI0059	0.018	783.20	205	3,469	0.059

Table 3.9. Total nitrogen loads estimated using measurements.

Stream	Water Quality Station	Harmonic Mean Total Nitrogen, mg/L	Harmonic mean flow, cfs	Estimated Load, kg/year	Drainage area, sq km	Estimated Yield, kg/sq km
Middle Fork Little Red River	WHI0043	0.17	21.75	57	782	0.07
South Fork Little Red River	ARK0170	0.22	15.81	51	383	0.13
Little Red River	WHI0059	0.38	783.20	4,436	3,469	1.3

Table 3.10. Nitrate + nitrite loads estimated using measurements.

Stream	Water Quality Station	Harmonic Mean Nitrate + Nitrite, mg/L	Harmonic mean flow, cfs	Estimated Load, kg/year	Drainage area, sq km	Estimated Yield, kg/sq km
Middle Fork Little Red River	WHI0043	0.026	21.75	8	782	0.01
South Fork Little Red River	ARK0170	0.045	15.81	11	383	0.03
Little Red River	WHI0059	0.149	783.20	1,738	3,469	0.50

As seen in Appendix D, *E. Coli* were measured at six locations in the Little Red River watershed during 2018, with similar numbers of measurements at all of the locations. These data were used to calculate *E. Coli* loads. Loads for *E. Coli* were calculated by multiplying the harmonic mean of measurements *E. Coli* from 2018 by harmonic mean flows estimated for the monitoring station locations using USGS StreamStats (USGS 2023). The resulting *E. Coli* loads and yields are summarized in Table 3.11. The greatest load was calculated for Little Red River near Searcy (WHI0059), followed by Middle Fork Little Red River (WHI0043). This makes sense as these locations have the highest flows. Ten Mile Creek, which has a low flow, has the third greatest load as a result of the high *E. Coli* concentration.

Table 3.11. *E. Coli* loads estimated using measurements.

Stream	Water Quality Station	Harmonic Mean *E. Coli*, cfu /100 mL	Harmonic mean flow, cfs	Estimated Load, 10^6 cfu /yr	Drainage area, sq km	Estimated Yield, 10^6 cfu /sq km
Overflow Creek	UWOFC01	26	0.43	1,673	76	22
Little Red River	WHI0059	28	31.3	131,504	4,324 (492)*	30 (267)+
Ten Mile Creek	UWTMC01	95	1.14	16,106	186	86
Middle Fork Little Red River	WHI0043	20	7.34	21,680	782	28
South Fork Little Red River	UWSRR02	23	2.38	8,077	383	21
South Fork Little Red River	UWSRR01	11	1.57	2,549	285	9

* drainage area between Greers Ferry dam and WHI0059
+ yield calculated using drainage area between Greers Ferry dam and WHI0059

If we calculate yield for station WHI0059 using the entire upstream drainage area, *E. Coli* yield at this location is comparable to the yields from upstream of the reservoir. However, it is likely that *E. Coli* that enter the reservoir do not survive to be transported downstream. Therefore, we also calculated *E. Coli* yield for station WHI0059 using just the drainage area downstream of the dam. The resulting yield is an order of magnitude higher than the other stations. Comparing this higher yield to the yield for station UWTMC01, the Ten Mile Creek yield seems less unusual.

3.1.6.2 USGS SPARROW Model

Recently, USGS updated SPARROW modeling of the US to the period 2000-2014, and estimated streamflow and nitrogen, TSS, and phosphorus yields for 2012 (Robertson and Saad 2019). Estimated 2012 yields from the Little Red River watershed from the updated Midwest SPARROW model are listed in Table 3.12. The estimated Little Red River 2012 nutrient and sediment yields are in the middle range for the Midwest (USGS 2019). Given that the area of the Little Red River watershed is 1,802 square miles, or 4,667 square kilometers, watershed nutrient and sediment loads can be calculated based on the SPARROW aggregated yields (see Table 3.12).

Table 3.12. Estimated yields from the Little Red River watershed for 2012 using SPARROW model (USGS 2019).

Parameter	Estimated 2012 aggregated yield	Midwest ranking	Yield * 4,667 sq km
Total nitrogen	518 kg/sq km	Third quintile (305-580)	2,417,506 kg
Total phosphorus	64.4 kg/sq km	third quintile (34.6-77.8)	300,555 kg
Suspended sediment	101 metric tons/sq km	third quintile (72.4-123)	471,367 metric tons
Streamflow	588 mm/year	Top quintile (>471)	-

As part of developing the regional SPARROW models, USGS estimated annual loads for over 3,000 water quality monitoring locations in the US (Saad, et al. 2019). Through this effort, 2012 annual loads of nitrogen and phosphorus were developed for one location, and sediment annual loads were developed for two locations within the Little Red River watershed. These loads are listed in Table 3.13. Flows from a nearby Little Red River flow gage were used to estimate the loads at DEQ station WHI0059.

Table 3.13. USGS estimated 2012 annual loads for water quality monitoring locations in the Little Red River watershed (Saad, et al. 2019).

Parameter	Estimated 2012 Loads	
	Station 07075270 (South Fork Little Red River)	**Station WHI0059 (Little Red River)**
Total nitrogen	-	1,002,345 kg/year
Total phosphorus	-	99,026 kg/year
Sediment	12,680 metric tons/year SSC	35,430 metric tons/year TSS

The Midwest SPARROW model estimates load contributions from a variety of sources (Robertson and Saad 2019). Figures 3.4 – 3.6 illustrate the estimated relative load contributions from sources in the Little Red River watershed. The SPARROW model identifies manure as the greatest contributor to total phosphorus, atmospheric deposition as the greatest contributor to total nitrogen, and agriculture on medium/coarse soils and channel sources as the greatest contributors to sediment yield. Given that atmospheric deposition contributes approximately two-thirds of the total nitrogen in this watershed, it could be difficult to reduce nitrogen concentrations in surface waters using local land management practices.

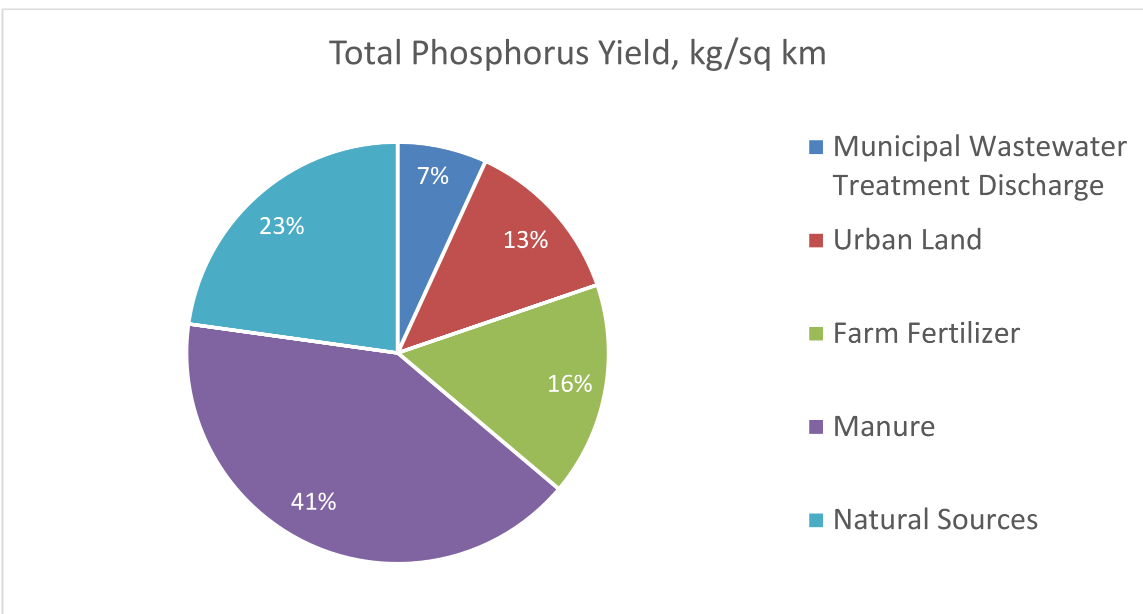


Figure 3.4. SPARROW model sources of total phosphorus load in Little Red River watershed.

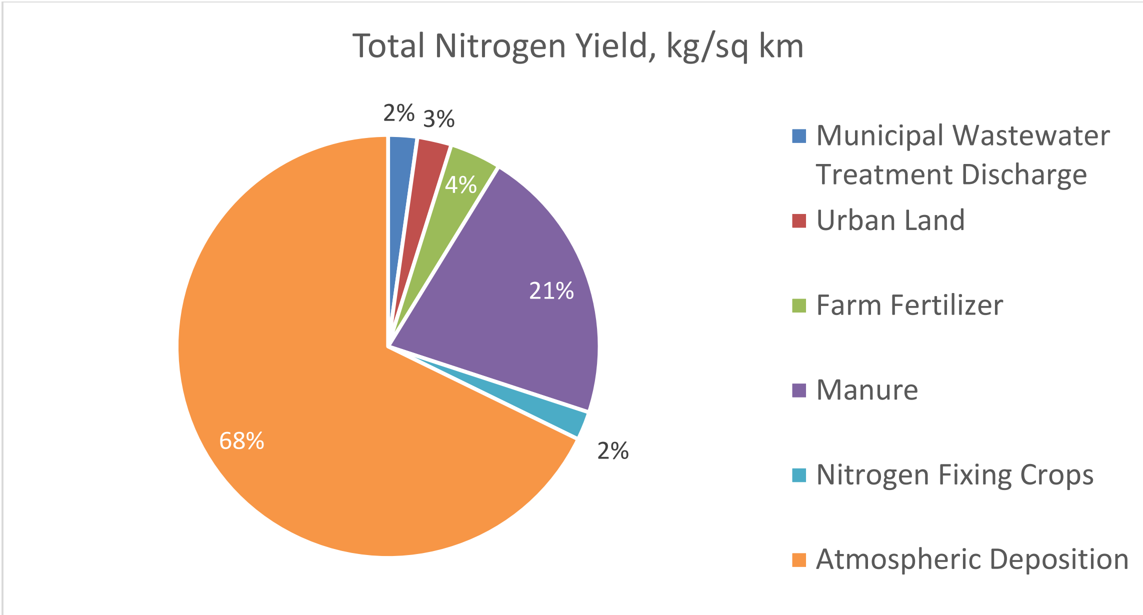


Figure 3.5 SPARROW model sources of total nitrogen load in Little Red River watershed.

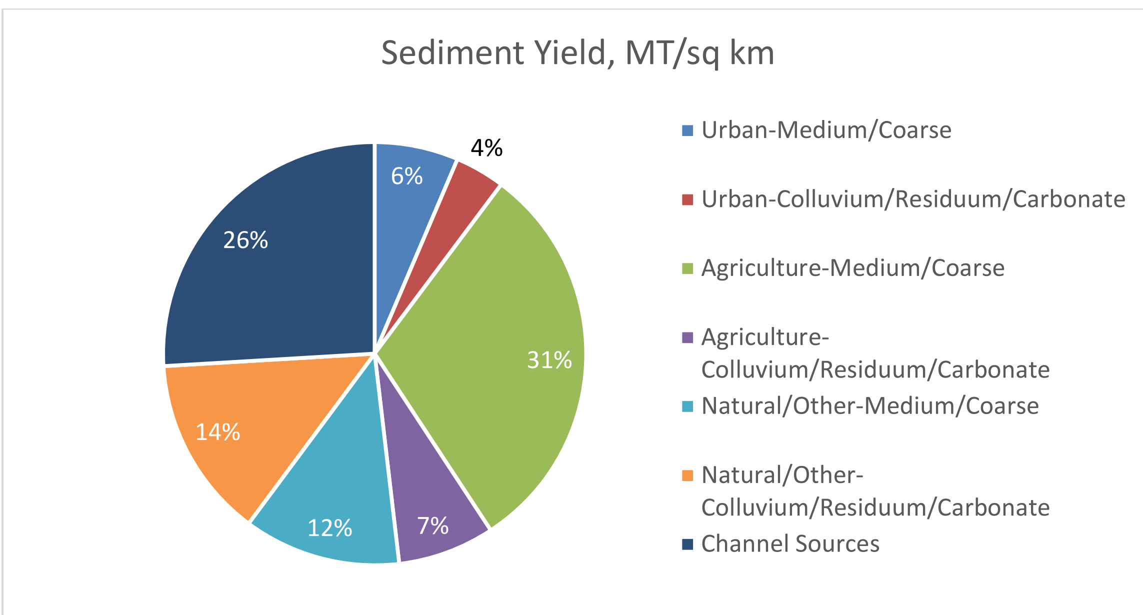


Figure 3.6. SPARROW model sources of sediment load in Little Red River watershed.

3.1.6.3 SWAT Model

A SWAT model of the Little Red River watershed was prepared in 2021. This model also simulates total nitrogen, total phosphorus, and sediment yields. Overall average annual loads and for the watershed from this model are listed in Table 3.14. This model was run for the period 1996-2019. The SWAT total nitrogen load is about half the SPARROW model total nitrogen load (see Table 3.12). The SWAT total phosphorus load is similar to the SPARROW total phosphorus load. The SPARROW sediment load is an order of magnitude greater than the SWAT sediment load.

Table 3.14. SWAT estimated average annual loads from the Little Red River watershed.

Parameter	Average annual load
Total Nitrogen	966,454 kg
Total Phosphorus	260,625 kg
Sediment	28,918 metric tons

The purpose of this SWAT modeling effort was to rank the HUC12 subwatersheds in terms of yields of nutrients and sediment from nonpoint sources. To estimate sediment and nutrient yields from nonpoint sources, the calibrated model was run without point sources. HUC12 subwatersheds were then ranked based on the yields from subwatershed runoff (excluding inputs from upstream subwatersheds). Figures 3.7 – 3.9 illustrate the relative rankings of the HUC12 subwatersheds based on simulated yields of total nitrogen, total phosphorus, and sediment from nonpoint sources (FTN Associates, Ltd. 2022).

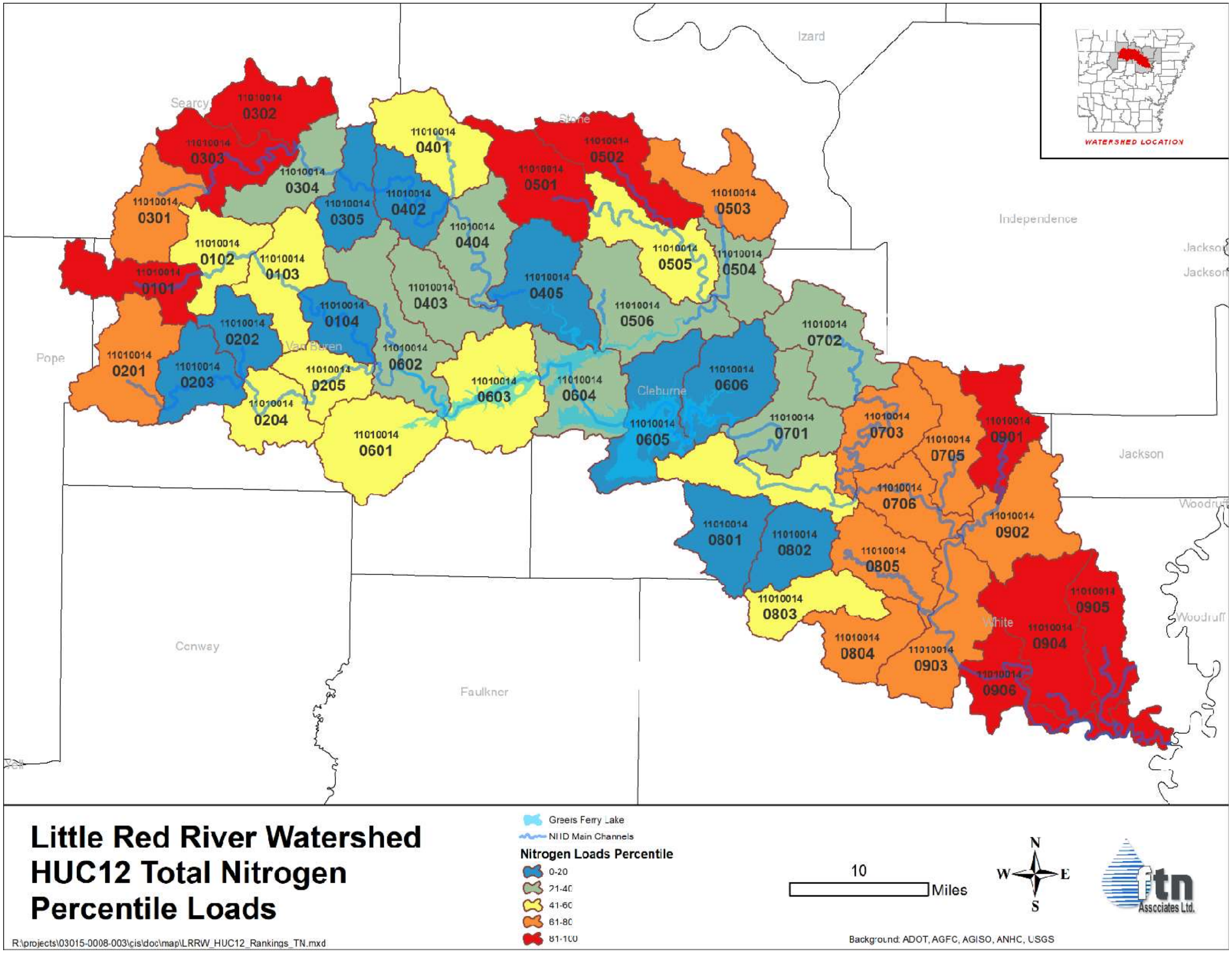


Figure 3.7. Ranking of Little Red River HUC12s based on total nitrogen yields from land.

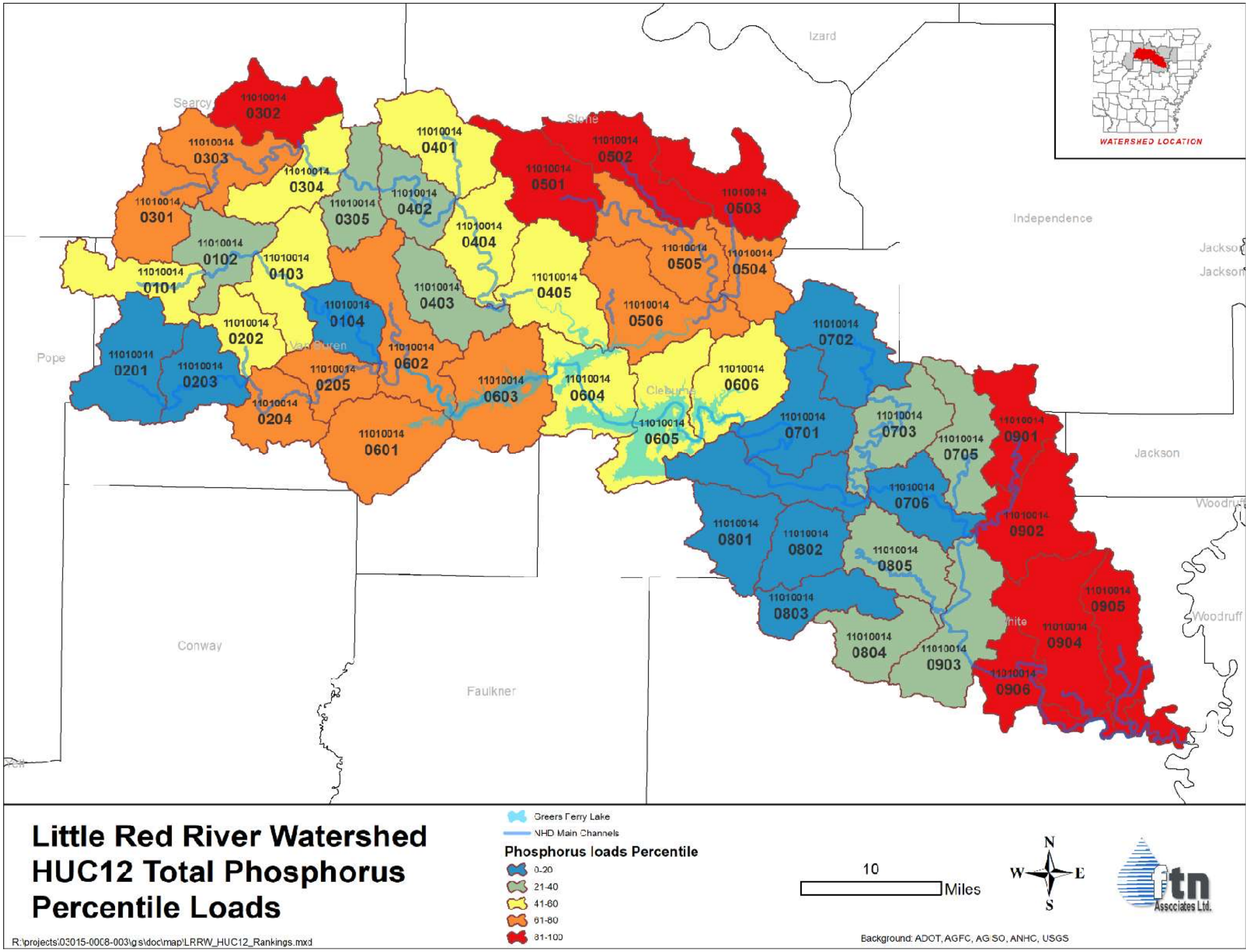


Figure 3.8. Ranking of Little Red River HUC12s based on total phosphorus yields from land.

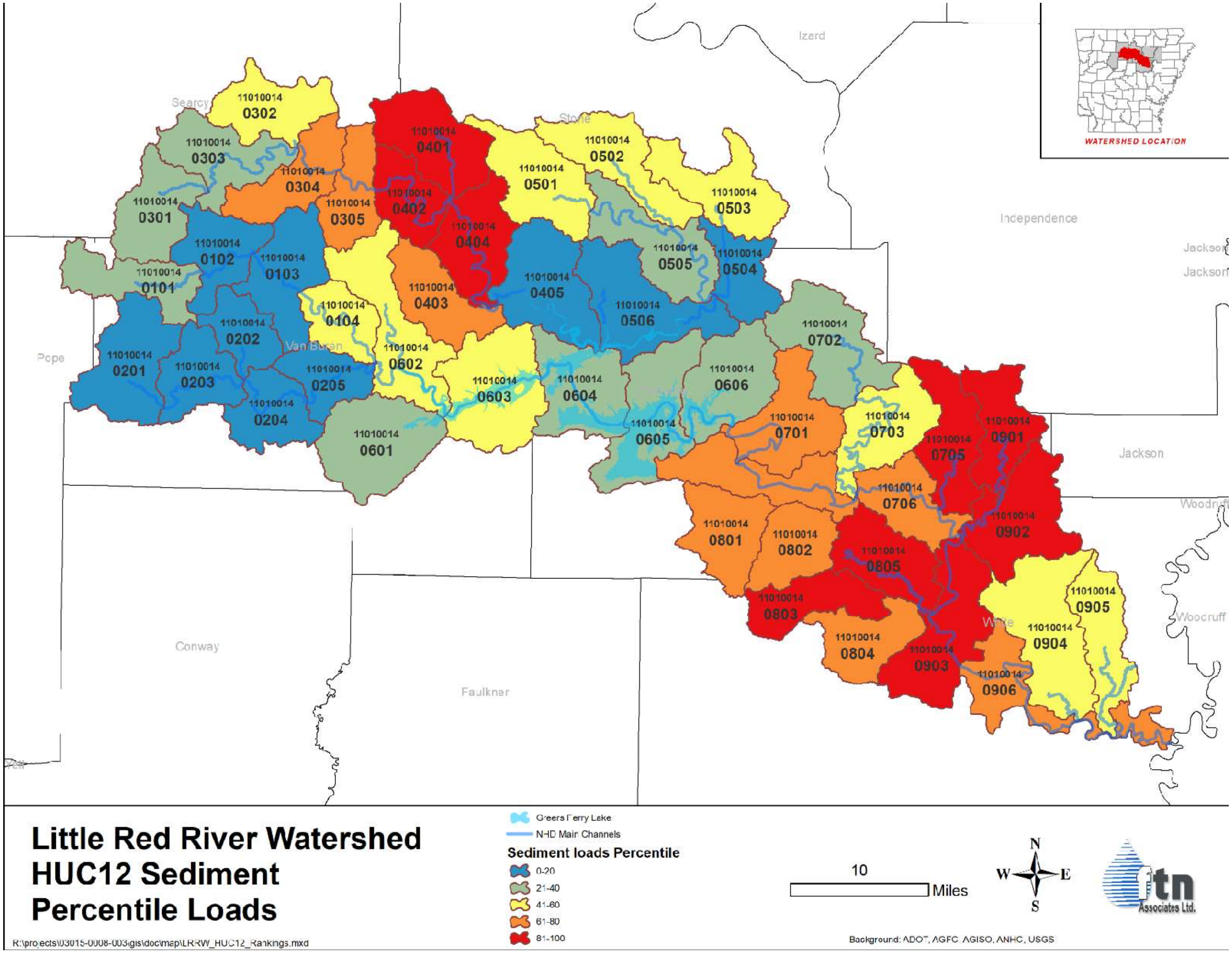


Figure 3.9. Ranking of Little Red River HUC12s based on sediment yields from land.

3.1.6.4 Discussion

Because Greers Ferry Lake is a drinking water supply, there is considerable interest in pollutant loads entering the reservoir. It is important that the lake water quality remains good so that treatment costs stay low, and there are concerns that sediment entering the reservoir will reduce its capacity to store water.

A recent hydrology and hydraulics assessment of Greers Ferry Lake states that, “The Little Red River above Greers Ferry Lake has a relatively low sediment load.” When the reservoir was designed, the estimated Little Red River sediment load was 315 acre-feet per year. Sediment surveys of Greers Ferry Lake conducted in 1964, 1974, and 1977 showed measurable sediment deposition at only three of the 12 transects. The assessment document further states that “there have been no reported issues with sedimentation” (USACE 2017).

Load calculations using measurements, and the SWAT model results, suggest that pollutant loadings from areas downstream of Greers Ferry Lake can be significant. Reservoirs trap some pollutants. As a result, loads from areas downstream of the dam have greater potential to impact water quality outside of the Little Red River watershed.

3.1.7 Data Gaps

Several water quality data gaps were identified during inventorying and analyzing recent water quality data. These are discussed in the paragraphs below.

DEQ has collected BOD measurements from only one of their stations in this watershed since 2010, WHI0059. There is one BOD measurement from the stream reach listed as impaired due to low DO, station WHI0189 in 2005. Although the single BOD measurement at this station in 2005 was <10 mg/L, measuring BOD again at this location may be useful. These measurements could be used to help evaluate how much the low DO conditions are influenced by organic matter in the water column (as opposed to organic matter on the stream bottom).

Turbidity data from UWTMC01 resulted in Ten Mile Creek being listed as not meeting turbidity standards. However, turbidity measurements have not been collected at this site since 2003. Turbidity measurements are needed to be able to determine whether this stream is meeting the turbidity water quality criteria.

There are few or no DO measurements from several stations during Critical Season, because water temperatures are rarely or never above 22 deg C. This includes monitoring stations on the stream reach currently classified as impaired due to low DO in 2018. A data set adequate to reevaluate attainment of the Critical Season DO criterion at this location needs to be generated.

For many of the DEQ monitoring stations, there are no measurements of lab water quality parameters after 2016.

Although there is less development in the Beech Creek (also known as Beech Fork) watershed than the watersheds of the other Little Red River forks upstream of Greers Ferry Lake, SWAT modeling suggests that nutrient loads from this subwatershed may be significant. Increased water quality and flow monitoring in this subwatershed may be useful.

3.1.8 Summary

There are over 130 miles of streams in the Little Red River watershed that do not meet water quality standards, i.e., impaired water quality. The pollutants causing water quality impairment include pathogens (*E. Coli*, 106 miles), acidifying materials or processes (low pH, 23 to 84 miles), turbidity (23.5 miles), oxygen demanding materials (low DO, 7.7 miles), and mercury (4 miles). *E. Coli* measurements collected from the impaired stream reaches in 2018 may indicate that the *E. Coli* criterion is being met at some of the sampled locations.

Low pH values in the Little Red River watershed appear to be a result of naturally low buffering capacity (i.e., alkalinity) in streams within the Boston Mountain physiographic region. Statistically significant decreasing trends in pH values were identified at several monitoring stations on the South Fork Little Red River, as well as the monitoring station on Ten Mile Creek, and one on the upper Middle Fork Little Red River. We do not know what is changing in these areas of the watershed that is increasingly overwhelming the buffering capacity of these streams. Also of note is that pH measurements at the South Fork Little Red River station near Clinton (ARK0170) from 2020 and 2021 are much higher than pH values from the previous five years. The cause for the abrupt and drastic change in pH at this location is currently unknown.

There are also some locations where pH values exhibited statistically significant increasing trends, in the lower Little Red River (near Searcy) and the lower Middle Fork Little Red River (near Shirley). Note that at the Middle Fork Little Red River station near Shirley, the median pH level from 2016-2020 was statistically significantly higher than the median pH levels at the rest of the stream stations during that period. Increasing pH at these locations may indicate increasing primary productivity. A statistically significant decreasing trend in total nitrogen was identified at the Middle Fork Little Red River station, as well as an increasing trend in turbidity. These two trends seem to contradict the idea that algal productivity is increasing at this monitoring location, even though the highest maximum DO value in the watershed was measured here, along with at least one DO percent saturation value greater than 100%. There was no statistically significant trend in DO at this location. The fact that median nutrient and turbidity levels at this location are not statistically different from those at other stream stations in the watershed upstream of Greers Ferry Lake also suggests that algal productivity may not be behind the pH trend. Thus, the cause behind the increasing trend in pH at the Middle Fork Little Red River station is unknown.

There are some factors that seem to support the supposition that the increasing trend in pH at the Little Red River station near Searcy may be related to increasing algal productivity, and others that do not. This station had the highest median total phosphorus concentration for 2016-2020, and some of the highest median nitrogen concentrations, but median nutrient concentrations at this location were not statistically significantly higher than the other stream stations. In addition, no trends were evident in nutrient concentrations at this location. This station had the highest median DO concentration 2016-2020, though not statistically significantly higher than most other stream stations, and 25% of 2016-2020 DO percent saturation values at this location were over 100%. No statistically significant trend in DO was identified at this location. Turbidity at this location is somewhat higher than at the other monitored locations and exhibits a statistically significant increasing trend. Overall, it is not clear if increasing pH at this location is related to increasing algal productivity.

There is no indication of a cause for the low DO impairment on the upper South Fork Little Red River. No statistically significant trend in DO was identified at the monitoring stations at the impaired stream reach.

The primary source of mercury causing the fish consumption advisory in the Little Red River watershed appears to be natural mineral sources. Water quality conditions of the listed section of the South Fork Little Red River support uptake of naturally occurring mercury by bacteria. The mercury then moves up the food chain, becoming more concentrated in animal tissues, until they reach unhealthy levels in some fish.

One other water quality trend identified is of interest, a decreasing trend in water temperature in the Little Red River near Searcy. This decreasing trend in water quality means that Critical Season DO conditions (i.e., water temperatures > 22 deg C) only rarely occur at this station. During 2016-2020, only six DO concentrations were measured at this location when water temperature was greater than 22 deg C. No cause was identified for the decrease in water temperature at this location.

Regarding pollutant loads, analyses indicate that yields of nutrients and sediment are greater from areas downstream of Greers Ferry Lake than from areas upstream of the reservoir. Two locations downstream of Greers Ferry Lake also had the highest estimated yield of *E. Coli*. The USGS SPARROW nutrient and sediment model identified manure as the greatest source of phosphorus in the Little Red River watershed, atmospheric deposition as the greatest source of nitrogen, and agriculture as the greatest source of sediment.

3.2 Groundwater Quality

In the Little Red River watershed, there are no formally recognized aquifers and groundwater is not a heavily used resource (USACE 2019). In 2015, less than 0.3 million gallons per day of groundwater were withdrawn in Cleburne and Van Buren Counties, primarily for home use and livestock (USGS 2015). However, there are springs in the watershed so there is transfer between groundwater and surface water. Thus, groundwater quality has the potential to impact surface water quality. This section describes groundwater quality in the Little Red River watershed in terms of measured concentrations of selected parameters. This includes a summary of the water quality standards that apply in the watershed and the water quality monitoring programs active in the watershed. Recent groundwater quality data are summarized and discussed.

3.2.1 Groundwater Quality Standards

There are various environmental regulations in Arkansas that are designed to prevent contamination of groundwater, but Arkansas has not promulgated any numeric water quality criteria that apply to groundwater. However, groundwater that is used for drinking water is evaluated based on national primary drinking water standards. These standards include numeric criteria for organic chemicals, metals, microorganisms, radioactive materials, and nitrate and nitrite (EPA 2020b).

3.2.2 Groundwater Quality Monitoring

DEQ and USGS have collected groundwater quality data in the Little Red River watershed. An inventory of historical groundwater quality monitoring locations is included in Appendix C. Table 3.15 lists wells and springs in the watershed where groundwater quality measurements were taken during 2016-2020. These locations are shown on Figure 3.10.

Table 3.15. Groundwater quality monitoring stations in the Little Red River watershed active during 2016-2020 (DEQ 2021a, USGS 2021).

Entity	Station ID	Aquifer*	Description	County	Depth, ft	Start Year	End Year	Number of dates
USGS	351616091314502	MS River Valley Alluvial Aquifer	08N05W34CAC2	White	70	2019	2019	1
DEQ	FSH036	Atoka or Hale	Heber Springs Park Spring 036	Cleburne	-	2010 (2018)	2018	1
DEQ	FSH037	Atoka or Hale	Heber Springs Park Spring 037	Cleburne	-	2010 (2018)	2018	1
DEQ	FSH038	Atoka or Hale	Heber Springs Park Spring 038	Cleburne	-	2010 (2018)	2018	1
DEQ	FSH040	Atoka or Hale	Heber Springs Park Spring 040	Cleburne	-	2010 (2018)	2018	1
DEQ	FSH041	Atoka or Hale	Public Water Supply Well 041	Cleburne	-	2010 (2018)	2018	1

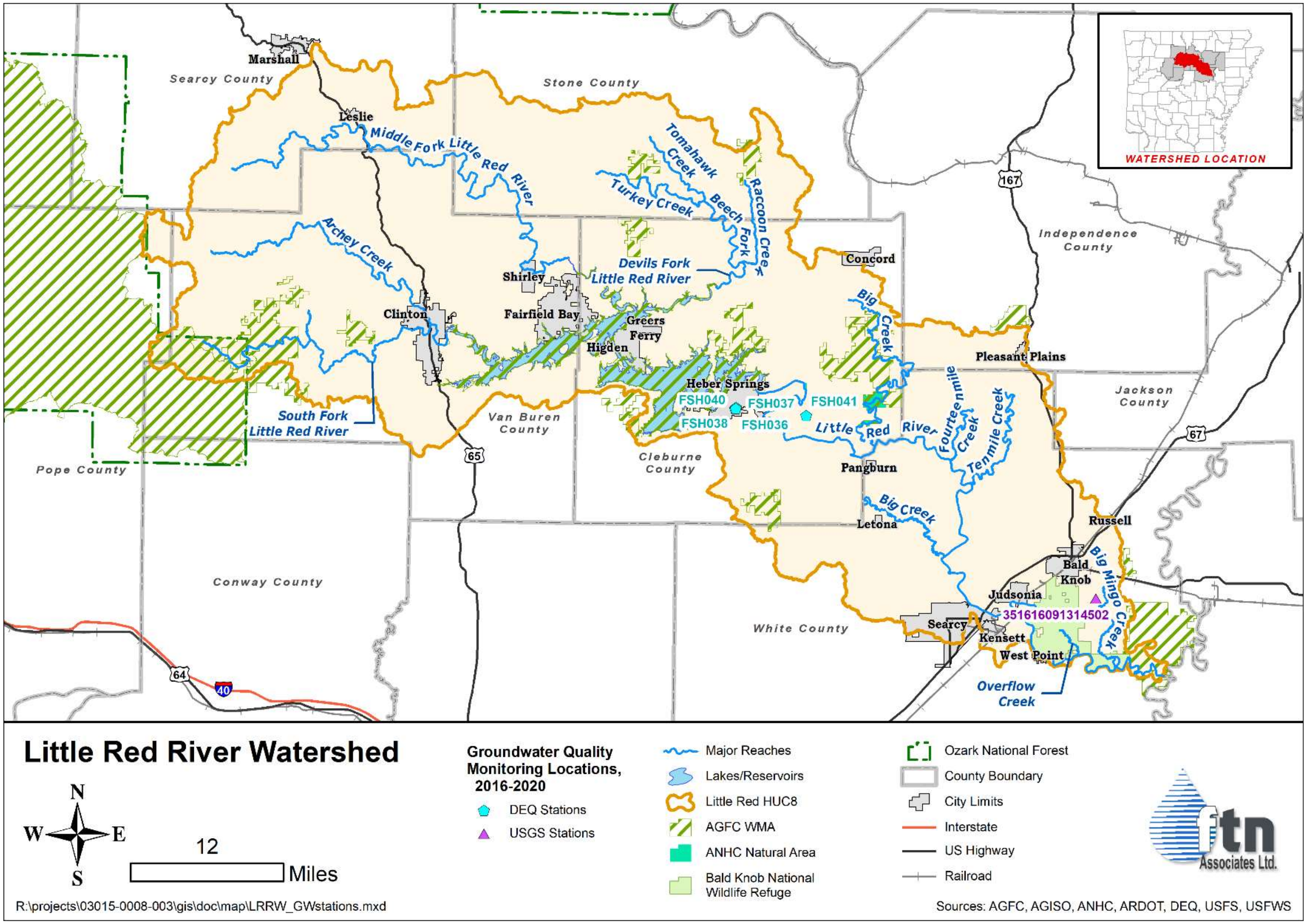


Figure 3.10. Locations of groundwater quality sampling during 2016-2020 in the Little Red River watershed.

DEQ monitors groundwater quality in the Little Red River watershed through its Ambient Groundwater Monitoring Program, initiated in 1986. This program consists of 12 areas sampled approximately every three years. A portion of the North Central monitoring area is located within the Little Red River watershed. The North Central monitoring area was initiated in 2010 to characterize water quality in the shale gas development "boom" area of the state (DEQ 2018a). Water quality parameters measured in the DEQ groundwater quality monitoring program are identified in Table 3.16.

Table 3.16. Summary of groundwater quality data collected by DEQ and USGS in the Little Red River watershed 2016-2020.

Parameter	DEQ	USGS
Metals	X	X
DO	-	X
Turbidity	X	-
Nitrate + nitrite nitrogen	X	X
Other nutrients	X	-
TSS	X	-
Alkalinity	X	-
TDS	X	X
Other minerals	X	X
Temperature	X	-
Specific conductance	X	X
pH	X	X
Hardness	X	X
Total organic carbon	X	-
Radioactivity	-	X
Gases	-	X

USGS has a routine groundwater quality monitoring network in Arkansas. However, none of the wells in that network are located in the Little Red River watershed. USGS did sample one well in this watershed in 2019. Parameters measured at this well are listed in Table 3.16. July of 2011, USGS sampled 54 wells in the Little Red River watershed as part of a study of groundwater in the Fayetteville Shale gas-production area in Arkansas (Kresse, et al. 2012). In 2015, USGS sampled 14 wells in the watershed.

The Arkansas Department of Agriculture Pesticides Section (formerly the Arkansas State Plant Board) monitors groundwater for agricultural chemicals through its Arkansas Ground Water Monitoring Program. Through this program, initiated in 2004, the Pesticides Section has sampled 271 wells in 30 counties for pesticides (Arkansas Department of Agriculture 2020). One sampled well in Van Buren County appears to be located within the Little Red River watershed (Arkansas State Plant Board pre-2020).

3.2.3 Groundwater Quality Summary

With regard to human health, the primary water quality parameters of concern are nitrate, nitrite, and toxics. A detailed evaluation of groundwater quality is provided in Appendix F. The findings of this evaluation are summarized below. Note that groundwater quality sampling by both USGS and DEQ did not identify groundwater quality impacts from shale gas development activities in north-central Arkansas (DEQ 2018a, Kresse, et al. 2012, Warner, et al. 2013).

- There is no indication that nitrate or nitrite in groundwater is an issue in the Little Red River watershed.
- Groundwater samples from 2016-2020 were not analyzed for organic chemicals but they were analyzed for metals. Barium was measured above the maximum contaminant level in one sample from the Mississippi River Valley Alluvial aquifer.
- Groundwater pH measurements are within 6 su to 9 su, indicating that groundwater does not contribute to low pH conditions in surface waters.

3.2.4 Groundwater Quality Vulnerability

A groundwater vulnerability map developed by The Nature Conservancy (TNC) using DRASTIK, indicates that groundwater quality is moderately to highly vulnerable to impacts from surface land management activities in the Boston Mountains region of the Little Red River watershed (Inlander, Gallipeau and Slay 2011).

3.2.5 Summary

Groundwater vulnerability modeling by The Nature Conservancy indicates that groundwater quality is moderately to highly vulnerable to impacts from land management activities in the Boston Mountains region of the Little Red River watershed. However, available groundwater data do not indicate groundwater quality issues within the Little Red River watershed.

3.2.6 Data Gap

Given the characteristics of the groundwater hydrogeology, and extent of groundwater use in this watershed, existing groundwater quality monitoring is adequate.

3.3 Ecological Condition

3.3.1 Geomorphology

Stream geomorphology addresses the relationships between characteristics of a stream watershed (i.e., topography, geology, and land use) and the shape of the stream channel (i.e., width, depth, and slope). A “stable” stream channel experiences only small changes in shape or location over time. Geomorphology in the Little Red River watershed has been influenced by several historical events, including removal of the original forest, modification of riparian areas, construction of Greers Ferry Lake, and channel modification.

Channel instability has been identified as an issue throughout the Little Red River watershed. A 2005 streambank survey of the Middle Fork Little Red River identified 54 unstable streambanks, totaling over four miles of unstable streambanks (DEQ 2006). A streambank survey of the Little Red River downstream of Greers Ferry Dam conducted in 2003 identified 11 unstable streambanks, all of which were upstream of Pangburn. This inventory found that streambank erosion contributed significantly to sedimentation in the Little Red River only 18 to 25 miles downstream of the dam (Cleburne County Conservation District 2003a). Downstream of the dam, reservoir water control activities are believed to contribute to bank erosion, along with changes to riparian vegetation (Cleburne County Conservation District 2003a). A 1986 channelization of the Archey Fork Little Red River where it flows through Clinton resulted in channel instability (TNC 2014).

3.3.2 Hydrology

Timing and magnitude of stream flows are part of the aquatic habitat. Native aquatic species are adapted to the natural seasonal variation in flow. Some even depend on this variation for reproduction success.

There were four active USGS flow gages in the Little Red River watershed in 2021 (Figure 3.11). Two additional gages were recently active. One stopped recording flows in 2020 (07076530) and the other stopped recording flows in 2019 (07075250). Table 3.17 lists summary statistics for flow measurements from these gages.

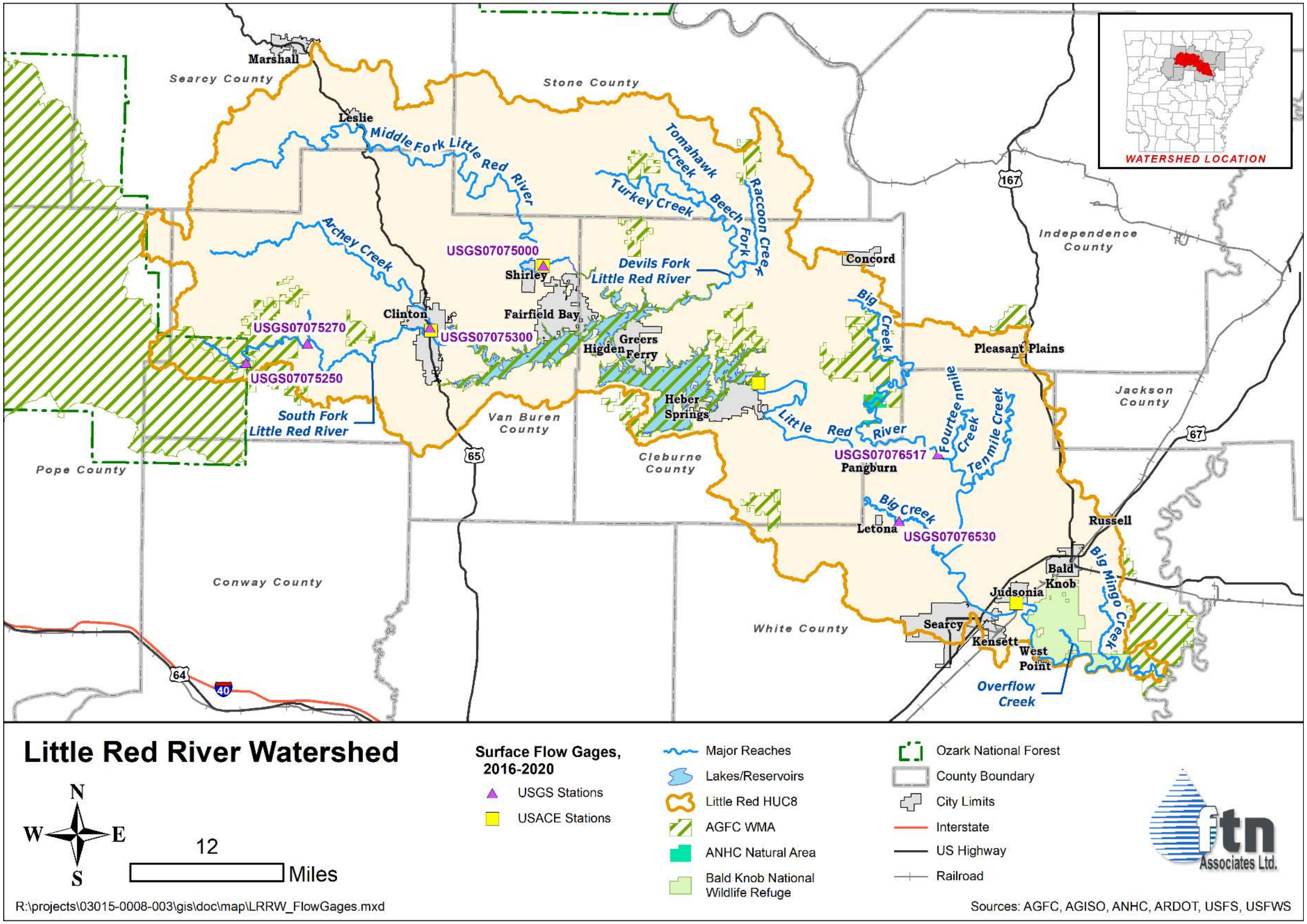


Figure.3.11. Locations of USGS and USACE flow and stage gages in Little Red River watershed active through 2020.

Table 3.17. Statistics for discharge data from USGS gages active through 2019 (USGS 2020).

Gage Number	Year Established	Site Name	Annual Average Discharge (cfs[a])	Lowest Mean Monthly Discharge, (cfs[a])	Highest Mean Monthly Discharge (cfs[a])	7Q10 Flow, (cfs[b])	90% Exceeds Flow, (cfs[c])	Peak Flow, (cfs[a])
07075270	2010	South Fork Little Red River near Scotland, AR	140.2	6.3 (September)	307 (March)	0.35	0.57	16,600 (2013)
07075300	1961	South Fork Little Red River at Clinton, AR	267.6	19 (September)	570 (March)	0.75	2.06	24,000 (2013)
07075000	1939	Middle Fork Little Red River at Shirley, AR	493.4	37 (September)	1,086 (March)	1.37	4.00	55,100 (2013)
07076517	1996	Little Red River near Dewey, AR	2,184	500 (October)	3,858 (March)	8.19	188	22,200 (2017 – affected by regulation)
07075250	2009	South Fork Little Red River us of Gulf Mt WMA near Scotland, AR	86.2	5.8 (September)	181 (March)	0.22	Not available	10,800 (2018) (12,900 estimated for 1/12/2013)
07076530	2012	Big Creek near Letona, AR	118.8	13 (September)	252 (February)	0.75	3.11	8,920 (2019)

a calculated for period 2012-2019, longest period when all stations have data. Annual average calculated for calendar year.
b from StreamStats, https://streamstats.usgs.gov/ss/, accessed April 2022
c from 2019 Water Year Summary, NWIS accessed April 2022

Graphs of monthly average flows at the USGS gages are provided in Figures 3.12 and 3.13. These graphs show the seasonal flow patterns at these gages. The seasonal pattern of flows in the unregulated streams in the Little Red River watershed is very similar (Figure 3.12). The seasonal pattern of flows at the Little Red River gage (07076517) is different from the patterns at the other gages, due to the influence of Greers Ferry Lake reservoir water control activities (Figure 3.13). Analysis of Little Red River flows before and after Greers Ferry Lake dam became operational show that reservoir releases have increased the magnitude of Little Red

River minimum flows, and decreased the magnitude of Little Red River maximum flows (Craig, Wise and Kitchens 2001, Nestler and Long 1997). Greers Ferry Lake minimum releases are governed by the demand for power generation and the need to maintain specific water temperature and DO concentration ranges in the designated trout waters downstream of the reservoir (https://www.swl.usace.army.mil/Missions/Water-Management/Water-Management-FAQ/#_Toc38481912). A graph of monthly average releases from Greers Ferry Lake for the period 1990 through 2019 indicates releases have increased during that period (Figure 3.14). Seasonal Mann-Kendall analysis of monthly average reservoir releases and monthly average flows at USGS gage 07076517 for the period 2010-2019 does not indicate a statistically significant trend (Appendix G).

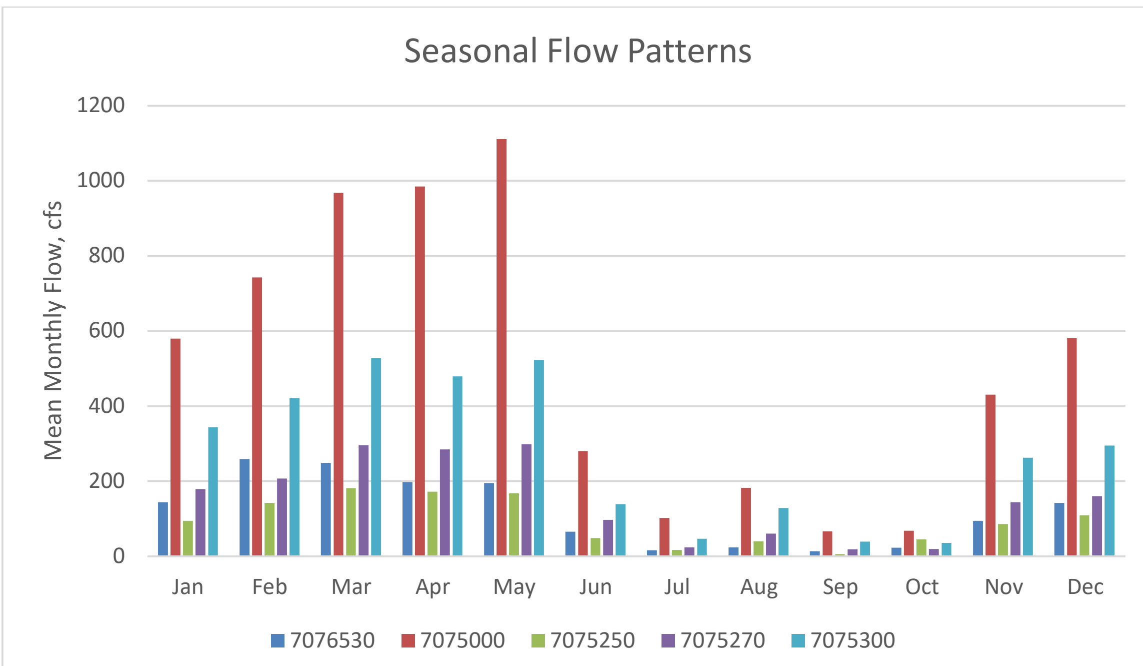


Figure 3.12. Mean monthly flows at USGS gages on unregulated streams, active during 2019 (USGS 2020).

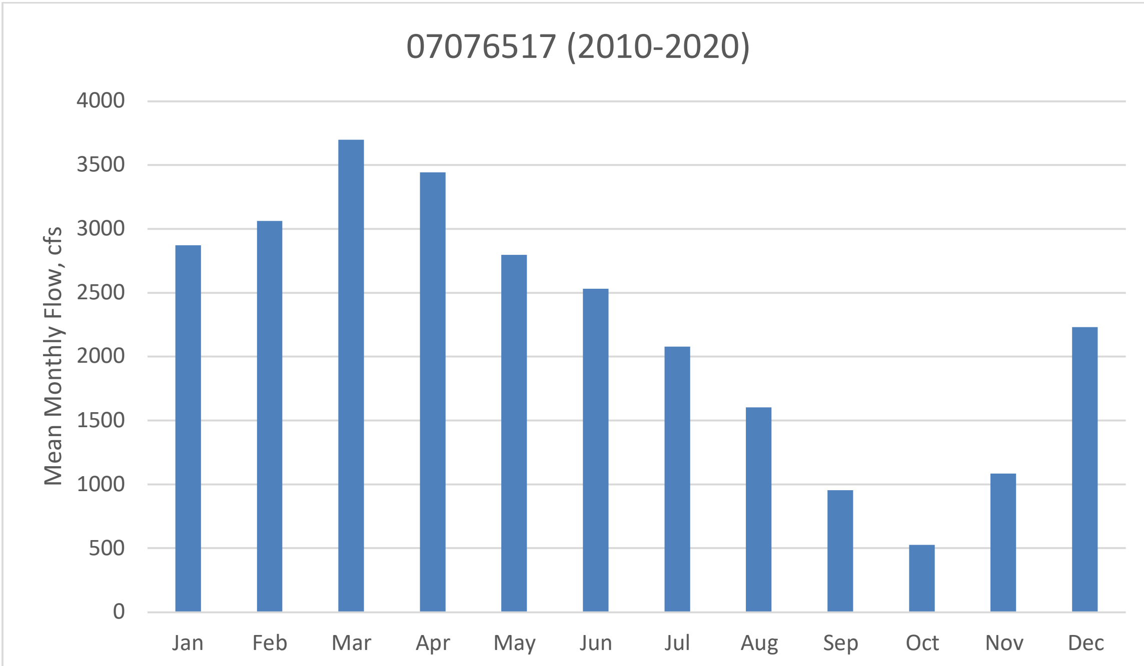


Figure 3.13. Mean monthly flows at USGS Gage 07076517 on Little Red River downstream of Greers Ferry Lake (USGS 2020).

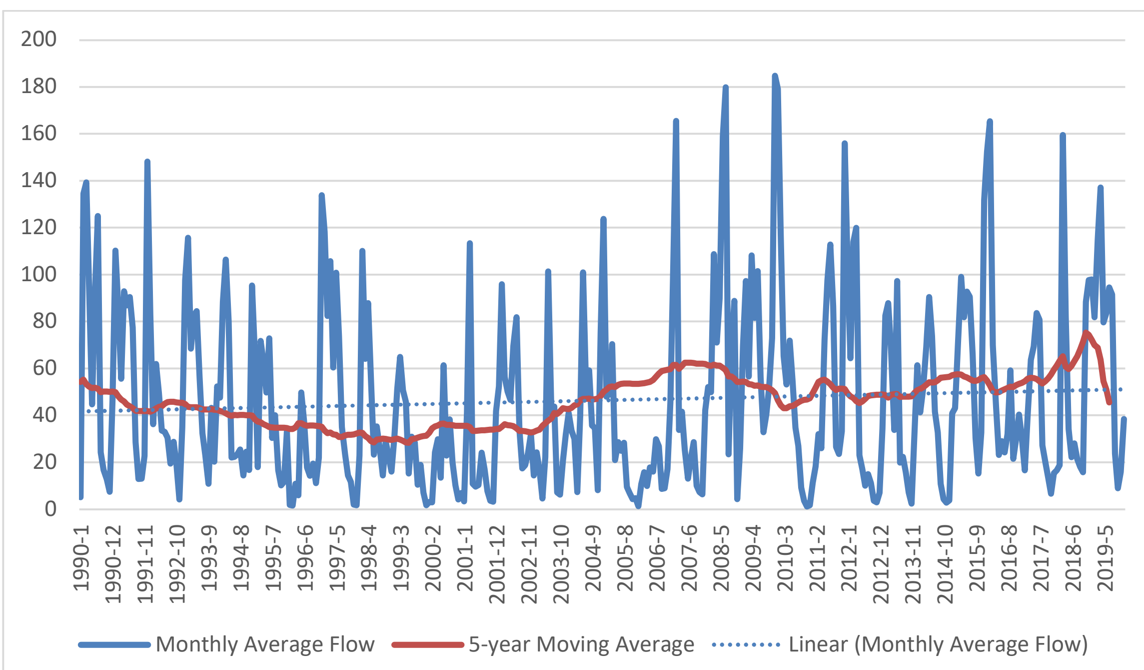


Figure 3.14. Monthly average releases from Greers Ferry Lake, 1990-2019 (USGS 2020).

Comparison of Middle Fork Little Red River flow at Shirley (07075000), before and after Greers Ferry Lake dam became operational did find some changes. Specifically, frequency and duration of minimum flows decreased after the dam became operational (Craig, Wise and Kitchens 2001). Researchers tracking populations of the endangered Yellowcheek Darter in Middle Fork Little Red River and South Fork Little Red River stated that there is a trend toward increased drying in these streams, beginning in the 1980s (Magoulick and Lynch 2015). However, flow measurements collected since 2015 seem to indicate less drying since then (Figures 3.15 and 3.16).

The changes in low flows in the Middle Fork and South Fork Little Red River may be the result of climate variation, and/or human activities in the watersheds. Van Buren County experienced drought conditions during several of the years that show unusually low flows on the graphs, including 1980, 2011, and 2012 (NOAA 2022). Magoulick and Lynch (2015) identified water withdrawals for shale gas development as a concern at the time of their research. Shale gas development in Arkansas began in 2004 (Taylor 2022). In 2014, it has been estimated that around 3 million gallons per day of surface water were being withdrawn for shale gas development in Van Buren County (CDM Smith 2014). However, by 2016, drilling for shale gas in Arkansas pretty much stopped (Taylor 2022). As a result, withdrawals of surface water in the Little Red River watershed upstream of Greers Ferry Lake have decreased significantly.

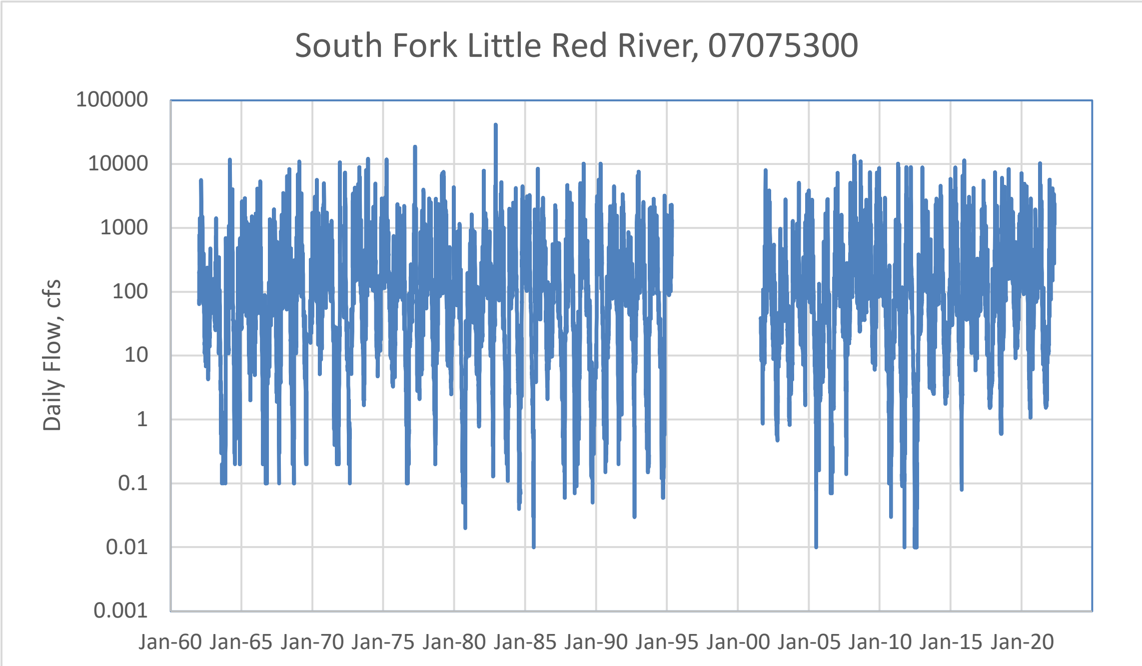


Figure 3.15. Daily average flows reported at USGS gage 07075300 on South Fork Little Red River (USGS 2022b).

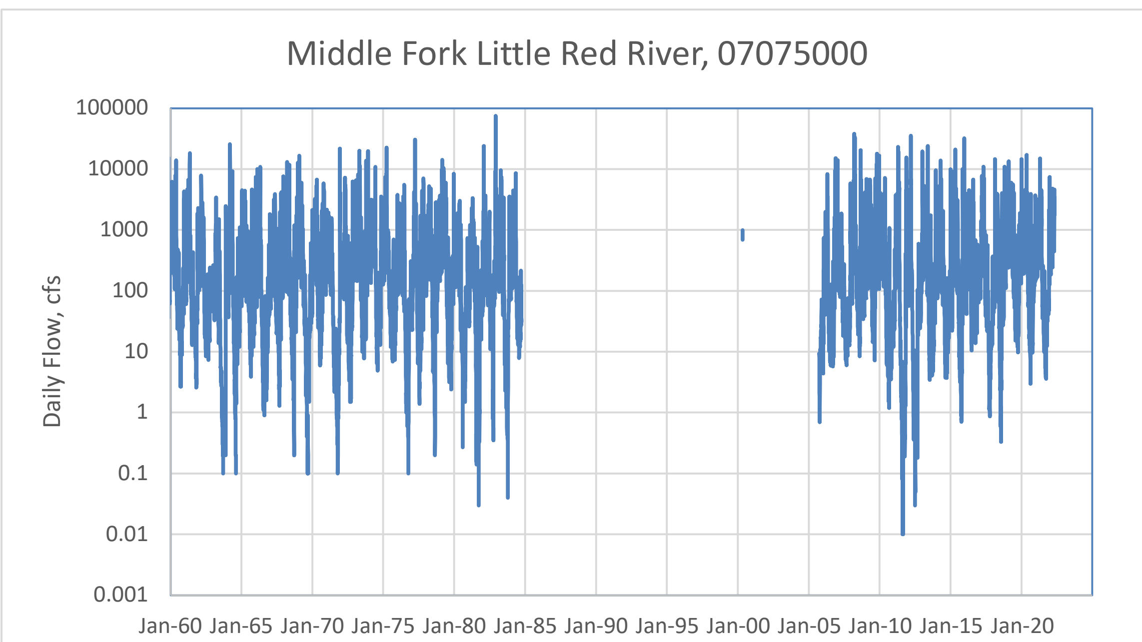


Figure 3.16. Daily average flows reported at USGS gage 07075000 on Middle Fork Little Red River, 1960-2022 (USGS 2022b).

In addition to flow gages, there are water level gages active in the Little Red River watershed. Most of these are located with flow gages. However, at some locations, only water level data is collected. Table 3.18 lists the water level, or stage, gages active in the Little Red River watershed 2016-2020.

Table 3.18. Water level monitoring locations in the Little Red River watershed (USACE 2023b, USGS 2020).

USGS gage ID	USACE gage ID	Site name	Year established
07075270	-	South Fork Little Red River near Scotland, AR	2010
07075300	CIGA4	South Fork Little Red River at Clinton, AR	1961
07075000	SRGA4	Middle Fork Little Red River at Shirley, AR	1939
-	GRRA4	Greers Ferry Lake at dam	-
07076517	DEWA4	Little Red River near Dewey, AR	1997
07075250	-	South Fork Little Red River us of Gulf Mt WMA near Scotland, AR	2009
07076530	-	Big Creek near Letona, AR	2012*
07076634 (last active 1987)	JUDA4	Little Red River at Judsonia	1981

* flow gage established 1964, stage readings start 2012

3.3.3 Aquatic Communities

Aquatic communities respond to changes in habitat, including water quality, and are useful indicators of stream health. The condition of aquatic communities is characterized based on information such as the abundance of animals, the number of different species present, the water quality and habitat requirements of the species that are present, and how sensitive the species that are present are to changes in water quality or physical habitat. In many cases, selected information about the aquatic communities present is used to develop a score or grade that reflects the health of streams, such as an Index of Biotic Integrity (IBI) or multimetric index (MMI).

DEQ has surveyed aquatic communities in the Little Red River watershed since the 1980s. EPA has also surveyed aquatic communities in the Little Red River watershed as part of its National Aquatic Resource Surveys. EPA surveyed locations in the watershed in 2004, 2009, 2013, and 2018. Universities and state and federal natural resource agencies have also conducted surveys of aquatic communities in the Little Red River watershed.

3.3.3.1 Fish Surveys

Fish surveys have been conducted in the Little Red River watershed by DEQ, EPA, and other entities. The most recent survey for which information was identified was conducted by EPA as part of the 2018-2019 National Aquatic Resources Survey (EPA 2020a). The most recent DEQ fish surveys in the watershed were conducted in 2014, as part of a project to develop state nutrient criteria for streams in the Boston Mountains ecoregion, and as part of a monitoring project for the Two Forks Restoration Project with The Nature Conservancy (DEQ 2021c).

No fish MMI values were calculated by EPA from the 2018-2019 National Aquatic Resources Survey. DEQ has developed a fish IBI for the Boston Mountains. Results from the DEQ 2014 fish surveys in the Little Red River watershed were used to calculate IBI values (Table 3.19). Overall, the 2014 fish surveys indicate the streams surveyed are in good condition. The locations of these surveys are mapped in Figure 3.17.

Table 3.19 Boston Mountain fish IBI scores and associated stream health rankings based on 2014 DEQ fish surveys.

Stream	Date	Survey IDs	Associated WQ Station ID	Index Score	Rating
Turkey Creek	8/6/2014	4E037	WHI0187	28	Good
Beech Fork Little Red River	9/16/2014	4E038	UWBHC01	18	Good
Archey Fork	9/18/2014	4E039	WHI0195	28	Good
Middle Fork Little Red River	9/17/2014	4E040	UWMFK01	24	Good
Middle Fork Little Red River	9/17/2014	4E041	WHI0043	24	Good
Middle Fork Little Red River	10/29/2014	4E042	-	28	Good
Archey Fork	10/29/2014	4E043	-	26	Good
South Fork Little Red River	10/30/2014	4E044	-	22	Good
Archey Fork	10/30/2014	4E045	-	20	Good

Status surveys of endangered Yellowcheek Darter populations have been repeatedly conducted in the forks of the Little Red River upstream of Greers Ferry Lake, even before the fish was listed as endangered in 2011, e.g., Robison and Harp (1981); Wine, Blumenshine, and Harp (2000); Wine, Weston, and Johnson (2008); Magoulick and Lynch (2015); and Yellowcheek Darter Recovery Team and US Fish and Wildlife Service (USFWS) (2018). The most recent survey, conducted in 2018 by USGS, did not find significant population decline since the previous survey (Bussell, Driver and Justus 2020).

3.3.3.2 Benthic Macroinvertebrate Surveys

Surveys of benthic macroinvertebrates have been conducted in the Little Red River watershed by DEQ, EPA, AGFC, USFWS, Stream Teams, and universities. The most recent surveys for which information was identified were conducted in 2018-2019 by EPA as part of the 2018-2019 National Aquatic Resources Survey (EPA 2020a), and by Stream Teams (AGFC 2021a). The most recent DEQ macroinvertebrate surveys were of four sites on Big Creek in 2011 and six sites on Opossum Walk Creek in 2012 (DEQ 2022a). Macroinvertebrate surveys were also conducted by University of Central Arkansas researchers during 2010-2014 at four sites on the South Fork Little Red River as part of a study to evaluate impacts of natural gas development in the Gulf Mountain Wildlife Management Area (Austin, et al. 2015). Locations surveyed are shown on Figure 3.18.

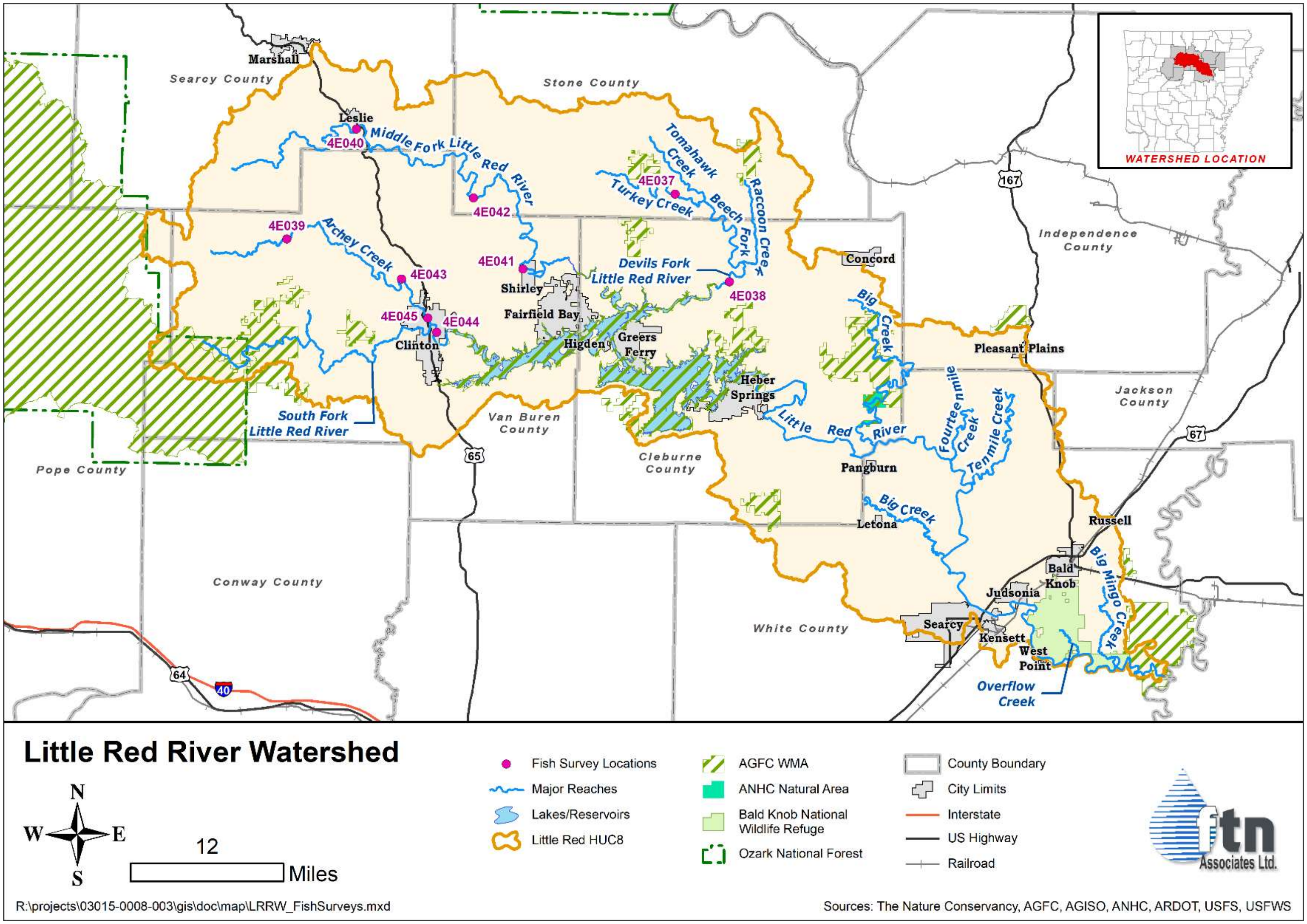


Figure.3.17. Locations of DEQ 2014 fish surveys in Little Red River watershed.

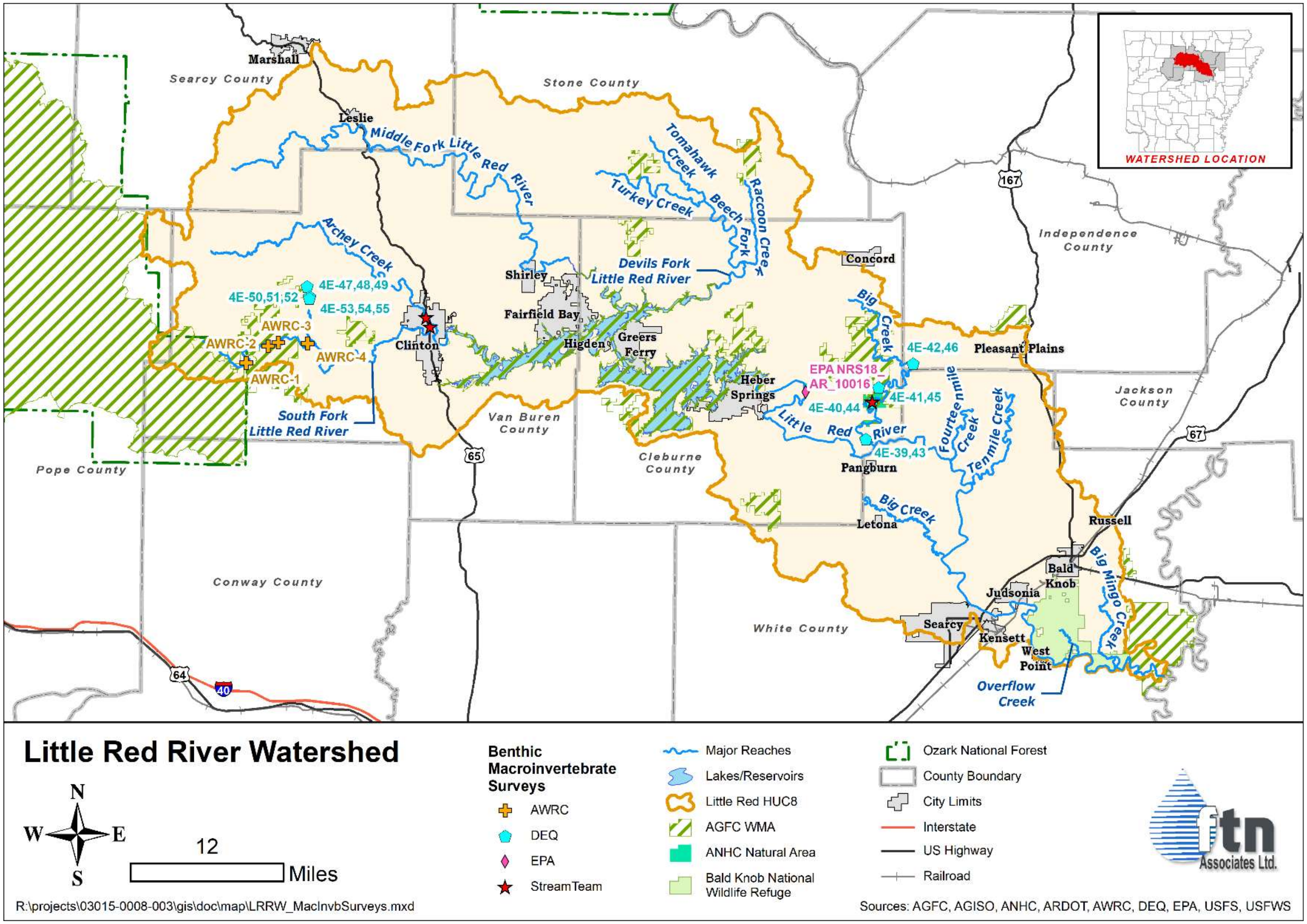


Figure.3.18. Locations of recent benthic macroinvertebrate surveys in Little Red River watershed.

No macroinvertebrate MMIs were calculated by EPA from the 2018-2019 National Aquatic Resources Survey. No indices were computed using the data from the University of Central Arkansas surveys. DEQ uses a modified Hilsenhoff Biotic Index to characterize stream condition based on macroinvertebrate surveys. Stream Teams also calculate an index of stream condition based on species found in their macroinvertebrate surveys. Table 3.20 lists stream condition ratings from macroinvertebrate surveys conducted in the Little Red River watershed since 2010. At the sites surveyed, macroinvertebrate communities indicate stream condition ranges from fairly poor to excellent.

There are three endangered mussels present in the Little Red River watershed. Populations of at least two of these mussels, Rabbitsfoot and Speckled Pocketbook, in the watershed are surveyed regularly by AGFC and USFWS. USFWS established 35 long-term monitoring sites for Specked Pocketbook mussel *(Lampsilis streckeri*) in the Little Red River watershed in 2009. In the 2021 5-year review of Speckled Pocketbook mussel, populations in Middle Fork and South Fork Little Red River were characterized as declining, no individuals were found in Big Creek (where a population existed in 2009), and populations in Beech Fork (tributary of Devil's Fork) and its tributaries were characterized as stable (USFWS 2021a). In the first 5-year review of Rabbitsfoot mussel *(Lampsilis abrupta)*, the population in the Middle Fork Little Red River was characterized as declining (USFWS 2020). No report on populations of the endangered Pink Mucket in the Little Red River was included in the 5-year review for that mussel (USFWS 2018).

Table 3.20. Summary of macroinvertebrate surveys conducted in Little Red River watershed since 2010.

Stream	Agency/ Organization	Date	Survey ID	Associated WQ Station ID	Taxa Richness	EPT	Index Value	Index Rating
Big Creek	ADEQ	4/23/2011	ADEQ4E-43	UWBCKO1	18	7	6.87	Fairly Poor
Big Creek	ADEQ	4/23/2011	ADEQ4E-44	UWBCKO2	20	9	5.42	Good
Big Creek	ADEQ	4/23/2011	ADEQ4E-45	UWBCKO3	24	9	5.55	Fair
Big Creek	ADEQ	4/23/2011	ADEQ4E-46	UWBCKO4	26	13	5.94	Fair
Big Creek	ADEQ	12/1/2011	ADEQ4E-39	UWBCKO1	26	9	6.55	Fairly Poor
Big Creek	ADEQ	12/1/2011	ADEQ4E-40	UWBCKO2	24	9	6.03	Fair
Big Creek	ADEQ	12/1/2011	ADEQ4E-41	UWBCKO3	27	11	5.65	Fair
Big Creek	ADEQ	12/1/2011	ADEQ4E-42	UWBCKO4	24	7	6.39	Fair
Oppossum Walk Creek	ADEQ	3/1/2012	ADEQ4E-47	-	18	12	4.14	Very Good
Oppossum Walk Creek	ADEQ	3/1/2012	ADEQ4E-48	-	26	13	6.40	Fair
Oppossum Walk Creek	ADEQ	3/1/2012	ADEQ4E-49	-	14	8	3.54	Very Good
Oppossum Walk Creek	ADEQ	3/1/2012	ADEQ4E-50	-	8	4	3.80	Very Good
Oppossum Walk Creek	ADEQ	3/1/2012	ADEQ4E-51	-	11	5	2.93	Excellent
Oppossum Walk Creek	ADEQ	3/1/2012	ADEQ4E-52	-	10	6	5.17	Good
Oppossum Walk Creek	ADEQ	3/1/2012	ADEQ4E-53	-	11	6	4.32	Very Good
Oppossum Walk Creek	ADEQ	3/1/2012	ADEQ4E-54	-	15	8	3.20	Excellent
Oppossum Walk Creek	ADEQ	3/1/2012	ADEQ4E-55	-	15	6	5.02	Good
Big Creek	Cabot Middle School CHEW	10/1/2017	-	-	-	-	27	Excellent
South Fork Little Red River	Foothills of Arkansas Master Naturalist	12/9/2017	-	-	-	-	17	Good
Archey Fork Little Red River	Foothills of Arkansas Master Naturalist	8/19/2017	-	-	-	-	31	Excellent
Archey Fork Little Red River	Foothills of Arkansas Master Naturalist	12/9/2017	-	-	-	-	15	Fair
Archey Fork Little Red River	Foothills of Arkansas Master Naturalist	11/28/2018	-	-	-	-	19	Good
Archey Fork Little Red River	Foothills of Arkansas Master Naturalist	11/19/2019	-	-	-	-	24	Excellent

3.3.3.3 Predicted Biological Condition

Researchers used the random forests approach and information from the 2008-2009 National Rivers and Streams Assessment to develop a predictive model of benthic condition based on local and upstream landscape features (Hill, et al. 2017). This model has been applied to the conterminous US and the results for stream segments of the National Hydrographic Dataset (NHD) are publicly available from the EPA StreamCat website (https://www.epa.gov/national-aquatic-resource-surveys/streamcat-dataset). Predicted biological condition results were available for approximately one-third of the NHD stream segments in the Little Red River watershed (1,520 kilometers of 5,058 kilometers). Kilometers of streams in the Little Red River watershed predicted to have Good, Fair, and Poor biotic condition are summarized in Table 3.21 Overall, only about 20% of classified stream segments in the Little Red River watershed were predicted to have poor biotic condition. The majority of the stream segments predicted to have poor biotic integrity are located downstream of Greers Ferry Lake. Overall, about 50% of classified stream segments were predicted to have good biotic condition. The majority of stream segments predicted to have good biotic condition were located upstream of Greers Ferry Lake.

Table 3.21 Summary of predicted biotic condition of NHD stream segments in Little Red River watershed.

Area	Condition	Length of streams, kilometers	Percentage of length with predicted biotic condition
Entire watershed	Good	783	52%
	Fair	446	29%
	Poor	291	19%
Upstream of Greers Ferry dam	Good	705	84%
	Fair	127	15%
	Poor	8	1%
Downstream of Greers Ferry dam	Good	78	11%
	Fair	319	47%
	Poor	282	42%

3.3.4 Aquatic Habitat

Physical habitat in streams is a combination of factors that support aquatic organisms, including water depth, water velocity, water temperature, channel substrate (i.e., what kind of material makes up the stream bottom), and cover. Physical habitat in streams, and the condition of that habitat, varies naturally, but can also be affected by human activities.

3.3.4.1 Habitat Surveys

ADEQ collects habitat information during fish surveys and uses this information to develop an index of fish habitat integrity score. Fish habitat integrity scores for the 2012 fish survey locations in the Little Red River watershed are summarized in Table 3.22 These fish and habitat surveys were conducted as part of the Two Forks Restoration Project, prior to initiation of restoration. Habitat information was not collected during the 2014 fish surveys. Higher scores indicate better fish habitat. Habitat integrity scores for the Archey Fork upstream of Clinton range from 5.2 to 34.1 with a median of 23. Habitat integrity scores for the South Fork Little Red River range from zero to 26.0. Habitat integrity scores for the Middle Fork Little Red River range from 8.3 to 26.0. Overall, habitat integrity scores from these locations are similar. The highest habitat integrity score is from the Archey Fork in Archey Fork Park, Clinton.

Table 3.22 ADEQ fish habitat integrity scores from 2012 fish survey locations in Little Red River watershed.

Stream	Date	Survey ID	Location	Associated WQ Station ID	Index Score
Archey Fork	10/23/2012	4E023	3 mi upstream Hwy 65 near Clinton Riffle 1	WHI0194	34.1
Archey Fork	10/23/2012	4E024	3 mi upstream Hwy 65 near Clinton Riffle 1	WHI0194	23.8
Archey Fork	10/24/2012	4E025	3 mi upstream Hwy 65 near Clinton Riffle 1	WHI0194	21.3
Archey Fork	10/23/2012	4E026	3 mi upstream Hwy 65 near Clinton Riffle 2	WHI0194	5.2
Archey Fork	10/24/2012	4E027	3 mi upstream Hwy 65 near Clinton Riffle 2	WHI0194	14.9
Archey Fork	11/09/2012	4E029	3 mi upstream Hwy 65 near Clinton Pool 1	WHI0194	29.0

Table 3.22 ADEQ fish habitat integrity scores from 2012 fish survey locations in Little Red River watershed (continued).

Stream	Date	Survey ID	Location	Associated WQ Station ID	Index Score
Archey Fork	11/02/2012	4E030	3 mi upstream Hwy 65 near Clinton Pool	WHI0194	23.3
Archey Fork	Not recorded*	4E028	Northwest of baseball fields (T11N, R14W, S015)	--	45.0
South Fork Little Red River	10/24/2012	4E034	Riffle 1	--	0.0
South Fork Little Red River	10/24/2012	4E035	Riffle 2	--	26.0
South Fork Little Red River	11/02/2012	4E036	Pool	--	23.0
Middle Fork Little Red	10/31/2012	4E031	5 mi downstream of Arleons Riffle 1	WHI0178	8.3
Middle Fork Little Red	10/31/2012	4E032	5 mi downstream of Arleons Riffle 2	WHI0178	10.0
Middle Fork Little Red River	10/31/2012	4E033	5 mi downstream of Arleons Pool 1	WHI0178	26.0

* The survey ID and other information in the DEQ habitat database suggest this habitat survey was conducted in 2012, about the same time as the other surveys included in this table.

EPA also collected habitat metrics during the National Aquatic Resources Survey. However, no classification of habitat quality was assigned to the station in the Little Red River watershed.

3.3.4.2 Habitat Degradation Risk

As part of the State Resource Assessment, the US Department of Agriculture Natural Resources Conservation Service (NRCS) develops a metric for risk of habitat (terrestrial and aquatic) degradation. Information used to develop this metric includes the presence of oil and gas wells, forest fragmentation, presence of waterbodies designated as Extraordinary Resource or Ecologically Sensitive, Audubon-designated Important Bird Areas, and land use within 30 meters of streams (NRCS 2016). Metric values were calculated in 2015 for each HUC12 within the state (see Figure 3.19). The majority of HUC12s within the Little Red River watershed are classified as having a greater than average risk of habitat degradation (i.e., shown as orange or red on the map in Figure 3.19).

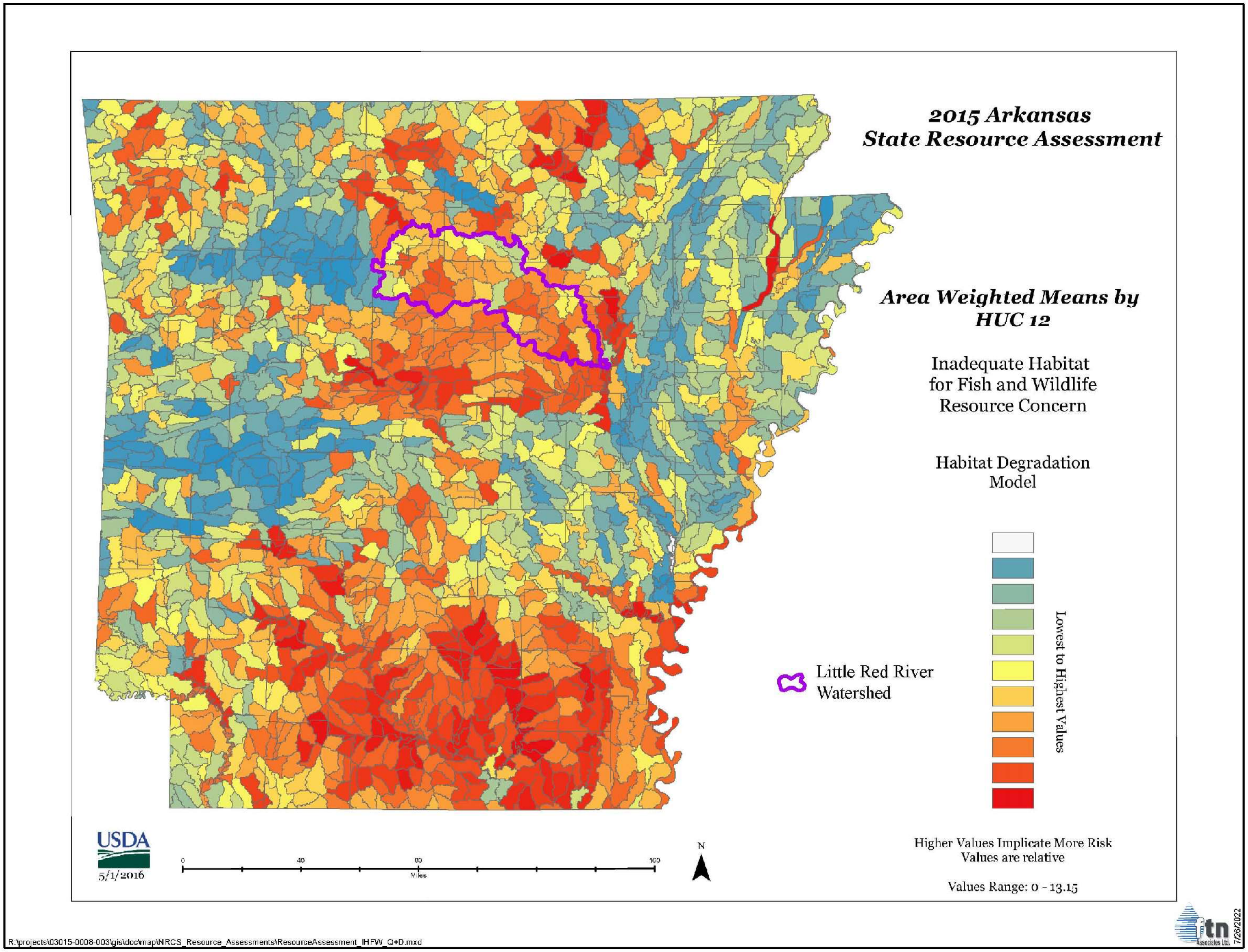


Figure 3.19. Habitat degradation risk metric from 2015 State Resource Assessment (from https://www.nrcs.usda.gov/wps/portal/nrcs/ar/technical/dma/NRCSEPRD1164606/).

3.3.4.1 Cave Aquatic Habitat and Species of Greatest Conservation Need

The Nature Conservancy has conducted a literature-based survey of the occurrence of state Species of Greatest Conservation Need associated with cave habitats in the Ozarks region of Arkansas (Inlander, Gallipeau and Slay 2011). In addition, Inlander, Gallipeau and Slay (2011) evaluated threats to these species. This study included two cave habitat sites within the Little Red River watershed where aquatic Species of Greatest Conservation Need have been identified. These sites were classified as having medium overall threat scores for aquatic Species of Greatest Conservation Need. These sites are also classified as having medium risk of groundwater contamination.

3.3.5 Watershed Integrity

EPA researchers have developed a metric of watershed integrity that uses national data sets (Thornburgh, et al. 2018). Information used to score this metric includes indicators of hydrologic regulation, water chemistry, sediment, hydrologic connectivity, temperature, habitat condition, and the extent of human activity. Basically, this index is an indicator of the modification of a watershed from its natural state. Index values have been calculated for the catchments associated with every stream segment of the National Hydrologic Dataset. Index values calculated for catchments in the Little Red River watershed are shown in Figure 3.20. Lower index values indicate lower integrity and greater modification, and higher index values indicate higher integrity with less modification.

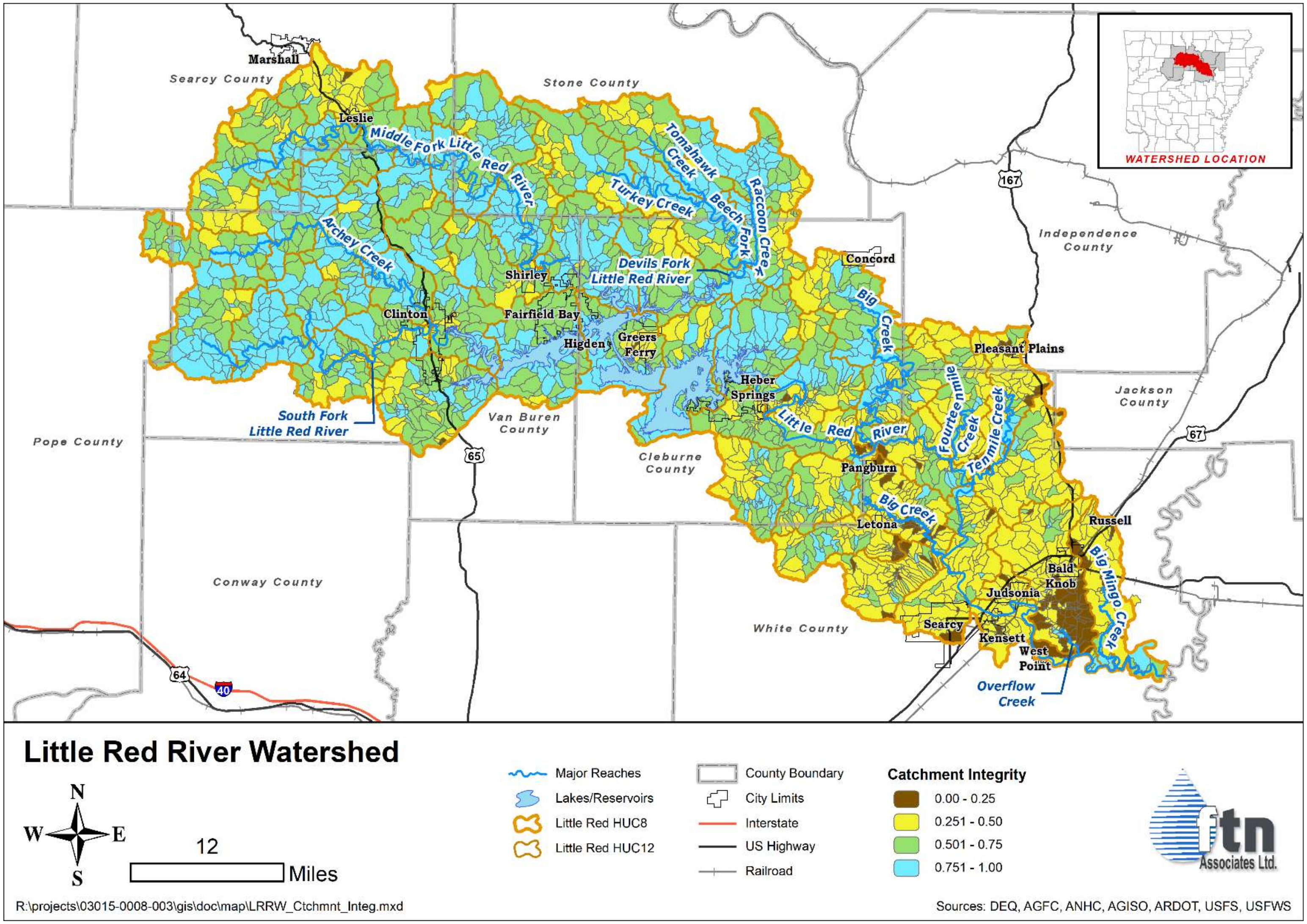


Figure 3.20. EPA catchment integrity index values for Little Red River watershed (Thornburgh, et al. 2018).

3.3.6 Summary/Discussion

There are issues with streambank stability throughout the Little Red River watershed. Hydrology in the watershed may have been affected by natural gas development between 2004 and 2016. Flows in the Little Red River downstream of Greers Ferry Lake are strongly influenced by releases from the reservoir. Aquatic communities are characterized as being in good condition based on DEQ indices. However, several populations of endangered mussels in the watershed are characterized as declining. The majority of HUC12s within the Little Red River watershed are classified as having a greater than average risk of habitat degradation in the 2015 NRCS State Resource Assessment, and The Nature Conservancy has concluded that aquatic Species of Greatest Conservation Need at two cave sites in the watershed have a medium risk of being negatively impacted by human activities. About half of the catchments in the Little Red River watershed have been significantly modified, with the majority of heavily modified catchments occurring in the downstream end of the watershed.

3.3.7 Data Gaps

Streambank instability continues to be an issue in the Little Red River watershed. The most recent streambank surveys published are from 2005. There are likely areas in the watershed where new surveys would be useful.

USFWS has identified the endangered Pink Mucket mussel as occurring in the Little Red River watershed. However, no report on populations in the Little Red River watershed was included in the 5-year review of the Pink Mucket mussel. Evaluation of the status of Pink Mucket populations in this watershed is needed.

Published fishery surveys we found were all conducted in the watershed upstream of Greers Ferry Lake. Surveys of fisheries downstream of the reservoir would also be useful.

3.4 Nonpoint Pollution Sources in Little Red River Watershed

Pollutants of concern in the Little Red River watershed include fecal contamination indicator bacteria (i.e., *E. Coli*), nutrients, organic matter (low DO), and sediment. Nonpoint sources of these pollutants have been identified by stakeholders, researchers, and resource managers working in the Little Red River watershed. These nonpoint sources are discussed below.

3.4.1 Unpaved Roads

A 2004 Watershed Restoration Action Strategy (WRAS) document for the Little Red River watershed identified unpaved roads as the nonpoint source of greatest concern. In 2003, an inventory of unpaved county roads in the Little Red River watershed in Cleburne, Independence, and White Counties determined that unpaved roads were "the greatest contributor of sediment in the watershed". The estimated sediment contribution from unpaved county roads in these three counties was 286,000 tons (Cleburne County Conservation District 2003a). Runoff from unpaved roads is also listed as a concern in recent assessments of endangered species in the Little Red River watershed (USFWS 2020, USFWS 2021, USFWS 2019), and information related to conservation activities in the watershed (e.g., https://www.nature.org/en-us/get-involved/how-to-help/places-we-protect/bluffton-preserve/, accessed 3/25/22). There are 1,653 miles of unpaved roads in the Little Red River watershed, 1,066 miles upstream of Greers Ferry Lake, and 587 miles in the watershed downstream of the reservoir dam (Board of Arkansas Geographic Information Systems 2022). As of May 2022, Cleburne, Independence, Pope, Searcy, and Van Buren Counties are current on training in environmentally sensitive road maintenance under the Arkansas Unpaved Roads Program (K. McGaughey, NRD, personal communication 5/23/22).

3.4.2 Streambank Erosion

Streambank erosion has been identified as a concern throughout the Little Red River watershed as reported by DEQ, The Nature Conservancy, and researchers (Cleburne County Conservation District 2003c, DEQ 2006, TNC 2014). The USGS Midwest SPARROW model indicates that channel sources contribute 26% of sediment load from the Little Red River watershed (Robertson and Saad 2019). Inventories of eroding streambanks have been performed both upstream of Greers Ferry Lake, and downstream of the reservoir. The 2016 NRCS State Resource Assessment characterized risk for excessive streambank erosion by HUC12 subwatersheds based on land use in riparian areas and stream impairment due to sediment (Figure 3.21). Several of HUC12s within the Little Red River watershed are classified as having a greater than average risk of excessive streambank erosion (i.e., shown as orange or red on the map in Figure 3.21). Several factors have been identified by stakeholders as contributing to excessive streambank erosion in this watershed, including:

- Livestock accessing streams,
- Poor quality riparian vegetation, and
- Hydrologic alteration/management (Greers Ferry Lake and Little Red River downstream of dam).

3.4.3 Poor Quality Riparian Buffers

Good quality riparian buffers stabilize streambanks, protecting them from erosion. Clearing trees and grazing in riparian areas results in destabilization and erosion of streambanks. Riparian buffers also filter pollutants from runoff, keeping them out of streams. Lack of riparian buffers along Ozark streams is correlated with levels of some pollutants and stream habitat condition (Panfil and Jacobson 2001). The EPA StreamCat database includes percentages of land cover types present within 100m of NHD stream segments (Hill et al. 2016). This information was summed for the HUC12 subwatersheds of the Little Red River. Riparian buffers with significant forest area are considered good quality riparian buffers. Riparian buffers with pasture or developed land are considered poor quality riparian buffers. Figure 3.22 summarizes the percentage of riparian buffers with agricultural (pasture and/or cropland) and developed (urban and/or barren land) land cover, based on the 2016 National Land Cover Dataset (NLCD) (Hill et al. 2021). The percentage of riparian buffer with agricultural and developed land cover in the Little Red River HUC12 subwatersheds ranged from 4% to 58%. The percentage of riparian buffer with agricultural land cover ranged from 3% to 50%. The percentage of riparian buffer with developed land cover ranged from <1% to 13%.

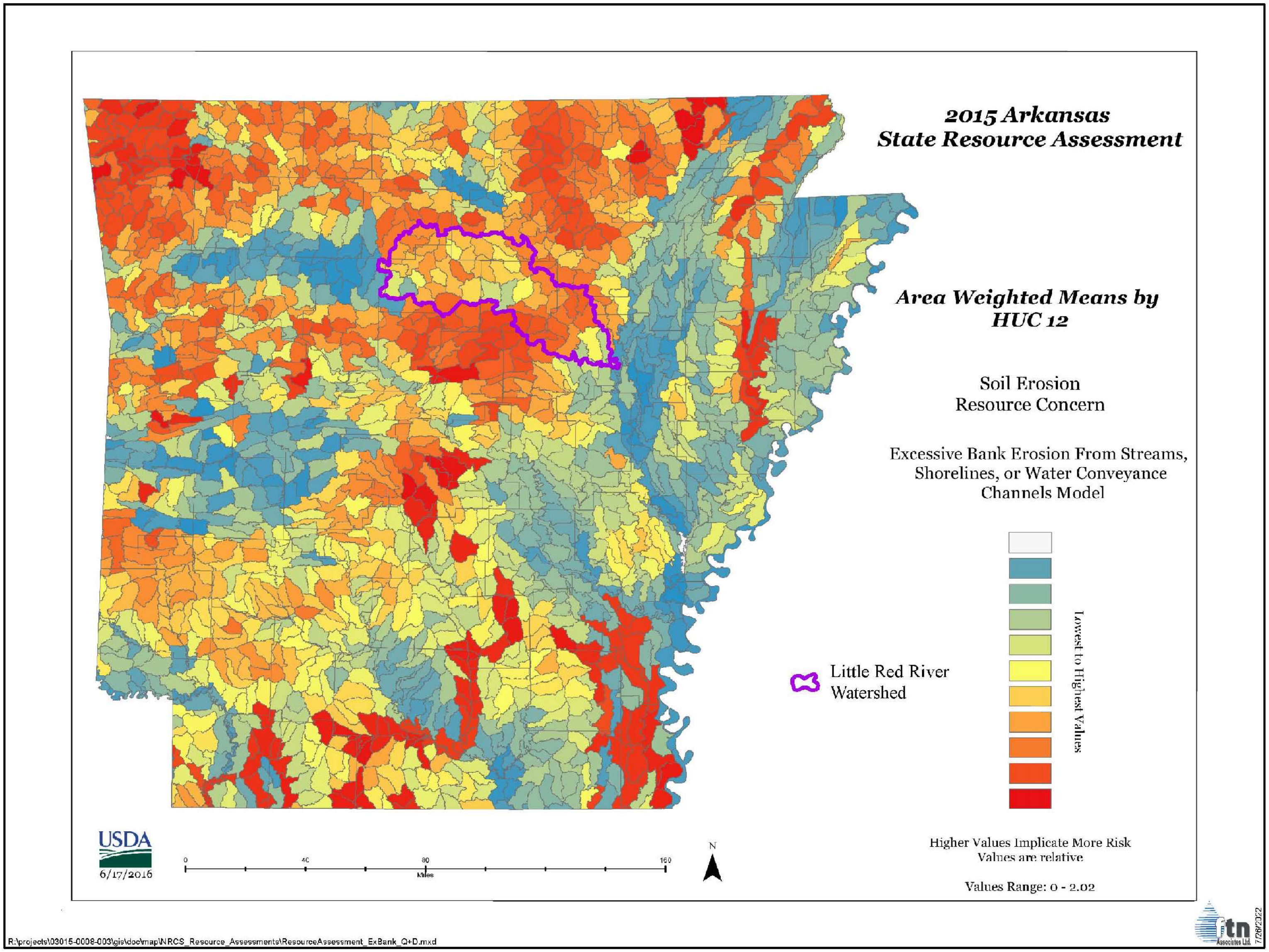


Figure 3.21. Streambank erosion risk metric from 2015 State Resource Assessment.

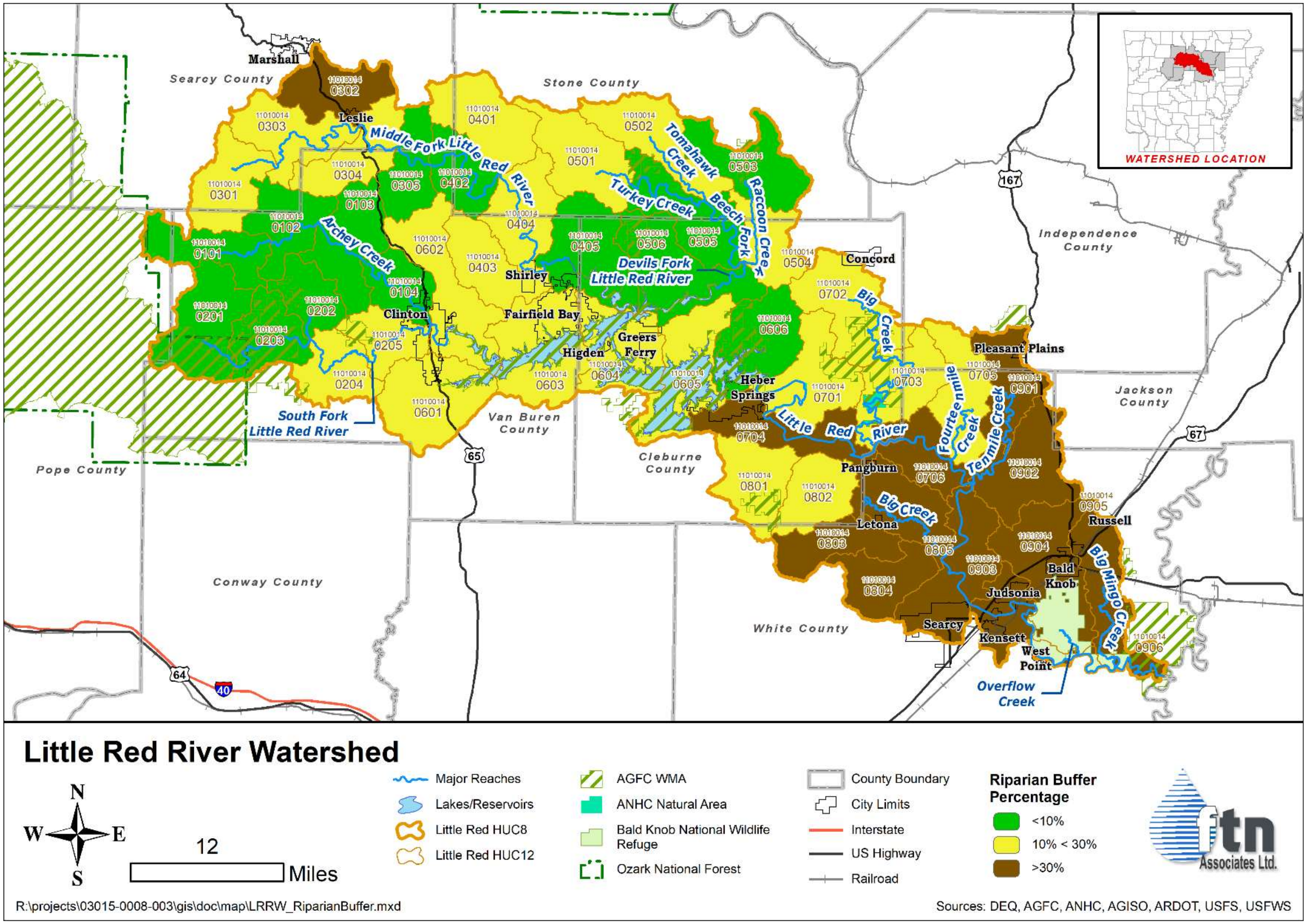


Figure 3.22. Percentage of HUC12 riparian buffers with agricultural and developed land cover (Hill et al 2016).

3.4.4 Livestock and Animal Waste

Cattle and other livestock using streams can make streambanks more susceptible to erosion, or change the shape of the stream channel, which can trigger channel erosion upstream or downstream. Justus et al. (2010) found that indices of algal, aquatic invertebrate, and fishery integrity declined as estimated cattle production in Ozark stream basins increased.

Waste from animal production facilities is a potential source of nutrients and coliforms. The USGS Midwest SPARROW model indicates that manure contributes 21% of the total nitrogen load from the Little Red River watershed, and 41% of the total phosphorus load (Robertson and Saad 2019). It is a common practice in the area to use litter from poultry houses as a fertilizer for pastures. This practice has been, and is being, studied most often in the state in Northwest Arkansas, where it is believed to have contributed to nutrient water quality issues in surface water and groundwater e.g., (Metcalf et al. 2014, Sauer et al. 2000). Wastes deposited by cattle in or beside streams can also provide nutrients and coliforms, e.g., as when cows loiter in streams. Studies have shown that, unless access to streams is restricted, cattle generally spend much of the day in the riparian area, no matter the season, or the availability of other water sources (Bagshaw et al. 2008, Zuo and Miller-Goodman 2004). James et al. (2007) found that pastured cattle deposited significantly more manure in and near streams than in other areas of the pasture. Justus et al. (2010) found that in the Ozark region, nutrient concentrations were highest for streams with the highest estimated cattle and poultry production.

Figure 3.23 shows numbers of cattle reported for Little Red River Counties in the Census of Agriculture since 1997. In most of these counties, cattle numbers remained fairly consistent from 1997 to 2017. In White County, cattle numbers declined between 1997 and 2017. Thus, overall, manure from cattle in the Little Red River watershed doesn’t appear to be changing much over time.

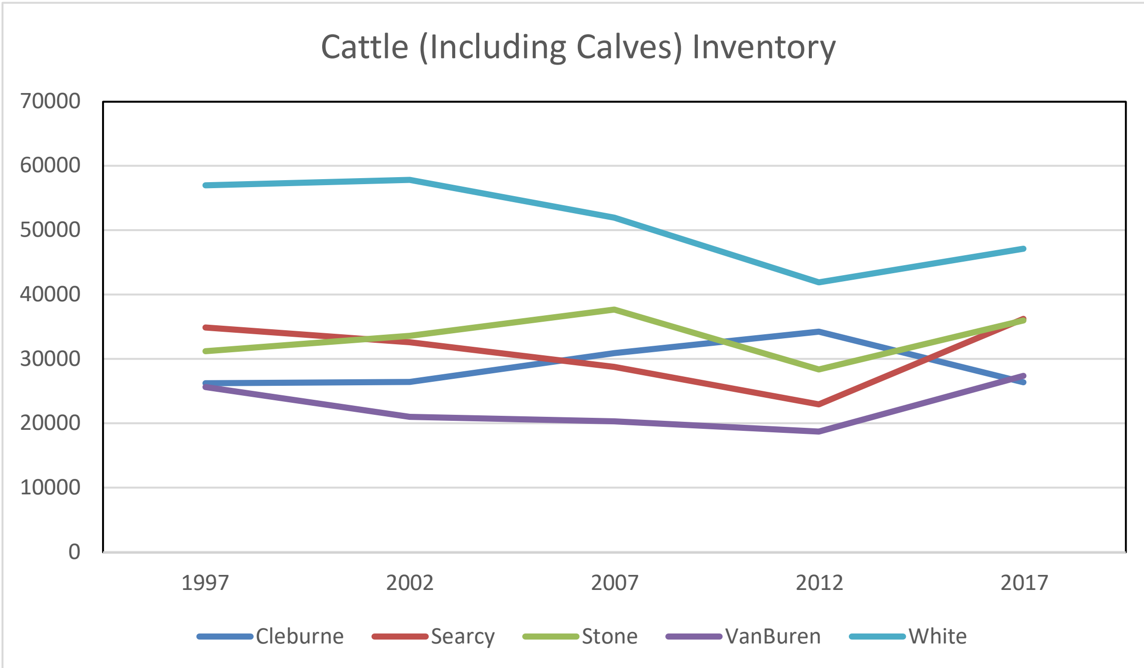


Figure 3.23. Cattle inventories for Little Red River watershed counties, from Census of Agriculture.

Figure 3.24 shows numbers of chickens reported for Little Red River Counties in the Census of Agriculture since 1997. In Cleburne, Stone, and Van Buren Counties chicken numbers have declined between 1997 and 2017. In White County, chicken numbers stayed fairly consistent during this period, while in Searcy County, chicken numbers tripled. Since chicken numbers have probably declined in the watershed, poultry litter use in the Little Red River watershed may have decreased over time. However, it is possible that poultry litter could be imported into the watershed for use as fertilizer on pasture. Thus, use of poultry litter on pasture in the watershed may not have decreased.

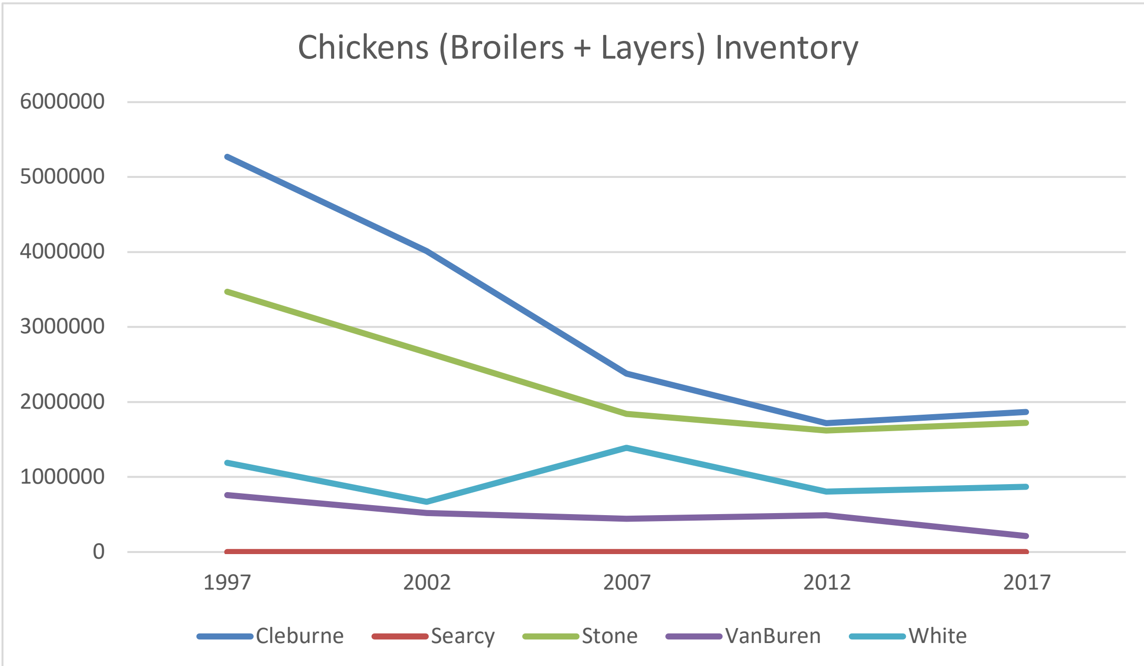


Figure 3.24. Chicken inventories for Little Red River watershed counties, from Census of Agriculture.

Waste from animals in developed areas can also contribute nonpoint source pollutants to surface waters. Waste from pets and resident wildlife, e.g., raccoons and Canada geese, can be carried into streams during storms, contributing nutrients and bacteria.

3.4.5 Resource Extraction

Resource extraction activities in the Little Red River watershed include timber harvest, rock and gravel mining, and gas wells. These activities have been identified as potential threats to endangered species present in the watershed (USFWS 2020, USFWS 2021, USFWS 2019).

The Fayetteville shale gas play includes the southern half of the Little Red River watershed. This area was developed primarily during the period 2004-2015. During that time, 2,824 natural gas wells were drilled in the watershed. Just over 80% of these wells (2,315) were still producing as of June 2021 (Figure 3.25). The majority of the active gas wells (1,490) are in the watershed downstream of Greers Ferry Lake (Arkansas Oil and Gas Commission 2021).

Erosion from well pads and unpaved roads serving them is a potential nonpoint source of sediment. This is the primary nonpoint source pollution concern associated with producing and abandoned wells. There is also the potential for spills of chemicals or wastewater associated with active wells (Arkansas Public Policy Panel 2011, Green 2015).

Mining is a significant activity in the Little Red River watershed. Stakeholders have identified mining near rivers and instream gravel mining as water quality concerns, primarily in the upper watershed (USFWS 2020, USFWS 2021, USFWS 2019). Materials mined in this watershed include gravel, rock, topsoil, and phosphate. There are 10 mines in the Little Red River watershed with active DEQ mine permits (DEQ 2022b). Table 3.23 lists these permitted mining locations. There are seven mines in the watershed that have NPDES permits to discharge wastewater (Table 3.24). There are no active DEQ instream mining permits in the watershed (DEQ 2022b). No historical DEQ instream mining permits were found for streams in the Little Red River were found, however instream gravel mining has been mentioned as a concern for endangered mussels in this watershed (USFWS 2021a). The Arkansas Geological Survey lists an additional 18 active and intermittent mines in the watershed (Arkansas Geological Survey 2012). These mines are listed in Table 3.25. Note that only three of the DEQ permitted mines are also listed by the Arkansas Geological Survey.

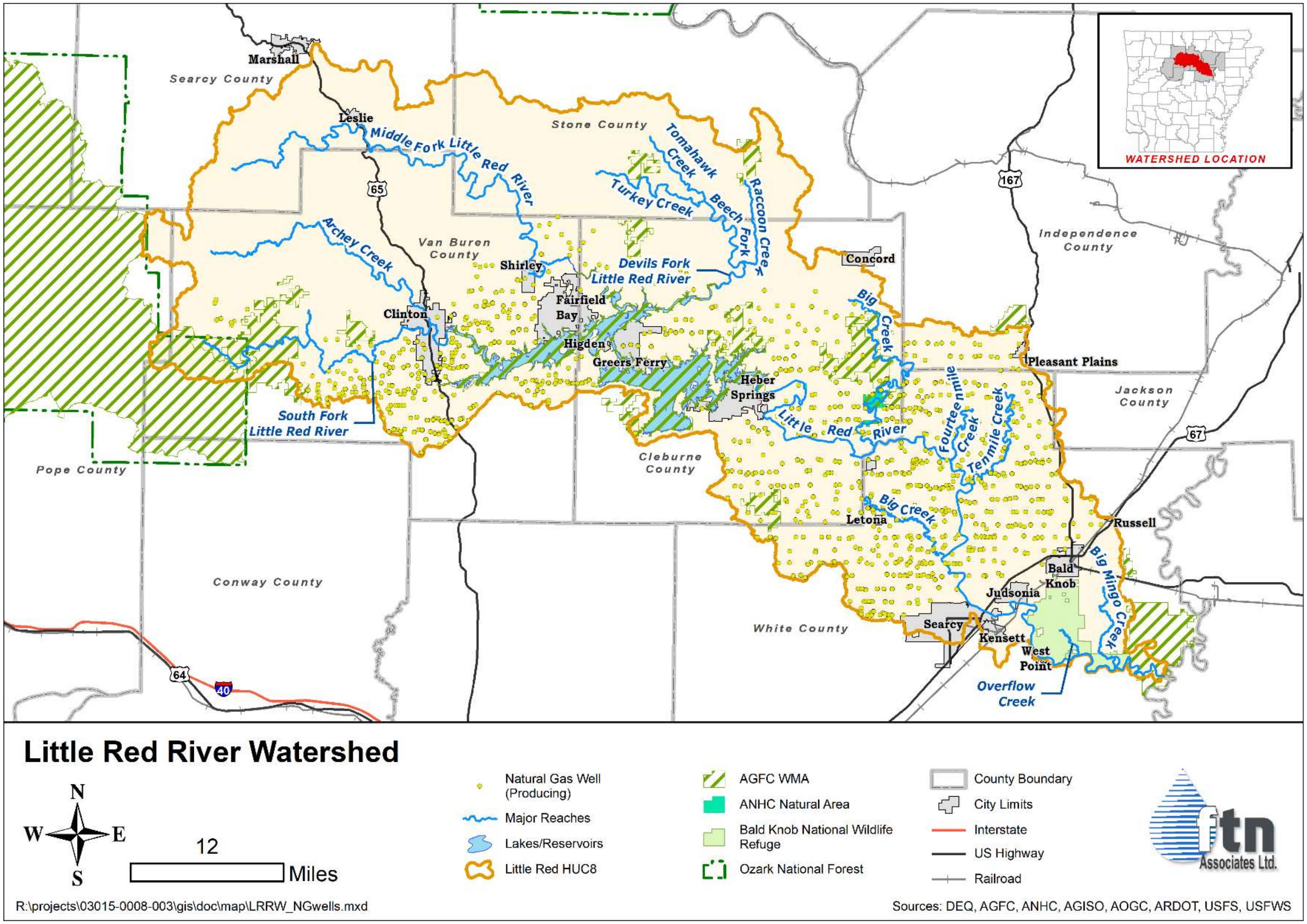


Figure 3.25. Active natural gas wells in Little Red River watershed as of June 2021 (Arkansas Oil and Gas Commission 2021).

Table 3.23. Mines in the Little Red River watershed with active ADEQ mine permits (DEQ 2022b).

Mine Name	Operator	County	City	Material	Permit ID
Quality Rock, Inc.	Quality Rock, Inc.	Cleburne	Rose bud	Crushed and Broken Stone NEC	0032-MQ-A3
L&N Quarry, Inc/Holstead #2	L&N Construction, Inc.	Searcy	Leslie	Rock	0036-MQ-A2
Peyton Creek Minerals, Inc.	Peyton Creek Minerals, Inc.	Van Buren	Leslie	Phosphate	0480-MN-A4
Van Buren County Quarry #1	Van Buren County Road Department	Van Buren	Dennard	Rock	0035-MQ
Clinton Quarry	Delta Asphalt of Arkansas, Inc.	Van Buren	Clinton	Rock	0082-MQ-A1
Clinton Quarry	Delta Asphalt of Arkansas, Inc.	Van Buren	Clinton	Rock	0082-MQ-A2
Aday Quarry	Privately/Individually Owned	Van Buren	Leslie	Rock	0055-MQ-A1
Vulcan Construction Materials	Vulcan Construction Materials, LLC.	White	Judsonia	Crushed and Broken Granite Mining	0057-MQ-A3
Morris School Borrow Pit	Johnny Brock Excavating & Landscaping, Inc.	White	Searcy	Top Soil/Dirt	0587-MN-A3
Privately/Individually Owned	Privately/Individually Owned	White	Pangburn	Shale	0692-MN-A1

Table 3.24. NPDES permitted mines in the Little Red River watershed (DEQ 2022b).

Facility Name	County	NPDES Permit No.	Receiving Stream
Thelma Bailey Properties	Cleburne	ARR001755	NR
L&N Quarry, Inc/Holstead #2	Searcy	ARR001810	NR
Delta Asphalt/Clinton Quarry	Van Buren	ARG500065/ ARR000024	unnamed tributary to Choctaw Creek, thence to Choctaw Creek, thence to Greers Ferry Lake, thence to the Little Red River, thence to the White River
Aday Quarry	Van Buren	ARG500035	unnamed tributary to Archey Creek, thence to Archey Creek, thence to the South Fork Little Red River, thence to the Little Red River, thence to the White River
Morris School Borrow Pit	White	ARR001619	NR
Shane Johnson	White	ARR000466	NR
Vulcan Construction Materials	White	ARG500004	Unnamed tributary of Adler Creek, thence to Adler Creek, thence to Little Red River, thence to the White River

NR = Not reported in Notice of Coverage letter

Table 3.25. Active and intermittent use mines within the Little Red River watershed listed by the Arkansas Geological Survey, without DEQ permits (Arkansas Geological Survey 2022).

Mine Name	Operator	County	City	Material	Status
Red River Stone Company	NR	Cleburne	Heber Springs	Crushed Stone	Intermittent
Lone Star Quarry	Quality Rock Inc.	Cleburne	Rosebud	Crushed Stone	Active
Heber Springs #2	Rock Products Inc.	Cleburne	Heber Springs	Crushed Stone	Active
Rock Products Myrick Quarry	Vulcan Materials Company	Searcy	Leslie	Crushed Stone	Active
Shale Pit	NR	Searcy	Marshall	Shale	Intermittent
County Mine	Searcy County Road Department	Searcy	Leslie	Crushed Stone	Active
Oram Green Quarry	NR	Stone	Mountain View	Crushed Stone	Intermittent
Purdom Quarry	NR	Stone	Mountain View	Crushed Stone/Stone Dimension	Intermittent
Ormond Quarry	NR	Van Buren	Dennard	Crushed Stone	Active
Clinton Treece Quarry	Clinton Redi-Mix Inc.	Van Buren	Clinton	Crushed Stone	Active
Gravel Pit	NR	White	Judsonia	Sand & Gravel	Intermittent
Gravel Pit	NR	White	Searcy	Sand & Gravel	Active
Gravel Pit	NR	White	Searcy	Sand & Gravel	Active
Alder Creek Quarry	Vulcan Materials Company	White	Judsonia	Crushed Stone	Active
Peacock Road Quarry	Vulcan Materials Company	White	Bradford	Crushed Stone	Active
Shale Pit	NR	White	Bald Knob	Shale	Intermittent
Russell Mountain Road Quarry	Ferris Stone Inc.	White	Bald Knob	Crushed Stone	Active
Gravel Pit	NR	White	Bald Knob	Sand & Gravel	Active

Timber harvest is not a large-scale activity in the Little Red River watershed. Timber output from the counties that account for the majority of the Little Red River watershed accounts for only 3% of state output (Table 3.26). However, there are small-scale lumber mills and timberlands in the watershed (Arkansas Department of Agriculture Forestry Division, 2022). Timber harvest activities in the Little Red River watershed have the potential to impact water quality in the watershed. Harvest activities that do not follow the Arkansas Forestry Commission recommended best management practices have the potential to negatively affect stream water quality at stream crossings, unpaved roads, riparian buffers, log landings, and skid trails.

Table 3.26. 2020 timber output for selected counties of the Little Red River watershed (USDA Forest Service, 2021).

County	Softwood Output, million cubic feet	Hardwood Output, million cubic feet	Total Output, million cubic feet
Cleburne	5,192	444	5,637
Van Buren	3,409	434	3,843
White	7,695	1,601	9,296
State total	787,356	75,887	563,243

3.4.6 Field Erosion

Both pastures and croplands tend to be located in valleys and alongside streams because these are the areas best suited for agriculture. In the uplands, soils tend to be stony and thin and not as fertile (soil surveys). The 2016 NRCS State Resource Assessment characterized risk for concentrated flow and sheet, rill, wind erosion by HUC12 subwatersheds based on soil characteristics and stream impairment due to sediment (Figures 3.26 and 3.27). The majority of HUC12s within the Little Red River watershed are classified as having a greater than average risk of erosion (i.e., shown as orange or red on the maps in Figures 3.26 and 3.27). The USGS Midwest SPARROW model indicates that 38% of the Little Red River sediment load is from erosion of agricultural lands, i.e., pasture and croplands (Robertson and Saad 2019).

3.4.7 Farm Fertilizer

The USGS Midwest SPARROW model indicates that 16% of total phosphorus and 4% of total nitrogen load in the Little Red River watershed comes from farm fertilizer use. Commercial fertilizers are used on pastures, haylands, and croplands in the watershed. The majority of commercial farm fertilizers are likely used on the croplands in the watershed.

3.4.8 Developed Areas

There are several cities and towns in the Little Red River watershed. Runoff from impervious surfaces such as parking lots, rooftops, and roads carry pollutants into storm drains that empty into nearby waterways. Common pollutants from developed areas include sediment from erosion on construction projects, lawn products (fertilizer and pesticides), motor oil and lead from cars, bacteria/pathogens from pets and urban wildlife, and other waste from homes, businesses, and municipalities. The USGS Midwest SPARROW model indicates that 10% of the Little Red River watershed sediment load, 3% of total nitrogen load, and 13% of total phosphorus load comes from developed areas (Robertson and Saad 2019).

3.4.9 Recreation

Recreation activities in the watershed have the potential to affect water quality. Use of trails, and river and lake access points can increase erosion. Improper disposal of waste by recreationists also has the potential to allow pollutants, including bacteria and nutrients, into surface waters.

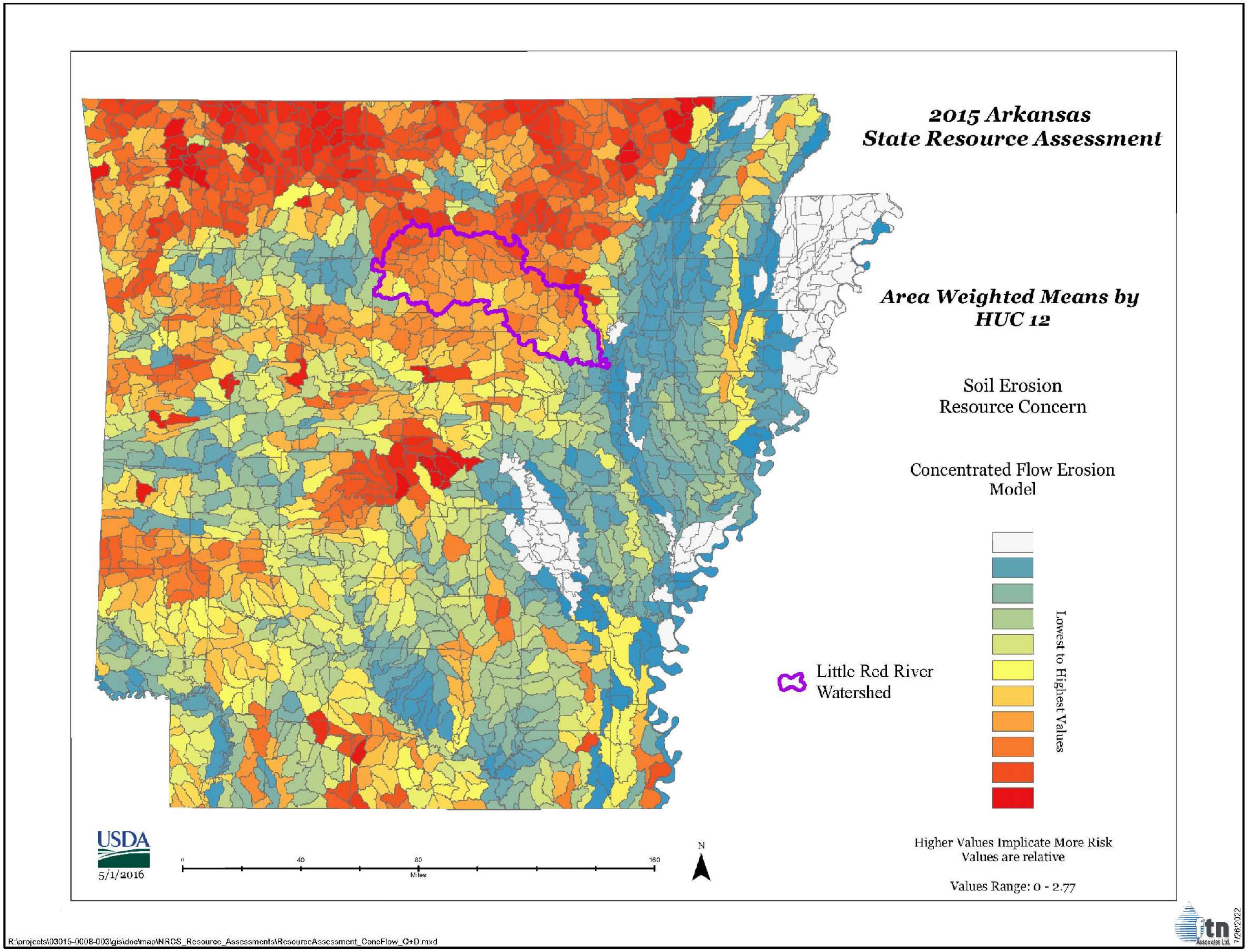


Figure 3.26. Concentrated flow erosion risk metric from 2015 State Resource Assessment.

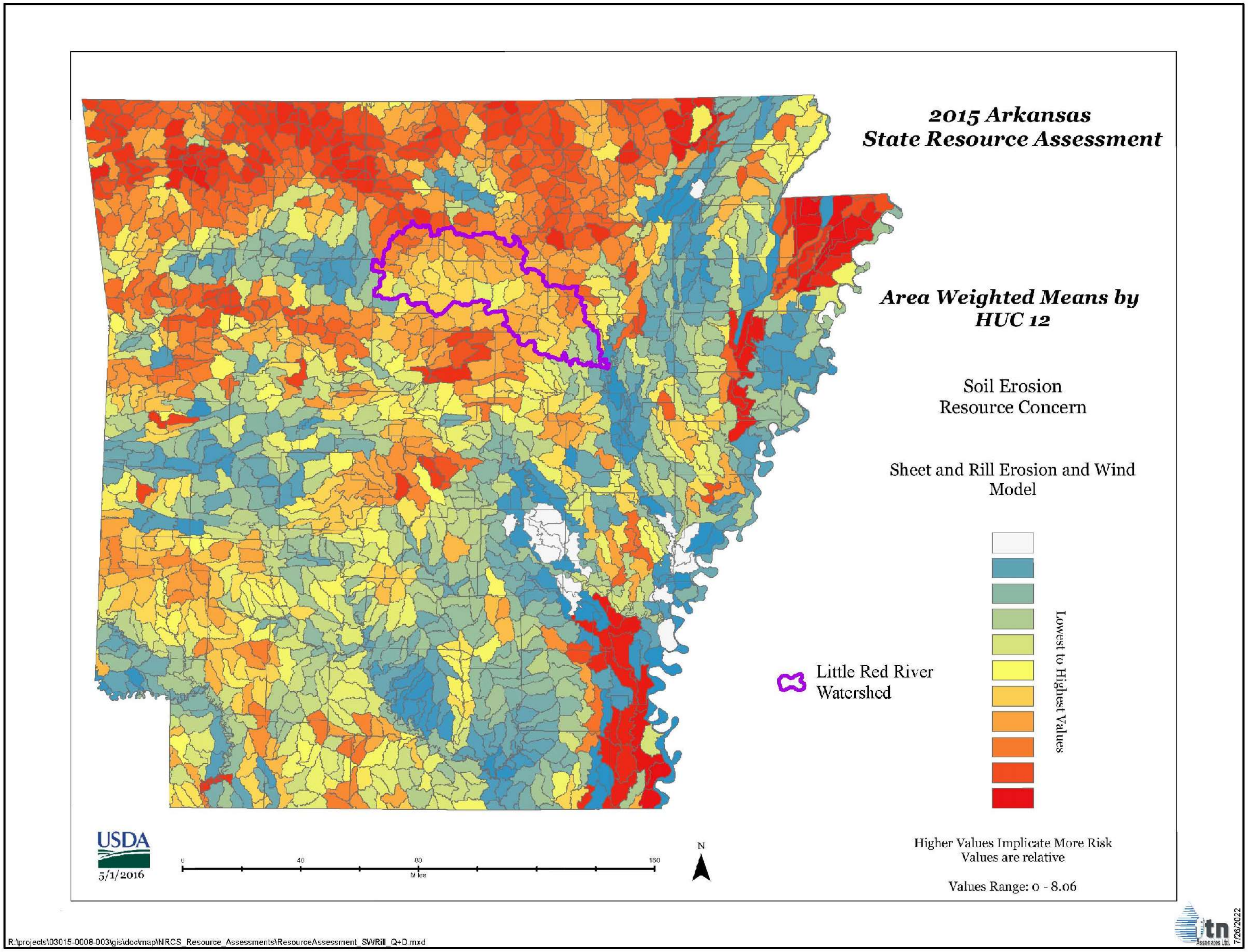


Figure 3.27. Sheet, rill and wind erosion risk metric from 2015 State Resource Assessment.

3.4.10 Illegal Dumping

Stakeholders have identified illegal dumping as an aesthetic concern, but it also has the potential to affect water quality. During the period from 2016 through 2020, DEQ confirmed over 50 locations in the Little Red River watershed where illegal dumping was occurring (DEQ 2022c). The majority of these locations were in White County.

3.4.11 Onsite Wastewater Treatment Systems

Given the rural setting of the majority of the Little Red River watershed, it is likely that onsite wastewater treatment systems (e.g., septic systems) are used by a large number of residents. Improper design, installation, and maintenance of these systems has the potential to cause nutrient and bacterial contamination of nearby waterbodies. However, there is currently no indication that onsite wastewater treatment systems are contributing significant water quality issues in the watershed.

3.4.12 Feral Hogs

Feral hogs may contribute to erosion, nutrient, or pathogen issues in the rural areas of the Little Red River watershed. Based on Arkansas Feral Hog Eradication Task Force removal rates, the Little Red River watershed counties with the greatest feral hog activity are Searcy and Stone Counties (Table 3.27). Over 500 feral hogs were removed from each of these counties in 2021 (12,699 feral hogs were removed state-wide in 2021) (Arkansas Feral Hog Eradication Task Force 2022).

Table 3.27. Numbers of feral hogs removed from Little Red River watershed counties in 2021 (Arkansas Feral Hog Eradication Task Force 2022).

County	Feral Hogs Removed by Task Force 2021	Feral Hogs Removed by Individuals 2021	Total Feral Hogs Removed 2021
Cleburne	32	38	70
Independence	0	0	0
Searcy	436	199	635
Stone	478	80	558
Van Buren	62	0	62
White	13	46	59

3.5 Conclusions

Water quality issues in the Little Red River watershed include excessive pathogens, low pH, turbidity, low DO, and a mercury fish consumption advisory. Low pH and conditions and the mercury fish consumption advisory appear to be at least partly the result of natural conditions in the watershed, and they will not be a focus for management under this plan. There are some recent changes in water quality that seem unusual, including a recent increase in pH in the South Fork Little Red River near Clinton, and decreasing water temperatures in the Little Red River near Searcy. Pollutant load estimates indicate that nonpoint source pollutant yields tend to be greater downstream of Greers Ferry Lake than upstream.

In general, fisheries appear to be in good condition at surveyed locations, and recent data indicate that populations of the endangered Yellowcheek Darter are currently stable. Some macroinvertebrate surveys indicate poor stream condition, and some populations of endangered mussel species present in the watershed have declined. NRCS has classified the majority of HUC12 subwatersheds within the Little Red River watershed to be at greater than average (for Arkansas) risk of habitat (aquatic and land) degradation.

Available groundwater data do not indicate water quality issues. However, the geology of the area is such that there is moderate risk to groundwater quality from surface land management activities.

A variety of nonpoint sources of pollutants of concern are present in this watershed. Some are present throughout the watershed, others are more prevalent in certain areas.

4.0 MANAGEMENT PLAN

This section identifies management concerns and goals for the Little Red River watershed, as well as areas to target management and practices to achieve the watershed goals.

4.1 Management Goals

There are five management goals to achieve the vision of the Little Red River watershed:

1. Restore waterbody uses currently not being attained,
2. Sustain waterbody uses that are being attained,
3. Keep pollutants out of surface water and groundwater,
4. Minimize activities that disturb the stream channel and streambank, and
5. Restore eroding streambanks and degraded riparian areas.

There are several stream reaches in the Little Red River watershed listed by DEQ as currently not meeting water quality standards required to support some of their designated uses (see Section 3.1.4). To achieve the vision for the Little Red River watershed (see Section 1.2), water quality in these streams will need to meet all water quality standards so that all designated uses are supported. In addition, good water quality needs to be protected and maintained in those streams that currently meet water quality standards and attain their designated uses. The management goals of keeping pollutants out of surface water and groundwater, minimizing activities that disturb the stream bed and its banks, and restoring eroding streambanks and degraded riparian areas all contribute to the goals of achieving water quality standards and attaining designated waterbody uses.

4.2 Management Concerns

Concerns about the Little Red River watershed were identified from public meetings and online information, in addition to waterbody impairments. Table 4.1 is a list of the water quality related issues identified by stakeholders for this watershed.

Table 4.1. Water quality related issues identified by Little Red River stakeholders.

In-stream	Watershed
Excess nutrients (nitrogen and phosphorus)	Septic systems
Algae blooms	Manure and chicken litter leachate
Streambank erosion	Erosion (pasture, unpaved roads)
Turbidity and sedimentation	Fertilizer application
Gravel mining	Pesticides applications
Bacteria	Clearcutting and forest/timber lands management
Invasive species	Cattle (in streams, overgrazing)
Threatened & endangered aquatic species	Feral hogs
Low dissolved oxygen	Degraded riparian areas
Fish consumption advisory	Resource extraction (mining and gas wells)

4.3 Subwatersheds Recommended for Management

For this watershed management plan, 12-digit HUC (HUC12) subwatersheds delineated by the USGS are utilized as focus areas for nonpoint source pollution management. There are 48 HUC12 subwatersheds in the Little Red River watershed (Figure 4.1). Because resources are limited for nonpoint source pollution management, we identified several HUC12s in the Little Red River watershed where it appears the return on investment of using nonpoint source pollution management activities would have greater benefits than in other HUC12s.

To identify the “recommended” HUC12 subwatersheds for this plan, available information was used to rank the water quality and habitat concerns in HUC12 subwatersheds of the Little Red River watershed. Thirteen water quality-related criteria were assessed and used to rank each of the HUC12 subwatersheds. The following information was used to rank the HUC12 subwatersheds:

- Water quality impairment;
- Water quality risk, including loads and natural resource concerns; and
- Aquatic communities and habitat, including habitat resource concern, condition of threatened and endangered species, and predicted stream biotic condition.

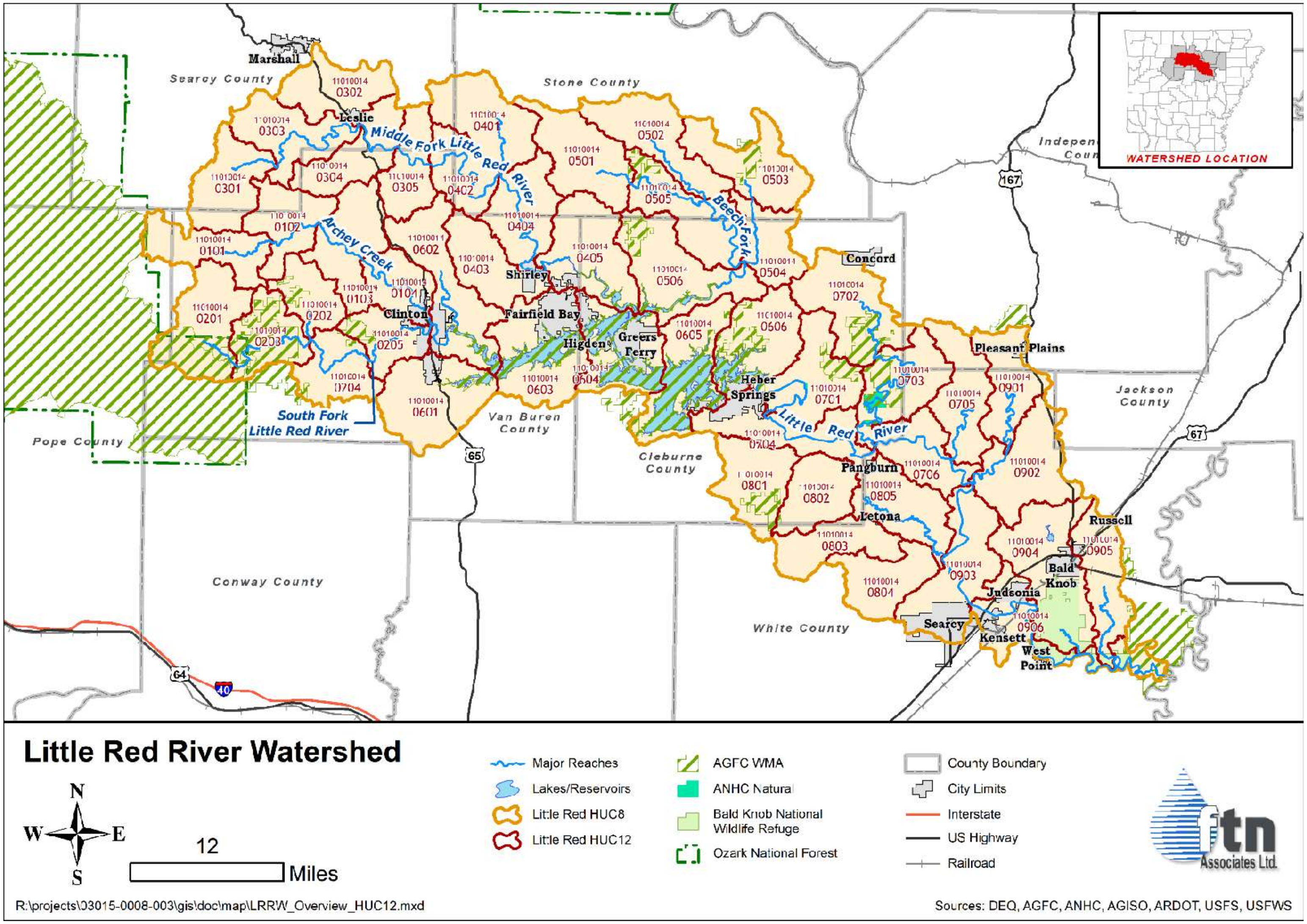


Figure 4.1 Map of HUC12 subwatersheds in the Little Red River watershed.

A detailed description of the data used and the ranking approach is included as Appendix H. The seven HUC12 subwatersheds with the highest total ranks were selected as the recommended subwatersheds for additional nonpoint source pollution management through this watershed management plan. The recommended HUC12 subwatersheds are listed in Table 4.2 and mapped on Figure 4.2. These are not the only Little Red River HUC12 subwatersheds with existing or potential water quality issues (see Appendix H). This plan is not intended to restrict management activities in areas outside the recommended HUC12 subwatersheds. Water quality management is essential, and is encouraged, anywhere in the Little Red River watershed.

Table 4.2. Little Red River HUC12 subwatersheds recommended for management under this watershed management plan. Note that land use percentages may not total 100 because barren and open water percentages are not listed.

Subwatershed Name	HUC12 ID	Ranking Score (out of 16 possible)	Cropland	Developed	Forested	Pasture and Hayland	Wetland	Other Undeveloped
Headwaters Ten Mile Creek	110100140901	10	0	4.7%	46%	44%	<0.1%	3.6%
Outlet Ten Mile Creek	110100140902	9	<0.1%	4.7%	51%	40%	<0.1%	1.8%
Little Red River – Alder Cr	110100140903	7	0.6%	19%	44%	32%	0.8%	1.8%
Overflow Creek	110100140904	6	30%	7.4%	26%	24%	8.6%	1.2%
Big Mingo Creek	110100140905	6	42%	5.5%	18%	9.8%	23%	0.7%
Fourteen Mile Creek	110100140705	6	<0.1%	4.7%	54%	36%	0.5%	3.8%
Little Red River – Cedar Br	110100140706	6	0.4%	4.4%	59%	28%	2.7%	2.7%

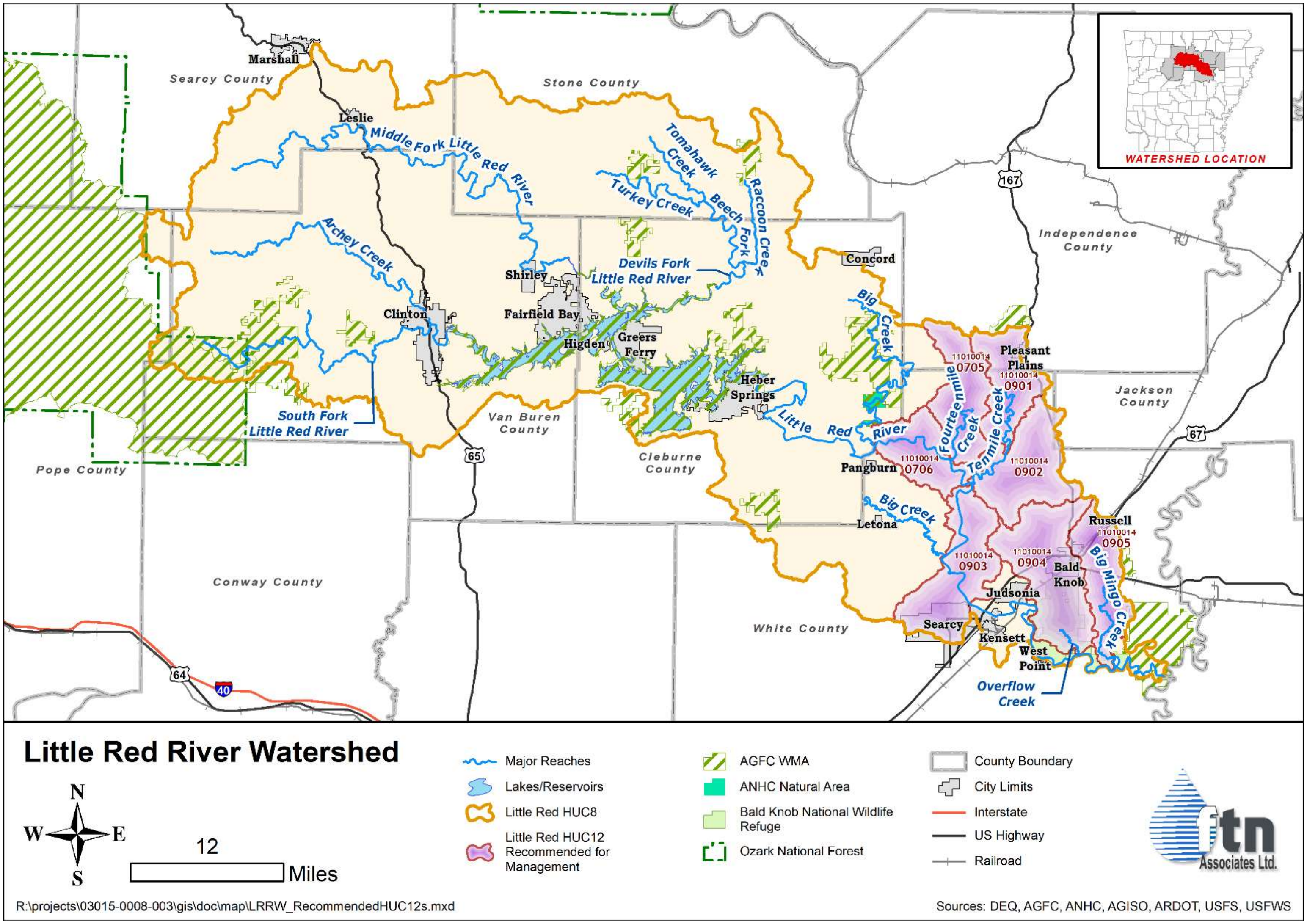


Figure 4.2. Map of HUC12 subwatersheds of Little Red River recommended for nonpoint source pollution management.

Table 4.3 identifies issues and concerns in the recommended subwatersheds. The subwatershed issues are identified based on assessed water quality impairments (bacteria and turbidity), NRCS State Resource Assessment (pesticides, excess nutrients, turbidity and sedimentation, aquatic habitat condition), SWAT model results (excess nutrients and sedimentation), water quality trends (water temperature, pH), EPA StreamCat analysis (aquatic habitat condition), and the presence of species of concern (endangered Scaleshell mussel and threatened Rabbitsfoot mussel) and invasive aquatic species, and the presence of protected aquatic habitat (e.g., National Wildlife Refuge).

Table 4.3. Little Red River watershed water quality issues of concern in recommended subwatersheds.

Issue	Little Red River Cedar Branch (706)	Fourteen Mile Creek (705)	Headwaters Ten Mile Creek (901)	Outlet Ten Mile Creek (902)	Little Red River Alder Creek (903)	Overflow Creek (904)	Big Mingo Creek (905)
Stakeholder Water Quality Concerns							
Excess nutrients (nitrogen and phosphorus)	N	N	N, S	N, S	N	S	S
Algae	M	--	--	--	--	--	--
Turbidity and sedimentation	S	S	S, I	S, I	S, T	--	N
Bacteria	N, I	N	N, I	N, I	N, I	N, I	--
Low dissolved oxygen	--	--	--	--	--	--	--
Water temperature	--	--	--	--	T	--	--
pH	--	--	T	T	--	t	--
Pesticides	N	N	N	N	N		N
Threatened and endangered aquatic species	X	X	X	X	X	X	X
Invasive aquatic species	U	--	--	--	--	--	--
Other Water Quality Concerns							
Presence of protected aquatic habitat	--	--	--	--	--	R	R
Aquatic habitat condition	--	E	E	E	E, N	E	E, N

E = EPA StreamCat, I = impairment, N = top quartile risk for watershed from 2015 NRCS State Resource Assessment, M = public meeting, S = top quartile SWAT modeled loads, T = statistically significant trend, t = apparent trend, not statistically significant, U = USGS Nonindigenous Aquatic Species mapper, R= AGFC wildlife management area or national wildlife refuge present, X=USFWS IPaC

4.4 Management Targets for Recommended Subwatersheds

Based on the water quality concerns listed in Table 4.3, pollutants of concern in the recommended subwatersheds are nutrients, sediment, bacteria, pH, and pesticides. These pollutants are targets for management under this plan. Management targets for these pollutants are discussed below.

4.4.1 Pesticides Management Targets

Management targets for organic compounds for which DEQ has established water quality criteria, are the water quality criteria. Table 4.4 lists the surface water numeric criteria promulgated for organic compounds used as pesticides. Note that the aquatic life criteria listed in Table 4.4 are also protective of human health (EPA 2020b). To be assessed as achieving the criteria in Table 4.4, DEQ requires that 100% of water measurements be less than the criteria (DEQ 2021d). Organics compounds have not been measured in the Little Red River watershed since the 1990s. The only recommended subwatershed where organics sampling has occurred is Overflow Creek. All analysis results for the organic compounds in Table 4.4 from the 1990s samples were reported as less than detection. Until more current measurements of the organic compounds in Table 4.4 have been collected from the recommended subwatersheds, it will not be possible to track achievement of the pesticide targets in those subwatersheds.

Table 4.4. Ambient water numeric water quality criteria for pesticides (Arkansas Pollution Control and Ecology Commission 2020).

Substance	Aquatic life acute criteria, ug/L	Aquatic life chronic criteria, ug/L
Aldrin	3.0	-
Dieldrin*	2.5	0.0019
DDT & metabolites*	1.1	0.0010
Endrin*	0.18	0.0023
Toxaphene*	0.73	0.0002
Chlordane*	2.4	0.0043
Endosulfan	0.22	0.056
Heptachlor*	0.52	0.0038
Hexachlorocyclohexane	2.0	0.080
Chlorpyrifos	0.083	0.041

* Banned pesticide or residue of banned pesticide

4.4.2 pH Management Target

The pH management target for this watershed management plan is to attain the pH water quality criteria. To be assessed as achieving the pH criteria, DEQ requires that at least 90% of at least 10 measurements from the assessment period meet the pH criteria (DEQ 2021d). This is the management target for this plan.

No streams in the recommended subwatersheds are currently classified as impaired due to pH. However, a statistically significant decline in pH was identified at the Ten Mile Creek water quality station, and pH also appears to be declining at the Overflow Creek water quality station (see Appendix E). This suggests that there is the potential for Ten Mile Creek or Overflow Creek to be listed as impaired in the future due to low pH if pH levels continue to decline.

4.4.3 Bacteria Management Targets

Bacteria management targets for this watershed management plan are the *E. Coli* water quality criteria. To be assessed as achieving the *E. Coli* criteria, DEQ requires that 75% or more of at least 8 *E. Coli* measurements from the assessment period (see Table 3.1 For Primary and Secondary Contact assessment periods) must be less than the criterion (DEQ 2021d). The applicable Primary Contact *E. Coli* criterion in the recommended subwatersheds is 410 cfu/100 mL. Note that *E. Coli* measurements have been collected recently (2018-2019) from the Outlet Ten Mile Creek (UWTMC01) and Overflow Creek (UWOFC01) recommended subwatersheds, and within the last 10 years (2011-2013) from Big Mingo Creek subwatershed (WHI0099). *E. Coli* measurements have not been collected from the remaining recommended subwatersheds. Until *E. Coli* measurements have been collected from the Little Red River Cedar Branch, Fourteen Mile Creek, Headwaters Ten Mile Creek, and Little Red River Alder Creek subwatersheds, it will not be possible to track achievement of the *E. Coli* targets in those subwatersheds.

Total Maximum Daily Loads (TMDLs) for fecal coliforms and *E. Coli* have been developed for stream reaches in several of the recommended subwatersheds (US EPA Region 6 TMDL Team 2007). TMDLs for stream reaches in recommended subwatersheds that protect the

Primary Contact use during summer are listed in Table 4.5. The Load Allocation shown in Table 4.5 is the portion of the TMDL allocated to background and nonpoint sources.

Table 4.5. *E. Coli* TMDLs for stream reaches in recommended subwatersheds (US EPA Region 6 TMDL Team 2007).

Recommended subwatershed HUC12 ID	DEQ Reach ID	Stream name	*E. Coli* TMDL, 10^{13} cfu/day	*E. Coli* Load Allocation, 10^{13} cfu/day
110100140901 110100140902	11010014-009	Ten Mile Creek	1.92	1.73
110100140903	11010014-007	Little Red River	1.92	1.72
	11010014-008	Little Red River	1.50	1.35
110100140904	11010014-004	Overflow Creek	0.16	0.14
	11010014-006	Overflow Creek	0.11	0.10
110100140706	11010014-010	Little Red River	1.00	0.90
	11010014-012	Little Red River	0.95	0.85

4.4.4 Nutrient Management Targets

There are no numeric criteria for nutrients that apply to the Little Red River watershed that could be used as management targets (Arkansas Pollution Control and Ecology Commission 2020). To address Gulf of Mexico hypoxia, Arkansas has committed to reduce nitrogen loads leaving the state. In the Arkansas Nutrient Reduction Strategy, the Little Red River watershed is classified as a Tier 3 watershed, with a focus on data collection and trend analysis (NRD 2022b). The USGS SPARROW nutrient and sediment modeling indicates that nutrient loads from the Little Red River watershed are about average for the Midwest (see Section 3.1.6).

The DEQ method for assessing whether wadeable streams are nutrient impaired uses the 75th percentile of total nitrogen and total phosphorus measurements from each of the state ecoregions, along with DO and pH measurements and the condition of biological communities (DEQ 2021d). Often, low-DO conditions in Arkansas waterbodies are a result of excessive algal production caused by nutrient inputs. In such situations, management of nutrient inputs will improve DO conditions. However, none of the stream reaches in the recommended subwatersheds are listed as impaired due to low DO.

Given the information outlined above, numeric nutrient target concentrations for this plan are the 75th percentile total nitrogen and total phosphorus concentrations for the Arkansas River Valley and Delta ecoregions (Table 4.6). The secondary management targets for nutrients are no statistically significant increase in total nitrogen or total phosphorus concentrations, and no new low DO impairments in the recommended subwatersheds.

Table. 4.6. DEQ ecoregion nutrient assessment values (75th percentiles) (J. Martin, DEQ, personal communication, 9/29/22; B. Olsen, DEQ, personal communication, 11/30/22).

Ecoregion	Total Nitrogen 75th percentile	Total Phosphorus 75th percentile
Arkansas River Valley	1.04 mg/L	0.110 mg/L
Delta	1.46 mg/L	0.34 mg/L

4.4.5 Sediment Management Targets

The sediment management targets for this watershed management plan are the turbidity water quality criteria. All the recommended subwatersheds except Fourteen Mile Creek have DEQ water quality stations where turbidity has been measured. However, turbidity has been measured at only two of these stations within the last ten years; at UWOFC01 on Overflow Creek in 2012 and at WHI0199 on Big Mingo Creek in 2013. The last time turbidity was measured in the recommended subwatersheds, only turbidity levels measured in Ten Mile Creek exceeded a turbidity criterion (in 2003). Until turbidity measurements have been collected from the Fourteen Mile Creek subwatershed, it will not be possible to track achievement of the turbidity target in this subwatershed. Current turbidity data are needed from all recommended subwatersheds to determine whether turbidity targets are currently being met.

A turbidity TMDL has been developed for Ten Mile Creek (FTN Associates, Ltd. 2005). Because turbidity cannot be expressed as a mass load, the TMDL is expressed in terms of TSS load. The Ten Mile Creek TSS TMDLs are listed in Table 4.7. The Load Allocation shown in Table 4.6 is the portion of the TMDL allocated to background and nonpoint sources, i.e., all of the TMDL load is allocated to background and nonpoint sources.

Table 4.7. TSS TMDLs for Ten Mile Creek (FTN Associates, Ltd. 2005).

Recommended subwatersheds HUC12 ID	DEQ Reach ID	Stream name	Flow category	TSS TMDL, tons/day	TSS Load Allocation, tons/day
110100140901	11010014-009	Ten Mile Creek	Baseflow	0.08	0.08
110100140902			Storm flow	5.01	5.01

4.5 Load Reduction Targets

Based on the water quality targets identified in Section 4.4 and available water quality information, it should be possible to determine pollutant load reductions needed to achieve the water quality targets. Determination of load reduction targets for this watershed management plan is discussed in the following subsections.

4.5.1 Bacteria Reduction Targets

Bacteria TMDLs have been prepared for several stream reaches within the recommended subwatersheds (see Table 4.5). No reductions were specified to achieve the bacteria criteria in the TMDL report (US EPA Region 6 TMDL Team 2007).

The DEQ approach for evaluating attainment of the *E. Coli* Primary Contact criterion uses a data set of at least eight measurements collected between May 1 and September 30 (DEQ 2021d). Data suitable for this evaluation was collected in 2018 from three stations within recommended subwatersheds, UWOFC01 (Overflow Creek subwatershed), UWTMC01 (Ten Mile Creek subwatershed), and WHI0059 (Little Red River, just downstream of Little Red River - Alder Cr subwatershed). Evaluation of these data following the DEQ evaluation protocol is summarized in Table 4.8. The results of this evaluation suggest that only Ten Mile Creek would be classified as impaired based on the 2018 data. Thus, for this watershed management plan, a bacteria load reduction target was developed only for Ten Mile Creek. Note that the Overflow Creek and the Little Red River stream segments are still listed as impaired due to *E. Coli* on the 2020 303(d) list. Therefore, *E. Coli* will be considered a target pollutant for management under this plan for Overflow Creek and the Little Red River, even though there are no load reduction targets for these subwatersheds.

Table 4.8. Evaluation of 2018 *E. Coli* data collected from stations associated with recommended subwatersheds during Primary Contact Season (May 1 – September 30).

WQ station ID	Stream name	Number of *E. Coli* measurements May 1- September 30	Number of measurements > 410 cfu/100 mL	Percentage of measurements > 410 cfu/100 mL
UWOFC01	Overflow Creek	9	2	22%
UWTMC01	Ten Mile Creek	9	4	44%
WHI0059	Little Red River	9	2	22%

To be classified as achieving the *E. Coli* individual sample criterion, no more than two out of nine *E. Coli* measurements from Ten Mile Creek can exceed 410 cfu/100 mL. The 2018 measurements from UWTMC01 that exceed 410 are listed in Table 4.9. If the two 700 cfu/100 mL measurements were instead 410 cfu/100 mL, Ten Mile Creek would be classified as meeting the *E. Coli* criterion. This would be equivalent to a 41% reduction in the *E. Coli* concentration (i.e., (700-410)/700). Therefore, the bacteria load reduction target for this watershed management plan, for subwatersheds 110100140901 and 110100140902, is 41%.

Table 4.9. *E. Coli* measurements from 2018 at station UWTMC01 greater than 410 cfu/100 mL.

Date	*E. Coli*, cfu/100 mL
7/16/2018	1,900
7/30/2018	2,800
9/4/2018	700
9/24/2018	700

After *E. Coli* measurement data sets that meet the DEQ criteria for evaluation of achievement of *E. Coli* criteria are collected from streams in the recommended subwatersheds Little Red River - Cedar Br, Fourteen Mile Creek, and Big Mingo Creek, bacteria reduction targets may be developed for these subwatersheds for future versions of the watershed management plan.

4.5.2 Nutrient Reduction Targets

No stream segments within the recommended subwatersheds have been classified as impaired due to nutrients. Total phosphorus and total nitrogen data have not been collected from most of the recommended subwatersheds within the last 10 years. The only water quality station associated with the recommended subwatersheds where data suitable for evaluating nutrient impairment has been collected within the last 10 years is WHI0059, on the Little Red River. It is not likely that this stream segment would be classified as wadeable, so DEQ would not assess it for nutrient impairment (DEQ 2021d).

To estimate nutrient reduction targets for this plan, nutrient measurements collected in the recommended subwatersheds were compared to the DEQ ecoregion nutrient assessment values (see Table 4.6). Nutrient measurements from stations WHI0059, WHI0199, UWOFC01, and UWTMC01 were used. As noted, nutrient measurements from the period 2016-2020 were available only from station WHI0059. For the other three stations, nutrient measurements from the most recent sampling period were used. For stations UWOFC01 and WHI0199 the most recent sampling period was during 2011-2013. For station UWTMC01, the most recent sampling period was 2001-2003. If any measurements were greater than the ecoregion assessment value, a reduction factor was calculated by dividing the assessment value by the maximum value reported from the assessment period. The results of the data evaluation, and the calculated reduction factors for total nitrogen are listed in Table 4.10 and for total phosphorus in Table 4.11. Note that for sample dates prior to April 2018, total nitrogen values were estimated by adding reported nitrate + nitrite nitrogen to total Kjeldahl nitrogen values.

Table 4.10. Total nitrogen load reduction target calculations.

Station ID	**WHI0059**	**UWTMC01**	**UWOFC01**	**WHI0199**
Stream Name	**Little Red River**	**Ten Mile Creek**	**Overflow Creek**	**Mingo Creek**
HUC12 ID	110100140706, 110100140903	110100140901, 110100140902	110100140904	110100140905
HUC12 Name	Little Red River - Cedar Br, Little Red River - Alder Cr	Headwaters Ten Mile Creek, Outlet Ten Mile Creek	Overflow Creek	Big Mingo Creek
DEQ Ecoregion	Arkansas River Valley	Arkansas River Valley	Arkansas River Valley	Delta

Table 4.10. Total nitrogen load reduction target calculations (continued).

Station ID	WHI0059	UWTMC01	UWOFC01	WHI0199
Stream Name	Little Red River	Ten Mile Creek	Overflow Creek	Mingo Creek
Assessment period	2016-2020	2001-2003	2011-2012	2011-2013
Number of total nitrogen values	49	12	5	8
Number of total nitrogen values > assessment value	0	1	0	1
Maximum value	0.94 mg/L	1.344 mg/L	0.871 mg/L	2.058 mg/L
Reduction factor so all total nitrogen values < assessment value	0	0.23	0	0.71

Table 4.11. Total phosphorus load reduction target calculations.

Station ID	WHI0059	UWTMC01	UWOFC01	WHI0199
Stream Name	Little Red River	Ten Mile Creek	Overflow Creek	Mingo Creek
HUC12 ID	110100140706, 110100140903	110100140901, 110100140902	110100140904	110100140905
HUC12 Name	Little Red River - Cedar Br, Little Red River - Alder Cr	Headwaters Ten Mile Creek, Outlet Ten Mile Creek	Overflow Creek	Big Mingo Creek
DEQ Ecoregion	Arkansas River Valley	Arkansas River Valley	Arkansas River Valley	Delta
Assessment period	2016-2020	2001-2003	2011-2012	2011-2013
Number of total phosphorus values	52	12	5	8
Number of total phosphorus values > assessment value	2	2	0	0
Maximum value	0.171 mg/L	0.51 mg/L	0.096 mg/L	0.257 mg/L
Reduction factor so all total phosphorus values < assessment value	0.36	0.78	0	0

Reported nutrient values exceed the assessment concentrations at three of the monitoring locations. This results in nutrient reductions targeted in five recommended subwatersheds, two with only total nitrogen reductions, two with only total phosphorus reductions, and one with both total nitrogen and total phosphorus reductions. Note that given the age of some of the data used to assess the need for nutrient reductions and calculate the reduction targets makes their applicability to current conditions suspect. It is likely that results would be different with more current data.

4.5.3 Sediment Reduction Targets

The turbidity TMDL for Ten Mile Creek determined that no reduction in TSS load was needed to meet the turbidity criteria in that waterbody (FTN Associates, Ltd. 2005). There is no recent data from Ten Mile Creek to use to check attainment of turbidity water quality criteria or estimate TSS loads. There are no stream segments in the other recommended subwatersheds classified as impaired due to sediment or turbidity. For most of the recommended subwatersheds turbidity and TSS data have not been collected within the last 10 years. Since there are no water quality data that indicate sediment impairment in the recommended subwatersheds, no reduction targets are specified in this plan for sediment. In this watershed management plan, pollutants of concern without load reduction targets are addressed through collecting data to assess whether the water quality criteria are being met or water quality is impaired, and through practices that reduce the release of these pollutants to surface water and groundwater.

4.5.4 Other Pollutants of Concern

At this time, it is not possible to identify load reduction targets for the recommended subwatersheds for pH or pesticides. At this point, the factors behind apparently declining pH at some locations in the watershed is unknown. Under this iteration of the watershed management plan, pH water quality concerns will be addressed through study, rather than management of unknown nonpoint sources.

There is no recent data (i.e., within the last 10 years) indicating that the water quality criteria for pesticides or pH are not being met in the recommended subwatersheds. Although the

NRCS Arkansas State Resource Assessment results suggest that pesticides and herbicides in runoff might be issues in the recommended subwatersheds, there are no recent water quality measurements from these subwatersheds that indicate organics numeric water quality criteria are not being met. In this watershed management plan, pollutants of concern without load reduction targets will be addressed through collecting data to assess whether the water quality criteria are being met or water quality is impaired, and through practices that reduce the release of these pollutants to surface water and groundwater.

4.6 Nonpoint Pollution Sources Targeted for Management

Although the only load reduction target for this plan is for bacteria, unregulated nonpoint sources of nutrients and sediment in the recommended subwatersheds will be targeted for management in this plan, along with nonpoint bacteria sources. These include runoff from pastures, croplands, and developed areas; livestock; pets; wildlife; septic systems; illicit discharges sewage; leaks in sewage collection systems; manure or poultry litter used as fertilizer; streambank erosion; and unpaved roads. The presence of these nonpoint sources in the recommended subwatersheds is discussed in the subsections below.

4.6.1 Livestock

Livestock using pastures are sources of bacteria and nutrients that can enter surface water (Justus, et al. 2010). Livestock wastes deposited in or beside streams can provide bacteria and nutrients to streams (e.g., cows loitering in streams) or riparian areas. In addition, livestock use of riparian areas and streams can increase streambank and channel erosion, contributing sediment. James et al. (2007) found that pastured cattle deposited significantly more manure in and near streams than in other areas of the pasture. Studies have shown that, unless access to streams is restricted, cattle generally spend much of the day in the riparian area, no matter the season or the availability of other water sources (Bagshaw, et al. 2008, Zuo and Miller-Goodman 2004). The 2017 cattle inventory for White County, where the majority of the pasture in the recommended subwatersheds is located, is higher than in 2012 but lower than previous years, and higher than the other counties in the Little Red River watershed (see Figure 3.23). Livestock number estimates for the recommended subwatersheds are listed in Table 4.12. Cattle are a nonpoint source of concern in all of the recommended subwatersheds, although to a lesser degree in the Big Mingo Creek subwatershed.

4.6.2 Poultry Litter

Poultry, primarily chicken, production occurs in White County. Based on 2017 aerial imagery, it appears there may be active poultry production facilities operating in the recommended subwatersheds (DEQ 2018b). Poultry inventories for White County have been relatively stable over the years and are about mid-range for counties in the Little Red River watershed (see Figure 3.24). Estimates of 2012 poultry numbers for the recommended subwatersheds are provided in Table 4.13.

Litter from poultry houses in the recommended subwatersheds is a potential source of nutrients and bacteria to surface and groundwater. Poultry litter has the potential to impact water quality when it is stored in the open and when it is applied to pastures, haylands, or croplands as fertilizer.

Assuming an annual litter production rate of 1 ton per 1,000 chickens, between 19 tons (Big Mingo Creek) and 114 tons (Headwaters Ten Mile Creek) of poultry litter would be produced each year in the recommended subwatersheds that could be applied to local pastures and haylands, or even croplands (Sharpley, et al. 2009, Tabler, et al. 2021). Producers in Independence and White Counties with nutrient management plans report litter applied on pasture to NRD. Table 4.14 lists annual county litter application totals reported for the last five years, 2017-2021. Poultry litter is assumed to be a concern only on pasture and haylands in the recommended subwatersheds. There is no indication that poultry litter is widely used on the croplands in the Overflow Creek and Big Mingo Creek subwatersheds. Therefore, poultry litter is not considered to be a nonpoint source of concern in cropland areas of the recommended subwatersheds.

Table 4.12. Estimate of livestock numbers for recommended subwatersheds based on 2012 Census of Agriculture (TetraTech, EPA 2013).

Livestock	110100140706 Cedar Branch-Little Red River	110100140902 Outlet Ten Mile Creek	110100140903 Alder Creek-Little Red River	110100140705 Fourteen Mile Creek	110100140901 Headwater Ten Mile Creek	110100140904 Overflow Creek-Little Red River	110100140905 Big Mingo Creek
Beef Cattle	1,045	2,212	2,032	1,857	2,003	2,490	994
Dairy Cattle	9	21	20	10	10	24	10
Swine	17	36	34	22	22	42	17
Sheep	10	24	23	19	20	28	11
Horses	81	179	165	114	115	202	81

Table 4.13. Estimate of poultry numbers for recommended subwatersheds based on 2012 Census of Agriculture (TetraTech, EPA 2013).

Livestock	110100140706 Cedar Branch-Little Red River	110100140902 Outlet Ten Mile Creek	110100140903 Alder Creek-Little Red River	110100140705 Fourteen Mile Creek	110100140901 Headwater Ten Mile Creek	110100140904 Overflow Creek-	110100140905 Big Mingo Creek
Chickens	24,583	41,308	39,447	94,129	113,517	48,335	19,290
Turkeys	1	3	3	2	2	3	1
Ducks	2	5	5	4	4	6	2

Table 4.14. Reported poultry litter applied (NRD, personal communication, 2022).

Litter applied, tons/year		
Year	**Independence County**	**White County**
2021	7,231	3,421
2020	7,844	3,421
2019	4,137	4,972
2018	8,087	3,847
2017	3,059	4,763

4.6.3 Fertilizer

Fertilizer is a potential source of nutrient loads. Commercial fertilizer applied to lawns in developed areas can be a significant source of nutrients to surface waters (Hobbie, et al. 2017). The same is true for commercial fertilizers applied to pastures, haylands, and croplands. Fertilizer is assumed to be a concern on pasture, haylands, residential and commercial areas, and croplands in the recommended subwatersheds.

4.6.4 Runoff from Pastures and Haylands

Based on 2016 land use information, pasture and hayland areas account for 44% to 10% of the land area in the recommended subwatersheds. Runoff from pastures can carry *E. Coli*, nutrients, sediment, and pesticides. A 2003 inventory of pasture condition in the lower Little Red River watershed (Cleburne, Independence, and White Counties) determined that overall, pastures were in good condition and not a significant source of sediment (Cleburne County Conservation District 2003b). Because pastures and haylands account for only 10% of the Big Mingo subwatershed, this nonpoint source will not be targeted in this subwatershed.

4.6.5 Pets and Wildlife

In populated areas, the waste from pets, if not properly disposed of, can be a significant source of bacteria (e.g., *E. Coli*) and nutrients to surface waters (Hobbie, et al., 2017; Northern Virginia Regional Commission, 2004). Wildlife associated with developed areas, such as racoons and Canada geese, also contribute bacteria and nutrients to surface waters (Northern Virginia Regional Commission 2004; Pieper 2013). "Hundreds of thousands of migratory waterfowl and other birds pass through Bald Knob" National Wildlife Refuge in Overflow Creek recommended subwatershed (USFWS 2022a). Feral hogs may contribute to erosion, nutrient, or bacteria issues in rural areas of the recommended subwatersheds. However, based on county removal numbers, feral hogs do not appear to be a significant concern in the recommended subwatersheds (see Section 3.4.12).

4.6.6 Runoff from Developed Areas

Runoff from developed areas can carry a wide variety of pollutants, including nutrients, bacteria, pesticides, and sediment. Based on 2016 land use data, developed lands account for 4.4% to 19% of the recommended subwatershed land area. The majority of the developed areas in the recommended subwatersheds are open space or residential (Wickham, et al. 2021). Poorly vegetated riparian areas can allow transport of pollutants from developed areas to enter surface waters. Municipal stormwater collection systems can carry pollutants washed from developed areas to surface waters.

4.6.7 Illicit Wastewater Discharges

Discharge of untreated wastewater to municipal stormwater collection systems can occur as the result of leaks in wastewater collection pipes, or accidental or purposeful connection of wastewater pipes to storm drains, ditches, or streams. If untreated sewage is entering the storm drains and/or streams within Searcy, Bald Knob, or other developments in recommended subwatersheds, it could be a source of human enteric bacteria, nutrients, and other pollutants. Residences and businesses located on the banks of the Little Red River must be particularly careful of wastewater disposal. Accidental combined sewer overflows are another potential source of human enteric bacteria and nutrients in streams in and near developed areas. Searcy reported sewer overflows in 2018 and 2019. Bald Knob has reported no sewer overflows since 2013 (DEQ 2022d).

4.6.8 On-site Wastewater Treatment Systems

Two of the recommended subwatersheds include incorporated areas of Searcy or Bald Knob, which are served by centralized sewer collection and treatment systems. However, there are residences, subdivisions, campgrounds, and businesses within the recommended subwatersheds that are known or suspected of treating sewage using on-site wastewater treatment systems (e.g., septic systems, small package treatment plants). This includes residences and businesses located along the banks of the Little Red River. Some on-site wastewater treatment systems are subject to discharge permitting and monitoring by DEQ, however, no DEQ permits for on-site wastewater systems were identified within the recommended subwatersheds (DEQ 2022b). Most on-site wastewater treatment systems are regulated by the Arkansas Department of Health. In some situations, monitoring of these systems is required (Arkansas State Board of Health 2014). Information on the number of systems permitted by the Arkansas Department of Health present in the recommended subwatersheds is not readily available. Table 4.15 lists 2000 population estimates for the recommended subwatersheds. An estimate of septic systems in the recommended subwatersheds is also provided. The septic system estimates are based on 1992 and 1998 surveys conducted by the National Small Flows Clearinghouse (TetraTech Inc. 2018). Based on these surveys 3% of septic systems in these subwatersheds are estimated to be failing (TetraTech, EPA 2013). Failing onsite wastewater treatment systems are assumed to be a concern in all the recommended subwatersheds. Failing onsite wastewater treatment systems can be sources of *E. Coli* and nutrients.

Table 4.15. Estimate of number of septic systems in recommended subwatersheds.

HUC12 ID	Subwatershed Name	Population (2000 Census)[a]	Estimated number of septic systems[b]
110100140901	Headwaters Ten Mile Creek	977	338
110100140902	Outlet Ten Mile Creek	1,949	381
110100140903	Little Red River – Alder Cr	20,140	2,273
110100140904	Overflow Creek	5,484	891
110100140905	Big Mingo Creek	1,150	202
110100140705	Fourteen Mile Creek	765	325
110100140706	Little Red River – Cedar Br	554	130

a (Arkansas Center for Advanced Spatial Technologies 2006)
b (TetraTech, EPA 2013)

The majority of the land within the recommended subwatersheds is classified as being of "very limited suitability" for septic systems (see Table 4.16). Given the geology underlying these subwatersheds, it is possible that pollutants discharged to the subsurface, as with septic systems, could find their way into groundwater and surface water.

Table 4.16. Suitability of soils in recommended subwatersheds for septic systems (Arkansas Center for Advanced Spatial Technologies 2006).

Subwatershed	Slightly limited	Moderately limited	Very limited	Not rated
Fourteen Mile Creek	<1%	0	99.8%	0
Cedar Branch -Little Red River	0	1%	98.6%	<1%
Headwater Ten Mile Creek	<1%	0	99.8%	0
Overflow Creek	7%	0	93%	0
Outlet Ten Mile Creek	1%	0	99%	0
Alder Creek -Little Red River	2%	0	98%	0
Big Mingo Creek	0	0	100%	0

4.6.9 Unpaved Roads

Runoff from unpaved roads contributes primarily sediment to surface waters. The extent of GIS-tagged roads in the recommended subwatersheds ranges from 30 miles to over 64 miles (Table 4.17). The most likely places for sediment from unpaved roads to enter surface waters is where they cross streams. White County, where much of the land in the recommended subwatersheds is located, is not currently active in the Arkansas Unpaved Roads Program (K. McGaughey, NRD, personal communication 5/23/2022). Unpaved roads are assumed to be a sediment source of concern in all of the recommended subwatersheds, except Overflow Creek and Big Mingo Creek. Though the largest number of miles of unpaved roads are present in the Overflow Creek subwatershed, other information reviewed indicates that sediment and erosion are minor concerns in the Overflow Creek and Big Mingo Creek subwatersheds (see Sections 4.3, 4.6.6, and 4.6.11).

Table 4.17. Miles of GIS-tagged unpaved roads in recommended subwatersheds of Little Red River (Board of Arkansas Geographic Information Systems 2022).

HUC12 ID	Subwatershed Name	Unpaved Roads, miles
110100140901	Headwaters Ten Mile Creek	31.13
110100140902	Outlet Ten Mile Creek	53.37
110100140903	Little Red River – Alder Cr	47.19
110100140904	Overflow Creek	64.57
110100140905	Big Mingo Creek	45.30
110100140705	Fourteen Mile Creek	43.15
110100140706	Little Red River – Cedar Br	30.35

4.6.10 Runoff from Croplands

Based on 2016 land use data, croplands account for <0.1% to 42% of the recommended subwatersheds land area. Croplands are a nonpoint source of concern only in the Big Mingo Creek subwatershed. Runoff from croplands is assumed to be a source of nutrient, sediment, and pesticide loads. Although the Overflow Creek subwatershed has significant cropland area, runoff from croplands is not expected to be a source of *E. Coli*, the pollutant of focus in this subwatershed.

Fertilizers applied to cropland can be carried to surface waters by runoff if they are not all used by the crop or retained in the field. If manure is used to fertilize croplands, runoff may also carry bacteria to surface waters. Runoff from croplands can also carry sediment eroded from fields to surface waters. Tilled and bare soil is a source of sediment in cropland runoff.

Results from recent edge-of-field water quality monitoring in northeast Arkansas indicate that higher loads of phosphorus (total phosphorus and orthophosphate), nitrate, and sediment come from furrow-irrigated crops (soybeans and cotton) than from flooded rice. For total nitrogen, though, measured loads (kg/hectare) from flooded rice were similar to those from furrow-irrigated row crops. This study also found that nutrient (total phosphorus and total nitrogen) and sediment loads from cultivated fields are statistically higher during the non-growing season than during the growing season (Reba, et al. 2020).

Based on these data, in Big Mingo Creek subwatershed, furrow-irrigated crops (e.g., soybeans) are expected to be the primary cropland sources of phosphorus and sediment during the growing season, and all crops contribute equally to the total nitrogen load from cropland.

During the non-growing season, fields without cover (i.e., not planted or flooded) are the primary source of cropland nutrient and sediment loads.

4.6.11 Erosion

NRCS has evaluated the risk of erosion from several sources for all HUC12 subwatersheds of Arkansas as part of the 2015 State Resource Assessment. NRCS-calculated risks of erosion from concentrated flow (i.e., gullies); sheet, rill, and wind; and streambanks for the Little Red River watershed HUC12s were ranked. Lower ranks indicate a higher risk of erosion. The lowest rank is 1 and the highest possible rank is 48. The ranking of the risks for the recommended subwatersheds are listed in Table 4.18. The Ten Mile Creek Headwaters and Fourteen Mile Creek subwatersheds have relatively high risk of all three types of erosion. The Big Mingo Creek and Overflow Creek subwatersheds have relatively low risk of all three types of erosion. Erosion can provide sediment, nutrients, and pesticide loads that may be transported to surface waters. A 2003 streambank erosion inventory of the Little Red River in Cleburne and White Counties estimated that five eroding Little Red River streambanks in White County (which would include the Little Red River-Alder Cr and Little Red River-Cedar Branch subwatersheds) were losing around 1,200 cubic feet of sediment per year (Cleburne County Conservation District 2003c).

4.6.12 Poor Quality Riparian Buffers

Good quality riparian buffers can filter nutrients, sediment, bacteria, and pesticides from runoff before they enter surface waters. Poor quality riparian buffers do not. Streambanks without significant riparian vegetation are also more susceptible to erosion. Riparian areas with significant forest land cover are considered good quality. Riparian buffers with significant agricultural or developed land covers are considered poor quality. The EPA StreamCat database includes percentages of land cover types present within 100m of NHD stream segments (Hill et al. 2016). Where agricultural (pasture or cropland) or developed land covers dominate riparian buffers, streambanks are more likely to become unstable and erode. Table 4.19 lists the percentages of 100m riparian buffers in agricultural and developed land uses within the recommended subwatersheds. More than one-quarter of riparian buffers in the recommended subwatersheds are considered poor quality. Overflow Creek subwatershed has the largest percentage of poor-quality riparian buffer, over 50%. The condition of riparian buffers in pasture is assumed to be a concern in all recommended subwatersheds. The condition of riparian buffers in developed areas is assumed to be a concern in the Little Red River-Alder Creek and Overflow Creek subwatersheds. The condition of riparian buffers in croplands is assumed to be a concern in the Overflow Creek and Big Mingo Creek subwatersheds.

Table 4.18. Ranking of erosion risks from Arkansas State Resource Assessment for recommended subwatersheds (lower ranks indicate higher risk of erosion).

Subwatershed Name	HUC12 ID Number	Concentrated Flow Erosion Risk	Sheet, Rill, Wind Erosion Risk	Streambank Erosion Risk
Headwaters Ten Mile Creek	110100140901	6	1	4
Outlet Ten Mile Creek	110100140902	28	9	9
Little Red River – Alder Cr	110100140903	39	10	18
Overflow Creek	110100140904	46	47	40
Big Mingo Creek	110100140905	48	42	45
Fourteen Mile Creek	110100140705	8	3	5
Little Red River – Cedar Br	110100140706	37	11	11

Table 4.19. Percentage of riparian buffers in recommended subwatersheds in agricultural or developed land uses (Hill, Weber, et al. 2016).

Subwatershed Name	HUC12 ID Number	Percentage of 100m riparian buffer in land use		
		Agricultural	Developed	Agriculture + Developed
Headwaters Ten Mile Creek	110100140901	33%	4%	37%
Outlet Ten Mile Creek	110100140902	28%	4%	32%
Little Red River – Alder Cr	110100140903	28%	13%	41%
Overflow Creek	110100140904	44%	7%	51%
Big Mingo Creek	110100140905	34%	4%	37%
Fourteen Mile Creek	110100140705	25%	3%	28%
Little Red River – Cedar Br	110100140706	27%	4%	31%

4.6.13 Summary

Each of the recommended subwatersheds contains more than one nonpoint source of bacteria, nutrients, and sediment discussed above. Table 4.20 lists the recommended subwatersheds with pollutants targeted for reduction and nonpoint pollution sources of these pollutants that are known or expected to be present. Also included is available information on the extent of the presence of the target nonpoint sources, and land use maps. Focus areas for management include pasture, haylands, and croplands along streams, developed areas, and unpaved roads. Of particular interest are areas within 50-100 feet of streams. Note that this watershed management plan is intended to address only unregulated nonpoint sources. Some nonpoint sources, such as select on-site wastewater treatment systems and stormwater runoff from construction sites, may be regulated by Arkansas Department of Health or DEQ.

In Table 4.20 there are several subwatersheds where a pollutant with a reduction target of zero is listed for a pollutant targeted for reduction. This is because stream segments in these subwatersheds are listed as impaired due to the pollutant, but analysis in Section 4.5 determined zero load reduction. Until DEQ determines that the listed stream segments are attaining the water quality standards for the pollutant with zero load reduction target, the use of practices that reduce this pollutant is supported by this plan.

Table 4.20. Summary of nonpoint pollution sources in recommended subwatersheds.

Fourteen Mile Creek (110100140705)
WQ Concerns: Excess nutrients, sediment, bacteria, pesticides and herbicides, aquatic habitat condition, threatened and endangered mussel species
No impairments (no active sampling station)
No load reduction targets
Management Goals: prevent impairment due to pollutants of concern, improve stream habitat, water quality sampling and evaluation

Likely nonpoint sources contributing to water quality concerns in this subwatershed include livestock, poultry litter, fertilizer, runoff from pasture and haylands, on-site wastewater treatment systems, and erosion from unpaved roads, fields, and streambanks. There are no specific pollutant reduction targets for this watershed. However, practices that reduce erosion, nutrient loss, and bacteria loads are encouraged. The primary focus for this subwatershed under this plan is water quality monitoring.

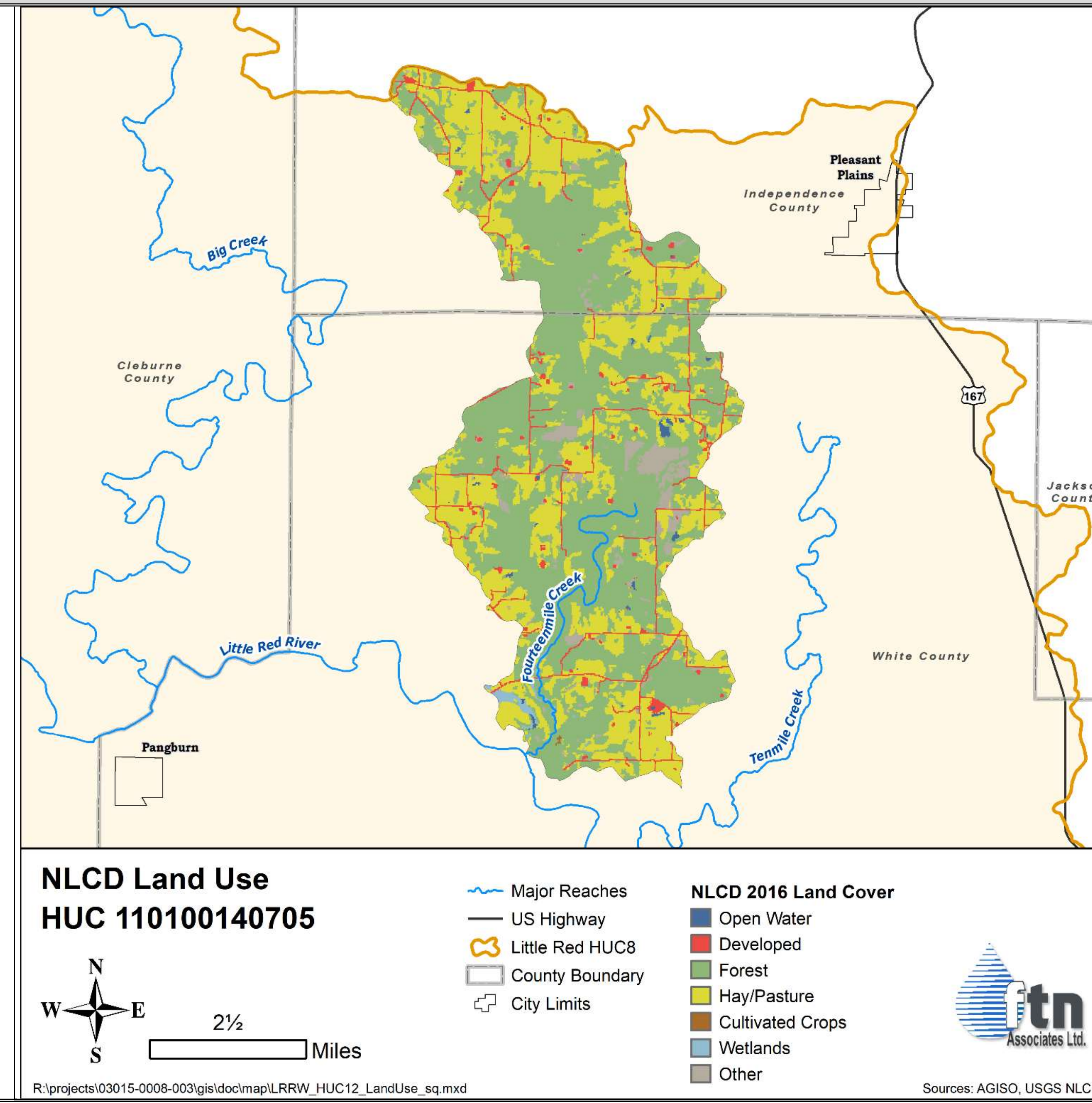


Table 4.20. Summary of nonpoint pollution sources in recommended subwatersheds (continued).

Little Red River – Cedar Br (110100140706)
WQ Concerns: Excess nutrients, algae, sediment, bacteria, pesticides and herbicides, threatened and endangered mussel species, invasive aquatic species
***E. Coli* load reduction target: 0**
Total phosphorus load reduction target: 36%
Management Goals: reduce phosphorus, prevent impairment due to *E. Coli* and other pollutants of concern, improve stream habitat, water quality sampling and evaluation

Target Pollutant	Target Sources	Extent of Source	Location
E. Coli and Total Phosphorus	Livestock	1,045 beef cattle in 2012	Pasture
	Poultry litter	24,583 chickens in 2012 could produce around 24 tons of litter per year	Pasture and haylands
	Runoff from pasture and hayland	5,419 acres of pasture and haylands, 28% of subwatershed	Pasture and haylands
	Onsite wastewater treatment systems	Unknown	Within 100 feet of surface water
	Poor quality riparian buffers	31% of riparian classified as poor quality	Pasture and haylands within 100 feet of streams
Total phosphorus	Fertilizer	Unknown	Pasture and haylands

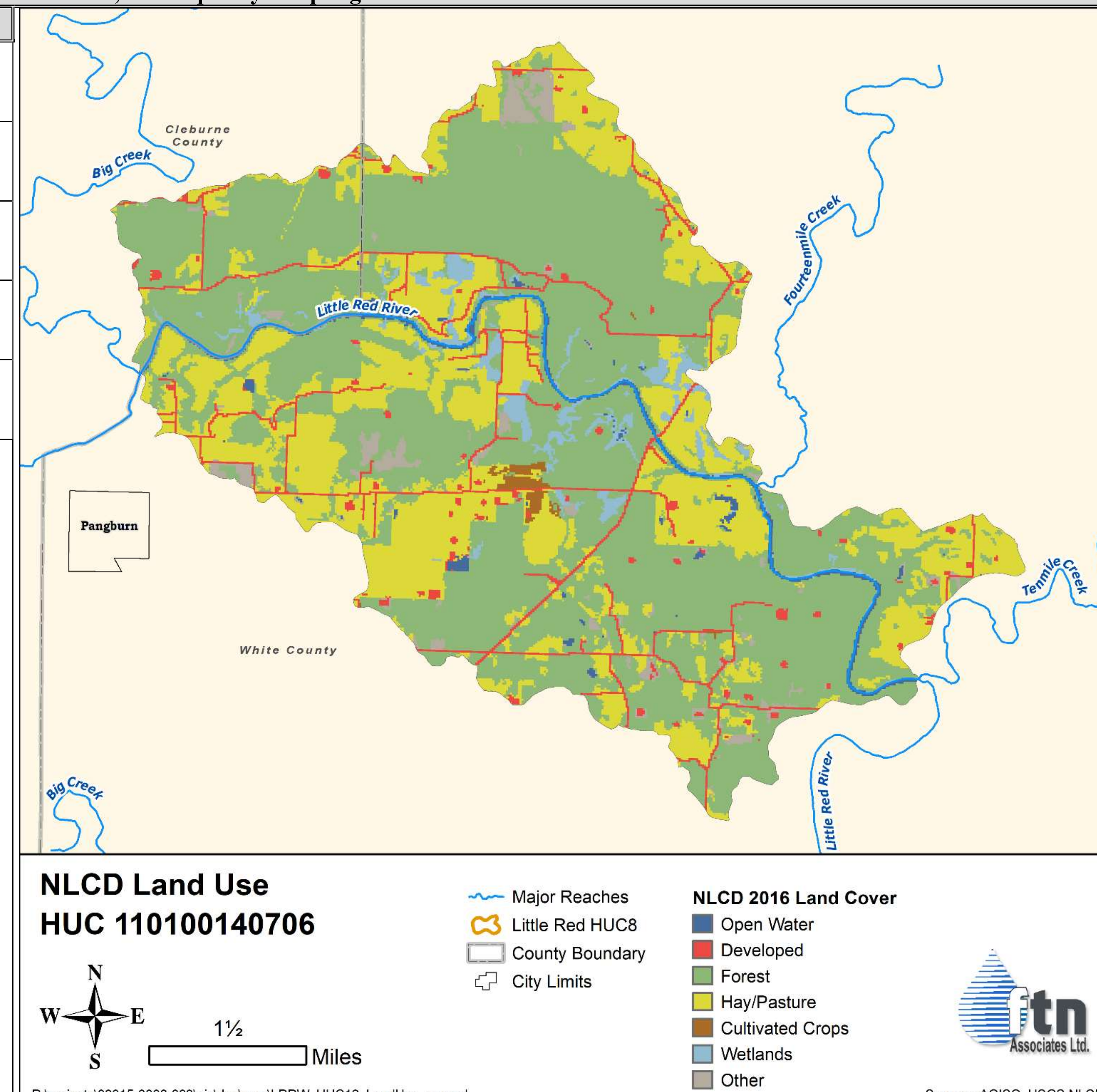


Table 4.20. Summary of nonpoint pollution sources in recommended subwatersheds (continued).

Headwaters Ten Mile Creek (110100140901)
WQ Concerns: Excess nutrients, sediment, bacteria, pesticides and herbicides, aquatic habitat condition, threatened and endangered mussel species
Pathogen and turbidity impairment (based on UWTMC01, pathogen impairment confirmed from 2018 *E. Coli* data, no turbidity data collected since 2003)
***E. Coli* load reduction target: 41%**
TSS load reduction target: 0 (from TMDL)
TN load reduction target: 23%
TP load reduction target: 78%
Management Goals: Reduce *E. Coli* and nutrient loads, prevent impairment due to turbidity and other pollutants of concern, improve stream habitat

Target Pollutant	Target Sources	Extent of Source	Location
E. Coli, total nitrogen, total phosphorus	Livestock	2,003 beef cattle in 2012	Pasture
	Poultry litter	113,517 chickens in 2012 could produce 113 tons of litter per year	Pasture and haylands
	Runoff from pasture and hayland	8,979 acres of pasture and haylands, 44% of subwatershed	Pasture and haylands
	On-site wastewater treatment systems	Unknown	Within 100 feet of surface water
	Poor quality riparian buffers	37% of riparian buffer classified as poor	Pasture and haylands within 100 feet of streams
Total nitrogen and total phosphorus	Fertilizer	Unknown	Pasture and haylands
Sediment (and total phosphorus)	Sheet and rill erosion of pasture & hayland	Unknown	Pasture and haylands
	Gully erosion of pasture & hayland	Unknown	Pasture and haylands
	Streambank erosion	Unknown	Streams in pasture and haylands
	Channel erosion	Unknown	Streams
	Unpaved roads	31 miles unpaved roads	Stream crossings and within 100 feet of surface water

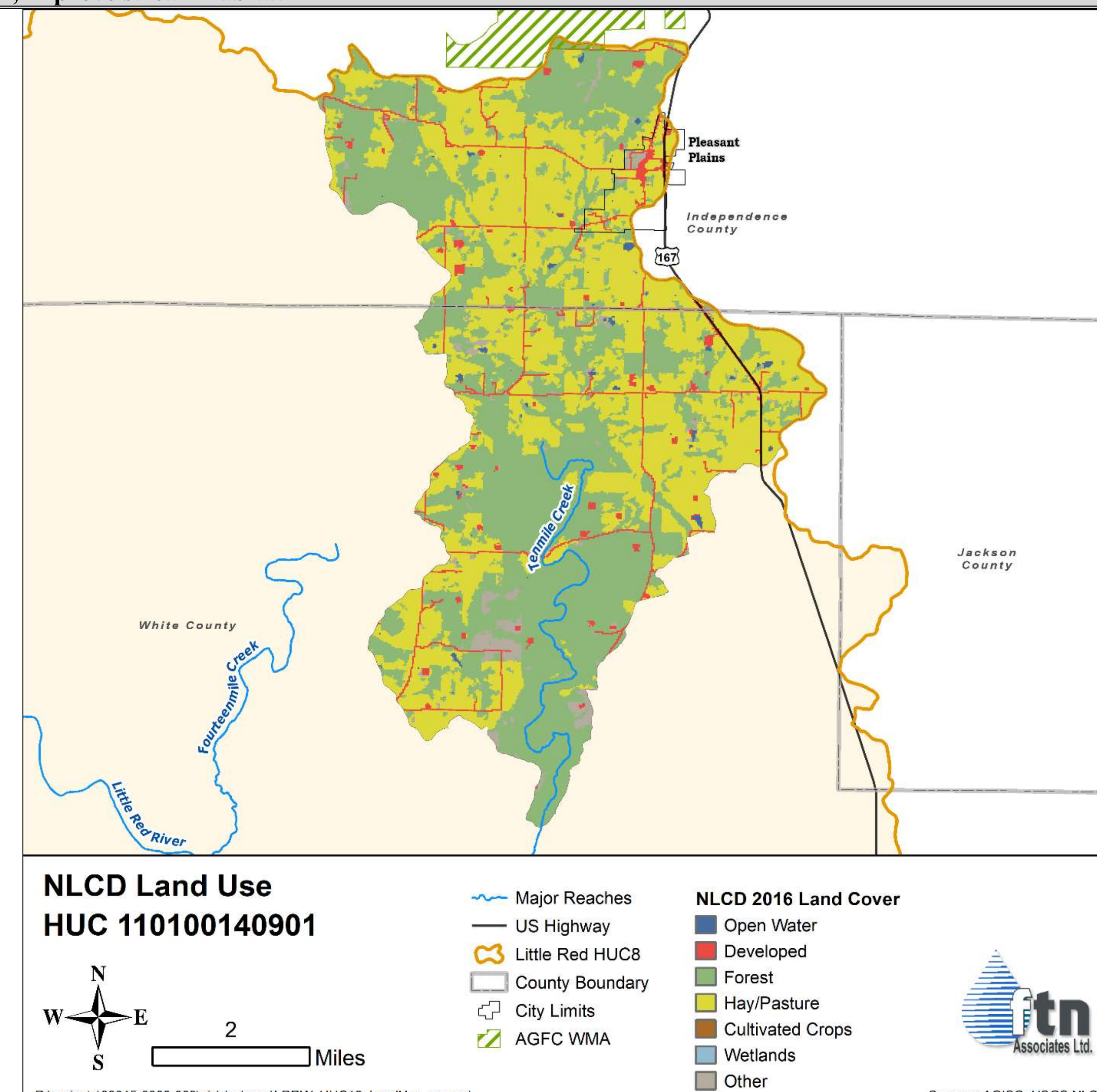


Table 4.20. Summary of nonpoint pollution sources in recommended subwatersheds (continued).

Outlet Ten Mile Creek (110100140902)
WQ Concerns: Excess nutrients, sediment, bacteria, pesticides and herbicides, aquatic habitat condition, threatened and endangered mussel species
Pathogen and turbidity impairment (pathogen impairment confirmed from 2018 *E. Coli* data, no turbidity data collected since 2003)
***E. Coli* load reduction target: 41%**
TSS load reduction target: 0 (from TMDL)
TN load reduction target: 23%
TP load reduction target: 78%
Management Goals: reduce *E. Coli* and nutrient loads, prevent impairment due to turbidity and other pollutants of concern, improve stream habitat, water quality sampling and evaluation

Target Pollutant	Target Source	Extent of Source	Location
E. Coli, total nitrogen, total phosphorus	Livestock	2,212 beef cattle in 2012	Pasture
	Poultry litter	41,308 chickens in 2012 could produce 41 tons of litter per year	Pasture and haylands
	Runoff from pasture and hayland	11,860 acres of pasture and haylands, 40% of subwatershed	Pasture and haylands
	On-site wastewater treatment systems	Unknown	Within 100 feet of surface water
	Poor quality riparian buffers	32% of riparian buffer classified as poor	Pasture and haylands within 100 feet of streams
Total nitrogen and total phosphorus	Fertilizer	Unknown	Pasture and haylands
Sediment (and total phosphorus)	Sheet and rill erosion of pasture & hayland	Unknown	Pasture and haylands
	Streambank erosion	Unknown	Streams in pasture and haylands
	Channel erosion	Unknown	Streams
	Unpaved roads	53 miles unpaved roads	Stream crossings and within 100 feet of surface water

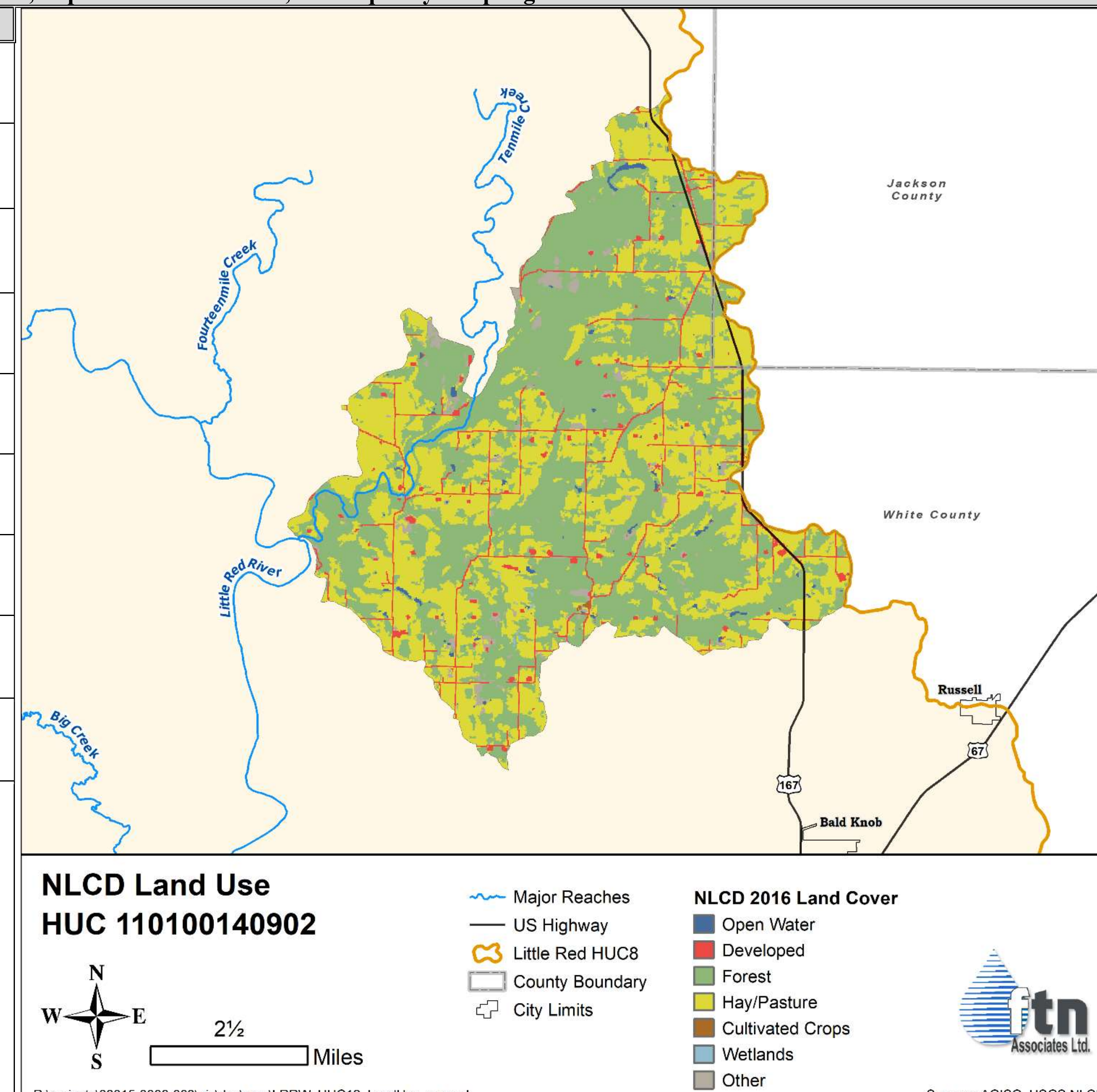


Table 4.20. Summary of nonpoint pollution sources in recommended subwatersheds (continued).

Little Red River - Alder Cr (110100140903)
WQ Concerns: Excess nutrients, sediment, pesticides and herbicides, aquatic habitat condition, threatened and endangered mussel species
Pathogen impairment (based on WHI0059, 2018 data from this station indicates *E. Coli* standard is met)
***E. Coli* load reduction target: 0**
TP load reduction target: 36%
Management Goals: reduce phosphorus, prevent impairments due to *E. Coli* and other pollutants of concern, improve stream habitat

Target Pollutant	Target Source	Extent of Source	Location
E. Coli, total phosphorus	Livestock	2,032 beef cattle in 2012	Pasture
	Poultry litter	39,447 chickens in 2012 could produce 39 tons of litter per year	Pasture and haylands
	Runoff from pasture and hayland	10,502 acres of pasture and hayland, 32% of subwatershed	Pasture and haylands
	On-site wastewater treatment systems	Unknown	Within 100 feet of surface water, particularly Little Red River
	Illicit wastewater discharges	Unknown	Searcy, development along Little Red River
	Poor quality riparian buffers	41% of riparian buffer classified as poor	Development and pasture and haylands within 100 feet of streams
	Runoff from developed areas	6,153 acres developed, 19% of subwatershed	Searcy, development along Little Red River
	Pet waste	Unknown	Residential areas in Searcy, development along Little Red River
Total phosphorus	Fertilizer	Unknown	Residential areas, pasture, and haylands

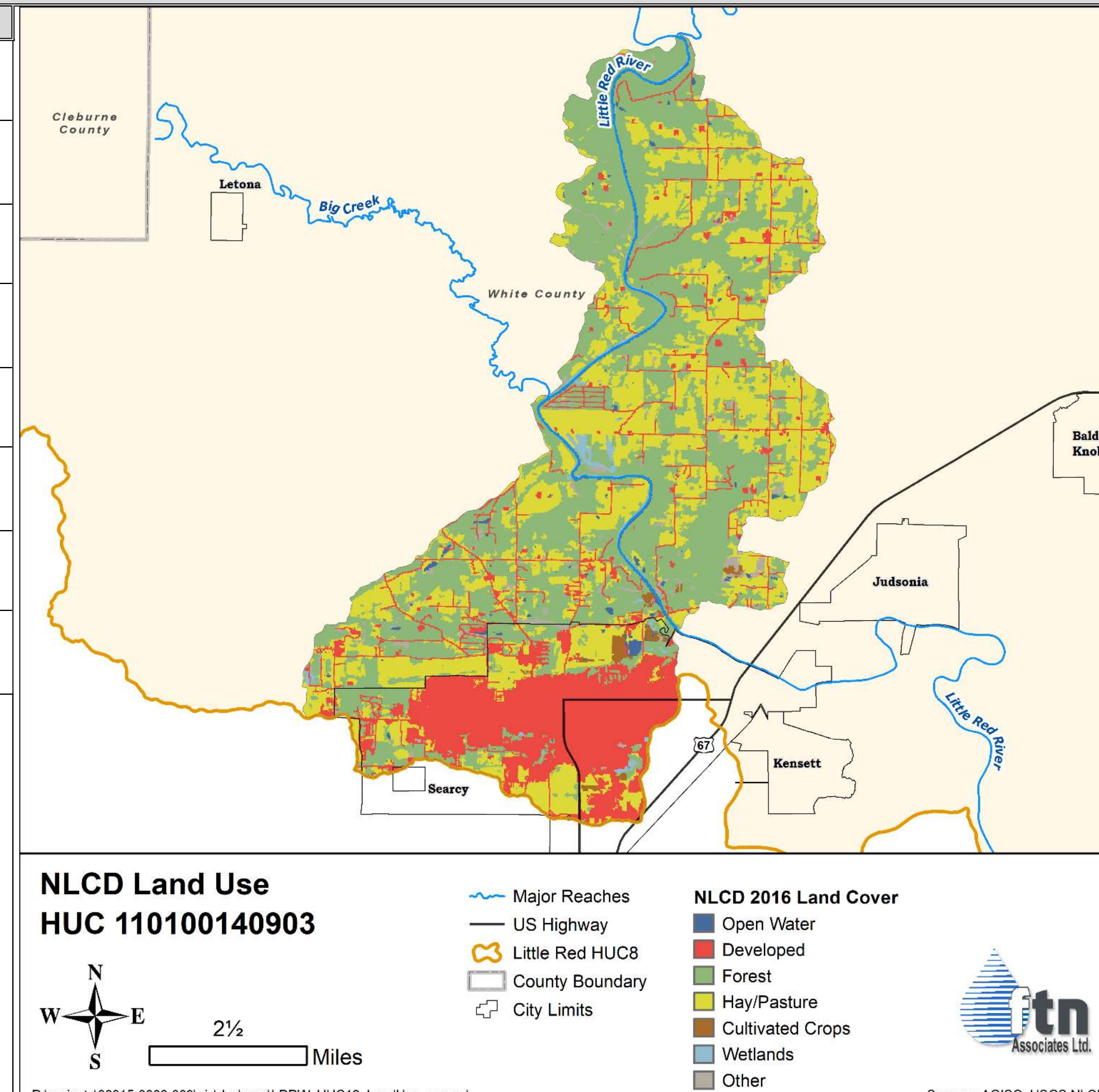
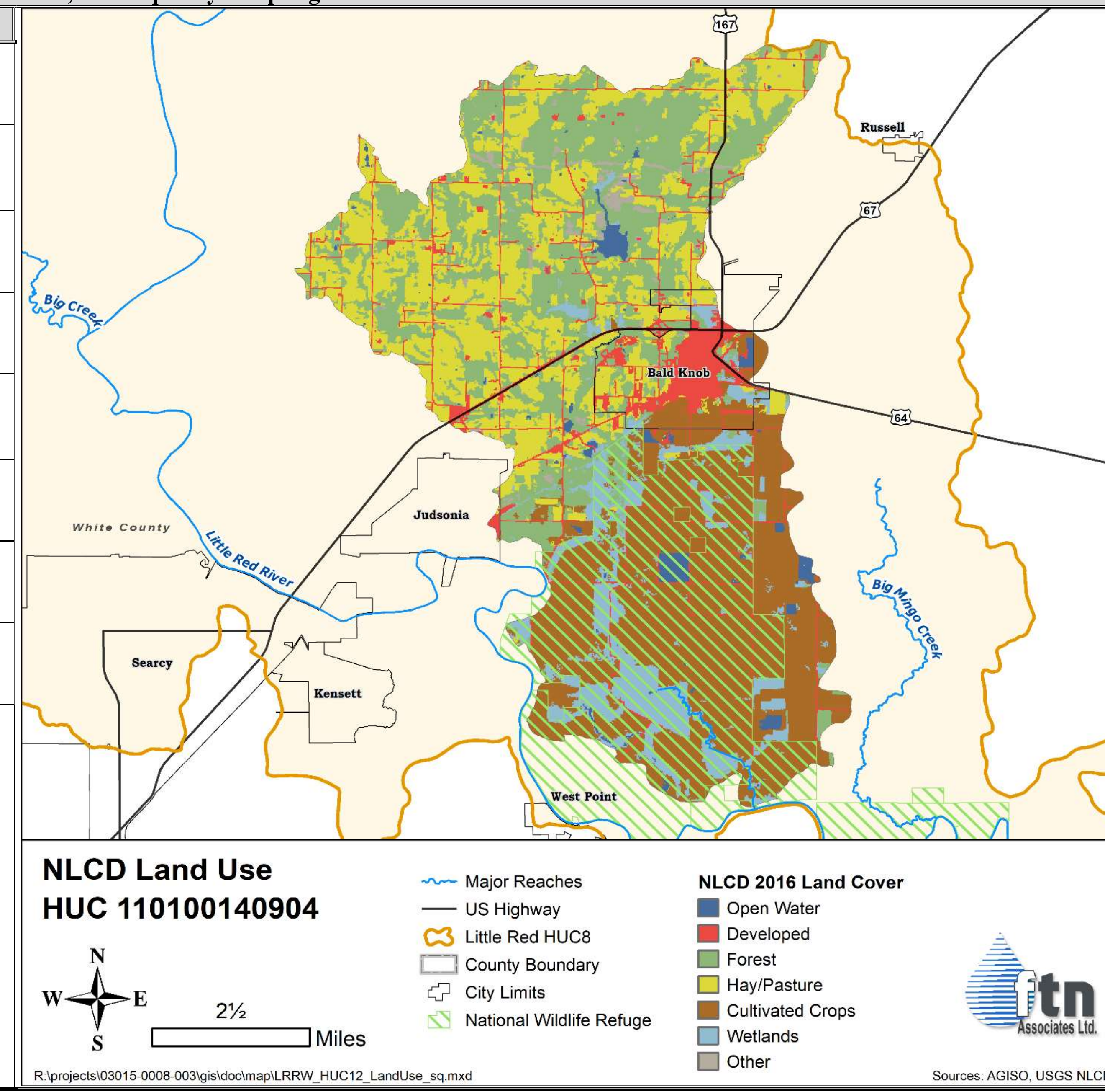


Table 4.20. Summary of nonpoint pollution sources in recommended subwatersheds (continued).

Overflow Creek (110100140904)
WQ Concerns: Excess nutrients, aquatic habitat condition, threatened and endangered mussel species
Pathogen impairment (data from 2018 indicate *E. Coli* criterion is met)
***E. Coli* load reduction target: 0**
Management Goals: prevent impairment due to *E. Coli* and other pollutants of concern, improve stream and wetland habitat, water quality sampling and evaluation

Target Pollutant	Target Source	Extent of Source	Location
E. Coli	Livestock	2,490 beef cattle in 2012	Pasture
	Poultry litter	48,335 chickens in 2012 could produce 48 tons of litter per year	Pasture and haylands
	Runoff from pasture and hayland	9078 acres of pasture and hayland, 24% of subwatershed	Pasture and haylands
	On-site wastewater treatment systems	Unknown	Within 100 feet of surface water
	Poor quality riparian buffers	51% of riparian buffer classified as poor	Development, cropland, pasture, and haylands within 100 feet of streams
	Runoff from developed areas	2,785 acres developed, 7.4% of subwatershed	Bald Knob
	Illicit wastewater discharges	Unknown	Bald Knob
	Pet waste	Unknown	Residential areas
	Wildlife	Hundreds of thousands of migrating waterfowl use the Bald Knob NWR[3], which accounts for a significant area of this subwatershed	Bald Knob NWR, cropland

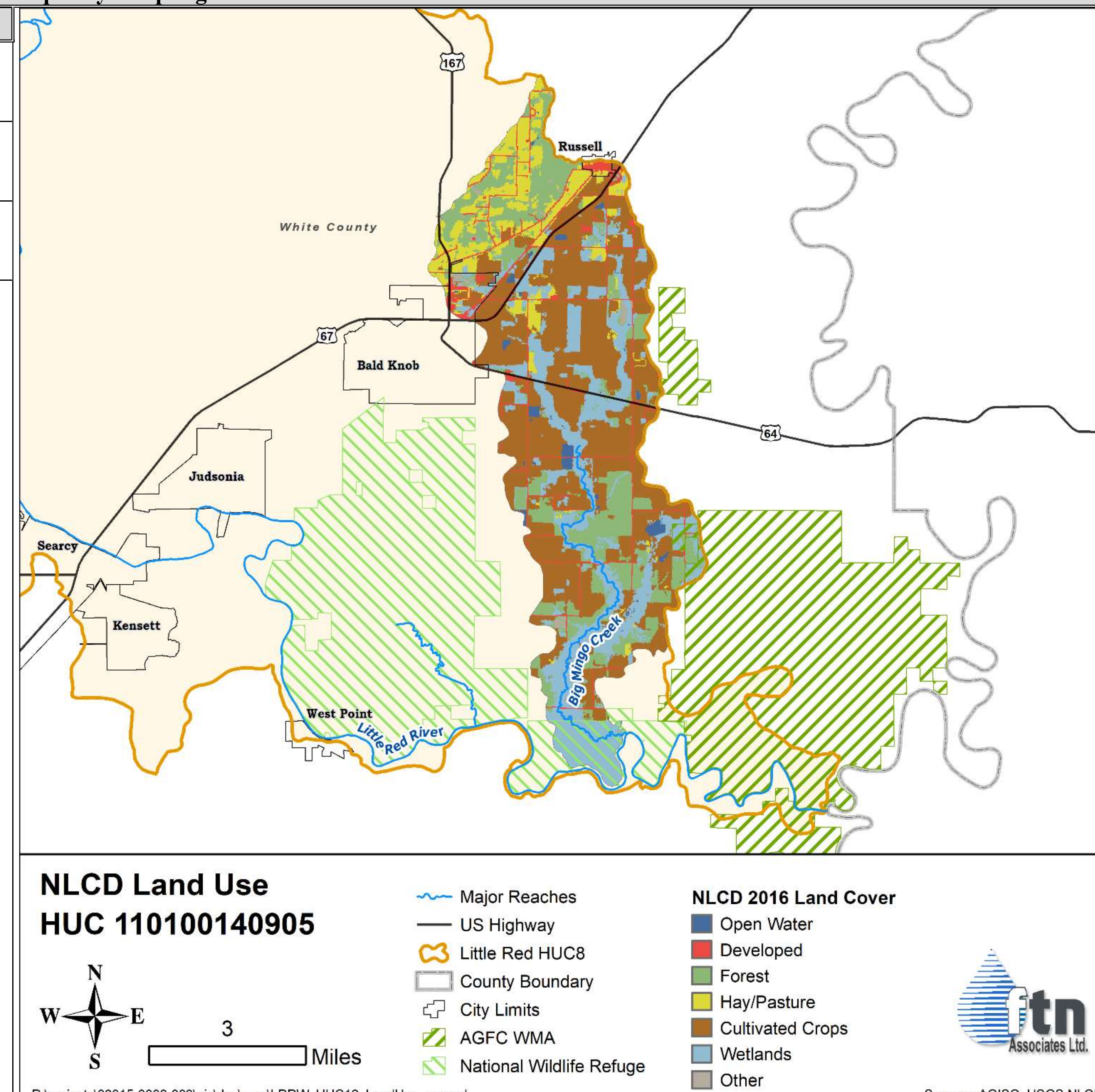


[3] https://www.fws.gov/refuge/bald-knob/species

Table 4.20. Summary of nonpoint pollution sources in recommended subwatersheds (continued).

Big Mingo Creek (110100140905)
WQ Concerns: Excess nutrients, sediment, pesticides and herbicides, aquatic habitat condition, threatened and endangered mussel species
No impairments (no active sampling station)
TN load reduction target: 71%
Management Goals: reduce nitrogen, prevent impairment due to other pollutants of concern, improve stream habitat, water quality sampling and evaluation

Target Pollutant	Target Source	Extent of Source	Location
Total nitrogen	Runoff from cropland	9,040 acres of cropland, 42% of subwatershed	Cropland
	Fertilizer	Unknown	Cropland, developed areas
	On-site wastewater treatment systems	Unknown	Within 100 feet of surface water
	Poor quality riparian buffers	37% of riparian buffer classified as poor	Cropland within 100 feet of streams



4.7 Management Practices

There are two approaches for managing nonpoint source pollution inputs. The first is to reduce the sources of the pollutant that can end up in runoff. Examples of this approach include activities that reduce the time livestock spend in streams. The second approach is to implement measures that remove or capture pollutants in runoff. Examples of this approach include practices such as forested or grassed (herbaceous) riparian buffers that capture or filter runoff.

Developed, residential, and agricultural land uses are present in the recommended subwatersheds and have potential nonpoint sources of bacteria, nutrients, and sediment associated with them (see Section 4.6). Below, best management practices (BMPs) appropriate to the unregulated nonpoint sources of bacteria, nutrients, and sediment associated with these land uses in the recommended subwatersheds are discussed separately.

4.7.1 Developed and Residential Areas

There are several towns and residential developments located in the recommended subwatersheds with streams listed as impaired due to pathogens. None of the communities within the recommended subwatersheds have MS4 NPDES stormwater permits, as of 2022 (per search of DEQ online permit database and Google search).

Identification and reduction or elimination of nonpoint enteric bacteria (e.g., *E. Coli*) sources in developed areas is recommended as the first step in controlling bacteria and pathogen loads from developed areas. This involves activities such as identifying sewer collection system leaks and illicit wastewater discharges, reducing combined sewer overflow incidents, requiring proper disposal of pet wastes, and dealing with urban wildlife wastes.

If source control does not adequately reduce bacteria concentrations in surface waters, retention ponds and wetland basins are stormwater BMPs used in developed areas that have been shown to be effective at reducing *E. Coli* concentrations in runoff. Detention basins, bioretention, and media filters have also been shown to statistically significantly reduce runoff *E. Coli* concentrations. Riparian buffers have also been shown to reduce *E. Coli* in runoff from residential areas (Lim, et al. 2022).

All of the stormwater BMPs listed above will also reduce nutrient and sediment levels. The listed BMPs most effective for reducing nutrient levels in stormwater runoff are bioretention basins and stormwater retention ponds (Clary, et al. 2020). Riparian buffers also help to stabilize streambanks, reducing streambank erosion. Riparian buffers, erosion control on construction sites, and guttering and drainage systems on houses along the river are BMPs that have been recommended for the lower Little Red River watershed (Cleburne County Conservation District 2003d).

Streambank stabilization and channel restoration projects in Clinton in the upper Little Red River watershed and communities throughout northern Arkansas have been shown to reduce sediment and nutrient loads to streams and improve stream habitat (TNC 2014, Van Epps 2014).

Fixing or replacing failing septic systems in rural residential areas, particularly at residences located near the Little Red River or other streams, is a practice that will reduce nutrient and bacteria loads to surface waters from these areas.

4.7.2 Unpaved Roads

Unpaved roads are a source of sediment in the Ten Mile Creek watershed listed as impaired due to turbidity. Erosion and sediment loss from unpaved roads is reduced through the application of BMPs as part of Environmentally Sensitive Maintenance (ESM) of unpaved roads. These BMPs have been developed and tested by the US Forest Service and other leaders in the road industry. Examples of ESM BMPs include appropriate bridge and pipe design at stream crossings, grade breaks and broad dips for drainage control, increasing the number of drainage ditch outlets, and management of roadside and streamside vegetation.

4.7.3 Pasture and Haylands

Nonpoint sources of enteric bacteria and nutrients associated with pasture and haylands that could be reduced include livestock access to streams, applied fertilizer, and use of poultry litter for fertilizer. Nonpoint sources of sediment associated with pasture and haylands that could be reduced are field and streambank erosion. Livestock access to streams can contribute to streambank erosion. Therefore, BMPs that reduce these sources of bacteria, nutrients, and sediment include those that reduce and/or control livestock access to streams, reduce erosion in fields, and ensure that fertilizers and poultry litter are appropriately and safely applied to fields.

Pasture-appropriate BMPs that have been implemented in the Little Red River watershed through NRCS Environmental Quality Incentives Program (EQIP) and Conservation Stewardship Program (CSP), and that the NRCS Conservation Practice Physical Effects program (CPPE) indicates reduce bacteria, nutrient, and sediment loads, include Prescribed Grazing, Fence, Watering Facility and other practices related to providing alternate water supplies, Heavy Use Area Protection, and Stream Crossing and managing livestock access to streams (Christianson 2020, NRCS 2021). Nutrient Management and Access Control also reduce bacteria, nutrient, and sediment sources (e.g., excess poultry litter fertilizer and livestock in streams) and have been shown to reduce bacteria loads to surface waters (NRCS 2021). Waste storage facilities can be used to remove stored poultry litter as a possible source of nutrients and bacteria. Table 4.21 lists pasture-appropriate BMPs identified by CPPE as providing the greatest reduction in bacteria, nutrient, and sediment loads.

The BMPs listed in Table 4.21 have also been identified as providing moderate to substantial reduction of nutrient loads in pasture runoff to surface waters. In addition, Watering Facility (practice 614), Nutrient Management (practice 590), and Silvopasture (practice 381) were also identified as providing moderate to substantial reduction of nutrients in pasture runoff.

BMPs that trap bacteria, nutrients, and sediment in runoff include Filter Strip, Riparian Buffer, and Vegetated Treatment Area. Note that riparian buffers can also help stabilize streambanks, reducing streambank erosion as a sediment source.

Conservation easements can reduce sources of pollutants from pastures and haylands such as gully erosion and sheet and rill erosion and the use of fertilizers and poultry litter. Depending on where easements are located, they can also act as riparian buffers or filter strips and trap pollutants in runoff.

Table 4.21. NRCS pasture BMPs identified through CPPE as providing substantial improvement in nutrient, pathogen, and/or sediment loads to surface waters (NRCS 2021).

Practice Name	Practice Code	Effects quantification					
		Nutrient load	Pathogen load	Sediment load	Sheet & rill erosion	Gully erosion	Streambank erosion
Saturated buffer	604	Substantial improvement	None	None	None	None	None
Nutrient management	590	Substantial improvement	Moderate to substantial improvement	None	None	None	None
Filter strip	393	Substantial improvement	Moderate to substantial improvement	Substantial improvement	Moderate to substantial improvement	None	Minor improvement
Riparian forest buffer	391	Substantial improvement	Moderate improvement	Substantial improvement	Moderate improvement	Moderate improvement	Moderate to substantial improvement
Riparian herbaceous buffer	390	Substantial improvement	Moderate improvement	Moderate to substantial improvement	Minor to moderate improvement	None	Moderate to substantial improvement
Sediment basin	350	Substantial improvement	Minor to moderate improvement	Moderate to substantial improvement	None	Minor to moderate improvement	None
Vegetated treatment area	635	Moderate to substantial improvement	Substantial improvement	Minor to moderate improvement	Moderate to substantial improvement	None	None
Constructed wetland	656	Moderate to substantial improvement	Moderate to substantial improvement	Substantial improvement	None	None	None
Lined waterway or outlet	468	None	None	Substantial improvement	None	Moderate improvement	None
Grassed waterway	412	Minor to moderate improvement	Minor improvement	Substantial improvement	None	Moderate to substantial improvement	Minor improvement
Critical area planting	342	Minor to moderate improvement	None	Moderate to substantial improvement	Substantial improvement	Moderate to substantial improvement	Moderate to substantial improvement
Access control	472	Minor improvement	Minor improvement	Moderate improvement	Moderate improvement	Moderate to substantial improvement	Substantial improvement
Watering facility	614	Moderate to substantial improvement	Minor to moderate improvement	Minor to moderate improvement	Minor to moderate improvement	Minor improvement	Moderate to substantial improvement

4.7.4 Croplands

Nonpoint sources of nutrients and sediment associated with croplands that can be reduced are over-application of commercial fertilizer and field erosion. Targeted BMPs for croplands therefore include practices that ensure fertilizers are applied appropriately, and that reduce field erosion. Examples of BMPs that reduce cropland sources of the target pollutants include Nutrient Management, Cover Crops, Reduced Till, No Till, winter flooding of rice fields, and agricultural land retirement (i.e., conservation easements). These BMPs have been implemented in the Little Red River watershed through EQIP and CSP programs (Christianson 2020). The fact that these BMPs have been implemented through EQIP and CSP suggests that they are accepted by local producers and conservation personnel.

Examples of BMPs that trap nutrients and sediment in cropland runoff include Filter Strip, Riparian Buffer, and Tailwater Recovery. Filter strips have not been implemented in the Little Red River watershed through EQIP or CSP, but riparian buffers and tailwater recovery have (Christianson 2020).

Table 4.22 lists cropland appropriate BMPs identified by CPPE as providing substantial reduction of nutrient loads to surface waters. Effectiveness for reduction of sediment load and erosion is also provided in Table 4.22. In addition, several other cropland BMPs implemented in the Little Red River watershed are listed with the effects quantification assigned by CPPE.

Conservation easements can reduce sources of pollutants from croplands such as gully erosion and sheet and rill erosion and the use of fertilizers. Depending on where easements are located, they can also act as riparian buffers or filter strips and trap pollutants in runoff.

4.7.5 Summary

Table 4.23 summarizes BMPs suggested for each of the recommended subwatersheds, based on the nonpoint source pollution sources in each that are proposed to be targeted under this plan.

Table 4.22. NRCS cropland BMPs identified through CPPE as providing substantial improvement in nutrient loads to surface waters with other cropland BMPs common in Arkansas (NRCS 2021).

Practice Name	Practice Code	CPPE Effects Quantification				
		Nutrient load	**Sediment load**	**Sheet & rill erosion**	**Gully erosion**	**Streambank erosion**
Nutrient management	590	Substantial improvement	None	None	None	None
Filter strip	393	Substantial improvement	Substantial improvement	Moderate to substantial improvement	None	Minor improvement
Riparian forest buffer	391	Substantial improvement	Substantial improvement	Moderate improvement	Moderate improvement	Moderate to substantial improvement
Riparian herbaceous buffer	390	Substantial improvement	Moderate to substantial improvement	Minor to moderate improvement	None	Moderate to substantial improvement
Sediment basin	350	Substantial improvement	Moderate to substantial improvement	None	Minor to moderate improvement	None
Vegetated treatment area	635	Moderate to substantial improvement	Minor to moderate improvement	Moderate to substantial improvement	None	None
Wetland enhancement	659	Moderate improvement	Minor to moderate improvement	None	None	None
Wetland restoration	657	Moderate improvement	Minor to moderate improvement	None	None	None
Cover crop	340	Minor to moderate improvement	Minor to moderate improvement	Moderate to substantial improvement	None	None
Reduced till	345	Minor to moderate improvement	Moderate improvement	Moderate to substantial improvement	None	None
No-till	329	Minor to moderate improvement	Moderate to substantial improvement	Moderate to substantial improvement	None	None
Field border	386	Minor to moderate improvement	Minor to moderate improvement	Moderate to substantial improvement	None	Minor
Tailwater recovery	447	Minor to moderate improvement	Moderate to substantial improvement	None	Minor improvement	Minor improvement

Table 4.23. BMPs proposed for recommended subwatersheds. E indicates *E. Coli* are reduced, N indicates nutrients are reduced, and S indicates sediment is reduced. Lower case letters in the cells indicate the pollutant will be reduced, but is not a pollutant with a load reduction target for the subwatershed.

BMPs	110100140705 Fourteen Mile Creek	110100140706 Cedar Branch-Little Red River	110100140901 Headwater Ten Mile Creek	110100140902 Outlet Ten Mile Creek	110100140903 Alder Creek-Little Red River	110100140904 Overflow Creek	110100140905 Big Mingo Creek
Developed Areas							
Fix sewer collection leaks	--	--	--	--	E, N	E, n	
Remove illicit wastewater discharges	--	E, N	--	E, N	E, N	E, n	
Remediate failing septic systems	e, n	E, N	E, N	E, N	E, N	E, n	e, N
Proper disposal of pet wastes	--	--	--	--	E, N	E, n	
Address excessive waste from urban wildlife	--	--	--	--	E, N	E, n	
Retention ponds	--	--	--	--	E, N, s	E, n, s	
Wetland basins	--	--	--	--	E, N, s	E, n, s	
Detention basins	--	--	--	--	E, N, s	E, n, s	
Bioretention	--	--	--	--	E, N[a], s	E, n[a], s	
Media filters	--	--	--	--	E, N, s	E, n, s	
Environmentally Sensitive Maintenance of unpaved roads	s	--	S	S	--	--	--
Bank stabilization, channel restoration	s	s	S	S	s	--	--
Riparian buffers	e, n, s	E, N, s	E, N, S	E, N, S	E, N, s	E, n, s	N, s
Pasture and Haylands							
Nutrient management plans	e, n, s	E, N, s	E, N, S	E, N, S	E, N, s	E, n, s	--
Prescribed grazing	e, n, s	E, N, s	E, N, S	E, N, S	E, N, s	E, n, s	--
Alternative water supply	e, n, s	E, N, s	E, N, S	E, N, S	E, N, s	E, n, s	--
Access control/stream crossing	e, n, s	E, N, s	E, N, S	E, N, S	E, N, s	E, n, s	--
Riparian buffers	e, n, s	E, N, s	E, N, S	E, N, S	E, N, s	E, n, s	--
Filter strip	e, n[a], s	E, N[a], s	E, N[a], S	E, N[a], S	E, N[a], s	E, n[a], s	--
Vegetated treatment area	e, n, s	E, N, s	E, N, S	E, N, S	E, N, s	E, n, s	--
Heavy use area protection	e, n, s	E, N, s	E, N, S	E, N, S	E, N, s	E, n, s	--
Sediment basin	e, n, s	E, N, s	E, N, S	E, N, S	E, N, s	E, n, s	--
Critical area planting	n, s	--	N, S	N, S	N, s	n, s	--
Conservation easements	e, n, s	E, N, s	E, N, S	E, N, S	E, N, S	E, n, s	--
Waste storage facility	e, n	E, N	E, N	E, N	E, N	E, n	--
Croplands							
Nutrient management plans	--	--	--	--	--	--	N, s
Cover crops	--	--	--	--	--	--	N, s
Conservation easements	--	--	--	--	--	--	N, s
Reduced/no till	--	--	--	--	--	--	N, s
Winter flooding for waterfowl	--	--	--	--	--	--	--
Filter strip	--	--	--	--	--	--	N, s
Riparian buffers	--	--	--	--	--	--	N, s

a = phosphorus in runoff may increase with this practice

4.8 Meeting Load Reduction Goals

This subsection explores whether it is possible to achieve the *E. Coli* and nutrient load reduction targets identified in Section 4.5. Information has been published on the effectiveness of many of the BMPs identified in Section 4.7 for reducing selected pollutants in surface waters, including *E. Coli* and nutrients. Table 4.24 shows reported reduction percentages for *E. Coli*, nutrients, and sediment. The data in Table 4.24 show that BMPs that reduce *E. Coli* and nutrients also reduce sediment. Note that BMPs must be properly installed, operated, and maintained to achieve reported pollutant reduction efficiencies.

As part of a Gulf of Mexico Hypoxia Task Force project, Arkansas experts identified expected large-scale nutrient reduction efficiencies for selected individual agricultural BMPs (FTN Associates, Ltd. 2019). These reduction efficiencies are shown in bold font in Table 4.24. This project also identified nutrient reduction efficiencies for several suites of agricultural BMPs often implemented together in Arkansas (Table 4.25).

The information in Tables 4.24 and 4.25 and Section 4.7 was used to evaluate the potential for meeting the pollutant reduction targets for the recommended subwatersheds. Note that, for the most part, *E. Coli* reductions listed in Table 4.24 from implementing BMPs are greater than 41%. This suggests that it is very likely that it will be possible to achieve the 41% *E. Coli* load reduction target by implementing appropriate BMPs. Also, for the most part, BMP nutrient reduction efficiencies listed in Table 4.24 are 50% or less. This suggests that it may be difficult to achieve nutrient load reduction targets greater than 50%.

Table 4.26 lists ranges of estimated potential load reductions from implementing BMPs in the recommended subwatersheds. The assumptions and calculations used to develop these load reductions are provided in Appendix I. Potential load reductions were calculated for only some of the many possible BMPs.

Table 4.24. Summary of available information on reduction efficiencies of selected BMPs for plan target pollutants. Note that negative values indicate pollutant increases from practice.

BMP	Target land use	*E. Coli* reduction	Fecal coliform reduction	Total nitrogen reduction	Total phosphorus reduction	Sediment reduction
Forested riparian buffer	All	No information found		47-59%[a], 37-57%[c], 44-70%[g], 68-89%[k], 45%-48%[r], 35% (pasture), 30% (cropland)[t]	53-63%[a], 45-70%[g], 30-80%[k], 40%-46%[r], 35% (pasture), 45% (cropland)[t]	76%[b], 94%[o] 55-95%[c], 45-70%[g], 60-90%[k], 53%-57%[r]
Grassed riparian areas	All	No information found	21-100%[k], 70-95%[l]	68%[d], 31-48%[g], 50-76%[k], 34%-87%[r], 35% (pasture), 20% (cropland)[t]	67%[d], 50-70%[g], 50-89%[k], 44%-77%[r], 35% (pasture), 45% (cropland)[t]	23%[d], 50-70%[g], 66-84%[k], 53%-65%[r]
Streambank stabilization	All	No information found	No information found	15%-75%[r]	22%-75%[r]	Up to 100%[m], 58%-75%[r]
Bioretention basin	Developed	-10,330% to 100%, median 50%[j], 43%[x]	90%[u]	64-90%[o], 25-80%[s], 75%[u], 24%[x]	55-90%[o], 45-85%[s], 75%[u], increase[x]	55-98%[s], 90%[u], 77%[x]
Filter strip	All	58-99%[v]	30-100%[v] -5,970% to 100%, median -5%[n]	1-93%[c] -586% to 70%, median 17%[n] 14%[x]	2-93%[c] 27-96%[v] -25,400% to 99%, median -46%[n] increase[x]	53% - 91%[b], 18-99%[c] 41-100%[v] -34,881% to 99% TSS, median 50%[n] 52%[x]
Controlled stream access	Pasture	46%[h]	30% - 95%[f] 44-52%[h]	32%[b], 60%[e], 10%[t]	76%[b], 60%[e], 15%[t]	83%[b], 75%[e], 60%[r]
Heavy use area protection	Pasture	No information found	92-99%[i]	86%[i], 10%[t]	50%[i], 15%[t]	75-98%[i]
Prescribed grazing	Pasture	60% - 72%[e]	90-96%[e]	20%[g], 10%[t]	20%[g], 15%[t]	60%[b], 20%[g], 33%[r]
Watering facility	Pasture	85%i	57%[b], 51-94%[i]	41%[a], 13-77%[c], 30%[e], 10%[t]	74-97%[c], 30%[e], 15%[t]	38%[a], 38-96%[c], 30%[e], 19%[r]
Stormwater detention pond	Developed	3,053% to 100%, median 52%[n]	78-97%, median 88%[p] -574,900% to 100%, median 31%[n]	-19% to 43%, median 24%[p] -418% to 86%, median 8%[n]	0-48%, median 20%[p] -1,072% to 92%, median 19%[n]	-1% to 90% TSS, median 49%[p] -5,378% to 100% TSS, median 57%[n]
Stormwater retention pond	Developed	-7,900% to 100%, median 68%[n]	-6% to 99%, median 70%[p] -7,900% to 100%, median 67%[n]	-12% to 76%, median 31%[p] -662% to 91%, median 27%[n]	12% to 91%, median 52%[p] -10,300% to 99%, median 49%[n]	-33% to 99% TSS, median 80%[p] -8,600% to 100% TSS, median 75%[n]
Media filters for stormwater	Developed	-4,005% to 100%, median 90%[j]	-85% to 83%, median 37%[p] -43,233% to 100%, median 45%[n]	-79% to 88%, median 59%[p] -621% to 99%, median 47%[n]	17-71%, median 32%[p] -312% to 94%, median 19%[n]	-4,900% to 95%, median 39%[n]
Fix failing septic systems	Residential	73.915% – 99.99%[w]	99%-99.9%[y]	10%-40%[y]	85%-95%[y]	
Environmentally sensitive road maintenance (ESRM)	Unpaved roads	None expected	None expected	None expected	No information found	
Nutrient management plans	Pasture, croplands	No information found	No information found	0-84%[c], 10%[t]	8-91%[c], 15%[t]	72-92%[c]
Vegetated treatment area	Pasture, croplands	No information found	64-87%[l]	>85%, average 70%[l]	12-97%, average 70%[l]	70-90% of solids[l]

a Ecological Conservation Organization 2009
b Merriman, Gitau and Chaubey 2009
c BMP Tool II
d Garrett 2011
e Peterson, Redmon and McFarland 2011a
f Peterson, Redmon and McFarland 2011b
g EPA 2010
h Stream crossing combined with other practices from Peterson, Redmon and McFarland 2011b-d
i Peterson, Redmon and McFarland 2011d
j (The Water Research Foundation, USACE Environmental and Water Resources Institute, EPA, US Department of Transportation, Geosyntec, Wright Water Engineers, 2020)
k Klapproth and Johnson 2009
l Koelsch, Lorimer and Mankin 2006
m Van Epps 2014
n (Geosyntec Consultants, 2018)
o https://swbmp.vwrrc.vt.edu/
p (Center for Watershed Protection, 2007)
r STEPL v4.4b
s Simpson & Weammert 2009
t FTN Associates, Ltd. 2019
u https://www.mapc.org/resource-library/fact-sheet-bioretention-areas
v (Peterson, Redmon, & McFarland2011e)
w (Wang, Zhu and Mao 2021)
x (Clary, et al. 2020), calculated from reported median inflow and outflow concentrations
y (US EPA Office of Water 2002)

Table 4.25. Nutrient reduction efficiencies for agricultural BMP suites of the Arkansas Nutrient Reduction Framework (FTN Associates, Ltd. 2019).

Practice Suite	Total Phosphorus Reduction	Total Nitrogen Reduction
Irrigation Water BMP Suite	40%	55%
Tailwater Recovery BMP Suite	35%	50%
Reduced Irrigation Water Use BMP Suite	5%	5%
Row Crop Soil Nutrient Management BMP Suite	25%	15%
Conservation Tillage and Cover Crop Suite	55%	50%
Pasture BMP Suite	65%	45%

Table 4.26. Estimated potential *E. Coli*, nutrient, and sediment load reductions from implementing example BMPs in the recommended subwatersheds.

Subwatershed	*E. Coli* (reduction target)	Total nitrogen (reduction target)	Total phosphorus (reduction target)	Sediment (reduction target)
Fourteen Mile Creek	0 - 90%	10% - 45%	15% - 90%	0 - 80%
Little Red River-Cedar Branch	**45% - 90% (0)**	10% - 45%	**15% - 90% (36%)**	30% - 60%
Ten Mile Creek Headwaters	**45% - 90% (41%)**	**10% - 45% (23%)**	**15% - 90% (78%)**	**0 - 60% (0)**
Ten Mile Creek Outlet	**45% - 90% (41%)**	**10% - 45% (23%)**	**15% - 90% (78%)**	**0 - 60% (0)**
Little Red River-Alder Creek	**45% - 90% (0)**	10% - 45%	**15% - 90% (36%)**	0% - 75%
Overflow Creek	**45% - 90% (0)**	10% - 35%	0 - 90%	0 - 75%
Big Mingo Creek	0 - 90%	**10% - 50% (71%)**	0 - 90%	0 - 75%

Bold text indicates the parameter is a targeted pollutant in the subwatershed.
Light text indicates that the parameter is a concern in the subwatershed but is not specifically targeted for management under this plan.

4.9 Summary

Nonpoint source pollution concerns and management goals have been identified. Seven HUC12 subwatersheds have been recommended in which to focus water quality improvement efforts under this plan. Pollutants targeted for reduction are pesticides, bacteria, nutrients, pH, and sediment. Load reduction targets have been determined for *E. Coli* and nutrients for six of the recommended subwatersheds. Potential sources of *E. Coli*, nutrient, and sediment loads have been identified, along with BMPs to reduce loads from these sources. Management summaries for each of the recommended subwatersheds are provided below.

- Fourteen Mile Creek: No data was available to develop load reduction targets for this subwatershed. BMPs that reduce pathogen, nutrient, and sediment from animal agriculture are encouraged, as well as BMPs that reduce erosion from unpaved roads, streambanks, pastures, and hayfields.
- Little Red River – Cedar Branch: Management in this subwatershed is focused on controlling *E. Coli* and reducing total phosphorus levels in the Little Red River. BMPs that reduce these pollutants from animal agriculture and on-site wastewater treatment systems within 100 feet of surface waters are recommended.
- Ten Mile Creek: Management in both the Headwaters and Outlet subwatersheds is focused on reducing *E. Coli*, total nitrogen, and total phosphorus, and controlling turbidity and TSS in Ten Mile Creek. Recommended BMPs are those that reduce these pollutants from animal agriculture and on-site wastewater treatment systems within 100 feet of surface waters, as well as those that reduce erosion from unpaved roads, streambanks, pastures, and hayfields.
- Little Red River – Alder Creek: Management in this subwatershed is focused on controlling *E. Coli* and reducing total phosphorus in Little Red River. BMPs are recommended are those that reduce these pollutants from animal agriculture, developed and residential areas, and on-site wastewater treatment systems within 100 feet of surface waters.
- Overflow Creek: Management in this subwatershed is focused on controlling *E. Coli* levels in Overflow Creek. Recommended BMPs are those that reduce *E. Coli* from animal agriculture, developed and residential areas, and on-site wastewater treatment systems within 100 feet of surface waters.
- Big Mingo Creek: Management in this subwatershed is focused on reducing total nitrogen in Big Mingo Creek. Recommended BMPs are those that reduce nitrogen from row crop agriculture and on-site wastewater treatment systems within 100 feet of surface waters.

5.0 IMPLEMENTATION STRATEGY

The implementation strategy for the Little Red River watershed management plan includes several elements and follows the adaptive management process. The strategy elements are described in this section. In addition to implementing practices to manage unregulated nonpoint pollution sources, the implementation strategy includes:

- Information and education activities for watershed stakeholders,
- An implementation lead to coordinate voluntary activities in recommended subwatersheds,
- Water quality and biological monitoring to document current conditions and any changes resulting from voluntary nonpoint source pollution management activities,
- Milestones for implementation,
- Criteria for evaluation of progress,
- Regular evaluation of progress toward plan goals,
- Update of this plan to accommodate changes in the watershed, and/or in understanding of the watershed, and
- Proposed implementation schedule.

5.1 Information and Education

Watershed management is fundamentally a social activity (Thornton and Laurin 2005). While technical solutions to problems are necessary for effective watershed management, they are not sufficient. Decisions on how to protect and improve water quality, and implement BMPs, are ultimately based on the socioeconomic perceptions, beliefs, and values of landowners and stakeholders about how these technical solutions will affect them. The Information and Education objectives of this watershed plan, therefore, include the following:

- Increase local landowner and public awareness of the need for, and the benefits of, watershed restoration and protection practices;

- Increase stakeholder support and participation in watershed management activities for water quality protection and improvement; and
- Improve stakeholder understanding of how water quality and environmental improvements contribute to increased economic and social capital in communities.

5.1.1 Existing Outreach and Education in the Little Red River Watershed

There are many organizations active in the Little Red River watershed that have outreach and education programs in place that could be used as vehicles to accomplish the Information and Education objectives of this watershed management plan. Examples are listed in Table 5.1. Outreach and education activities of some of these organizations are described in Appendix J. Many of these organizations are active throughout the Little Red River watershed. The outreach and education activities of these organizations are expected to continue.

5.1.2 Proposed Information and Education Activity

Quantification of the ecosystem services of the Little Red River watershed is proposed as an additional information and education activity. Ecosystem services are the benefits people obtain from ecosystems (Millennium Ecosystem Assessment 2005) and the direct and indirect contributions of ecosystems to human well-being (Kumar 2010). As categorized by the Millennium Ecosystem Assessment, these include *provisioning* services such as food, water, timber and fiber; *regulating* services that affect climate, floods, disease, wastes, and water quality; *cultural* services that provide recreational, aesthetic, and spiritual benefits; and *supporting* services such as soil formation, nutrient cycling, pollination, and photosynthesis (Millennium Ecosystem Assessment 2005). Typically, only provisioning services have market value, with the monetary benefits determined within the marketplace where goods and services are bought and sold. However, there are many more benefits and values provided by ecosystem services than just provisioning services.

Table 5.1. Little Red River watershed stakeholder groups and outreach programs.

Stakeholder Groups	Organizations with Information and Education Programs for the Stakeholders
Agriculture producers	NRCS, University of Arkansas Division of Agriculture, County Conservation Districts, Arkansas Grazing Lands Coalition, Arkansas Cattlemen's Association, Arkansas Farm Bureau, Rice Stewardship Partnership, Agriculture Council of Arkansas, Arkansas Soil Health Alliance, AGFC, Arkansas Resource Conservation and Development Council (ARCDC), Arkansas Soybean Promotion Board, USA Rice, Arkansas Corn and Grain Sorghum Board, Arkansas Rice Research and Promotion Board, Little Red River Irrigation District
Recreationists and other tourists	USFWS; USACE; AGFC; Audubon Arkansas; The Nature Conservancy; Ducks Unlimited; Arkansas Department of Parks, Heritage, and Tourism; Trout Unlimited; Chambers of Commerce; South Fork Nature Center (Gates Foundation); Little Red River Foundation, Friends of the Little Red River, Greers Ferry Lake & Little Red River Tourism Association
Landowners and residents	Rural Water Associations, NRCS, University of Arkansas Division of Agriculture, County Conservation Districts, AGFC, Arkansas Natural Heritage Commission, The Nature Conservancy, Arkansas Master Naturalists, ARCDC, South Fork Nature Center, Trout Unlimited, Little Red River Foundation, Friends of the Little Red River, Save Greers Ferry Lake Inc., USACE, USFWS, Quail Forever, Arkansas Department of Health, water utilities
Local and county governments	Arkansas Economic Development Commission, NRD, ARCDC, Arkansas Farm Bureau
Concessioners, guides, vendors, hostelers, restaurants	Arkansas Economic Development Commission; Arkansas Department of Parks, Heritage, and Tourism; Trout Unlimited; AGFC; Little Red River Foundation; USACE;
Teachers	AGFC, DEQ, Arkansas Farm Bureau, Arkansas Soybean Promotion Board, Arkansas Wildlife Federation

A taxonomy of economic values for ecosystem services has been developed based on whether there is a physical relationship between the ecosystem and human use (National Research Council 2004). Use values can be consumptive, non-consumptive, or indirect use. Consumptive uses, for example, include water withdrawals for drinking or irrigation (i.e., market-based provisioning services). Non-consumptive uses of water include boating, recreational fishing, or health impacts. Indirect uses include habitat for birds and birdwatching, hunting areas, or spawning habitat for fish. There are also non-use values, which are not tied directly or indirectly to human use. For example, there are option values, where there currently is no desire to use the ecosystem, but there may be in the future and people value having that future option. Bequest and altruistic values relate to wanting the resource or service available for future generations (bequest) or available for others now (altruistic).

Economists have developed methods for quantifying the value of many of the non-consumptive, indirect, and non-use ecosystem services (Table 5.2). Many of these methods are applicable for estimating the value of services provided by Little Red River and its tributaries. Quantifying and presenting the value of services provided by ecosystems in the Little Red River watershed may increase local interest in protecting or improving those ecosystems.

The value of ecosystem services is generally unknown and rarely considered by society because the services are “free”. Because most people are risk averse and their fear of incurring loss is significantly greater than their fear of missing out on gain (Kahneman and Tversky 1979, Thaler, et al. 1997), the ecosystem services will be quantified so the differential loss of valued services (e.g., monetary value) can be estimated. For example, manure decomposition (supporting service) makes nutrients available for grass and hay production that offsets the cost of fertilizer application. Soil health represents a category of ecosystem services with significant value to farmers, cattle ranchers and hay producers that can also contribute to improved water quality.

The initial quantification of ecosystem services is proposed for one of the recommended subwatersheds. A DPSIR model framework (Bradley and Yee 2015) is proposed to illustrate the linkages among drivers (D), pressures (P), status (S), impacts (I), and responses (R – DPSIR) and their relationship with ecosystem service changes and well-being in Little Red River subwatersheds. The voluntary set of practices and activities proposed in Section 4.7 represents one set of responses to the impacts on these ecosystem services.

Table 5.2. Monetary valuation methods for ecosystem goods and services.

Market Place Method – value based on ecosystem goods and services bought and sold in commercial markets	**Productivity Method** – value-based products or services that contribute to the production of commercially marketed goods
Hedonic Pricing Method – value based on services that directly affect market price of another good (e.g., streamside vs non-streamside property)	**Travel Cost Method** – value associated with ecosystem used for recreation and willingness of people to pay to travel to the site
Damage Cost Avoided/Replacement Cost Method – value based on cost of avoiding damages from lost services or cost of replacing services (e.g., drinking water treatment costs)	**Contingent Valuation Method** – value based on asking people their willingness to pay (WTP) for specific ecosystem services based on scenario (most widely used method for estimating nonuse values)
Contingent Choice Method – value based on asking people to make trade-offs among choices of services or characteristics. Does not ask for WTP, but infers value from trade-offs	**Benefit Transfer Method** – value based on transferring existing benefit estimates to similar location, issue, or use.

Ecosystem services will be quantified following the frameworks proposed by Grizzetti et al. (2016), and Ready (2016), and using the tools assessed by Bagstad et al. (2013) and InVEST (www.naturalcapitalproject.org/invest/). InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) is a suite of open-source ecosystem service models developed by the Natural Capital Project. The Natural Capital Project is a joint initiative of the University of Minnesota, The Nature Conservancy, Stanford University, World Wildlife Fund, the Chinese Academy of Sciences, and the Stockholm Resilience Centre (https://naturalcapitalproject.stanford.edu/). The set of ecosystem services considered for initial valuation, along with the proposed valuation method, is shown in Table 5.3.

Table 5.3. Freshwater Ecosystem services, type of value and applied valuation methods. The classification of ecosystem services has been developed for fresh and transitional water (Reynaud and Lanzanova 2017).

Ecosystem services	Category[a]	Value type	Valuation method[b]	Examples of economic good provided
1-Water for Drinking	Provisioning	Direct	MP, CV	Water for domestic uses
2-Raw (biotic) materials	Provisioning	Direct	MP, RC	Algae as fertilizers
3-Water for non-drinking purposes	Provisioning	Direct	MP, PF	Water for industrial or agricultural uses
4-Raw materials for energy	Provisioning	Direct	RC	Wood from riparian zones
5-Water purification	Regulation	Indirect	RC, CV	Excess nitrogen removal by microorganisms
6-Erosion prevention	Regulation	Indirect	RC	Vegetation controlling soil erosion
7-Flood protection	Regulation	Indirect	RC, CV	Vegetation acting as barrier for the water flow
8-Maintaining populations and habitats	Regulation	Indirect	RC	Habitats use as a nursery
9-Pest and disease control	Regulation	Indirect	RC, CV	Natural predation of diseases and parasites
10-Soil formation	Regulation	Indirect	RC	Rich soil formation in flood plains
11-Carbon sequestration	Regulation	Indirect	RC, MP	Carbon accumulation in sediments
12-Location climate regulation	Regulation	Indirect	RC, MP	Maintenance of temperature patterns
13-Recreation	Cultural	Direct	CV, TC, DC, HP	Swimming, recreational fishing, sightseeing
14-Recreational fishing	Cultural	Direct	TC, CV	Sportfishing for smallmouth bass
15-Recreational canoeing/swimming	Cultural	Direct	MP, TC, CV	Canoing/kayaking, swimming
16-Intellectual and aesthetic appreciation	Cultural	Non-use	CV, DC	Matter for research, artistic representation
17-Spiritual and symbolic appreciation	Cultural	Non-use	CV, TC, DC	Sense of being
18-Raw abiotic materials	Extra abiotic	Direct	PF, MP	Extraction of sand and gravel
19-Abiotic energy sources	Extra abiotic	Direct	PF, MP	Hydropower generation

a Provisioning, Regulation and maintenance, Cultural, Extra abiotic

b contingent valuation (CV), choice experiment (CE), hedonic price (HP), market price (MP), production function (PF), replacement cost (RC), travel costs (TC)

5.2 Implementation Lead

The greatest efficacy in implementing watershed management plans, and protecting and improving water quality, is typically achieved through locally-led watershed groups or teams. There is empirical evidence that nonprofit watershed groups or teams can provide public goods (Grant and Langpap 2018). In economics, a public good is a commodity or service available to all individuals and where one individual cannot reduce the availability to others. Grant and Langpap reviewed information from 2,150 watersheds across the lower US from 1996 to 2008. Watershed groups in these watersheds increased from 500 to 1,500 over this same period. They found the activity of these watershed groups resulted in improved water quality, specifically a decrease in DO deficiency (i.e., increase in DO concentrations in waterbodies), compared to watersheds in which there were no groups. Donations to watershed groups were associated with reduced DO deficiency. Watershed groups can make a significant difference in improved water quality within a watershed through their activities.

There are locally-led interest groups in the watershed that focus on protection of Greers Ferry Lake and the trout waters of the Little Red River downstream of the reservoir; Little Red River Foundation, Friends of the Little Red River, and Save Greers Ferry Lake Inc. The Nature Conservancy is also active in this watershed. One or more of these organizations will act as implementation lead for this watershed management plan.

5.3 Implement Nonpoint Source Pollution BMPs

Section 4.7 identifies nonpoint source pollution BMPs appropriate for Little Red River watershed and the recommended subwatersheds. Focus areas for management are identified in Sections 4.3 and 4.6. There is no legal requirement that anyone implement any of the practices listed in Section 4.7. These are practices that are suggested for landowners, operators, and other stakeholders interested in improving or protecting water quality in the Little Red River watershed. In addition to protecting water quality, these practices can increase the value and returns on the property where they are implemented (when they are properly installed, operated, and maintained). These are not the only practices appropriate for the watershed, but rather those that are generally accepted within the watershed and suggested by stakeholders. There are other practices not listed that could also improve or protect water quality and habitat. Programs that can provide technical and financial assistance to landowners, operators, and other stakeholders for implementing (i.e., installing, operating, and maintaining) these BMPs are listed in Section 6.

5.3.1 Existing Implementation of Practices in Watershed

Many of the BMPs listed in Section 4.7 are already in use in the Little Red River watershed and in the recommended subwatersheds. Figures 5.1 and 5.2 summarize practices implemented in the Little Red River watershed through NRCS EQIP and CSP programs during the period 2008-2020. The 2017 Census of Agriculture reported the area within each county on which selected conservation practices were implemented in 2017. These data for the counties associated with the recommended subwatersheds are listed in Table 5.4. The US Department of Agriculture (USDA) Farm Services Agency (FSA) reports acres enrolled in the Conservation Reserve Program (CRP) annually by county (FSA 2021a). Acres enrolled during 2019 in the counties associated with the recommended subwatersheds are included in Table 5.4. Table 5.5 lists examples of past conservation projects with BMPs funded by other sources.

Table 5.4. Extent of conservation practices by county reported in the 2017 Census of Agriculture (USDA National Agricultural Statistics Service 2017) and by FSA *(FSA 2020)*.

Practices	Reporting year	Extent in:				
		Cleburne County	**Searcy County**	**Stone County**	**Van Buren County**	**White County**
Prescribed grazing	2017	128 operations	118 operations	127 operations	111 operations	186 operations
Cover crops	2017	436 acres	892 acres	318 acres	142 acres	2,191 acres
Conservation tillage	2017	181 acres	1 operation	39 acres	1 operation	12,228 acres
No-till	2017	611 acres	641 acres	565 acres	80 acres	21,666 acres
Conservation Reserve Program	2001-2019	127 acres	61 acres	13 acres	0	17,507 acres

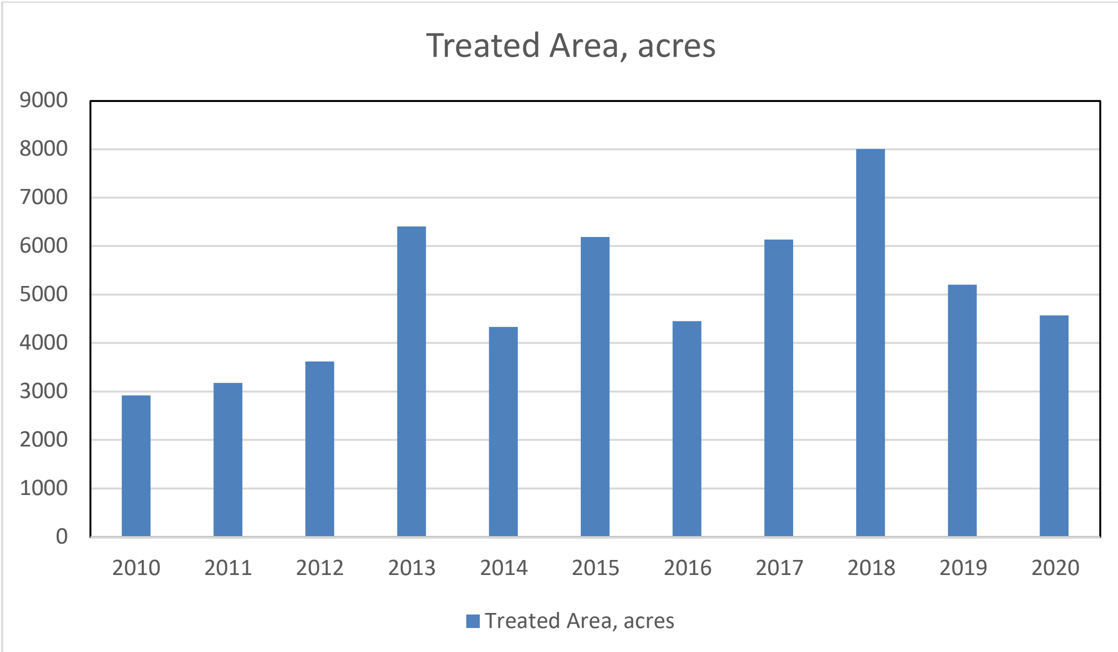


Figure 5.1 Summary of area treated by BMPs implemented through EQIP and CSP programs 2008-2020 in Little Red River watershed.

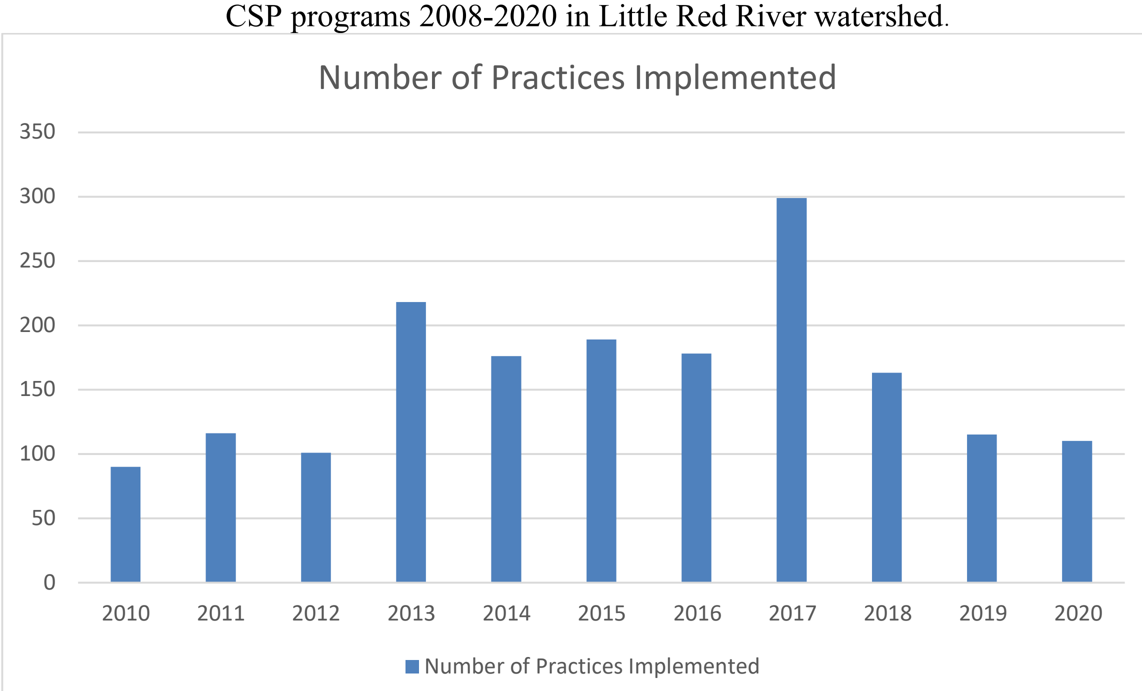


Figure 5.2 Number of BMPs implemented in Little Red River watershed through EQIP and CSP programs 2008-2020.

Table 5.5. Examples of BMPs installed through projects funded by other sources.

Project Title (Lead Organization)	Start year	End year	BMPs	Type of Project/funding source
Upper Little Red River Watershed Project (Van Buren County Conservation District)[a]	2000	2003	WRAS (Watershed Business Plan) 120 Comprehensive Management plans Pasture Nutrient Management 4,363 acres Pasture Establishment 3,703 acres Prescribed grazing 3,008 acres Pest management 1,311 acres Buffer and filter strips 68 acres	319 project number 00-500
Proper Cattle Heavy Use Area Design and Management (University of Arkansas Cooperative Extension)[a]	2001	2004	Heavy Use Area Protection	319 project number 01-1400
Lower Little Red River Watershed Project (Cleburne County Conservation District)[a]	2001	2003	WRAS Purchase and rent 2 Haybuster no-till pasture drills (Cleburne & Independence Counties) used to establish 2,200 acres of pasture 27 streambank stabilization demonstration sites	319 project number 01-1700
Upper Little Red River Project (Stone County Conservation District)[a]	2002	2006	113 Conservation Plans (12,600 acres) Brush management 218 acres Fence 78,995 feet Irrigation water conveyance 87,120 feet Pasture & hay planting 975 acres Pest management 238 acres Pipeline 3,720 feet Ponds 2 Water facility 4 No-till 2,015 acres Purchased 2 no-till drills	319 project number 02-400
Upper Little Red River Watershed BMP Implementation Project (Van Buren County Conservation District)[a]	2004	2006	Purchased no-till drill (used to establish 2,607 acres of pasture) Purchased fertilizer spreader and boom sprayer (used 20 times) Purchased liquid waste spreader (used 39 times) Purchased pasture aerator (used 7 times) 120 CMPs Prescribed grazing 2,968 acres Nutrient management 3,308 acres Pest management 1,652 acres Pasture & hayland planting 1,935 acres Fence 44,020 feet 7 Animal mortality facilities Firebreak 82,545 feet Tree/shrub establishment 321 acres 1 Water control structure Access road 6,060 feet Streambank protection 0.25 acres Critical area planting 18 acres 1 pond	319 project number 03-300
Two Forks Stream Restoration Phases I and II (TNC, USFWS)[b,c]	2008	2015	One mile of Archey Fork channel restored	TNC Ozark and Ouachita Rivers Program

Table 5.5. Examples of BMPs installed through projects funded by other sources (continued).

Project Title (Lead Organization)	Start year	End year	BMPs	Type of Project/funding source
Middle Fork Little Red River Safe Harbor Project (TNC)[b]	2009	2009	375 feet of streambank stabilized	TNC Ozark and Ouachita Rivers Program
Innovative Construction and Maintenance Practices to Reduce Sedimentation from Unpaved Roads (TNC)[d]	2008?	2014	Installation of ESM practices along 3,600 ft of Line Ridge Road in Gulf Mountain WMA along South Fork Little Red River	State Wildlife Grant Program project number T33-03
Little Red River Landowner Assistance and Bank Stabilization[e]	2015	2017	Bank stabilization	AGFC Stream Habitat Program
Greers Ferry Tailwater Landowner Assistance/ Bank Stabilization (AGFC)[e]	2015	2018	Bank stabilization	AGFC Stream Habitat Program
Applying and Demonstrating Innovative construction and Maintenance Practices to Reduce Sedimentation from Low-Volume Unpaved Roads (TNC)[f]	2016	2017	Installation of BMPs on over 3 miles of unpaved roads in Bluffton Preserve on Archey Fork, including: Geocell installed at 10 wetland/seep locations Reroute stream crossing Stabilize 3 stream crossings	State Wildlife Grant Program project number T34-07
Little Red River Irrigation Project (Little Red River Regional Irrigation Water District)[g]	2018	2019	?	NRCS RCPP
Van Buren County Peyton Rd[h]	2020	2020	Improved ¼ mile of unpaved road (Peyton Rd)	Arkansas Unpaved Roads Program
Van Buren County[h]	2021	2022	Unpaved road improvement on Silver Rock Road	Arkansas Unpaved Roads Program

a https://www.arkansaswater.org/319/Document%20Database/Public_view.php
b https://www.nature.org/en-us/about-us/where-we-work/united-states/arkansas/stories-in-arkansas/minimizing-sediment-at-the-upper-little-red-river/
c https://clintonark.com/archey-fork-phase-ii-restoration-complete/d (Gallipeau 2014)
e (ANRC 2016, ANRC 2017, ANRC 2018)
f (Allen 2018)
g (NRD 2020a)
h K. McGaughey, NRD, personal communication, 5/23/2022

5.3.2 Planned Implementation Projects

As shown in Section 5.3.1, there have been BMP implementation projects within the Little Red River watershed over the years. There are also BMP implementation projects currently planned in the watershed. Examples are described below.

NRCS is conducting watershed assessments of Overflow Creek and Ten Mile Creek subwatersheds in preparation for establishing National Water Quality Initiative (NWQI) projects in these subwatersheds. If selected, NWQI projects could be initiated in these subwatersheds in 2023 (T. Wentz, NRD, personal communication, 9/20/22).

AGFC is initiating streambank stabilization projects on Wilburn and Canoe Creeks through the Coldwater Habitat Program (E. Powers, AGFC, personal communication, 9/20/2022).

There is a third phase of the Clinton ditch restoration project planned, i.e. Two Forks Stream Restoration. The need for this restoration will likely be reevaluated prior to pursuing funding (T. Wentz, NRD, personal communication 3/2/2023).

There are two stream barrier removal projects in the works within the watershed. Removal of a low water crossing at Arlberg and a second barrier at Lydalisk is planned for 2023, along with a barrier inventory project for the Little Red River watershed (T. Wentz, NRD, personal communication 3/2/2023).

5.3.3 Influencing Implementation of BMPs and Activities

Over the past decade, there has been considerable work conducted on ways of leading and implementing change within organizations and communities (Grenny, et al. 2013). In general, there are three important domains, and two important subdomains within each domain, that are critical in influencing change. The domains are personal, social, and structural and the sub-domains are motivation and ability. These three domains and two sub-domains form a six-celled matrix (Table 5.6).

Table 5.6. Domain, sub-domain, and elements that can influence behavioral change in implementing BMPs and activities *(Grenny, et al. 2013)*.

Domain	Sub-domain: Motivation	Sub-domain: Ability
Personal	Links to Values and Personal Benefits	Training, Skill Building
Social	Peer Pressure	Social Support
Structural	Rewards, Accountability	Change the Environment

In many instances, the emphasis has only been on personal motivation and ability, ensuring that individuals have the motivation to change and are provided with the training and ability to make the change. However, the importance of social elements of peer pressure and support groups (e.g., Neighborhood Associations, Grazing Land Coalition, Soil Health Alliance) is also critical in supporting the personal domain. Research into adoption of BMPs has identified the importance of social networks in increasing adoption of practices (Froelich 2010, Liu, Bruins and Heberling 2018). In addition, making changes in the social environment (i.e., structural domain) through cost-share and rewards (i.e., motivation), and changing the physical environment in which individuals interact (e.g., native grass pasture vs. fescue or bermudagrass) are also critical in bringing about changes in how land and water are viewed and managed. The key is to simultaneously address all six cells, not just one or two of the cells. In some cases, it might not be possible to address all six, but the emphasis should be on implementing as many of the six cells as possible to encourage and promote change.

Pasture management is a recommended approach for improving water quality within the Little Red River watershed. Examples of factors that might influence change for each of the elements in the matrix for pasture management are shown in Table 5.7. The recommendation is that all six elements of the influence matrix be considered when working with local stakeholders in the Little Red River watershed.

Table 5.7. Elements that might help influence implementation of pasture BMPs.

Domain	Motivation	Ability
Personal	• Better pasture/forage quality • Increased rate of gain • Reduced hay feeding • Sustain water supply • Cost-share programs • Increased profit	• Grazing land conference • Field days • YouTube/other videos • Grazing stick • NRCS technical assistance • University of Arkansas Cooperative Extension
Social	• Leaders implementing practices • Cattleman of the Year Award	• Grazing land coalition • Field days • Rancher to rancher exchanges • Conferences
Structural	• NRCS EQIP funding • NRCS RCPP funding • 319 funding	• Grow grass, not algae campaign • Grazing stick • Promote electric fence or invisible fence • AGFC Acres for Wildlife • 4-5 forage paddocks • Stockpile paddock • Alternative water supply

5.4 Monitoring

Monitoring is an essential element of adaptive watershed management. The objectives of the ongoing and proposed monitoring programs and special studies in the Little Red River watershed include:

- Determine compliance with state water quality standards;
- Characterize current water quality conditions, including patterns;
- Characterize water quality trends and impacts; and
- Identify sources of pollutants.

For all water quality monitoring, existing and proposed, it is recommended that the frequency and timing of sampling result in data that meet DEQ data requirements for the biennial assessment of streams and lakes in Arkansas, e.g., 2022 Assessment Methodology (DEQ 2021d). For example, the requirement for DO data is that at least 10 measurements be collected per season (primary and critical seasons), evenly distributed over at least two years and three quarters per year.

5.4.1 Existing Monitoring Programs

Existing monitoring programs in the Little Red River watershed are expected to continue into the future (descriptions provided in Section 3.1.2). DEQ will continue to monitor its ambient stream surface water quality stations (WHI0043, ARK0170, WHI0059) and the water quality stations in Greers Ferry Lake (LWHI010A, LWHI010B), as well as selected spring and well groundwater quality monitoring stations in the Little Red River watershed (the stations listed in Table 3.15). USGS and USACE will also continue to monitor water quality in the watershed. DEQ, AGFC, and USFWS are also expected to conduct future fish and macroinvertebrate surveys in the watershed. AGFC conducts creel surveys in the Little Red River trout waters and is expected to continue to do so as part of their Greers Ferry Tailwater Management Plan (AGFC Trout Management Program and Trout Habitat Program 2017). The USFWS and its partners are expected to continue to monitor populations of endangered and threatened fish and mussel species within the watershed. The Arkansas Department of Agriculture Pesticides Section is expected to continue to analyze groundwater samples submitted from the watershed.

5.4.2 Future Special Studies

Special studies are proposed to address data gaps. These studies will include data quality assurance planning.

5.4.2.1 Proposed Study – Resampling at DEQ Intermittent Station Locations

DEQ has collected water quality data from stations within several recommended subwatersheds that have not been sampled recently (see Table 5.8). For example, Ten Mile Creek is listed as impaired due to turbidity, but turbidity measurements have not been collected from this stream in almost 20 years. It is proposed that a full suite of water quality measurements appropriate for evaluating attainment of water quality standards be collected from these stations. At least two to five years of sampling is suggested. Sampling frequency and analytical methods will be determined by DEQ data requirements for the biennial statewide assessment of water quality. These studies could be conducted by a Stream Team, or, with funding, by the USGS, a university, or a contractor. Collecting water quality data from Ten Mile and Overflow Creeks could also benefit the NWQI projects proposed for those subwatersheds.

Table 5.8. Inactive DEQ water quality stations located within recommended subwatersheds.

Station ID	Stream Name	Station Location	Year Last Sampled
WHI0199	Mingo Creek	Lone Star Rd, east of Searcy	2013
UWOFC01	Overflow Creek	Huntsman Rd 1 ½ mi. SE of Judsonia	2018 for *E. Coli* & field parameters; 2012 for all other parameters
UWTMC01	Ten Mile Creek	CR157/Sunny Dale Rd. 3 mi. N of Providence	2019 for *E. Coli* & field parameters; 2003 for all other parameters

5.4.2.2 Proposed Study – Subwatershed Water Quality Assessments

Currently there are no water quality monitoring data associated with two of the recommended subwatersheds: Cedar Branch-Little Red River and Fourteen Mile Creek. However, these subwatersheds were ranked as having a high potential for water quality issues (see Appendix H). Therefore, it is recommended that a set of water quality data that can be used to assess whether applicable water quality standards are being met, that includes *E. Coli,* be collected from the primary streams in these subwatersheds, Little Red River and Fourteen Mile Creek. A single water quality monitoring location is proposed near the downstream end of Fourteen Mile Creek around the Highway 124 crossing, and on the Little Red River around the Highway 124 crossing. At least two to five years of sampling is suggested. Sampling frequency and analytical methods will be determined by DEQ data requirements for the biennial statewide assessment of water quality. These studies could be conducted by a stream team, or, with funding, by the USGS, a university, or a contractor.

5.4.2.3 Proposed Study – pH in Ten Mile Creek and Overflow Creek

In Appendix E graphs of pH at stations UMTMC01 and UMOFC01 appear to show pH decreasing over time. Data from the proposed subwatershed water quality monitoring project (Section 5.4.1.2) would be used to determine if pH values have continued to decline at these stations. If so, an intensive study of the cause of the pH declines would be initiated. These studies could be conducted by a university, contractor, or agency.

5.4.2.4 Proposed Study – Aquatic Community Surveys

No DEQ fishery survey reports were found for locations downstream of Greers Ferry Lake. No DEQ macroinvertebrate survey reports were found for locations within the recommended subwatersheds, however, in StreamCat, predicted benthic condition in the recommended subwatersheds is predominantly fair or poor (see Appendix H). Fishery and benthic surveys could be useful for characterizing water quality conditions in the recommended subwatersheds. Streams in these subwatersheds are identified by USFWS as potential habitat for endangered Scaleshell mussel and threatened Rabbitsfoot mussel(USFWS 2021b).

5.5 Evaluation

It is recommended that an evaluation of plan implementation occur approximately every seven years. Therefore, the first evaluation of this plan would occur in 2030. This evaluation will be conducted by the plan implementation lead organization(s). Performance measures for this evaluation are listed in Section 5.6. If the criteria identified in Section 5.6 are not satisfied, the management approaches, scientific knowledge, and stakeholder knowledge and opinions in the recommended subwatersheds will be re-evaluated by the stakeholders involved in managing water quality and nonpoint sources in the recommended subwatershed(s), and management elements will be adjusted accordingly. This evaluation will need to take into account the fact that it can take more than five years, or even decades, before in-stream water quality improvements resulting from implementation of management measures become apparent (Meals, Dressing and Davenport 2010). The time required to see significant changes in water quality is, in part, a function of how close water quality measurement locations are to where management activities are implemented.

5.6 Performance Measures

The performance measures outlined below consider three major elements of the implementation of a watershed management plan: program inputs, outputs, and outcomes. Performance measures for these elements are identified for information/education, monitoring, and implementation of BMPs.

5.6.1 Inputs

The inputs for implementation of this plan are the assistance programs available and stakeholder participation. Indicators that measure this component of the plan implementation are listed in Table 5.9. The stakeholders and organizations that participate in implementation of this plan should provide the implementation lead with annual totals for these input indicators for the period 2023 through 2028 by February 2029.

5.6.2 Outputs

The outputs for implementation of this plan are formation of partnerships, implementation of nonpoint source BMPs, information and education, and monitoring and special studies. Indicators that measure this component of the plan implementation are listed in Table 5.10. The stakeholders and organizations that participate in implementation of this plan should provide the implementation lead with annual totals for these indicators for the period 2021 through 2028 by February 2029.

Table 5.9. Indicators of inputs for implementation of this watershed management plan.

Implementation Task	Activity	Indicators
Monitoring	Agency monitoring programs	Resources spent on monitoring in Little Red River watershed Hours and number of personnel involved
	Stream Teams	Number of inquiries Number of teams formed Number of participants on teams Hours and number of AGFC personnel involved
	Special studies	Resources spent on special studies Hours and number of personnel involved
Information/Education	Arkansas grazing lands conference (Arkansas Grazing Lands Coalition)	Resources spent on putting on the conference Hours and number of personnel involved
	Events – field days, festivals, lake and river clean-ups	Hours and number of people involved in putting on events Cost
	Community presentations	Hours and number of people involved in putting on presentations Cost
	K-12 education programs, including Fishing Camp	Hours and number of people involved in running education programs Cost
	Interest groups meetings, websites, newsletters	Number of website posts/updates Hours and number of people involved Cost
	Social media	Number of posts, Tweets, etc. Hours and number of people putting content on social media Cost
Implement (install, operate, and maintain) BMPs	Assistance programs in the Little Red River watershed	Resources distributed to Little Red River watershed Hours and number of people assisting stakeholders in Little Red River watershed Number of Little Red River watershed stakeholders requesting assistance
	Implementation projects	Number of people/organizations partnering

Table 5.10. Indicators of outputs of implementation of this watershed management plan.

Implementation Task	Activity	Indicators
Monitoring	Agency monitoring programs	Number of active water quality monitoring stations Number of stations sampled Number of water quality parameter measurements collected Number of sampling events Number of biological surveys
	Stream Teams	Number of teams Number of streams monitored Number of active water quality monitoring stations Number of stations sampled Number of water quality parameters measured Number of sampling events Number of invertebrate surveys
	Special studies	Number of studies completed Number of subwatersheds studied Study results reported
Information/Education	Arkansas grazing lands conference (Arkansas Grazing Lands Coalition)	Number of conferences Number of attendees
	Events	Number of events in watershed Number of events outside watershed where watershed information presented Number of attendees
	Community presentation	Number of presentations Number of attendees
	K-12 education programs	Number of programs Number of attendees
	Interest group meetings, websites, newsletters	Number of meetings Number of attendees Number of website visits Number of newsletters distributed
Implement (install, operate, and maintain) BMPs	Assistance programs in the Little Red River watershed	Number/amount of BMPs implemented Number of contracts/projects started and finished
	Implementation projects	Number of partnerships formed Number of subwatersheds with implementation projects and/or studies Number of projects and studies organized through partnerships Number/amount of BMPs implemented through partnerships

5.6.3 Outcomes

The intended outcomes for this watershed-based management plan include assessment of water quality in all of the recommended subwatersheds; improvement in water quality and aquatic habitat, particularly in the recommended subwatersheds Cedar Branch-Little Red River, Headwater Ten Mile Creek, Outlet Ten Mile Creek, Alder Creek-Little Red River, and Overflow Creek; and increased awareness of, and interest in, water quality and aquatic habitat concerns of the Little Red River watershed. The long-term objectives of this watershed-based plan are that waterbodies in the Little Red River watershed will meet water quality criteria and attain their designated uses, nutrient loads from this watershed will be reduced, and populations of threatened and engendered species will continue. The primary indicators suggested for this goal are *E. Coli*, turbidity, total nitrogen, and total phosphorus concentrations; pH levels; and threatened and endangered species surveys. DO, biochemical oxygen demand (BOD), and total suspended solids (TSS) concentrations; and fish and macroinvertebrate surveys are suggested as secondary indicators. These parameters, which are currently being monitored at several locations, are recommended for use in evaluation of the overall effectiveness of nonpoint source pollution management within the Little Red River watershed. Within the next four to six years, the goal of this plan is to see incremental progress toward the target *E. Coli*, pH, turbidity, total nitrogen, and total phosphorus levels, stable or increasing populations of threatened and endangered species, and documented stakeholder activities contributing to good water quality and quality of life in the Little Red River watershed.

The monitored waterbodies in the Little Red River watershed are assessed by DEQ every two years to develop the Arkansas integrated water quality assessment report, which includes the 303(d) list of impaired waterbodies. This assessment will be used to evaluate achievement of the goals of delisting impaired waterbodies, and no new impaired waterbodies in the watershed.

Implementation of this plan will be considered successful if the following are achieved by 2030:

- At least one implementation project or proposed study has been initiated in a recommended subwatershed;
- At least one waterbody is removed from the state impaired waters list;

- Water quality data sufficient for the DEQ biennial assessment have been collected from all of the recommended subwatersheds; and
- No new water quality impairments resulting from unregulated nonpoint pollution sources are identified in the Little Red River watershed.

5.7 Update Watershed Management Plan

A comprehensive update of this watershed management plan will be initiated in 2030 by the implementation lead organization(s).

This update will consider and address the following information:

- Results of the evaluation of the implementation of this plan, described in Section 5.5;
- Relevant information about the Little Red River system and how it works, nonpoint source BMPs, and pollutant sources in the watershed that has been developed since 2022;
- Changes in water quality related issues in the watershed;
- Changes in water quality management assistance programs; and
- Changes in land use, industry, population, and/or economy in the watershed.

A summary of changes in the watershed over the period since completion of the previous watershed management plan, will be prepared. This summary will be presented at one or more public stakeholder meetings. At the meeting(s), stakeholders will provide input on adjustments to management of, and/or goals for, the Little Red River watershed. This may include a focus on management in other subwatersheds for water quality improvement or protection.

An update of this watershed management plan, utilizing the information from the implementation evaluation and the public meeting(s), and any other information deemed appropriate, will be prepared. This update will be presented at one or more public stakeholder meetings to elicit feedback. The final update of the watershed management plan will then be prepared, incorporating stakeholder comments.

5.8 Implementation Schedule

A schedule for implementing the elements of this watershed management plan described previously is summarized in Table 5.11. Included in Table 5.11 are milestones, indicators, and long-term goals. This schedule incorporates the adaptive management process, where practices are implemented, monitoring is conducted to document results, the results are evaluated relative to the goals and criteria specified in the plan, and the plan is modified based on the results of the evaluation, accommodating any changes in regulations, available assistance programs, understanding of the watershed, or management priorities.

Table 5.11. Proposed implementation schedule for Little Red River watershed management plan.

Activity	Action (Lead)	Start	Anticipated Completion	2028 Milestones	Indicator	Long Term Goal
Monitoring	Ambient Surface Water Quality Monitoring Program (DEQ)	1973	Expected to continue indefinitely	Five additional years of water quality data collected at existing stations	Number of sampling events Number of sampling locations	Identify and track changes in water quality Assess water quality relative to water quality standards
	Significant Publicly-owned Lakes Monitoring Program (DEQ)	1994	Expected to continue indefinitely	At least one year of additional water quality data collected	Number of sampling events	Identify and track changes in water quality Assess water quality relative to water quality standards
	Water quality monitoring at Greers Ferry Dam (USGS)	1973	Expected to continue indefinitely	Five additional years of water quality data collected at existing station	Number of sampling events Number of sampling locations	Identify and track changes in water quality Assess water quality relative to water quality standards
	Tailwater water quality monitoring at Greers Ferry Dam (USACE)	2005	Expected to continue indefinitely	Five additional years of water quality data collected at existing station	Number of sampling events	Identify and track changes in water quality
	Stream Team Water Quality Sampling and Aquatic Invertebrate Surveys	2019	Expected to continue indefinitely	At least two additional years of water quality and/or benthic sampling at one or more locations	Number of sampling events Number of sampling locations	Characterize water quality and biology Identify and track changes in water quality
	DEQ Fish Surveys	1986	Expected to continue indefinitely	At least one new fish survey in the Little Red River watershed	Number of sampling events Number of sampling locations	Assess fishery condition
	Groundwater Quality Monitoring Program (DEQ)	2010	Expected to continue indefinitely	At least one additional water quality sample from at least two established monitoring locations	Number of sampling events Number of sampling locations	Characterize water quality Identify and track changes in water quality
	Yellowcheek Darter surveys (USFWS)	1981	Expected to continue until de-listed	At least one additional survey	Number of locations surveyed	Healthy, self-sustaining populations in three of the four forks of the Little Red River
	Surveys of endangered mussel species populations (USFWS)	2009	Expected to continue until de-listed	At least one additional survey for each listed mussel species	Number of species surveyed Number of locations surveyed	Healthy, stable populations
Special Studies	Resampling at intermittent DEQ stations (DEQ)	2025	2030	Initiate water quality monitoring for at least one intermittent DEQ station on an impaired stream reach	Sampling plan Sampling initiated Sampling completed	Identify and track changes in water quality Assess water quality relative to water quality standards
	Subwatershed Water Quality Assessments (DEQ)	2025	2029	Initiate water quality monitoring in at least one recommended subwatershed	Study plan Study initiated Study completed Study report	Determine if water quality standards are being achieved in two recommended subwatersheds lacking water quality data
	pH Intensive Study (DEQ)	2026	2030	Initiate intensive study at one or more monitoring stations with decreasing trend in pH	Study plan Study initiated Study completed Study report	Determine cause(s) of decreasing pH
	Aquatic community surveys in recommended subwatersheds	2024	2029	At least one survey completed in at least one recommended subwatershed	Number of survey dates Number of locations surveyed	Characterize health of aquatic communities and quality of water

Table 5.11. Proposed implementation schedule for Little Red River watershed management plan (continued).

Activity	Action (Lead)	Start	Anticipated Completion	2028 Milestones	Indicator	Long Term Goal
Information and Education	Field demonstrations	2023	Expected to continue indefinitely	At least one field demonstration in one of the recommended subwatersheds	Number of demonstrations Number of people attended	Increase use of BMPs to protect or improve water quality
	Quantification of ecosystem services in recommended subwatersheds	2025	2027	Quantification of ecosystems services completed for at least one recommended subwatershed	Study initiated Study report Study completed	Increased understanding of the services and value provided by natural resources in Little Red River watershed Increase use of BMPs to protect or improve water quality
	Booths at fairs and festivals	2023	Expected to continue indefinitely	At least three booths or presentations by conservation partners within Little Red River watershed	Number of events Number of people attending Number of people visit booth	Increase use of BMPs to protect or improve water quality
	Social media posts (conservation agencies, USACE, local watershed groups, TNC)	2023	Expected to continue indefinitely	At least three posts about Little Red River watershed	Number of views Number of likes Number of retweets Reach	Increase use of BMPs to protect or improve water quality
	Arkansas Watershed Stewardship Program (Arkansas Cooperative Extension)	2023	Expected to continue indefinitely	At least one training in Little Red River watershed	Number of training sessions Number of trainees Number of watershed stewards	Increase awareness and understanding of water resources and how to protect and improve them. Increase use of BMPs to protect and improve water quality.
Implement (install, operate, and maintain) BMPs	Implementation Lead	2023	2024	Implementation lead active	Implementation lead identified and active	All surface waters meet water quality standards Improve instream habitat Increase use of BMPs to protect and improve water quality
	319 program (NRD, County Conservation Districts)	1990	Expected to continue indefinitely	At least one 319 project in a recommended subwatershed	Number of project proposals submitted Number of projects funded Number of projects completed Number of people participating	All surface waters meet water quality standards Reduce pollutant loads from Little Red River watershed
	Acres for Wildlife (AGFC)	2011	Expected to continue indefinitely	At least one project in Little Red River watershed	Number of projects Amount of BMPs implemented	All surface waters meet water quality standards
	Stream Habitat Program (AGFC)	2000	Expected to continue indefinitely	At least one streambank or aquatic habitat project in a recommended subwatershed	Number of projects Amount of BMPs implemented	All surface waters meet water quality standards
	Cold Water Habitat Program (AGFC)	?	Expected to continue indefinitely	At least one habitat improvement project in a recommended subwatershed	Amount of BMPs implemented	All surface waters meet water quality standards Reduce pollutant loads from Little Red River subwatersheds
	Arkansas Unpaved Roads Program (NRD)	2015	Expected to continue indefinitely	Stone and White Counties current on ESM training	Number of projects Amount of BMPs implemented Personnel trained	All surface waters meet water quality standards Reduce road erosion

Table 5.11. Proposed implementation schedule for Little Red River watershed management plan (continued).

Activity	Action (Lead)	Start	Anticipated Completion	2028 Milestones	Indicator	Long Term Goal
Implement (install, operate, and maintain) BMPs	EQIP (NRCS)	1996	Expected to continue indefinitely	Increased implementation of BMPs in recommended subwatersheds	Amount of BMPs implemented	All surface waters meet water quality standards Reduced pollutant loads from Little Red River subwatershed
	National Water Quality Initiative (NWQI) planning for Overflow Creek and Big Mingo Creek subwatersheds (NRCS)	2022	2024	At least one NWQI implementation watershed in Little Red River watershed	Number of NWQI implementation watersheds Amount of BMPs implemented	All surface waters meet water quality standards Reduced pollutant loads from implementation watershed
	Regional Conservation Partnership Program (NRCS)	2014	Expected to continue indefinitely	At least one new RCPP proposed or active in Little Red River watershed	Number of RCPP projects Amount of BMPs implemented	
	Arkansas Waterfowl Rice Incentive Conservation Enhancement (AGFC)	2019	Unknown	Increased winter flooding of rice fields in recommended subwatersheds	Acres of rice fields flooded	Reduce sediment and nutrient loads from Little Red River subwatersheds
	Partners for Fish and Wildlife Program (USFWS)	1988	Expected to continue indefinitely	Increased implementation of BMPs in recommended subwatersheds	Amount of BMPs implemented	All surface waters meet water quality standards Reduce pollutant loads from Little Red River subwatersheds
	State Acres for Wildlife Enhancement Initiative (FSA)	2007	Expected to continue indefinitely	At least one proposal submitted for the Little Red River watershed	Number of proposals submitted Number of proposals funded Amount of BMPs implemented	All surface waters meet water quality standards
	Stream Barrier Removal at Arlberg and Lyadisk (Arkansas Stream Heritage Program)	2018	2024	Barrier removals complete	Barriers removed	Improve instream habitat
	Conservation Reserve Program (FSA)	1985	Expected to continue indefinitely	At least one new easement in a recommended subwatershed	Acres of easements Amount of BMPs implemented on easements	All surface waters meet water quality standards Reduce pollutant loads from Little Red River subwatersheds
	Conservation Stewardship Program (NRCS)	2008	Expected to continue indefinitely	Increased implementation of BMPs in recommended subwatersheds	Amount of BMPs implemented	All surface waters meet water quality standards Reduce pollutant loads from Little Red River subwatersheds
	Two Forks Stream Restoration, Phase III	2015	Unknown	Evaluation of need for Phase III	Decision whether or not to proceed Project funded Amount of BMPs implemented	All surface waters meet water quality standards Reduce sediment inputs to Greers Ferry Lake Improve instream habitat
	Wetlands and Riparian Zones Tax Credit Program (NRD)	1995	Expected to continue indefinitely	At least one application for tax credit in Little Red River watershed	Number of applications for tax credit Amount of land with tax credit applied	All surface waters meet water quality standards Improve instream habitat
	Technical assistance	varies	Expected to continue indefinitely	Assistance provided in recommended subwatersheds	Number of contacts Number of plans prepared Amount of BMPs implemented	All surface waters meet water quality standards Reduce pollutant loads from Little Red River subwatersheds

Table 5.11. Proposed implementation schedule for Little Red River watershed management plan (continued).

Activity	Action (Lead)	Start	Anticipated Completion	2028 Milestones	Indicator	Long Term Goal
Evaluate	State Biennial Water Quality Assessment (DEQ)	1980s	Expected to continue indefinitely	EPA approved final impaired waters lists for 2024 and 2026	Attaining and non-attaining waterbodies in the Little Red River watershed	All water quality criteria met in all monitored waterbodies in the Little Red River watershed
	Track implementation of BMPs in Little Red River watershed	2024	Expected to continue indefinitely	Information for 2024 – 2028 compiled	Amount of BMPs implemented	All water quality criteria met in monitored waterbodies Reduce pollutant loads to impaired waterbodies
	Track education and outreach (implementation lead)	2024	2028	Information for 2024 – 2028 compiled	Amount of events Amount of documents Amount of people attended or reached	All water quality criteria met in monitored water bodies Threatened and endangered species stable
	Track monitoring (implementation lead)	2024	2028	Information for 2024 – 2028 compiled	Number of sampling locations Number of sampling events Parameters analyzed Species surveyed	All water quality criteria met in monitored water bodies Threatened and endangered species stable
	Evaluation of watershed management plan (implementation lead)	2028	2028	Data needed for evaluation compiled	Evaluation completed Evaluation made public	All water quality criteria met in monitored water bodies Threatened and endangered species stable
Update watershed management plan	Public meetings (implementation lead)	2027	2028	Begin planning public meetings	Number of meetings Number of attendees	Stakeholder input to water and water quality management
	Update watershed management plan (implementation lead)	2028	2030	Initiate preparations for update	Updated watershed management plan complete and approved by NRD and EPA Recommended subwatersheds identified Stakeholders involved	Maintain watershed management plan as a living document that reflects stakeholder interest and concerns related to protecting and improving water quality in the Little Red River watershed

6.0 IMPLEMENTATION COSTS, BENEFITS, AND AVAILABLE ASSISTANCE

This section characterizes costs and benefits associated with implementation of the Little Red River watershed management plan and identifies potential sources of technical and financial assistance for implementing this plan.

6.1 Implementation Cost Estimates

Estimates of costs for implementing activities identified in this watershed management plan are provided below. Actual costs may differ from these estimates.

6.1.1 Existing Monitoring

The costs of existing routine water quality and biological monitoring in the Little Red River watershed are included in agency budgets.

6.1.2 Proposed Special Studies

The cost of sampling new water quality monitoring stations for Fourteen Mile Creek and Little Red River would depend on who conducts the sampling and analysis. The cost of sample analysis by a commercial laboratory for DEQ standard parameters is estimated to be around $800 per sample in 2023. EQIP fiscal year 2023 reimbursements for installing edge of field monitoring systems (practice 201) range from $20,000 to $30,000, with another $2,000 to $30,000 a year to collect and analyze data (NRCS 2022a).

6.1.3 Nonpoint Source Pollution Management

The cost of implementing BMPs to reduce nonpoint source pollution can be variable, depending on materials markets and site conditions (e.g., slope, soil type). Table 6.1 lists available cost information for selected BMPs identified in Section 4.7. While NRCS EQIP reimbursement allocations do not reflect the actual cost of implementing the practice, they provide an idea of relative costs of the shown BMPs. In addition, the Illinois River Watershed Partnership reports that costs for septic tank remediation projects through their Septic Tank Remediation Program have ranged from $2,500 to almost $500,000, with an average around $11,000 (44 projects 2021-2022) (L. Kindberg, IRWP, personal communication 2/10/2023).

Table 6.1. EQIP reimbursements and reported implementation costs for selected nonpoint source pollution BMPs applicable in the Little Red River watershed.

Practice (NRCS ID Number)	Unit	2023 EQIP (non-HU*) 75% reimbursement per unit[a]	Unit Costs from Other Sources
Fence (382)	Feet	$2.08-$3.22	$2.15-$2.60[b]
Watering facility <5,000 gallons (614)	Gallons	$0.63-$3.92	--
Watering facility, fountain (614)	Each	$980.47	$2,000-$10,000[b]
Watering facility (614)	Each	-	$256.02-$1,065.39[j]
Livestock pipeline (516)	Feet	$1.60-$4.50	--
Riparian forest buffer plants (391)	Each	$0.92-$1.71	--
Hardwood riparian forest buffer with forgone pasture income (391)	Acres	$371.41	--
Hardwood riparian forest buffer with forgone crop income (391)	Acres	$601.50	--
Riparian forest buffer establishment & maintenance (391)	Acres	--	$218- $7,112[b-e]
Riparian herbaceous buffer (390)	Acres	$209.10-$222.35	$168- $400[b]
Prescribed grazing, medium intensity (528)	Acres	$31.00	$30-$70[f], $15.45[j]
Grazing management, design & implementation, <501 ac (159)	Each	$1,227.36 - $1,534.20	--
Comprehensive nutrient management plan, planning < 300 animal units (102)	Each	$3,841.80-$4,897.70	--

Table 6.1. EQIP reimbursements and reported implementation costs for selected nonpoint source pollution BMPs applicable in the Little Red River watershed. (continued).

Practice (NRCS ID Number)	Unit	2023 EQIP (non-HU*) 75% reimbursement per unit[a]	Unit Costs from Other Sources
Comprehensive nutrient management plan, planning and implementation, non-dairy/ livestock (101)	Each	$4,995.15 - $7,127.69	--
Nutrient management design & implementation, cropland <=100 acres (157)	Each	$2,433.38-$4,055.63	--
Nutrient management, basic (590)	Acres	$6.60 - $28.02	--
Heavy use area protection (561)	Square feet	$0.52 - $3.65	--
Filter strip (393)	Acres	$166.66-$201.72	--
Filter strip with forgone income (393)	Acres	$486.94 - $521.99	--
Bioretention basins (rain gardens)	Square foot	--	$3-$15[g]
Cover crops (340)	Acres	$59.88-$80.50	$15-$78[h]
Residue and tillage management, reduced till (345)	Acres	$19.00	--
Residue and tillage management, no-till (329)	Acres	$15.38	--
Soil testing for nutrient management (217)	Sample	$318.51-$609.69	--
Streambank and shoreline protection (580)	Linear foot	$11.83-$253.08	--
Streambank/channel restoration	100 feet		$30,000[i]
Critical area planting (342)	Acre	$333.21-$919.84	--
Field border (386)	Acre	$91.61-$662.67	--
Grassed waterway (412)	Acre	$1,150.42	--
Waste storage facility, dry stack (313)	Square foot	$2.80-$6.57	--
Sediment basin (350)	Cubic yards	$1.60-$4.65	--
Vegetated treatment area (635)	Acres	$1,678.45-$10,618.12	--

HU = historically underserved producers
a (NRCS 2022a), avg farm size 192 ac Cleburne, 213 White
b (Lynch & Tjaden 2000)
c (Butler & Long 2005)
d (Whitescarver 2013)
e (Washington State University 2006)
f (Undersander, et al. 2002)
g http://raingardenalliance.org/what/faqs
h (Myers, Weber and Tellatin 2019)
i (E. Powers, AGFC, personal communication, 9/20/2022)
j (Christianson 2020)

Table 6.2 provides examples of estimated potential relative costs for implementation of selected BMPs in the pasture-dominant recommended subwatersheds of Little Red River to achieve load reduction targets. Cost estimates are not listed for the Fourteen Mile Creek or Overflow Creek subwatersheds because this plan does not specify load reduction targets for those subwatersheds. Table 6.3 lists estimated potential relative costs for implementation of selected BMPs in the Big Mingo Creek subwatershed. Note that the estimated costs in Tables 6.2 and 6.3 have been rounded to two significant digits. The BMPs amounts listed in Table 6.3 are not expected to achieve the total nitrogen load reduction target for this subwatershed, because nitrogen reduction efficiencies for these BMPs are less than the load reduction target. It is possible that the load reduction target may be reached by implementing several of these BMPs in combination. Appendix K provides a detailed description of how these costs were calculated.

Table 6.2. Estimated costs for reducing nonpoint source pollutant loads from pasture-dominant recommended subwatersheds of Little Red River.

HUC12		Little Red River-Cedar Branch		Ten Mile Creek Headwaters		Ten Mile Creek Outlet		Little Red R
BMPs		**Amount**	**Estimated cost ($1,000)**	**Amount**	**Estimated cost ($1,000)**	**Amount**	**Estimated cost ($1,000)**	**Amount**
Prescribed grazing		4,173 acres	$170	4,418 acres	$200	5,760 acres	$230	8,087 acres
Watering facility		139 facilities	$170	147 facilities	$180	192 facilities	$230	270 facilities
Pasture stream access control (stream fencing)		205,392 feet	$880	179,520 feet	$770	227,040 feet	$980	290,928 feet
Pasture forested riparian buffer		1,546 acres	$1,200	1,389 acres	$1,100	1,676 acres	$1,300	3,236 acres
Pasture herbaceous riparian buffer		1,546 acres	$430	1,389 acres	$390	1,676 acres	$470	3,236 acres
Pasture nutrient management plan		43 plans	$180	92 plans	$290	121 plans	$390	107 plans
Pasture management suite		24 operations	$790	42 operations	$1,400	55 operations	$1,800	46 operations
Septic system remediation		1 or 2 systems	$11-$22	9 systems	$100	10 systems	$110	27 systems

Table 6.3. Estimated costs for reducing total nitrogen load from Big Mingo Creek subwatershed.

BMPs	Amount	Estimated cost ($1,000)
Septic system remediation	6 systems	$66
Cropland forested riparian buffer	1,737 acres	$1,400
Cropland herbaceous riparian buffer	1,737 acres	$490
Cropland nutrient management plan	66 plans	$210
Cover crop	3,522 acres	$350
Conservation tillage	3,797 acres	$76
Cover crop + conservation tillage	3,522 acres	$420

6.2 Benefits of Practices

While there are costs associated with implementing BMPs, as noted in Section 6.1, there are also benefits. These include direct economic benefits to the producers implementing BMPs, as well as benefits that are more difficult to quantify economically both to the producer implementing practices, as well as to society.

Benefits that humans receive from nature are called ecosystem services. These services have been grouped into four categories: provisioning, regulating, cultural, and supporting (see Section 5.1.2.2). Provisioning services refer to the materials used by humans that are provided by nature, including, food, fiber, wood, and minerals. Regulating services refer to the benefits nature provides by regulating or contributing to air quality, soil fertility, flood control, and pollination. Supporting services refer to providing habitat for plants and animals and maintaining genetic diversity. Cultural services refer to non-material benefits from nature including aesthetic enjoyment, inspiration, emotional well-being, spirituality, and cultural identity.

BMPs recommended for the Little Red River watershed are expected to improve the health of ecosystems and their ability to provide services. In some cases, this can result in economic benefits that can be quantified relatively easily. In other cases, the benefits are more difficult to quantify economically. Examples of economic and non-material benefits of recommended BMPs are provided below.

6.2.1 Economic Benefits

While not all ecosystem services improved by BMPs have directly marketable economic value, there have been assessments of economic benefits of a number of practices. Economic benefits from BMPs occur due to improved livestock and crop production; reduced need for inputs such as fertilizer, pesticides, fuel, and labor; and additional opportunities for income-producing activities, such as hunting leases. Table 6.4 summarizes economic benefits associated with the BMPs recommended for Little Red River watershed. Note that economic benefits have been associated with most, but not all, of the recommended practices. Much of the information in this table is based on the NRCS 2022 Conservation Practice Physical Effects tool (https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/econ/tools/?cid=nrcs143_00

9740). Other information sources include studies by USGS, NRCS, USDA, and other researchers (NRCS 2006, USGS and USDA 2018, Zeckoski, Benham and Lunsford 2012).

One concern with stream exclusion fencing is damage to fences from debris carried by floods, requiring repeated maintenance or replacement. Virtual fencing for cattle is an alternative method of controlling cattle that is generating a lot of interest and shows good potential (Smith Thomas 2021). Use of this technology would eliminate the cost of replacing stream-side fences damaged by flooding.

6.2.2 Other Benefits

BMPs also improve ecosystem services in ways that do not translate well into direct economic benefits. Table 6.5 lists examples of ecosystem service provided by BMPs recommended for the Little Red River watershed. Specific BMPs proposed for the Little Red River recommended subwatersheds are listed in Table 6.6 along with the non-material environmental benefits that accrue from the implementation of these practices.

Table 6.4. Summary of economic benefits associated with recommended BMPs for the Little Red River watershed.

Practice	Increased cattle production	Decreased fuel use/cost	Decreased fertilizer use/cost	Decreased labor cost	Decreased pesticide use/cost	Increased crop production	Increased honey production	Additional income from hunting lease	Additional income from timber production	Decreased damage *
Nutrient management plans			X							
Prescribed grazing	X				X					X
Alternative water supply	X									X
Access control/stream crossing	X				X					X
Forested riparian buffer					X			X	X	X
Herbaceous riparian buffer					X		X	X		X
Filter strip										X
Vegetated treatment area										X
Heavy use area protection										X
Sediment basin										X
Critical area planting					X					X
Waste storage facility										
Cover crops		X	X		X	X	X	X		X
Conservation tillage		X		X		X		X		X
Winter flooding for waterfowl								X		X

* from erosion/soil loss

Table 6.5. Examples of ecosystem service benefits associated with BMPs recommended for Little Red River watershed that don't translate well into direct economic benefits.

Ecosystem service benefit	Description of how practice results in benefit
Erosion control	Practice reduces erosion.
Aquatic habitat	Practice provides or improves habitat for aquatic animals, e.g., by reducing water temperature, providing structure or organic matter inputs, or restoring more natural hydrology.
Nutrient cycling	Practice reduces nutrient losses from fields or encourages chemical transformation to non-bioavailable forms.
Carbon storage	Practice increases soil organic matter and vegetation growth that increase removal of greenhouse gases from atmosphere and regulate climate.
Soil health	Practice adds organic matter to soils, increases infiltration, reduces compaction, and improves soil structure and soil health.
Water purification	Practice increases water filtering through soils and vegetative/organic debris, or water contaminants are stored in plant matter.
Waterfowl habitat	Practice increases or improves available waterfowl habitat.
Other Wildlife habitat	Practice increases or improves habitat for pollinators and other beneficial insects, sport birds (other than waterfowl), sport game, and other wildlife.

Table 6.6. Environmental benefits associated with implementing selected agriculture BMPs in the Little Red River watershed.

Practice	Erosion control	Aquatic habitat	Nutrient cycling	Carbon sequestration	Soil health	Water purification	Waterfowl habitat	Other wildlife habitat
Nutrient management plan			X					
Prescribed grazing	X		X	X	X	X		
Alternative water supply	X	X	X					
Access control/stream crossing	X	X	X					
Forested riparian buffer	X	X	X	X	X	X		X
Herbaceous riparian buffer	X		X	X	X	X		X
Filter strip	X		X	X	X	X		X
Vegetated treatment area	X		X	X	X	X		X
Heavy use area protection	X				X			
Sediment basin	X					X		
Critical area planting	X		X	X	X			X
Waste storage facility			X					
Cover crops	X		X	X	X	X		X
Conservation tillage	X		X	X	X	X		
Winter flooding for waterfowl	X		X				X	

6.3 Technical Assistance

This section describes programs that can provide technical assistance for implementation of the activities recommended in this plan. The programs described here are examples. This is not intended to be a complete listing of all available programs that can provide technical assistance.

6.3.1 Monitoring

Agencies and universities conducting water quality monitoring generally have their own technical resources. Technical assistance for volunteer water quality monitoring programs is available through the AGFC Stream Habitat Program.

6.3.2 Information and Education

Information for and assistance with education and outreach activities is available through the Arkansas Environmental Education Association (Project WET), AGFC (Project WILD), Watershed Conservation Resource Center, Arkansas Cooperative Extension Service, and others. Resources are also available from EPA through the Nonpoint Source Outreach Toolbox (http://cfpub.epa.gov/npstbx/index.html).

Arkansas Cooperative Extension Service implements stormwater education programs required by municipal storm runoff NPDES permits in Northwest and Southeast Arkansas (UofA Cooperative Extension Service 2018). Information and education sources related to public education about urban stormwater are available on the Arkansas Cooperative Extension Service website, https://www.uaex.uada.edu/environment-nature/water/stormwater/default.aspx.

The Arkansas Cooperative Extension Service and NRD together implement the Arkansas Watershed Steward Program. This program includes training that outreach professionals and educators can use to educate and recruit farmers to play more active roles in watershed management and their communities.

6.3.3 Implementing BMPs

There are agencies and organizations that provide technical assistance for installing, operating, and maintaining s identified for the recommended subwatersheds. Examples are summarized in Table 6.7 and discussed below.

6.3.3.1 County Conservation Districts

Conservation Districts for the counties in the Little Red River watershed are active in nonpoint source management within the watershed. They work with NRCS to provide technical support to landowners, including information and guidance about BMPs for protecting soil and water resources, including benefits, costs, installation, operation, and maintenance.

Table 6.7. Examples of sources of technical assistance available for implementing BMPs in the Little Red River watershed.

BMPs	AR Department of Agriculture Forestry Division	AR Department of Agriculture Natural Resources Division	AR Game and Fish Commission	AR Soil Health Alliance	Cooperative Extension Service	County Conservation Districts	Ducks Unlimited	EPA	Farm Services Agency	NRCS	National Sustainable Agriculture Information Service	Sustainable Agriculture Education Programs	The Nature Conservancy	US Fish and Wildlife Service	USDA Wildlife Services
Developed Areas															
Address excessive waste from urban wildlife			X												X
Bank stabilization, channel restoration*			X					X		X			X	X	
Bioretention (rain gardens)					X			X							
Detention basins								X							
Environmentally Sensitive Maintenance of unpaved roads	X	X						X					X		
Fix sewer collection leaks								X							
Media filters								X							
Proper disposal of pet wastes					X			X							
Remediate failing septic systems								X							
Remove illicit wastewater discharges								X							
Retention ponds								X							
Riparian buffers	X		X		X			X		X			X		
Wetland basins								X							
Pasture and Haylands															
Access control/stream crossing					X	X				X	X				
Alternative water supply						X				X					
Conservation easements									X	X	X		X	X	
Critical area planting						X				X					
Filter strip						X			X	X					
Heavy use area protection					X	X				X					
Nutrient management plans						X				X		X			
Prescribed grazing					X	X				X	X	X			
Riparian buffers	X		X		X	X			X	X	X		X	X	
Sediment basin						X				X					
Vegetated treatment area						X				X					
Waste storage facility						X				X					
Croplands															
Conservation easements							X		X	X	X			X	
Cover crops				X	X	X				X	X	X			
Filter strip						X			X	X					
Nutrient management plans						X				X		X			
Reduced/no till				X	X	X				X	X	X			
Riparian buffers			X		X	X			X	X	X		X	X	
Winter flooding for waterfowl			X		X	X	X			X					

6.3.3.2 U of A Division of Agriculture

The UofA Cooperative Extension Service provides technical assistance through a range of programs and services including testing of manure, hay, soil, and water; assistance with cropland, pasture, and livestock management; and field days and on-farm demonstrations. Cooperative Extension Service also maintains an extensive library of up-to-date, research-based fact sheets, applied research publications, and manuals and guidelines that address both agricultural and urban BMPs. The experiment station and Discovery Farm programs of the UofA Division of Agriculture generate, interpret, and distribute information and technology useful to farmers in Arkansas. Arkansas Cooperative Extension Service is also partnering with NRD to provide training in water quality management through the Arkansas Watershed Steward Program.

6.3.3.3 Arkansas Game and Fish Commission

Through the AGFC Private Lands Program and Acres for Wildlife Program, Private Lands Biologists can provide technical assistance to volunteer landowners and tenants with managing their lands to improve both upland and aquatic wildlife habitat, in working pastures and haylands, farm ponds, and in set-aside areas like riparian areas and crop field borders. Management actions that improve wildlife habitat usually also reduce nonpoint source pollution and improve water quality. AGFC is working with the National Bobwhite Conservation Initiative to help restore quail habitat in Arkansas. The majority of the Little Red River watershed is classified as having a medium to high quail restoration potential (Jackson, et al. 2015). Van Buren County and White County are part of the AGFC Central Focal Landscape for Bobwhite quail restoration, and Stone County is part of the North Focal Landscape for this effort (AGFC n.d.).

Through the Stream Habitat Program and Coldwater Habitat Program, AGFC can provide technical assistance to riparian landowners and stream users in planning, designing, and implementing streambank stabilization projects to reduce erosion, and sediment and turbidity in streams. AGFC can also assist landowners with identifying and obtaining necessary permits and identifying additional potential sources of financial assistance. These programs are available to non-agriculture landowners (E. Powers, AGFC, personal communication, 9/20/2022). The

Coldwater Habitat Program focuses on the Greers Ferry Lake tailwaters and trout waters areas of the Little Red River.

6.3.3.4 NRD

NRD houses the Arkansas Unpaved Roads Program. This program provides training in Environmentally Sensitive Road Maintenance and conducts demonstrations of road maintenance techniques that reduce water quality and other environmental impacts of unpaved roads (NRD 2020b). NRD also partners with Arkansas Cooperative Extension Service to provide training through the Arkansas Watershed Stewardship Program.

6.3.3.5 Arkansas Department of Agriculture Forestry Division

Arkansas Department of Agriculture Forestry Division (Forestry Division) provides education and planning assistance to private landowners with timberland management. This can include guidance on riparian area management, construction and maintenance of runoff control waterbars on unpaved roads, and assistance with prescribed burning. The Forestry Division also assists landowners with locating contractors to implement unpaved road and timberland BMPs, and with finding programs to provide financial assistance with implementation of BMPs (S. Bennet, Forestry Division, personal communication, 9/20/2022).

6.3.3.6 USDA Natural Resources Conservation Service and Farm Services Agency

The NRCS offers several programs to help landowners address natural resources concerns related to cropland, livestock, and pasture management. NRCS conservationists and specialists at county field service centers can work with farmers on resource assessments of pastures and fields, designing practices, developing management plans, and can provide guidance on implementation, and maintenance of implemented practices. Technical assistance is available for a variety of cropland and pasture practices through the NRCS County Service Centers, through NRCS programs such as Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP) (NRCS 2022b). FSA also provides technical assistance for planning and implementing habitat improvement on Conservation Reserve Program (CRP) lands (FSA 2021b).

6.3.3.7 Sustainable Agriculture Education Programs

The Sustainable Agriculture Research and Education program (SARE) and National Sustainable Agriculture Information Service (ATTRA) (both funded by USDA) support farmers, researchers, and educators exploring practices that improve farm stewardship and profitability, and the vigor of farm communities. These programs emphasize outreach and distribution of the results of program research. This information is available from websites and includes a variety of print and electronic materials appropriate for producers (http://www.southernsare.org/About-Us, www.attra.ncat.org). On-site technical assistance is also available from ATTRA (ATTRA 2018).

6.3.3.8 US Environmental Protection Agency

The EPA website provides access to information on a variety of water quality subjects, including management measures for agriculture, unpaved roads, and developed areas. Specific information sources available through the EPA website include the Watershed Academy (https://www.epa.gov/watershedacademy/online-training-watershed-management), Nonpoint Source Pollution (https://www.epa.gov/nps), and Green Infrastructure (https://www.epa.gov/green-infrastructure) webpages.

6.3.3.9 US Fish and Wildlife Service

Through its Partners for Fish and Wildlife program, the USFWS provides technical assistance to private landowners on projects to protect, improve, or restore native habitats. Assistance is available for designing, installing, and maintaining habitat-enhancing projects, including restoration of riparian habitats, wetlands, and native grasslands, and removal of stream barriers. The USFWS can also assist with locating funding for implementation and provide information to landowners about the Safe Harbor Agreements for endangered species in the Little Red River watershed.

6.3.3.10 The Nature Conservancy

The Nature Conservancy has developed Bluffton Preserve in the watershed that showcases BMPs like Ecologically Sensitive Road Maintenance, prescribed fire, and riparian buffers. The Nature Conservancy also has experience with streambank and channel restoration and assisted with restoration of the Clinton Ditch in the upper watershed.

6.3.3.11 Other Non-government Interest Groups

There are a number of non-government organizations that provide technical assistance related to practices that reduce nonpoint sources of pollution. For example, Ducks Unlimited can provide technical assistance to cropland farmers related to managing croplands to support migrating waterfowl, including winter flooding of fields (Ducks Unlimited n.d.). The Arkansas Soil Health Alliance provides technical assistance primarily related to cover crops and conservation tillage. Quail Forever and Pheasants Forever can provide technical assistance related to creating and improving habitat for quail and pheasants on private lands (Pheasants Forever n.d.).

6.4 Financial Assistance

This section describes programs that can provide financial assistance for implementation of the activities recommended in this plan. The programs described here are examples. This is not intended to be a complete listing of all available programs that can provide funding assistance.

6.4.1 Monitoring

DEQ, USACE, and USGS have funded water quality monitoring projects in the Little Red River watershed. USGS flow and/or water quality monitoring sites could be added in the watershed if a local entity would provide funds. The USGS 104b grant program funds water research projects of the Arkansas Water Resources Center.

SARE grants are available to support agricultural research, which could include water quality and/or biological monitoring. SARE has funded 49 research grants totaling over

$5,000,000 in Arkansas since 1988. In 2021, one Research and Education grant was awarded in Arkansas (Pollock 2021).

The AGFC Stream Habitat program has supported water quality monitoring by Stream Teams in the Little Red River watershed. This program can provide funding for volunteer monitoring programs through mini grants. State Wildlife Grant funding from AGFC can be used for biological surveys. In 2019, federal funds totaling $597,556 were distributed as State Wildlife Grants in Arkansas (https://www.agfc.com/en/wildlife-management/awap/state-wildlife-grants/).

NRD can assist with funding water quality monitoring projects through the 319 Program. In fiscal year 2022, NRD allocated approximately 55% of Nonpoint Source Program federal funds to monitoring projects (NRD 2023a).

NRCS EQIP and RCCP programs can fund monitoring of water quality (practice 201) and habitats for rare or declining species (practice 643).

6.4.2 Information and Education

AGFC offers Conservation Education Grants. These grants are funded using fines money from convictions for breaking Arkansas game laws (https://www.agfc.com/en/education/classroom/conservation-education-grants/). For the 2021-2022 school year, over $769,000 was available for Conservation Education Grants https://www.agfc.com/en/news/2021/09/01/agfc-aedc-offer-nearly-770000-for-education-grants-from-wildlife-fines/).

Projects funded through the NRD Nonpoint Source Pollution Management Program (Section 319[h] funds) usually include an education and outreach component. State funds available through the Arkansas Unpaved Roads Program are used primarily for outreach and education of county road crews (T. Wentz, personal communication, 9/20/2022). In 2020, approximately $100,000 were spent on outreach projects in Arkansas through the 319 Grant Program (NRD 2022a). The annual allocation for the Arkansas Unpaved Roads Program is $3,000 (T. Wentz, personal communication, 9/20/2022).

SARE offers Research and Education grants. Since 1988 SARE has funded 37 Research and Education grants in Arkansas, totaling over $5,000,000. In 2021, one Research and Education grant was awarded in Arkansas (Pollock 2021).

Projects funded through NRCS and Farm Services Agency cost-share and easement programs are often used as demonstrations in NRCS and Conservation District outreach and education programs.

The EPA provides grants for environmental education (https://www.epa.gov/education/grants).

There are several private foundations that fund education, which may include environmental education. Examples include the Arkansas Forestry Association Education Foundation. In addition, organizations can often find local businesses or organizations to sponsor information and education activities, such as painting storm drains, festivals, and clean-up days.

6.4.3 Implementing BMPs

Over the years, funding has been provided for implementation of BMPs in the Little Red River watershed. There are a number of agencies and programs that offer financial assistance for implementation of nonpoint source pollution BMPs recommended for the Little Red River watershed. The majority of these are grant programs, many of which require matching funds from the grant recipient. In addition, there are low interest loan programs and at least one tax incentive program that address practices that reduce nonpoint source pollution. Table 6.8 lists BMPs for the recommended subwatersheds along with examples of funding sources. It is notable that many federal assistance programs are seeing reductions in available funds. However, it is also notable that use of many of these BMPs can improve the bottom line for producers or communities (see Section 6.2), providing an incentive for implementation even without financial assistance.

Table 6.8. Examples of sources of financial assistance available for BMPs in the Little Red River watershed.

Lead Organization	**AGFC**			**NRD**					**NRCS**			**Farm Services Agency**	**US Fish and Wildlife Service**
Program name	Acres for Wildlife	Waterfowl Rice Incentive Conservation Enhancement	Stream Habitat Program	Nonpoint Source Grant Program (Section 319 and Infrastructure funds)	Arkansas Unpaved Roads Program	State Revolving Loan Fund	Agriculture Water Quality Loan Program	Arkansas Wetland and Riparian Zones Tax Credit Program	Conservation Stewardship Program	Environmental Quality Incentive Program	Working Lands for Wildlife – Bobwhite Quail	Conservation Reserve Programs	Partners for Fish and Wildlife
Who can receive funds	Individuals	Individuals	Individuals	Cities, counties, organizations	Counties	Communities, utilities	Individuals	Individuals	Individuals	Individuals	Individuals	Individuals	Individuals, organizations
Focus area within Little Red River watershed	Pastures	Rice fields in White County within 10 miles of WMA or NWR	Streams & rivers & adjacent land	All	County unpaved roads	All	Agricultural land	Wetlands and riparian zones	Agriculture and forest lands	Agriculture and forest lands	Searcy and Stone County pastures	Agriculture lands	Wetlands, prairies, habitat for species of concern
Developed Areas													
Bank stabilization, channel restoration*			X	X				X	X	X			X
Bioretention (rain gardens)				X		?							
Detention basins				X		?							
Environmentally Sensitive Maintenance of unpaved roads				X	X								
Fix sewer collection leaks						X							
Media filters				X		?							
Proper disposal of pet wastes													
Remediate failing septic systems													
Remove illicit wastewater discharges						X							
Retention ponds				X		?							
Riparian buffers			X	X				X					X
Wetland basins				X		?							

Table 6.8. Examples of sources of financial assistance available for management practices in the Little Red River watershed (continued).

Lead Organization	AGFC			NRD					NRCS			Farm Services Agency	US Fish and Wildlife Service
Pasture and Haylands													
Access control/stream crossing				X			X		X	X			
Alternative water supply				X			X		X	X			
Conservation easements	X										X	X	
Critical area planting	X			X						X			
Filter strip				X					X	X		X	
Heavy use area protection				X						X			
Nutrient management plans				X						X			
Prescribed grazing				X			X		X	X	X		
Riparian buffers			X	X				X	X	X		X	X
Sediment basin				X						X			
Vegetated treatment area				X					X	X			
Waste storage facility				X			X			X			
Croplands													
Conservation easements											X	X	
Cover crops				X					X	X			
Filter strip				X					X	X		X	
Nutrient management plans				X					X	X			
Reduced/no till				X			X		X	X	X		
Riparian buffers			X	X				X	X	X		X	X
Winter flooding for waterfowl		X		X					X	X		X	

*This BMP and financial incentives can also be used on streams associated with haylands, pasture, and croplands.

6.4.3.1 USDA NRCS

There are NRCS programs active in Arkansas that provide funding assistance for development and installation of nonpoint source pollution BMPs that are applicable to the recommended subwatersheds of Little Red River. These programs provide funding to individuals rather than groups or organizations. This includes the Conservation Stewardship Program, Regional Conservation Partnership Program (RCPP), and EQIP. In these programs, a cost-share is usually required to implement practices. There are no active RCPP projects in the Little Red River watershed for fiscal year 2023, although in the past there have been RCPP projects in this watershed (see Table 5.5) (NRCS 2023). Two special initiatives under EQIP that are of interest in the Little Red River watershed are the Working Lands for Wildlife and National Water Quality Initiatives. Searcy and Stone Counties are focus areas for Bobwhite Quail under the Working Lands for Wildlife Initiative. Overflow Creek subwatershed is a planning watershed for the fiscal year 2023 EQIP National Water Quality Initiative (NRCS 2022c). Information about NRCS financial assistance programs, including application deadlines, cost-share requirements, and funding caps, is available online (https://www.nrcs.usda.gov/conservation-basics/conservation-by-state/arkansas) or from a local USDA service center, local conservation district, or local cooperative extension agents.

During the period 2008-2020 NRCS provided around $3,000,000 in funding assistance to producers in the Little Red River watershed through these programs (Christianson 2021). Table 6.9 shows funding provided to individuals in Arkansas through NRCS programs active in the Little Red River watershed during the 2021 fiscal year (Arkansas NRCS 2021). Table 6.9 also shows the 2023 fiscal year national budget for NRCS conservation programs that can provide funding assistance in the Little Red River watershed.

Table 6.9. Funding provided to individuals in Arkansas through NRCS programs during the 2021 fiscal year *(Arkansas NRCS 2021)* and 2023 fiscal year national budgets for selected NRCS conservation programs *(USDA 2022)*.

Program	FY2021 Funds distributed, millions of dollars	FY2023 budget, millions of dollars
Agricultural Conservation Easement Program	$19.9	$450
Conservation Stewardship Program	$22.9	$1,000
Environmental Quality Incentives Program	$51.5	$2,025
Regional Conservation Partnership Program	$0.8	$300

6.4.3.2 Farm Services Agency

The FSA administers the CRP. Through this land conservation program, landowners receive yearly rental payments for land enrolled in the program. CRP land contracts typically are for 10 to 15 years. Marginal pasture and cropland along streams that can be used for establishment of riparian buffers can be eligible for CRP enrollment. In addition to rental payments, the FSA may pay up to 50% of eligible costs for establishing vegetation on eligible lands, and an additional cost share for Climate-Smart practices that reduce greenhouse gases or increase carbon sequestration (FSA 2022a). Additional financial incentives are available in Arkansas for conservation easements through the FSA CLEAR30, State Acres for Wildlife Enhancement, and Farmable Wetlands Program (FSA 2022b, FSA 2022c, FSA 2022d). The fiscal year 2023 national budget for CRP is $2,475 million (USDA 2022).

6.4.3.3 US Fish and Wildlife Service

The USFWS Partners for Fish and Wildlife program can provide funding assistance to individuals for installing nonpoint source BMPs. Funding from this program may require cost-share (USFWS 2022b). The 2022 fiscal year national budget for the Partners for Fish and Wildlife program is $67,397 million (USFWS 2022c). It is unknown how much of these funds will be available for projects in Arkansas, or in the Little Red River watershed.

6.4.3.4 NRD

NRD manages the Arkansas Section 319 grant program. This program provides cost-share grants to non-profit groups, organizations, communities, and academic institutions for projects related to reduction, control, or abatement of nonpoint source pollution. Eligible projects can include implementation of BMPs on pastures or croplands, as well as stormwater management and low impact development practices in developed areas, and Environmentally Sensitive Maintenance of unpaved roads. Organizations seeking grants must be capable of implementing projects and are typically required to provide a minimum of 43% non-federal matching contributions. Through the NRD Title X program, conservation districts can distribute Section 319 grant funds to individuals. In 2021, around $2.25 million in federal funds were spent on implementing BMPs in Arkansas through the Clean Water Act Section 319 grant program (NRD 2022a). The 2023 fiscal year national budget for the Section 319 grant program is $189 million (EPA 2022).

NRD manages the state Agriculture Water Quality Loan Program and State Revolving Loan Funds. Through the Agriculture Water Quality Loan Program landowners can borrow up to $250,000 at a low interest rate to implement BMPs to reduce NPS (NRD 2021b). Communities and utilities can borrow money from the State Revolving Loan Fund at a low interest rate to fund improvements to drinking water and wastewater systems and infrastructure, BMPs that protect drinking water sources, and projects that use or promote green approaches and facilitate compliance with the Clean Water Act (NRD 2023b, NRD 2022c).

Funds from the Arkansas Unpaved Roads Program can be used for installation of BMPs as part of demonstration projects for Environmentally Sensitive Road Maintenance. Funding for this program is $3,000 annually (T. Wentz, NRD, personal communication, 9/20/2022).

Funds for wetland and riparian area restoration projects are available through the Arkansas Wetland & Riparian Zones Tax Credit Program. Through this program, landowners can receive up to $50,000 in tax credits, up to $5,000 per year over 10 years, as reimbursement for the expenses of wetland or riparian restoration projects.

6.4.3.5 Arkansas Game and Fish Commission

AGFC has programs that can provide financial assistance with implementation of BMPs. The Acres for Wildlife program can provide up to $5,000 to landowners to assist with establishment of plantings for wildlife habitat. Stream Habitat program funds can be used to provide up to $5,000 to private landowners to assist with streambank stabilization or riparian restoration projects (https://www.agfc.com/en/education/onthewater/streamteam/habitat-restoration/). Landowners with fields within 10 miles of waterfowl-focused wildlife management areas or national wildlife refuges (such as Bald Knob National Wildlife Refuge) can earn up to $150/acre through the Arkansas Waterfowl Rice Incentive Conservation Enhancement (WRICE) program. Landowners with Wetland Reserve Easements are also eligible for this program. Through WRICE, landowners can earn incentive payments for managing their rice fields after harvest to provide waterfowl habitat and allowing waterfowl viewing and hunting (permits required) on their land (https://www.agfc.com/en/wildlife-management/private-lands-program/wrice/).

In addition, AGFC can help landowners identify and apply for other state and federal funding incentives for implementation of BMPs that reduce nonpoint source pollution (J. Sheehan, AGFC, personal communication, 2/24/2023).

6.4.3.6 Arkansas Department of Health

The Arkansas Department of Health can provide financial assistance to drinking water utilities to implement NPS BMPs that protect or improve water quality in drinking water sources. In the Little Red River watershed, drinking water sources are Greers Ferry Lake and the Little Red River downstream of Greers Ferry Lake.

6.5 Non-monetary Assistance with BMP Implementation

Agencies, organizations, and individuals can support implementation of nonpoint source BMPs in ways other than providing funds or technical assistance. One way is through offering free or low-cost materials. Examples are listed below.

- The AGFC competitive program under their Acres for Wildlife initiative provides warm season grass seed to landowners who want to establish native habitat for bobwhite quail (AGFC 2021b).
- The Arkansas Forestry Commission, Arkansas Urban Forestry Council, and National Arbor Day Foundation provide low-cost or free tree seedlings.
- Quail Forever has a crew that can perform prescribed burns on private lands free of charge. This crew has performed prescribed burns in the Little Red River watershed (R. Denier, Quail Forever, personal communication, 9/20/2022).

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APPENDIX A

Examples of Entities Active in the Little Red River Watershed with Vision, Mission, and Goals for the Watershed

1.1 US Army Corps of Engineers

The US Army Corps of Engineers (USACE) manages Greers Ferry Lake, its dam and tailwaters, and associated federal lands. Through this management, USACE fulfills its responsibilities mandated by federal laws to “preserve, conserve, restore, maintain, manage, and develop” the waters, lands, and associated resources under their jurisdiction as part of the Greers Ferry Lake project. They manage the reservoir, tailwater, and associated federal lands for the following purposes:

- Flood control,
- Hydropower generation,
- Recreation,
- Forestry,
- Soil conservation,
- Fish and wildlife habitat, and
- Water supply (US Army Corps of Engineers Little Rock District, 2019).

Management of the reservoir and associated USACE lands is guided by Water Control Manuals, a Master Plan, and a Shoreline Management Plan.

The Greers Ferry Lake tailwaters are part of the USACE and The Nature Conservancy Sustainable Rivers Program. The purpose of this program is to “find more sustainable ways to manage river infrastructure to optimize benefits for people and nature.” (The Nature Conservancy, 2020).

1.2 US Department of Agriculture Forest Service

The US Department of Agriculture Forest Service (USFS) manages the Ozark National Forest, part of which is located in the upper Little Red River watershed. National level management goals for the National Forests are 1) reduce the risk from catastrophic wildfires, 2) reduce impacts from invasive species, 3) provide outdoor recreation opportunities, 4) help meet energy resource needs, and 5) improve watershed condition. The vision for the Ozark National Forest is provided below.

“The Ozark-St. Francis National Forests are a model of sustainable ecosystem management, featuring healthy ecosystems that provide a balanced and sustainable flow of goods and services for a growing, diverse population. The OSFNFs landscapes are characterized by healthy ecosystems, clean water, scenic beauty, and biological diversity. Forest watersheds are managed to provide many benefits including flood protection and quality drinking water for downstream communities, as well as protection of wildland urban interface areas from wildfire. They offer a haven for native plants and animals and provide irreplaceable habitat for threatened, endangered, and sensitive species. The National Forests provide a wide variety of recreation opportunities. The approximately 1.2 million acres within the OSFNFs serve as an outdoor classroom, a "living laboratory" for learning about our natural and cultural heritage and the importance of conservation.” (USFS, 2005).

1.3 US Fish and Wildlife Service

The US Fish and Wildlife Service manages the Bald Knob National Wildlife Refuge in the Little Red River watershed. The “primary objective of refuge is to provide habitat for migratory waterfowl.” (US Fish and Wildlife Service, 2022).

US Fish and Wildlife Service is also part of a Safe Harbor Agreement active in the watershed to protect the endangered Yellowcheek Darter and Rabbitsfoot mussel, and their habitats (https://www.federalregister.gov/documents/2014/11/18/2014-27232/amendment-of-a-joint-programmatic-candidate-conservation-agreement-with-assurances-and-safe-harbor). Recovery plans have been prepared for the Yellowcheek Darter and Speckled Pocketbook. The Yellowcheek Darter recovery plan has the goal “ensure the long-term viability of Yellowcheek Darter in the wild to the point that it can be delisted from the *Federal list of Endangered and Threatened Wildlife* (50 CFR 17.11)” (Yellowcheek Darter Recovery Team, USFWS Arkansas Ecological Field Office, 2018). The Speckled Pocketbook recovery plan goal is “reclassify the speckled pocketbook mussel, *Lampsilis streckeri*, from endangered to threatened status” (Stewart, 1992).

1.4 USDA Natural Resources Conservation Service

The Natural Resources Conservation Service (NRCS) is a partner in the Safe Harbor Agreement active in the Little Red River watershed to protect endangered species (see Section 1.3). In addition, NRCS is assessing two tributary subwatersheds of the Little Red River downstream of Greers Ferry Lake, Ten Mile Creek and Overflow Creek, for the National Water Quality Initiative (T. Wentz, NRD, personal communication 9/20/2022). NRCS has developed nutrient and sediment reduction goals for the National Water Quality Initiative (NRCS, 2022).

1.5 Arkansas Game and Fish Commission

All or part of six Wildlife Management Areas (WMAs) owned and managed by the Arkansas Game and Fish Commission (AGFC) are located within the Little Red River watershed. The mission of the AGFC is "to conserve and enhance Arkansas's fish and wildlife and their habitats while promoting sustainable use, public understanding and support." The WMAs in the watershed are managed to provide diverse and good quality habitat to support a variety of wildlife, while also providing opportunities for public use of these lands, including hunting and fishing. A master plan has been developed for the Scott Henderson Gulf Mountain WMA (Arkansas Game and Fish Commission, 2018).

AGFC also works to maintain the sport fishery in Greers Ferry Lake. A fishery management plan was completed for the reservoir in 2021. The goal of this plan is to "[p]romote and enhance angling opportunities at Greers Ferry Lake with an emphasis on managing sport fish populations that are acceptable to a majority of anglers under existing and future fishing pressure." (Bly, Schroeder, & Horton, 2021). This plan outlines objectives and management activities to achieve this goal. Management activities include monitoring sport fish populations, stocking sport fish species, and projects to enhance sport fish habitat. The plan also includes consideration of stocking native crayfish.

In addition, AGFC maintains a trout fishery in the Little Red River downstream of Greers Ferry Lake (tailwaters). A fishery management plan has been prepared for the Greers Ferry Lake tailwaters. The mission statement from this plan is "Maintain and enhance the recreational fishing experience on Greers Ferry Tailwater (GFTW) by improving angler access, assessing

physical habitat for fish, and providing more quality trout fishing opportunities while maintaining satisfactory angler catch rates." (AGFC Trout Management Program and Trout Habitat Program, 2017). This plan outlines six goals to accomplish the mission as well as objectives and activities to achieve the goals. The trout fishery is maintained primarily through stocking programs and fishing regulations (e.g., catch limits and length requirements).
The AGFC is also a part of the Safe Harbor Agreement active in the watershed (see Section 1.3).

1.6 The Nature Conservancy

The mission of The Nature Conservancy is "To conserve the lands and waters on which all life depends." The Nature Conservancy is a partner in the Safe Harbor Agreement active in the Little Red River watershed to protect endangered species (see Section 1.3). The Nature Conservancy was also a partner in the Archey Fork restoration project at Clinton, and created the nearby Bluffton Nature Preserve on the Archey Fork upstream of Clinton. The Nature Conservancy also partners with the USACE to guide management of the GFTW as part of the Sustainable Rivers Program (see Section 1.1).

1.7 Little Red River Foundation

The mission of the Little Red River Foundation is "To preserve, protect, and enhance the Little Red River's natural beauty and resources, while improving the overall fishing experience so that it earns a reputation as one of the top ten fisheries in the United States." (Little Red River Foundation, 2021). The goals and focus of the foundation are primarily the Little Red River trout fishery downstream of Greers Ferry Lake.

1.8 Save Greers Ferry Lake

The mission of Save Greers Ferry Lake is "To protect Greers Ferry Lake for present and future generations" (Save Greers Ferry Lake, Inc., 2019). The focus of this organization is "activities that might adversely impact Greers Ferry Lake".

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APPENDIX B

Summaries of Public Meeting Attendees

Little Red River Watershed Management Plan
First Set of Stakeholder Meetings – June 14, 2022

Meeting Attendance Summary

Upper Little Red River Meeting in Clinton

Organization / Category	Number of attendees
Arkansas Game and Fish Commission	3
US Fish and Wildlife Service	1
University of Arkansas Cooperative Extension Service	1
USDA Natural Resources Conservation Service	2
Arkansas Dept. of Agriculture Natural Resources Division	5
Interested citizens	1
FTN Associates	3

Lower Little Red River Meeting in Searcy

Organization / Category	Number of attendees
Arkansas Game and Fish Commission	2
University of Arkansas Cooperative Extension Service	1
USDA Natural Resources Conservation Service	4
Arkansas Dept. of Agriculture Natural Resources Division	2
County Conservation Districts	1
National Wild Turkey Federation	1
Little Red River Foundation	1
Interested citizens	1
US Senator’s Office	1
FTN Associates	3

Little Red River Watershed Management Plan
Third Stakeholder Meeting – September 20, 2022

Meeting Attendance Summary

Organization	Number of attendees
Arkansas Department of Health	1
Arkansas Department of Agriculture Forestry Division	1
Arkansas Department of Agriculture Natural Resources Division	2
Arkansas Game and Fish Commission	1
FTN Associates	2
Office of US Representative French Hill	1
Office of US Senator John Boozman	1
Quail Forever	1
US Fish and Wildlife Service	1

Little Red River Watershed Management Plan
Fourth Stakeholder Meeting – March 14, 2023

Meeting Attendance Summary

Organization	Number of attendees
Arkansas Department of Health	1
Arkansas Department of Agriculture Forestry Division	1
Arkansas Department of Agriculture Natural Resources Division	5
Arkansas Game and Fish Commission	2
Arkansas Conservation Districts	1
Little Red River Foundation	1
FTN Associates	2
H2Ozarks	1
Office of US Representative	1
Office of US Senator	2
Private citizens	1
US Fish and Wildlife Service	2

APPENDIX C

Inventory of Historic Water Quality Monitoring in Little Red River Watershed

Table 1. Active and historical surface water quality monitoring stations in the Little Red River watershed (US WQ portal).

Entity	Station ID	Stream	County	Location	Start Year	End Year	Number of dates
USGS	7075270	South Fork of Little Red River	Van Buren	South Fork of Little Red River near Scotland, AR	2011	2021	132
USGS	7075300	South Fork of Little Red River	Van Buren	South Fork of Little Red River at Clinton, AR	1978	1979	7
USGS	7075000	Middle Fork of Little Red River	Van Buren	Middle Fork of Little Red River at Shirley, AR	1945	1979	22
USGS	7076000	Little Red River	Cleburne	Little Red River near Heber Springs	1945	2020	738
USGS	7075900	Greers Ferry Lake	Cleburne	Greers Ferry Lake near Heber Springs, AR	1973	2020	8380
USGS	7076530	Big Creek	White	Big Creek near Letona, AR	1964	1988	2
USGS	7076634	Little Red River	White	Little Red River at Judsonia, AR	1974	1987	109
USGS	7075240	South Fork of Little Red River	Van Buren	South Fork Little Red River U.S. WMA	2013	2014	7
USGS	7075245	Brushy Fork	Van Buren	Brushy Fork nr Austin, AR	2013	2014	4
USGS	7075250	South Fork of Little Red River	Van Buren	S Fk Lit Red Riv us of Gulf Mt WMA nr Scotland, AR	2011	2017	77

Table 1. Active and historical surface water quality monitoring stations in the Little Red River watershed (US WQ portal). (Continued)

Entity	Station ID	Stream	County	Location	Start Year	End Year	Number of dates
USGS	7075250	South Fork of Little Red River	Van Buren	S Fk Lit Red Riv us of Gulf Mt WMA nr Scotland AR	2011	2017	77
USGS	7075252	Unnamed Trib A	Van Buren	Unnamed Trib A in Gulf Mt WMA nr Scotland, AR	2013	2014	36
USGS	7075255	Cedar Creek	Van Buren	Cedar Creek in Gulf Mt WMA nr Scotland, AR	2012	2014	44
USGS	353308092400901		Van Buren	Floater Isco Gulf Mnt, AR 01	2013	2013	29
USGS	7075390	Archery Creek	Van Buren	ARCHEY CREEK AT CLINTON, ARK.	1964	1988	4
USGS	7075490	Greers Ferry Lake	Van Buren	GREERS FERRY LK NR CLINTON AR	1975	1995	176
USGS	7075602	Greers Ferry Lake	Van Buren	GREERS FERRY LK NR CHOCTAW AR	1975	1995	166
USGS	7075500	South Fork of Little Red River	Van Buren	SOUTH FORK LITTLE RED RIVER NR CLINTON, ARK.	1945	1954	15
USGS	7074990	Middle Fork of Little Red River	Van Buren	MIDDLE FORK LITTLE RED RIVER NR SHIRLEY, ARK	1974	1994	246

Table 1. Active and historical surface water quality monitoring stations in the Little Red River watershed (US WQ portal). (Continued)

Entity	Station ID	Stream	County	Location	Start Year	End Year	Number of dates
USGS	7075638	Greers Ferry Lake	Cleburne	GREERS FERRY LAKE AT HIGDEN, ARK	1974	1995	385
USGS	7075025	Greers Ferry Lake	Cleburne	GREERS FERRY LK @ BRUSH CK	1975	2015	564
USGS	7075627	Greers Ferry Lake	Cleburne	Greers Ferry Lake nr Greers Ferry, AR	2009	2015	994
USGS	7075215	Greers Ferry Lake	Cleburne	GREERS FERRY LK AB HILL CK AR	1975	2015	763
USGS	7075660	Greers Ferry Lake	Cleburne	GREERS FERRY LK NR EDEN ISLE AR	1975	1995	261
USGS	7075870	Greers Ferry Lake	Cleburne	GREERS FERRY RES ABOVE HEBER SPRINGS ARK	1967	1967	1
USGS	7075200	Devils Fork Little Red River	Cleburne	DEVILS FORK LITTLE RED RIVER NR BROWNSVILLE, ARK.	1968	1988	4
USGS	7076200	Little Red River	Cleburne	LITTLE RED RIVER NR WILBURN, ARK.	1974	1983	122
USGS	7076510	Big Creek	Cleburne	BIG CREEK NEAR PANGBURN, ARK.	1964	1988	3
USGS	7076626	Little Red River	White	LITTLE RED RIVER ABOVE SEARCY, AR	1983	1993	94

Table 1. Active and historical surface water quality monitoring stations in the Little Red River watershed (US WQ portal). (Continued)

Entity	Station ID	Stream	County	Location	Start Year	End Year	Number of dates
USGS	7076632	Little Red River	White	LITTLE RED RIVER BELOW SEARCY, AR	1983	1994	136
USGS	351627091333201		White	WLDLF SANCT SITE 1 (BALD KNB NWR) NR BALD KNOB, AR	2008	2008	1
ADEQ	ARK0170	South Fork Little Red River	Van Buren	South Fork Little Red River on County Road 23	2011	2021	104
ADEQ	LWHI010A	Greers Ferry Lake	Cleburne	Greers Ferry Lake near Dam	1999	2019	37
ADEQ	LWHI010B	Greers Ferry Lake	Cleburne	Greers Ferry Lake above Narrows near Higden	1999	2019	36
ADEQ	UWAFK01	Archey Fork Little Red River	Van Buren	Archey Fork Little Red River in Clinton on Hwy. 65	1994	2016	44
ADEQ	UWBCK01	Big Creek	Cleburne	Big Creek off Hwy. 110 near Hiram, 1 mi. above Little Red R.	1993	2013	42
ADEQ	UWBCK02	Big Creek	Cleburne	Big Creek at end of Big Creek Tr. on Big Creek Natural Area	2010	2013	20
ADEQ	UWBCK03	Big Creek	Cleburne	Big Creek at low-water bridge crossing at Warren Mountain Rd	2010	2013	22
ADEQ	UWBCK04	Big Creek at low-water	Cleburne	Big Creek at low-water bridge crossing at County Rd. 75	2010	2013	20

Table 1. Active and historical surface water quality monitoring stations in the Little Red River watershed (US WQ portal). (Continued)

Entity	Station ID	Stream	County	Location	Start Year	End Year	Number of dates
ADEQ	UWBCR01	Big Creek	White	Big Creek at Hwy. 16 near Letona	1993	2003	21
ADEQ	UWBHC01	Beech Fork	Cleburne	Beech Fork at co. rd. 2.5 mi S.E. Hwy. 263 near Woodrow	1994	2016	16
ADEQ	UWMFK01	Middle Fork Little Red River	Searcy	Middle Fork Little Red River at Hwy. 65 near Leslie, AR	1994	2016	56
ADEQ	UWOFC01	Overflow Creek	White	Overflow Creek at Huntsman Rd 1 1/2 i. SE of Judsonia	1993	2018	38
ADEQ	UWSRR01	South Fork Little Red River	Van Buren	South Fork Little Red River at Hwy. 95 near Scotland, AR	1994	2019	47
ADEQ	UWSRR02	South Fork Little Red River	Van Buren	South Fork Little Red River at Hwy. 65 at Clinton, Arkansas	1994	2019	56
ADEQ	UWTMC01	Tenmile Creek	White	Tenmile Creek at CR157/Sunny Dale Rd 3 mi. N of Providence	1993	2019	37
ADEQ	WHI0041	Little Red River	Cleburne	Little Red River on Swinging Bridge Dr near Heber Springs	2010	2010	1
ADEQ	WHI0043	Middle Fork Little Red River	Van Buren	Middle Fork Little Red River on SR9/Guffy Ln near Shirley	1990	2021	402
ADEQ	WHI0059	Little Red River	White	Little Red River on SR367/Lakeshore Dr S of Searcy	1990	2021	395

Table 1. Active and historical surface water quality monitoring stations in the Little Red River watershed (US WQ portal). (Continued)

Entity	Station ID	Stream	County	Location	Start Year	End Year	Number of dates
ADEQ	WHI0075	Little Red River	White	Little Red River on CW Rd AB Searcy AR	1990	1993	32
ADEQ	WHI0150	Wilburn Creek	Cleburne	Wilburn Creek off School Ln NE of Heber Springs	1998	1998	1
ADEQ	WHI0153	Meadow Creek	Stone	Meadow Creek on CR2 W of Fox	1998	2006	24
ADEQ	WHI0176	Cove Creek	Searcy	Cove Creek off Hwy 65 S of Leslie	2004	2015	20
ADEQ	WHI0177	Middle Fork Little Red River	Searcy	Middle Fork Little Red River off Hwy 65 S of Leslie	2004	2016	30
ADEQ	WHI0178	Middle Fork Little Red River	Stone	Middle Fork Little Red River on CR1 near Alberg	2004	2008	23
ADEQ	WHI0179	Weaver Creek	Van Buren	Weaver Creek on CR16 S of Shirley	2004	2006	21
ADEQ	WHI0180	Little Red Creek	Searcy	Little Red Creek on CR40 S of Marshall	2004	2006	15
ADEQ	WHI0181	Middle Fork Little Red River	Searcy	Middle Fork Little Red River on CR39 S of Marshall	2004	2006	20
ADEQ	WHI0182	Cove Creek	Searcy	Cove Creek off Hwy 65 at Leslie	2004	2006	17
ADEQ	WHI0183	City of Leslie WWTP on	Searcy	City of Leslie WWTP on Hwy 65 S of Leslie	2004	2006	20
ADEQ	WHI0184	Pee Dee Creek	Van Buren	Pee Dee Creek on SR9 NE of Clinton	2005	2006	4
ADEQ	WHI0185	Archey Fork	Van Buren	Archey Fork on CR255/Watergate Rd S of Botkinburg	2005	2006	5

Table 1. Active and historical surface water quality monitoring stations in the Little Red River watershed (US WQ portal). (Continued)

Entity	Station ID	Stream	County	Location	Start Year	End Year	Number of dates
ADEQ	WHI0186	Archey Fork	Van Buren	Archey Fork on CR166 SW of Dennard	2005	2006	5
ADEQ	WHI0187	Turkey Creek	Stone	Turkey Creek on CR21/Hanover Rd N of Prim	2005	2016	19
ADEQ	WHI0188	Beech Fork Creek	Cleburne	Beech Fork Creek on Everett Ridge Rd E of Woodrow	2005	2006	5
ADEQ	WHI0189	South Fork Little Red River	Van Buren	South Fork Little Red River on CR9/Low Gap N of Scotland	2005	2008	7
ADEQ	WHI0190	South Fork Little Red River	Van Buren	South Fork Little Red River off SR95 E of Walnut Grove	2005	2006	5
ADEQ	WHI0194	Archey Fork Little Red River	Van Buren	Archey Fork Little Red River on CR79 NW of Clinton	2008	2008	2
ADEQ	WHI0195	Archey Fork Little Red River	Van Buren	Archey Fork Little Red River on CR166 SW of Dennard	2008	2016	16
ADEQ	WHI0199	Mingo Creek	White	Mingo Creek on Lone Star Rd E of Searcy	2011	2013	10
EPA	NRS18_AR_10016	Little Red River	Cleburne	East of Heber Springs	2018	2018	1
EPA	NARS-OWW04440-0197	Elbow Creek	Independence		2004	2004	1
EPA	NARS-OWW04440-0709	Rocky Branch	Cleburne		2004	2004	1
EPA	FW08AR070	Coon Creek	White		2009	2009	1

Table 2. Active and historical groundwater quality monitoring stations in the Little Red River watershed (DEQ online database, USGS NWIS).

Entity	Station ID	Aquifer	Well Name	County	Depth, feet	Start Year	End Year	Number of dates
USGS	331724091351401	Alluvial aquifers	08N05W30BCC1	White	75	1983	1983	1
USGS	351148091324301	Mississippi River Valley alluvial aquifer	07N05W28DBC1	White	48	1955	1955	1
USGS	351203091335701	Mississippi River Valley alluvial aquifer	07N05W29CAB1	White	NR	1955	1955	1
NRD	351323091300901	Mississippi River Valley alluvial aquifer	07N05W14DD1	White	80	1995	1995	1
USGS	351344091411501	Mississippi River Valley alluvial aquifer	07N06W18DBC1	White	34	1955	1955	1
USGS	351348091380701	Mississippi River Valley alluvial aquifer	07N06W15CAA1	White	26	1955	1955	1
USGS	351349091433601	Alluvial aquifers	07N07W14CAB1	White	52	1955	1955	1
USGS	351352091401801	Mississippi embayment aquifer system	07N06W17BDD1	White	217	1954	1954	1
USGS	351401091394801	Mississippi River Valley alluvial aquifer	07N06W17ADB1	White	182	1950	1950	1
USGS	351421091310801	Mississippi River Valley alluvial aquifer	07N05W10DDA1	White	19	1983	1983	1
USGS	351427091310601	Mississippi River Valley alluvial aquifer	07N05W11CBC1	White	25	1982	1982	1
USGS	351507091302901	Mississippi River Valley alluvial aquifer	07N05W02DCC1	White	42	1982	1982	1
USGS	351515091321101	Mississippi River Valley alluvial aquifer	07N05W04DDA1	White	42	1982	1982	1

Table 2. Active and historical groundwater quality monitoring stations in the Little Red River watershed (DEQ online database, USGS NWIS). (Continued)

Entity	Station ID	Aquifer	Well Name	County	Depth, feet	Start Year	End Year	Number of dates
USGS	351530091313401	Mississippi River Valley alluvial aquifer	07N05W03DBB1	White	35	1982	1982	1
USGS	351551091320701	Mississippi River Valley alluvial aquifer	07N05W03BBC1	White	NR	1982	1982	1
USGS	351559091310501	Mississippi River Valley alluvial aquifer	08N05W34DDD1	White	35	1982	1982	1
USGS	351606091423201	NR	08N07W36CCD1	White	141	1955	1955	1
USGS	351616091314501	Mississippi River Valley alluvial aquifer	08N05W34CAC1	White	NR	1982	1982	1
USGS	351625091285701	Mississippi River Valley alluvial aquifer	08N05W36ADD1	White	45	1983	1983	1
USGS	351628091360601	Mississippi River Valley alluvial aquifer	08N06W36CAB1	White	60	1983	1983	1
USGS	351634091371301	Mississippi River Valley alluvial aquifer	08N06W35BCD1	White	65	1983	1983	1
USGS	351636091382201	NR	08N06W34BCD1	White	NR	1983	1983	1
USGS	351640091321601	Mississippi River Valley alluvial aquifer	08N05W33AAD1	White	NR	1982	1982	1
USGS	351640091341401	Mississippi River Valley alluvial aquifer	08N05W32BCB1	White	60	1983	1983	1
USGS	351725091335801	Mississippi River Valley alluvial aquifer	08N06W29BDC1	White	60	1983	1983	1
USGS	351745091323801	Mississippi River Valley alluvial aquifer	08N05W28ABB1	White	NR	1983	1983	1

Table 2. Active and historical groundwater quality monitoring stations in the Little Red River watershed (DEQ online database, USGS NWIS). (Continued)

Entity	Station ID	Aquifer	Well Name	County	Depth, feet	Start Year	End Year	Number of dates
USGS	351754091303501	Mississippi River Valley alluvial aquifer	08N05W23CDA1	White	45	1983	1983	1
USGS	351802091314401	Mississippi River Valley alluvial aquifer	08N05W22CAC1	White	NR	1983	1983	1
USGS	351811091333801	Mississippi River Valley alluvial aquifer	08N05W20DBB1	White	103	1954	1954	1
USGS	351818091323301	Mississippi River Valley alluvial aquifer	08N05W21ACC1	White	34	1983	1983	1
USGS	351818091323302	Mississippi River Valley alluvial aquifer	08N05W21ACC2	White	23	1983	1983	1
USGS	351822091383401	NR	08N06W22BCC1	White	80	1983	1983	1
USGS	351843091391401	NR	08N06W21BAB1	White	35	1983	1983	1
USGS	351849091383601	NR	08N06W16DDD1	White	90	1983	1983	1
USGS	351928091314701	Mississippi River Valley alluvial aquifer	08N05W15BAB1	White	NR	1982	1982	1
USGS	351934091352101	NR	08N06W13AAA1	White	65	1983	1983	1
USGS	351943091302701	Mississippi River Valley alluvial aquifer	08N05W11DBC1	White	60	1983	1983	1
USGS	352008091302901	Mississippi River Valley alluvial aquifer	08N05W11BAD1	White	65	1983	1983	1
USGS	352008091341501	Alluvial aquifers	08N05W07ADA1	White	86	1983	1983	1
USGS	352010091335701	Alluvial aquifers	08N05W08BDB1	White	60	1983	1983	1
USGS	352020091324801	NR	08N05W09BAB2	White	318	1983	1983	1
USGS	352022091324801	Alluvial aquifers	08N05W09BAB1	White	75	1983	1983	1
USGS	352024091315701	Mississippi River Valley alluvial aquifer	08N05W03CCC1	White	78	1983	1983	1

Table 2. Active and historical groundwater quality monitoring stations in the Little Red River watershed (DEQ online database, USGS NWIS). (Continued)

Entity	Station ID	Aquifer	Well Name	County	Depth, feet	Start Year	End Year	Number of dates
USGS	352111091302501	Mississippi River Valley alluvial aquifer	08N05W02ABB1	White	NR	1982	1982	1
USGS	352114091325301	NR	08N05W04BBA1	White	NR	1983	1983	1
USGS	352114091335201	NR	08N05W05BAB1	White	NR	1983	1983	1
USGS	352146091325001	NR	09N05W33BDC1	White	NR	1983	1983	1
USGS	352207091333701	NR	09N05W32ABB1	White	72	1983	1983	1
USGS	353123092002801	NR	10N10W12ABB1	Cleburne	74.9	1960	1960	1
USGS	353219091373601	NR	11N06W34CAA1	Independence	64.5	1964	1964	1
USGS	354055092302001	NR	12N14W17BDD1	Van Buren	NR	1968	1968	1
USGS	354924092325401	St. Peter Sandstone	14N15W26DBC1	Searcy	1,210.00	1957	1957	1
USGS	354924092325402	NR	14N15W26DBC2	Searcy	32	1957	1957	1
USGS	354924092325403	NR	14N15W26DBC3	Searcy	60	1958	1958	1
USGS	355127092340101	Gunter Sandstone Member of Van Buren Formation	14N15W15AAC1	Searcy	3,534.00	1984	1994	2
USGS	353018092283201	Atoka Formation	10N14W15CBB1	Van Buren	NR	2011	2011	1
USGS	353017092282801	Atoka Formation	10N14W15CBA1	Van Buren	NR	2011	2011	1
USGS	353420092490501	Atoka Formation	11N17W29ACD1	Pope	NR	2011	2011	1
USGS	353146092155601	Bloyd Shale	10N12W03CBB1	Van Buren	NR	2011	2011	1
USGS	353449092150901	Bloyd Shale	11N12W22BAA1	Van Buren	NR	2011	2011	1
USGS	353339092315701	Atoka Formation	11N15W25DDB1	Van Buren	NR	2011	2011	1
USGS	353159092343501	Atoka Formation	10N15W03CDB1	Van Buren	NR	2011	2011	1
USGS	353551092183401	Bloyd Shale	11N12W07CDC1	Van Buren	NR	2011	2011	1
USGS	353455092152201	Bloyd Shale	11N12W15CDC1	Van Buren	NR	2011	2011	1
USGS	353507092154701	Bloyd Shale	11N12W16DDA1	Van Buren	NR	2011	2011	1
USGS	353530092210801	Bloyd Shale	11N13W15ADD1	Van Buren	NR	2011	2011	1
USGS	353545092181301	Bloyd Shale	11N12W18ABB1	Van Buren	NR	2011	2011	1
USGS	353532092340801	Bloyd Shale	11N15W15DBD1	Van Buren	NR	2011	2011	1

Table 2. Active and historical groundwater quality monitoring stations in the Little Red River watershed (DEQ online database, USGS NWIS). (Continued)

Entity	Station ID	Aquifer	Well Name	County	Depth, feet	Start Year	End Year	Number of dates
USGS	353544092435701	Bloyd Shale	11N16W18DBC1	Van Buren	NR	2011	2011	1
USGS	353809092185501	Bloyd Shale	12N13W36ADA1	Van Buren	NR	2011	2011	1
USGS	353807092220001	Bloyd Shale	12N13W34BCC1	Van Buren	NR	2011	2011	1
USGS	353727092182001	Bloyd Shale	11N12W06BAD1	Van Buren	NR	2011	2011	1
USGS	353617092184301	Bloyd Shale	11N12W07BCD1	Van Buren	NR	2011	2011	1
USGS	353555092340101	Bloyd Shale	11N15W15AAC1	Van Buren	NR	2011	2011	1
USGS	353717092414301	Bloyd Shale	11N16W04DCB1	Van Buren	NR	2011	2011	1
USGS	353915092190101	Bloyd Shale	12N13W25AAB1	Van Buren	NR	2011	2011	1
USGS	353919092153901	Bloyd Shale	12N12W21DDD1	Van Buren	NR	2011	2011	1
USGS	353923092160101	Bloyd Shale	12N12W21DCB1	Van Buren	NR	2011	2011	1
USGS	353925092225501	Bloyd Shale	12N13W28BBA1	Van Buren	NR	2011	2011	1
USGS	353913092390501	Bloyd Shale	12N16W26ADD1	Van Buren	NR	2011	2011	1
USGS	354044092212901	Bloyd Shale	12N13W15DDD1	Van Buren	NR	2011	2011	1
USGS	354127092180501	Bloyd Shale	12N12W07DBB1	Van Buren	NR	2011	2011	1
USGS	353936092200301	Bloyd Shale	12N13W23DAC1	Van Buren	NR	2011	2011	1
USGS	354123092180601	Cane Hill Member of Hale Formation	12N12W07DBC1	Van Buren	NR	2011	2011	1
USGS	354110092390001	Bloyd Shale	12N16W14ADA1	Van Buren	NR	2011	2011	1
USGS	353934092392401	Bloyd Shale	12N16W26ABA1	Van Buren	NR	2011	2011	1
USGS	354149092193401	Bloyd Shale	12N13W12BBD1	Van Buren	NR	2011	2011	1
USGS	354132092181401	Bloyd Shale	12N12W07BDD1	Van Buren	NR	2011	2011	1
USGS	354142092161501	Bloyd Shale	12N12W09BAC1	Van Buren	NR	2011	2011	1
USGS	354144092163901	Bloyd Shale	12N12W08AAD1	Van Buren	NR	2011	2011	1
USGS	354147092164801	Bloyd Shale	12N12W08AAC1	Van Buren	NR	2011	2015	2
USGS	354139092160601	Bloyd Shale	12N12W09BDA1	Van Buren	NR	2011	2011	1
USGS	354140092182101	Cane Hill Member of Hale Formation	12N12W07BDB1	Van Buren	NR	2011	2011	1
USGS	354336092225101	Cane Hill Member of Hale Formation	13N13W33BBC1	Van Buren	NR	2011	2011	1

Table 2. Active and historical groundwater quality monitoring stations in the Little Red River watershed (DEQ online database, USGS NWIS). (Continued)

Entity	Station ID	Aquifer	Well Name	County	Depth, feet	Start Year	End Year	Number of dates
USGS	354213092194001	Bloyd Shale	12N13W01CBD1	Van Buren	NR	2011	2011	1
USGS	354152092164701	Bloyd Shale	12N12W08AAB1	Van Buren	NR	2011	2011	1
USGS	354329092282701	Bloyd Shale	13N14W33ADC1	Van Buren	NR	2011	2011	1
USGS	354326092290001	Bloyd Shale	13N14W33CAB1	Van Buren	NR	2011	2011	1
USGS	354313092353001	Cane Hill Member of Hale Formation	13N15W33CCA1	Van Buren	NR	2011	2011	1
USGS	354223092382701	Bloyd Shale	12N16W01CDA1	Van Buren	NR	2011	2011	1
USGS	354344092292401	Bloyd Shale	13N14W32AAD1	Van Buren	NR	2011	2011	1
USGS	354345092294701	Bloyd Shale	13N14W32ABC1	Van Buren	NR	2011	2011	1
USGS	354407092284801	Cane Hill Member of Hale Formation	13N14W28DBC1	Van Buren	NR	2011	2011	1
USGS	354358092341001	Bloyd Shale	13N15W27CDD1	Van Buren	NR	2011	2011	1
USGS	354457092340801	Bloyd Shale	13N15W22CDA1	Van Buren	NR	2011	2011	1
USGS	354419092344301	Bloyd Shale	13N15W28DAA1	Van Buren	NR	2011	2011	1
USGS	354429092303201	Bloyd Shale	13N14W30ADA1	Van Buren	NR	2011	2011	1
USGS	354357092334701	Bloyd Shale	13N15W27DDC1	Van Buren	NR	2011	2011	1
USGS	354521092331401	Bloyd Shale	13N15W23BDB1	Van Buren	NR	2011	2011	1
USGS	354515092331601	Bloyd Shale	13N15W23BDC1	Van Buren	NR	2011	2011	1
USGS	354617092315601	Cane Hill Member of Hale Formation	13N15W13BAD1	Van Buren	NR	2011	2011	1
USGS	353449092151001	Bloyd Shale	11N12W22BAA2	Van Buren	NR	2011	2011	1
USGS	353601092254601	NR	11N14W13ABB01	Van Buren	NR	2015	2015	1
USGS	352208091493901	NR	09N08W35BDB01	White	NR	2015	2015	1
USGS	352340091430601	NR	09N07W23ACD01	White	NR	2015	2015	1
USGS	352634091583201	NR	09N09W05ADA01	Cleburne	NR	2015	2015	1
USGS	352822091490601	NR	10N08W26ABD01	Cleburne	NR	2015	2015	1
USGS	353422092021001	NR	11N10W23BCB01	Cleburne	NR	2015	2015	1
USGS	351955091421401	NR	08N07W12CAD01	White	NR	2015	2015	1
USGS	353130091391101	NR	10N06W04BCC01	White	NR	2015	2015	1
USGS	353401091415401	NR	11N07W24CBC01	Independence	NR	2015	2015	1
USGS	352212091435601	NR	09N07W34AAB01	White	NR	2015	2015	1
USGS	352701091455701	NR	10N07W32DAD01	White	NR	2015	2015	1
USGS	351616091314502	Mississippi River Valley alluvial aquifer	08N05W34CAC2 HS-02-EC	White	69.5	2019	2019	1

APPENDIX D

Characterization of Current Water Quality in Little Red River Watershed

Measurements of selected parameters of concern collected during the period 2016-2020 by USGS and DEQ are summarized below. The data used for this summary were downloaded in May 2021 from online databases managed by DEQ and USGS (DEQ 2021, USGS 2021) Parameters examined in this section include those related to current assessed water quality impairments; bacteria, pH, alkalinity, turbidity, TSS, suspended sediment, DO, temperature, DO saturation, BOD, and nutrients. Note that when a measurement is reported as not detected, a value equal to half the detection limit has been used in analyses. Also, when multiple results are reported for the same sample date and depth, a single value was derived by averaging the reported values. This average value was used in analyses.

This appendix includes several box and whisker graphs. Box and whisker graphs show the range and distribution of values. They show the minimum and maximum values as well as the 25th percentile, median or 50th percentile, and 75th percentile. Figure 1 illustrates the elements of the box and whisker graphs in this appendix. Note that the interquartile range is equal to the 75th percentile value minus the 25th percentile value.

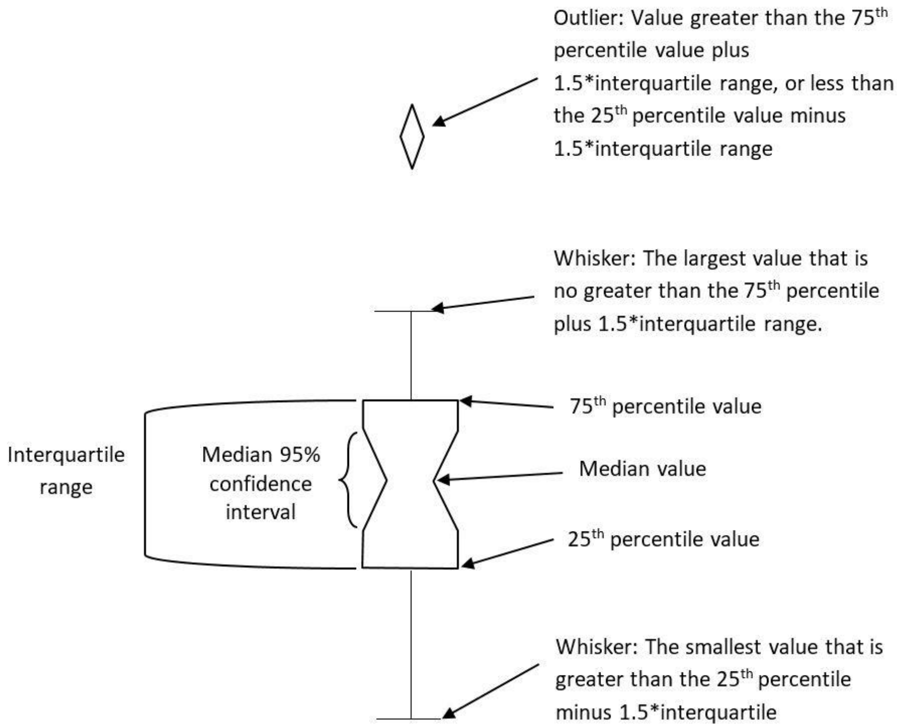

Figure 1. Elements of box and whisker graphs.

1.1 Bacteria Indicator of Pathogens

Bacteria and viruses in water have the potential to infect people who come into contact with the water, making them sick. Historically, water borne pathogens from human and animal waste were responsible for a significant number of human deaths (e.g., typhoid fever). *Escherichia coli* (*E. Coli*) is a group of bacteria that is present in human and animal waste. Certain types of *E. Coli* can make people sick, but primarily *E. Coli* are monitored as an indicator of the presence of human or animal waste. The presence of *E. Coli* above certain levels indicates contamination by human or animal wastes, and the possible presence of other water borne pathogens that could make people sick. Thus, *E. Coli* are used as “pathogen indicator bacteria”.

Table 1 lists summary statistics for *E. Coli* measurements from streams in the watershed during the period 2016-2020. Note that *E. Coli* measurements were not collected at all the stations active during 2016-2020. Locations where more than 25% of *E. Coli* measurements exceed the criteria may be classified as impaired (DEQ 2019). All of the DEQ stations included in Table 1 are located on stream reaches that have been classified as impaired (i.e., unsafe) for primary contact recreation (i.e., swimming) due to high *E. Coli* levels. The stream reaches on which the USGS stations in Table 1 are located are not classified as impaired due to high *E. Coli* levels (DEQ 2020).

Table 1. Summary statistics for stream *E. Coli* measurements during 2016-2020 (stations listed in downstream order, first column is farthest upstream station).

Statistic	07075250	07075270	UWSRR01	UWSRR02	WHI0043	UWTMC01	WHI0059	UWOFC01
Stream ID+	SF	SF	SF	SF	MF	TMC	LRR	OFC
Number of measures	7	29	15	15	15	16	16	11
Minimum value	2	1	2	12	16	36	12	16
25^{th} percentile	22	8	16	24	28	111	39	40
Median	31	18	32	96	36	550	68	60
Mean	267	400	41	245	195	1028	945	575
75^{th} percentile	245	330	54	276	124	1431	1894	282
Maximum	1300	3000	120	1800	1850	5000*	5000*	3375
Primary contact criterion	410	298	298	298	298	410	410	410
Number of values > primary contact criterion	1	8	0	3	1	8	6	3
Percentage of values > primary contact criterion	14%	28%	0	20%	7%	50%	38%	27%
Secondary contact criterion	2050	1490	1490	1490	1490	2050	2050	2050
Number of values > secondary contact criterion	0	3	0	1	1	3	3	2
Percentage of values > secondary contact criterion	0	10%	0	7%	7%	19%	19%	18%

+ LRR = Little Red River, MF = Middle Fork of the Little Red River, OFC = Overflow Creek, SF = South Fork of the Little Red River, TMC = Ten Mile Creek.

* Reported as "too numerous to count".

Figure 2 shows a box and whisker graph of *E. Coli* measurements from the Little Red River watershed during the period 2016-2020. The highest median *E. Coli* value occurs at station UWTMC01 (Ten Mile Creek). Note that, because of the amount of variation in *E. Coli* measurements at all of the stations, this high median value is not statistically significantly different from the median values at the rest of the stations. High *E. Coli* values at UWTMC01 may be the result of agricultural influences. Station UWSRR02 (South Fork of the Little Red River), which has the second highest median *E. Coli* value, is located within the city limits of Clinton and could be influenced by runoff from developed areas. It is upstream of permitted point source discharges that could contribute *E. Coli*. Station WHI0059 (Little Red River) has several *E. Coli* measurements greater than 1,000 cfu/100 mL. It is located downstream of where the majority of runoff from Searcy enters the river, and the outfall of the Searcy municipal wastewater treatment facility. The lowest median *E. Coli* value occurs at station 07075270 (South Fork of the Little Red River, upstream of Station UWSRR02).

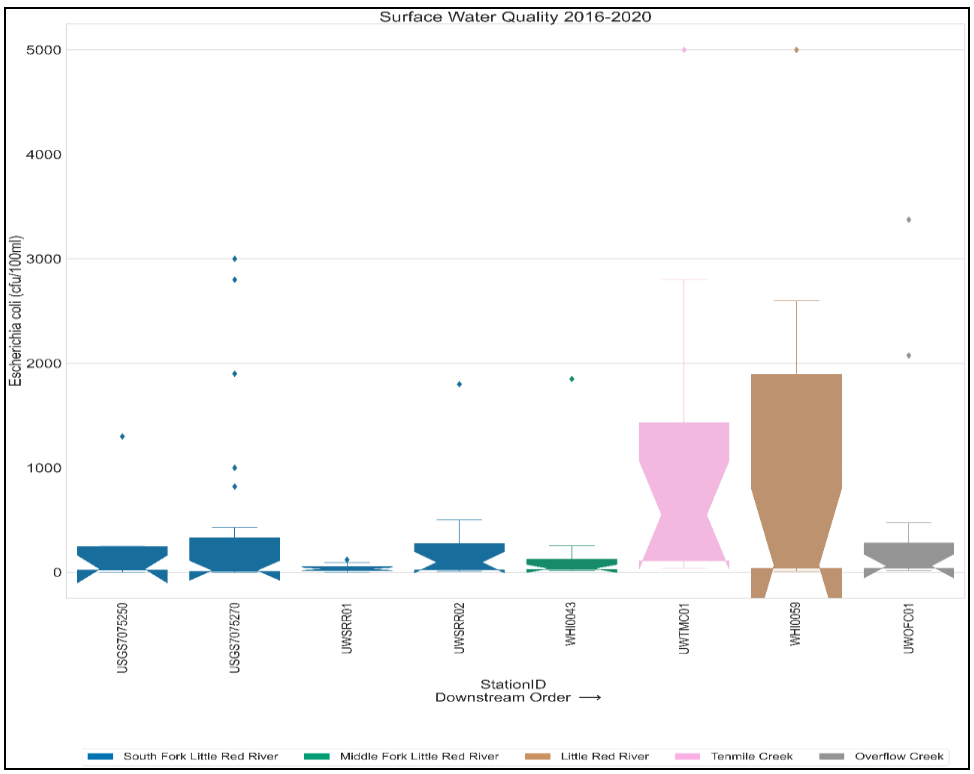

Figure 2. Box and whisker graph of *E. Coli* measurements from stations with more than 10 values from 2016-2020.

1.2 pH

When water is too acidic or too alkaline creatures and plants living in the water can be negatively affected. People who come into contact with water that is too acidic or too alkaline may experience skin reactions or skin damage.

Table 2 lists summary statistics for stream pH measurements from the period 2016-2020. Table 3 lists summary statistics for reservoir pH measurements from the period 2016-2020. Numeric pH criteria for lakes apply to measurements taken from depths less than 1 meter (Arkansas Pollution Control and Ecology Commisison, 2022). Therefore, summary statistics of measurements taken from the epilimnion and depths of 3 feet or less are included in Table 3 and compared to the pH criteria. Note that DEQ station LWHI010A and USGS station 07075900 are both located near the dam. Nine of the 16 stream water quality stations active during 2016-2020 reported pH values below the 6 su minimum pH criterion, as did the Greers Ferry Lake station at the narrows (LWHI010B).

To determine pH impairment of water quality DEQ requires at least 10 measurements. Locations where more than 10% of at least 10 measurements do not meet pH criteria may be classified as impaired (DEQ 2019). At all but one (WHI0043) of the stream stations with more than 10 pH measurements also had more than 10% of the pH measurements less than 6 su (Table 2). The monitoring station in the upper end of Greers Ferry Lake also had more than 10% of pH measurements less than 6 su (Table 3). All epilimnion pH measurements from the two Greers Ferry Lake stations near the dam (LWHI010A and 07075900) meet the water quality criteria. Four of the stream stations with more than 10% of pH measurements less than 6 su are located on reaches of the South Fork Little Red River classified by DEQ as impaired due to low pH levels (DEQ 2020).

Table 2. Summary statistics for stream pH measurements during 2016-2020 (stations listed in downstream order, first row is farthest upstream station).

Station ID	Stream ID+	Number of measures	Minimum Value, su	25th Percentile, su	Median, su	Mean, su	75th Percentile, su	Maximum Value, su	Number of Values do not meet Criteria	Percentage of Values do not meet Criteria
07075250	SF	8	5.2	5.7	5.9	5.9	6.2	6.4	5	-*
07075270	SF	31	5.5	6.2	6.4	6.4	6.6	7.0	6	19%
UWSRR01	SF	15	4.89	6.29	6.41	6.23	6.43	6.70	3	20%
UWSRR02	SF	17	5.17	6.21	6.41	6.30	6.66	6.98	4	24%
WHI0195	AF	1	6.31	-	-	-	-	-	0	-
UWAFK01	AF	3	5.89	-	6.79	6.53	-	6.92	1	-
ARK0170	SF	50	5.53	6.07	6.39	6.35	6.62	7.20	10	20%
UWMFK01	MF	3	6.10	-	6.11	6.38	-	6.92	0	-
WHI0177	MF	2	6.46	-	-	6.97	-	7.48	0	-
WHI0043	MF	74	5.72	7.30	7.61	7.59	8.03	8.63	1	1%
WHI0187	TC	2	6.21	-	-	6.47	-	6.73	0	-
UWBHC01	BF	2	6.55	-	-	6.74	-	6.93	0	-
07076000	LRR	13	6.5	6.7	6.9	6.9	7.0	7.3	0	0
UWTMC01	TMC	16	5.22	5.89	6.24	6.17	6.60	6.90	4	25%
WHI0059	LRR	64	5.17	6.36	6.72	6.68	7.06	8.08	11	17%
UWOFC01	OFC	11	5.23	6.50	6.57	6.43	6.75	6.89	2	18%

+ AF = Archey Fork of the Little Red River, BF = Beech Fork, LRR = Little Red River, MF = Middle Fork of the Little Red River, OFC = Overflow Creek, SF = South Fork of the Little Red River, TC = Turkey Creek, TMC = Ten Mile Creek * DEQ requires at least 10 samples to evaluate pH criteria attainment (DEQ 2019).

Table 3. Summary statistics for Greers Ferry Lake pH measurements from 2016-2020.

Station ID	LWHI010A		07075900		LWHI010B
Sample Location	Epilimnion, thermocline, hypolimnion	Epilimnion	0.4-167 feet	0.4-3 feet	Epilimnion
Number of Measures	50	26	430	18	14
Minimum Value, su	5.51	6.31	6.1	6.4	5.69
25th Percentile, su	6.43	6.51	6.4	7.2	6.26
Median, su	6.79	6.96	6.6	7.7	6.64
Mean, su	6.77	6.90	6.9	7.5	6.58
75th Percentile, su	7.09	7.21	7.2	7.8	6.74
Maximum Value, su	8.16	7.52	9.0	8.1	7.57
Number of Values Not Meet Criteria	-	0	-	0	2
Percent of Values Not Meet Criteria	-	0	-	0	14%

Figure 3 shows a box and whisker graph of pH measurements from monitoring locations in the Little Red River watershed with more than 10 measurements during the period 2016-2020. The graphed station with the lowest median pH is UWTMC01 (Ten Mile Creek). The median pH value at this station is statistically significantly lower than the median pH values at the Little Red River stations downstream of Greers Ferry Lake. However, this median value is not statistically significantly different from the median pH values for most of the stream stations with more than 10 measurements upstream of Greers Ferry Lake. The station with the highest median pH value is WHI0043 (Middle Fork of the Little Red River). The median pH value at this station is statistically significantly higher than the median pH values at all the other stream stations with more than 10 measurements. The median pH value at this station is statistically similar to the median of pH values measured by USGS in the epilimnion of Greers Ferry Lake near the dam (station 07075900).

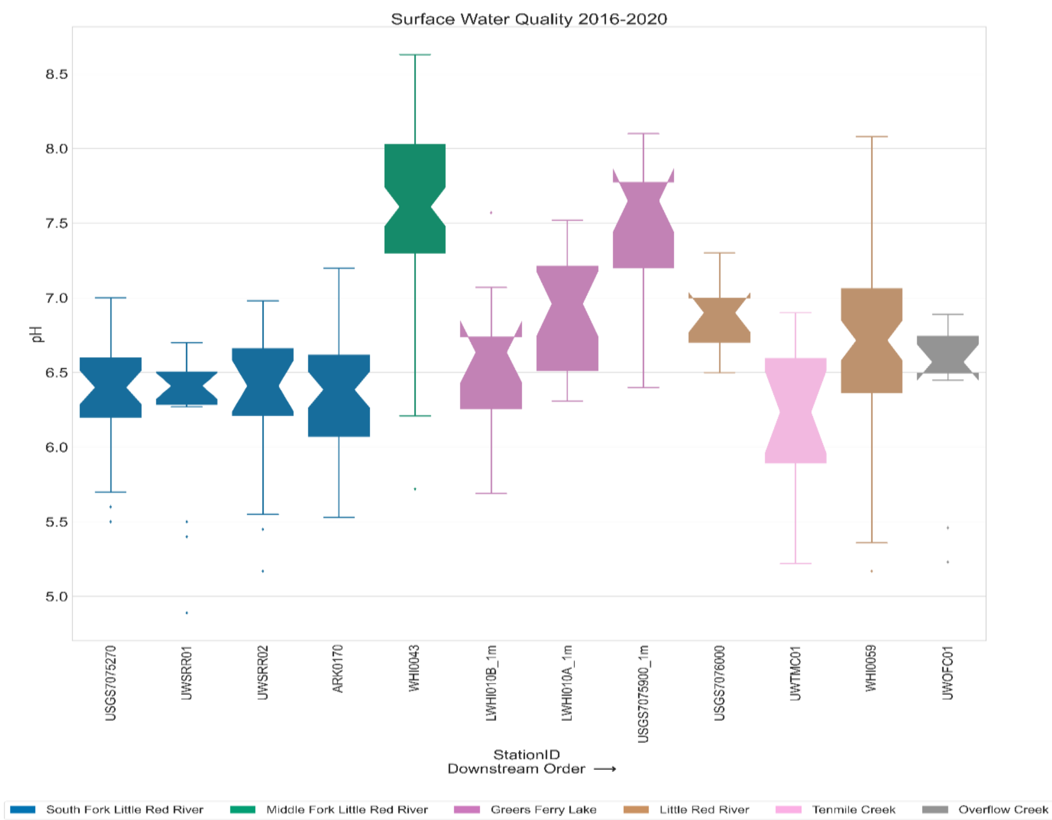

Figure 3. Box and whisker graph of pH measurements from stations with more than 10 values from 2016-2020.

1.3 Alkalinity

Alkalinity is a measure of the ability of water to neutralize acids, also called buffering capacity. Because low pH is an issue in the Little Red River watershed, alkalinity is also characterized. Note that there are no numeric water quality standards for alkalinity. In Arkansas, alkalinity in surface water is typically greater than 100 mg/L as CaCO3. However, in the Boston Mountains, alkalinity in surface water is typically less than 100 mg/L as CaCO3 (Adamski, et al. 1995).

Table 4 lists summary statistics for stream alkalinity measurements from the period 2016-2020. Table 5 lists summary statistics for reservoir alkalinity measurements from the period 2016-2020. As is typical of the Boston Mountains region, alkalinity measurements from the Little Red River watershed are all less than 100 mg/L as CaCO3.

Table 4. Summary statistics for stream alkalinity measurements during 2016-2020 (stations listed in downstream order, first row is farthest upstream station).

Station ID	Stream ID+	Number of measures	Minimum Value, mg/L	25^{th} Percentile, mg/L	Median, mg/L	Mean, mg/L	75^{th} Percentile, mg/L	Maximum Value, mg/L
UWSRR02	SF	2	<6.0	-	-	5.1	-	7.2
WHI0195	AF	1	9.6	-	-	-	-	-
UWAFK01	AF	3	6.4	-	7.5	7.7	-	9.2
ARK0170	SF	50	<6.0	<6.0	10.0	9.9	13.4	20.0
UWMFK01	MF	3	22.1	-	25.7	27.2	-	33.7
WHI0177	MF	2	50.8	-	-	54.7	-	58.6
WHI0043	MF	58	21.4	28.3	32.6	32.8	35.8	53.7
WHI0187	TC	1	<6.0	-	-	-	-	-
UWBHC01	BF	2	18.0	-	-	20.0	-	21.9
WHI0059	LRR	53	3.0	10.2	12.8	13.0	14.6	26.6

Table 5. Summary statistics for Greers Ferry Lake alkalinity measurements from 2016-2020.

Station ID	LWHI010A		LWHI010B
Sample Location	Epilimnion, thermocline, hypolimnion	Epilimnion	Epilimnion
Number of Measures	51	26	14
Minimum Value, mg/L	8.8	10.0	8.1
25th Percentile, mg/L	11.5	11.2	12.7
Median, mg/L	12.4	11.8	13.2
Mean, mg/L	12.7	12.4	13.0
75th Percentile, mg/L	13.4	13.2	14.5
Maximum Value, mg/L	19.1	17.6	17.3

Figure 4 shows a box and whisker graph of alkalinity measurements from surface water monitoring locations in the Little Red River watershed with more than 10 measurements during the period 2016-2020. The station with the lowest median alkalinity is on the South Fork Little Red River, ARK0170. This median value is not statistically significantly different from the median values in the reservoir or in the Little Red River downstream of the reservoir (WHI0059). Both the South Fork Little Red River, and its tributary, Archey Fork, are included on the impaired waters list for low pH, as are segments of the Little Red River associated with station WHI0059 (DEQ 2020). Low alkalinity levels in these streams contributes to the low pH level. The station with the highest median alkalinity is on the Middle Fork Little Red River, WHI0043. The median alkalinity at this station is statistically significantly greater than the median values at the other graphed stations. Note that maximum alkalinity values at all of the Middle Fork Little Red River water quality stations are higher than at stations on other streams (see Table 4). This is at least part of the reason pH levels in the Middle Fork Little Red River meet the water quality criteria.

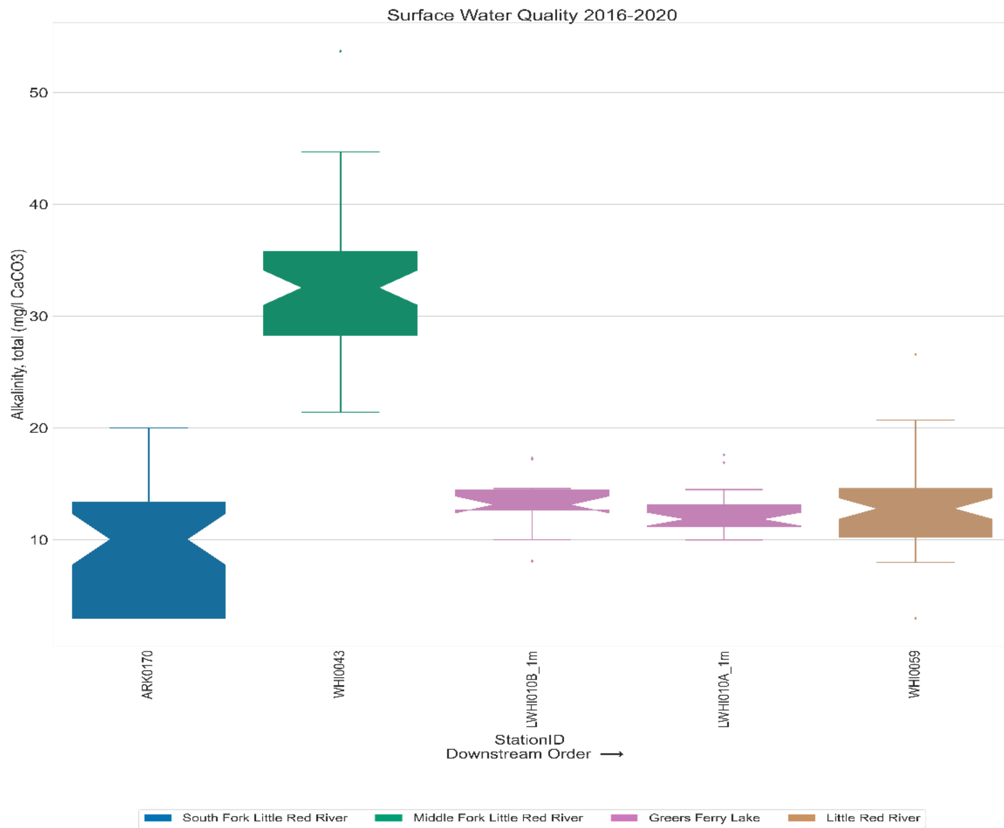

Figure 4. Box and whisker graph of alkalinity measurements from stations with more than 10 values from 2016-2020.

1.4 Sediment Parameters

DEQ monitors turbidity and total suspended solids (TSS) as indicators of sediment water quality issues. USGS measures suspended sediment concentration (SSC) as an indicator of sediment water quality issues. Sediment or other solids suspended in water can make it difficult for fish to catch prey, reducing their ability to eat. Sediment deposited in streams can change the stream habitat, making it unsuitable for some aquatic species currently or historically present in the stream. Sediment deposited in reservoirs reduces their capacity to store water. Arkansas water quality standards include numeric criteria for turbidity, but not TSS or SSC (Arkansas Pollution Control and Ecology Commisison 2022). However, turbidity cannot be converted to a load, so DEQ collects TSS concentration measurements to calculate loads. Measurements of turbidity are often strongly correlated with TSS and/or SSC.

1.4.1 Turbidity

Turbidity is a measured by how much light can pass through a water sample. A higher turbidity value means less light can pass through the water. Both suspended and dissolved material in water can contribute to turbidity. Turbidity was measured only at DEQ stations during 2016-2020, not at any of the USGS stations.

Table 6 lists summary statistics for stream turbidity measurements from the period 2016-2020. Table 7 lists summary statistics for Greers Ferry Lake turbidity measurements from the period-2016-2020. Numeric turbidity criteria for lakes apply to measurements taken from depths less than 1 meter (Arkansas Pollution Control and Ecology Commisison, 2022). Therefore, summary statistics of measurements taken just from the epilimnion are included in Table 7. To determine turbidity impairment of water quality DEQ requires at least 24 measurements. Locations where more than 10% of at least 24 measurements do not meet turbidity criteria may be classified as impaired (DEQ 2019). Only three stream stations have more than 24 measurements between 2016 and 2020. Less than 10% of the measurements at these stations exceed the turbidity criteria. At station UWTMC01, located on the DEQ reach listed as impaired due to high turbidity (DEQ 2020), no turbidity measurements were collected during 2016-2020. No turbidity measurements have been collected from this station since 2003 (DEQ 2021)

Figure 5 shows a box and whisker graph of turbidity measurements from the Little Red River watershed stations with more than 10 measurements for the period 2016-2020. The highest median turbidity measurement occurs at the farthest downstream station, WHI0059. The median turbidity values for all three stream stations are not statistically significantly different. Median turbidity values at the Greers Ferry stations are statistically significantly lower than the stream median turbidity values. Settling that occurs in the reservoir is expected to result in lower turbidity levels.

Table 6. Summary statistics for stream turbidity measurements during 2016-2020 (stations listed in downstream order, first row is farthest upstream station).

Station ID	Stream ID+	Number of measures	Minimum Value, NTU	25th Percentile, NTU	Median, NTU	Mean, NTU	75th Percentile, NTU	Maximum Value, NTU	Criteria, NTU	Number of Values > Criteria	Percentage of Values > Criteria
UWSRR02	SF	3	5.00	5.38	5.75	5.85	6.28	6.81	19	0	-
WHI0195	AF	1	2.30	-	-	-	-	-	19	0	-
UWAFK01	AF	3	3.57	-	4.55	4.41	-	5.12	19	0	-
ARK0170	SF	49	2.69	4.57	6.86	9.81	10.4	57.90	19	4	8%
UWMFK01	MF	3	5.13	-	5.20	5.38	-	5.82	19	0	-
WHI0177	MF	2	4.56	-	-	4.66	-	4.76	19	0	-
WHI0043	MF	59	2.30	4.51	6.11	8.26	9.43	28.60	19	4	7%
WHI0187	TC	2	3.20	-	-	3.70	-	4.21	19	0	-
UWBHC01	BF	2	2.99	-	-	3.72	-	4.44	19	0	-
WHI0059	LRR	51	3.31	5.46	6.88	11.42	11.85	64.70	40	2	4%

+ AF = Archey Fork of the Little Red River, BF = Beech Fork, LRR = Little Red River, MF = Middle Fork of the Little Red River, SF = South Fork of the Little Red River, TC = Turkey Creek.

Table 7. Summary statistics for Greers Ferry Lake turbidity measurements from 2016-2020.

Station ID	LWHI010A		LWHI010B
Sample Location	Epilimnion, thermocline, hypolimnion	Epilimnion	Epilimnion
Number of Measures	44	21	13
Minimum Value, NTU	0.60	1.09	1.00
25th Percentile, NTU	1.40	1.47	1.40
Median, NTU	1.87	1.76	2.27
Mean, NTU	2.47	2.44	3.78
75th Percentile, NTU	2.62	2.45	3.70
Maximum Value, NTU	9.14	9.14	13.00
Criteria	-	45 NTU	45 NTU
Number of Values > Criteria	N/A	0	0

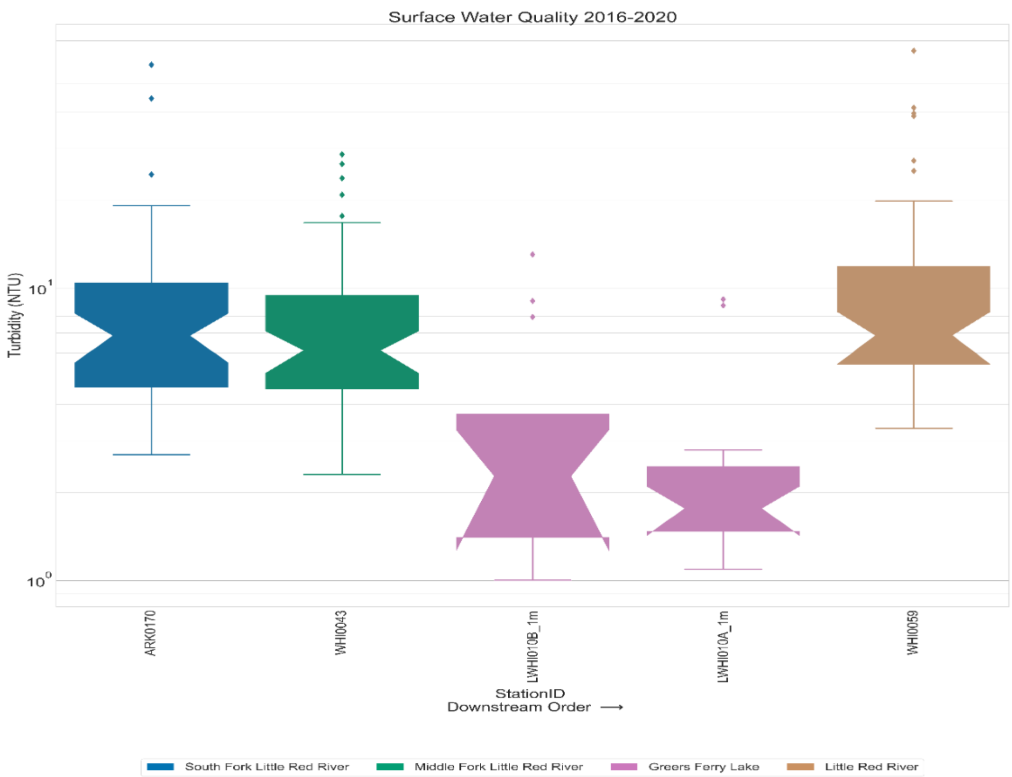

Figure 5. Box and whisker graph of turbidity measurements from stations with more than 10 values from 2016-2020.

Separate numeric criteria are used to evaluate surface water turbidity levels during Baseflow conditions (June - October). In natural systems, Baseflow conditions are usually characterized by reduced runoff and slower flows, which results in lower turbidity levels. Thus, Baseflow turbidity criteria are lower than the All Flow criteria (Arkansas Pollution Control and Ecology Commisison 2022). In the Little Red River watershed, streams that are tributaries to Greers Ferry Lake or the Little Red River are most likely to exhibit the patterns of natural systems (e.g., stations ARK0170 and WHI0043). Graphs of all available turbidity measurements by day of the year show that higher turbidity levels usually occur during the times of year with more rainfall and runoff (Figure 6). Box and whisker graphs comparing turbidity measurements from the Baseflow season to those from the rest of the year show that median turbidity levels are lower during the Baseflow season at stations ARK0170 and WHI0043, but not necessarily statistically significantly lower (Figure 7).

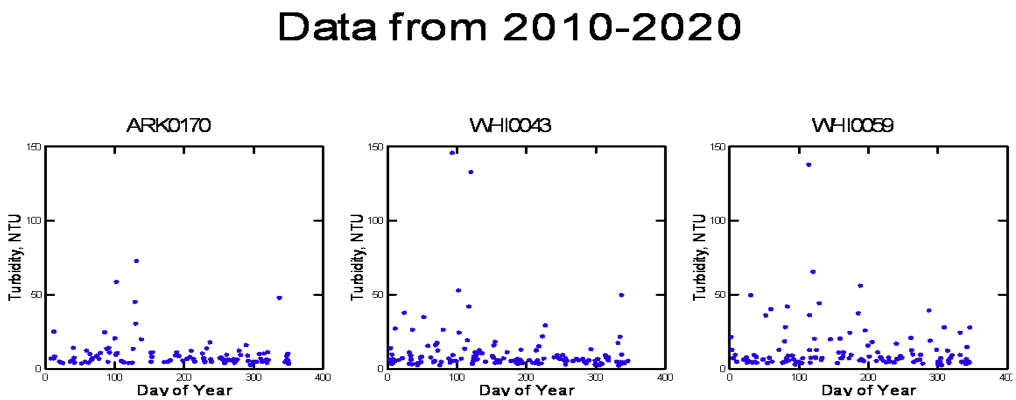

Figure 6. Graph of turbidity measurements from 2010-2020 by day of year.

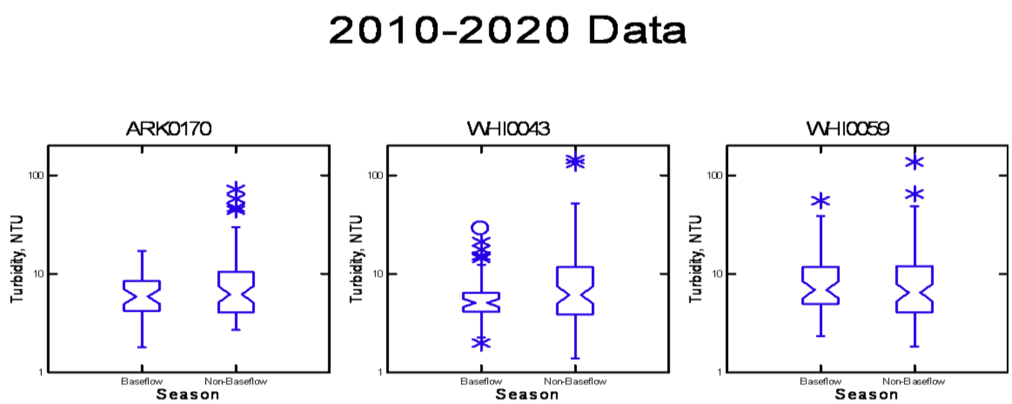

Figure 7. Box and whisker graph comparing turbidity measurements from 2010-2020 for Baseflow season and the rest of the year.

Table 8 lists summary statistics for Baseflow turbidity measurements from streams in the Little Red River watershed during the period 2016-2020. Included in this table is a listing of the applicable Baseflow turbidity numeric water quality criteria, and the number and percentage of measurements that exceed the applicable criteria. Table 9 lists summary statistics for Baseflow turbidity measurements from Greers Ferry Lake during the period 2016-2020. There are no exceedences of the lake Baseflow turbidity criterion at these stations during 2016-2020. There are not significantly more instances of stream turbidity exceeding the Baseflow numeric criteria than the All Flow criteria (Table 6), however, with a smaller number of Baseflow samples overall, the percentage of measurements exceeding the Baseflow criteria ends up being higher.

Figure 8 shows a box and whisker graph of stream turbidity measurements from the Little Red River watershed stations with more than 10 baseflow measurements for the period 2016-2020. The median baseflow values from these three stations are not statistically significantly different.

Table 8. Summary statistics for Baseflow turbidity measurements from Little Red River watershed streams, 2016-2020 (stations listed in downstream order, first row is farthest upstream station).

Station ID	Stream ID+	Number of measures	Minimum Value, NTU	25th Percentile, NTU	Median, NTU	Mean, NTU	75th Percentile, NTU	Maximum Value, NTU	Criteria, NTU	Number of Values > Criteria	Percentage of Values > Criteria
ARK0170	SF	22	3.22	5.42	6.19	7.54	10.30	17.10	10	6	-*
WHI0043	MF	25	3.47	4.52	5.18	7.68	8.39	28.60	10	5	20%
WHI0059	LRR	20	4.08	5.91	7.62	11.57	12.60	38.70	21	3	-

+ LRR = Little Red River, MF = Middle Fork of the Little Red River, SF = South Fork of the Little Red River.
* DEQ requires at least 24 samples to evaluate attainment of the All Flows turbidity criteria (DEQ 2019).

Table 9. Summary statistics for Greers Ferry Lake Baseflow turbidity measurements from 2016-2020.

Station ID	LWHI010A		LWHI010B
Sample Location	**Epilimnion, thermocline, hypolimnion**	**Epilimnion**	**Epilimnion**
Number of Measures	20	6	6
Minimum Value, NTU	0.60	1.2	1.00
25th Percentile, NTU	1.21	1.49	1.31
Median, NTU	1.51	1.59	1.36
Mean, NTU	2.64	3.95	1.50
75th Percentile, NTU	2.44	6.93	1.63
Maximum Value, NTU	9.14	9.14	2.27
Criteria	-	25 NTU	25 NTU
Number of Values > Criteria	-	-	-

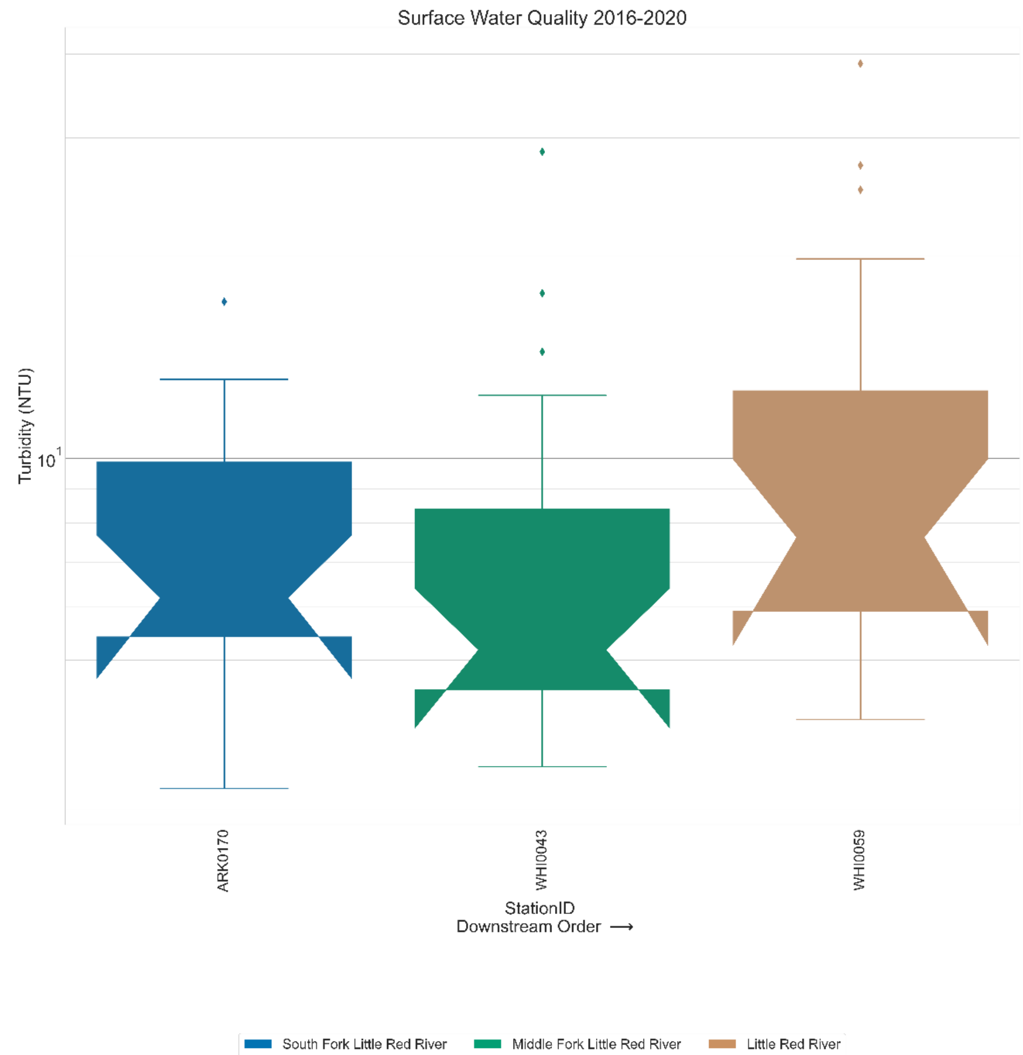

Figure 8. Box and whisker graph of Baseflow turbidity measurements from stations with more than 10 values from 2016-2020.

1.4.2 TSS

TSS is a measure of solid material that can be filtered out of a water sample. This solid material can include organic debris as well as inorganic material such as soil particles. Table 10 lists summary statistics for TSS measurements from streams in the Little Red River watershed during the period 2016-2020. Table 11 lists summary statistics for TSS measurements from Greers Ferry Lake during the period 2016-2020.

Table 10. Summary statistics for TSS measurements from Little Red River watershed streams, 2016-2020 (stations listed in downstream order, first row is farthest upstream station).

Station ID	Stream ID+	Number of measures	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L
UWSRR02	SF	1	0.50	-	-	-	-	-
WHI0195	AF	1	0.50	-	-	-	-	-
UWAFK01	AF	3	0.50	-	0.50	0.67	-	1.00
ARK0170	SF	50	0.50	2.00	3.28	4.95	5.20	38.20
UWMFK01	MF	3	0.50	-	1.00	0.93	-	1.30
WHI0177	MF	2	1.30	-	-	1.40	-	1.50
WHI0043	MF	57	0.50	1.50	2.70	3.25	3.80	13.00
WHI0187	TC	2	0.50	-	-	1.40	-	2.30
UWBHC01	BF	2	0.50	-	-	1.00	-	1.50
WHI0059	LRR	49	0.50	2.50	5.00	6.86	8.80	21.20

+ AF = Archey Fork of the Little Red River, BF = Beech Fork, LRR = Little Red River, MF = Middle Fork of the Little Red River, SF = South Fork of the Little Red River, TC = Turkey Creek.

Table 11. Summary statistics for Greers Ferry Lake TSS measurements from 2016-2020.

Station ID	LWHI010A		LWHI010B
Sample Location	Epilimnion, thermocline, hypolimnion	Epilimnion	Epilimnion
Number of Measures	51	23	14
Minimum Value, mg/L	0.50	0.50	0.50
25th Percentile, mg/L	0.50	0.50	0.63
Median, mg/L	1.00	1.00	1.00
Mean, mg/L	0.76	0.78	1.14
75th Percentile, mg/L	1.00	1.00	1.43
Maximum Value, mg/L	1.00	1.00	2.25

Figure 9 shows a box and whisker graph of TSS concentrations measured at stations in the Little Red River watershed with more than 10 measurements during the period 2016-2020. The highest median TSS concentration occurs at the farthest downstream Little Red River station (WHI0059), and the lowest median TSS concentration occurs in the reservoir. The median TSS concentrations at the reservoir stations are statistically significantly lower than in the streams, which is not unexpected. Settling that occurs in the reservoir is expected to result in lower epilimnion TSS concentrations. The median TSS concentrations at only two of the stream stations are statistically significantly different, the median for WHI0043 (Middle Fork of the Little Red River) is statistically significantly lower than the median for WHI0059.

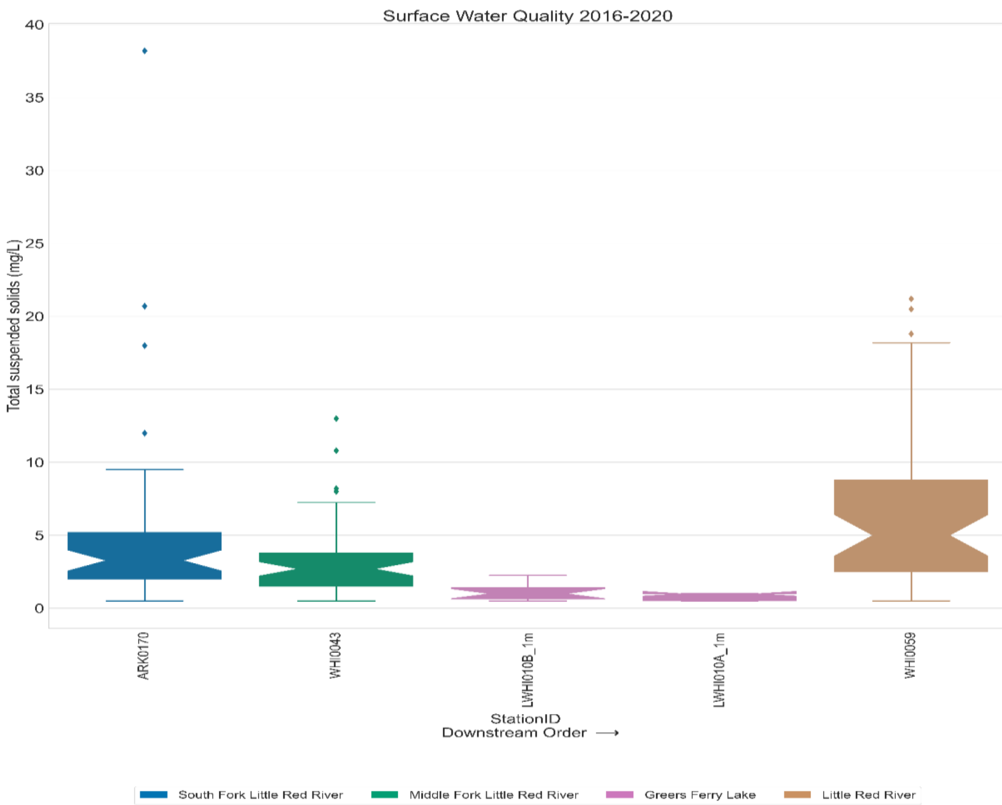

Figure 9. Box and whisker graph of TSS measurements from stations with more than 10 values from 2016-2020.

1.4.3 Suspended Sediment

The USGS measures suspended sediment concentrations (SSC) in the Little Red River watershed, instead of TSS. Table 12 lists summary statistics for available SSC measurements from the Little Red River watershed collected during the period 2016-2020. Both of these stations are located on the upper South Fork of the Little Red River (see Figure 3.2 in main text). When comparing data from the same sampling period, the summary statistics appear very similar, although the median values appear very different. A Kruskal-Wallis test of the data from the two stations collected during the same sampling period confirms that SSC at these two stations are not statistically different (p-value = 0.625). The stream distance between these two stations is around nine miles (measured on USGS National map in DEQ Aquaview online mapping utility, 4/1/22).

Table 12. Summary statistics for SSC measurements from Little Red River watershed streams, 2016-2020 (stations listed in downstream order, first row is farthest upstream station).

Station ID	Number of measures	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L
07075250	9	2	3	20	19	24	69
07075270	28	2	3	4	44	19	843
07075270*	9	2	2	6	18	32	54

*Statistics for same period of record as for station 07075250.

1.4.4 Turbidity vs TSS

When measured turbidity is primarily the result of sediment or other solid materials suspended in the water, there can be a strong statistical correlation between TSS and turbidity measurements. Figure 10 shows graphs of turbidity versus TSS data from the Little Red River stations with more than 10 measurements during 2010-2020. These graphs appear to indicate that TSS and turbidity are positively, although not strongly, correlated in the Little Red River watershed.

Data are not available from the USGS stations during 2016-2020 to evaluate relationships between turbidity and SSC.

1.5 Water Temperature

Water temperature can affect fish and other aquatic creatures living in waterbodies, as well as water chemistry. Table 13 lists summary statistics for stream temperature measurements from the period 2016-2020. Table 14 lists summary statistics for Greers Ferry Lake temperature measurements from the period 2016-2020. The highest median temperatures are from station UWOFC01 (Overflow Creek) and UWSRR01 (South Fork Little Red River). There are two stations where measured water temperatures occasionally exceed the water quality criterion, ARK0170 (South Fork Little Red River) and WHI0043 (Middle Fork Little Red River). There are no permitted thermal wastewater discharges to these streams, so the high water temperatures are naturally occurring. The high water temperatures are rare enough that these stream reaches are not classified as impaired due to water temperature. The USGS water temperature measurements in Greers Ferry Lake near the dam are warmer than the DEQ water temperatures measurements at this location. This area of the reservoir is classified as trout waters. However, surface water temperatures do not meet the trout waters temperature criterion.

Table 13. Summary statistics for stream water temperature measurements from 2016-2020 (stations listed in downstream order, first row is farthest upstream station).

Station ID	Stream ID+	Number of measures	Minimum Value, deg C	25th Percentile, deg C	Median, deg C	Mean, deg C	75th Percentile, deg C	Maximum Value, deg C	Criteria, deg C	Number of values > criterion	Percent values > criterion
07075250	SF	9	7.50	8.40	11.30	11.94	15.30	17.10	31	-	-
07075270	SF	31	5.50	9.50	14.80	15.77	22.65	28.00	31	0	0
UWSRR01	SF	15	4.20	8.20	23.70	18.03	25.20	30.90	31	0	0
UWSRR02	SF	18	4.00	8.08	17.05	17.38	25.00	29.50	31	0	0
WHI0195	AF	1	-	-	-	13.30	-	-	31	-	-
UWAFK01	AF	3	6.40	-	15.20	14.37	-	21.50	31	-	-
ARK0170	SF	50	3.80	12.43	17.75	18.78	26.88	33.40	31	4	8
UWMFK01	MF	3	4.40	-	13.40	12.23	-	18.90	31	-	-
WHI0177	MF	2	14.30	-	-	16.55	-	18.80	31	-	-
WHI0043	MF	74	3.80	11.10	16.40	18.06	26.95	32.10	31	3	4
WHI0187	TC	2	12.40	-	-	16.35	-	20.30	31	-	-
UWBHC01	BF	2	12.90	-	-	17.10	-	21.30	31	-	-
07076000	LRR	15	9.40	11.65	12.20	12.39	13.10	17.20	20	0	0
UWTMC01	TMC	16	4.10	9.80	22.05	18.33	26.05	28.60	31	0	0
WHI0059	LRR	70	6.00	10.33	14.85	14.97	19.70	26.60	31	0	0
UWOFC01	OFC	11	8.10	20.05	24.20	22.55	27.00	28.90	31	0	0

+ AF = Archey Fork of the Little Red River, BF = Beech Fork, LRR = Little Red River, MF = Middle Fork of the Little Red River, OFC = Overflow Creek, SF = South Fork of the Little Red River, TC = Turkey Creek, TMC = Ten Mile Creek.

Table 14. Summary statistics for Greers Ferry Lake water temperature measurements from 2016-2020.

Station ID	LWHI010A		07075900		LWHI010B
Sample Location	Epilimnion, thermocline, hypolimnion	Epilimnion	0.4-167 feet	0.4-3 feet	Epilimnion
Number of Measures	43	15	15	15	14
Minimum Value, deg C	2.46	3.49	11.91	12.7	2.13
25th Percentile, deg C	8.72	11.44	16.44	21.25	9.6
Median, deg C	9.68	18.7	17.53	28.5	17.75
Mean, deg C	14.01	18.96	16.59	24.81	17.83
75th Percentile, deg C	19.05	28.25	17.89	29.2	27
Maximum Value, deg C	30.6	30.6	18.95	31.4	30.2
Criteria, deg C	-	20	-	20	32
Number of Values > criterion	-	6	-	11	0
Percent values > criterion	-	47%	-	73%	0

Figure 11 shows a box and whisker graph of water temperature measurements from monitoring locations in the Little Red River watershed with more than 10 measurements during the period 2016-2020. Median water temperatures at most of the monitoring locations are not statistically significantly different. The median of the USGS surface water temperature measurements from the reservoir near the dam is statistically significantly higher than the median of DEQ surface water temperature measurements from the reservoir. Water temperatures at station 07076000 (Little Red River just downstream of the dam) exhibit less variability than the other monitoring locations, showing the temperature of releases from the reservoir. The median water temperature at station 07076000 is statistically significantly lower than the median water temperatures at the other monitoring locations in the watershed downstream of the reservoir. The dashed line on Figure 11 is at 22 deg C. For waterbodies not designated as trout waters, only water temperatures above 22 deg C are used to evaluate attainment of the temperature water quality criteria (DEQ 2019). Note that there are several stream monitoring locations where the majority of the water temperature measurements are less than 22 deg C.

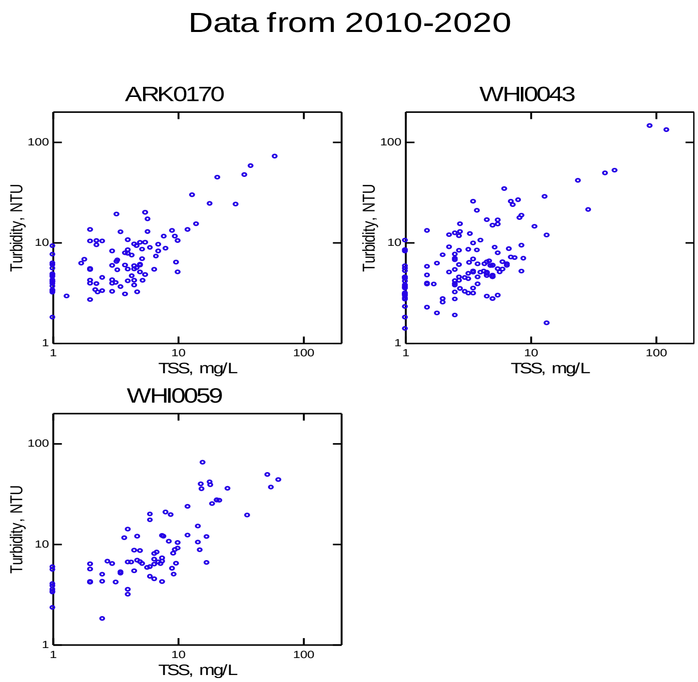

Figure 10. Graphs of turbidity versus TSS measurements from selected DEQ stations.

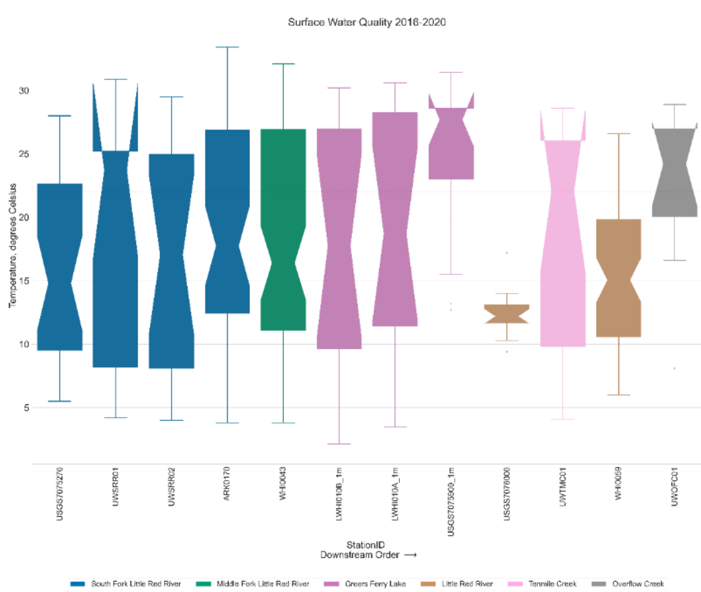

Figure 11. Box and whisker graph of water temperature measurements from stations with more than 10 values from 2016-2020.

1.6 Dissolved Oxygen

DO in water is used by fish and other aquatic creatures living in waterbodies. Table 15 lists summary statistics for stream DO measurements from the period 2016-2020. Table 16 lists summary statistics for Greers Ferry Lake DO measurements from the period 2016-2020. All the epilimnion DO measurements from Greers Ferry Lake meet the lake DO criterion (5 mg/L). Note that DEQ station LWHI010A and USGS station 07075900 are both located near the dam.

Table 15. Summary statistics for stream DO measurements from 2016-2020 (stations listed in downstream order, first row is farthest upstream station).

Station ID	Stream ID+	Number of measures	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L
07075250	SF	8	8.20	8.80	10.0	9.80	10.8	11.0
07075270	SF	31	5.80	7.95	9.50	9.40	11.0	12.4
UWSRR01	SF	15	5.70	7.32	8.00	9.18	11.8	12.5
UWSRR02	SF	18	6.17	7.21	9.35	9.37	11.8	12.6
WHI0195	AF	1	10.4	-	-	-	-	-
UWAFK01	AF	3	9.17	-	10.5	10.8	-	12.7
ARK0170	SF	49	3.89	7.39	9.52	8.96	10.3	12.7
UWMFK01	MF	3	9.20	-	10.3	10.8	-	13.0
WHI0177	MF	2	9.30	-	-	10.2	-	11.0
WHI0043	MF	74	5.66	7.55	9.14	9.23	10.8	15.1
WHI0187	TC	2	8.40	-	-	9.50	-	10.6
UWBHC01	BF	2	9.48	-	-	10.2	-	10.9
07076000	LRR	15	5.40	7.90	8.70	8.79	9.80	11.3
UWTMC01	TMC	16	4.14	5.29	7.95	8.30	11.4	13.3
WHI0059	LRR	68	6.95	8.43	9.78	9.80	11.2	12.5
UWOFC01	OFC	11	4.30	6.08	7.64	7.44	8.43	10.3

+ AF = Archey Fork of the Little Red River, BF = Beech Fork, LRR = Little Red River, MF = Middle Fork of the Little Red River, OFC = Overflow Creek, SF = South Fork of the Little Red River, TC = Turkey Creek, TMC = Ten Mile Creek.

Table 16. Summary statistics for Greers Ferry Lake DO measurements from 2016-2020.

Station ID	LWHI010A		07075900		LWHI010B
Sample Location	Epilimnion, thermocline, hypolimnion	Epilimnion	0.4-167 feet	0.4-3 feet	Epilimnion
Number of Measures	43	26	430	15	14
Minimum Value, mg/L	0.48	7.71	0.30	7.00	7.38

Table 16. Summary statistics for Greers Ferry Lake DO measurements from 2016-2020 (continued).

Station ID	LWHI010A		07075900		LWHI010B
25th Percentile, mg/L	5.65	8.11	5.38	7.60	7.85
Median, mg/L	8.41	8.52	7.10	7.90	9.18
Mean, mg/L	7.84	9.22	6.63	7.87	9.28
75th Percentile, mg/L	10.1	10.2	8.20	8.10	10.4
Maximum Value, mg/L	11.9	11.9	11.8	9.50	12.7
Number of Values <5 mg/L	-	0	-	0	0

Figure 12 shows a box and whisker graph of DO measurements from monitoring locations in the Little Red River watershed with more than 10 measurements during the period 2016-2020. The highest median DO concentration occurs at the farthest downstream station on the Little Red River (WHI0059). In the reservoir, the highest median epilimnion DO concentration is at the upstream station (LWHI010B). The lowest median DO concentration occurs at the station on Overflow Creek (UWOFC01). While the median DO values at some stations appear quite different from those at other stations, there are few stations where the median DO values are statistically significantly different.

Separate numeric criteria are used to evaluate stream DO conditions during the Primary Season (when water temperature is 22°C or less, usually mid-September to mid-May), and during the Critical Season (when water temperature is > 22°C, usually mid-May to mid-September) (Arkansas Pollution Control and Ecology Commisison, 2022). Seasonal DO conditions are discussed in two subsections below. To determine DO impairment of water quality DEQ requires at least 10 measurements. Locations where more than 10% of at least 10 measurements do not meet DO criteria may be classified as impaired (DEQ 2019).

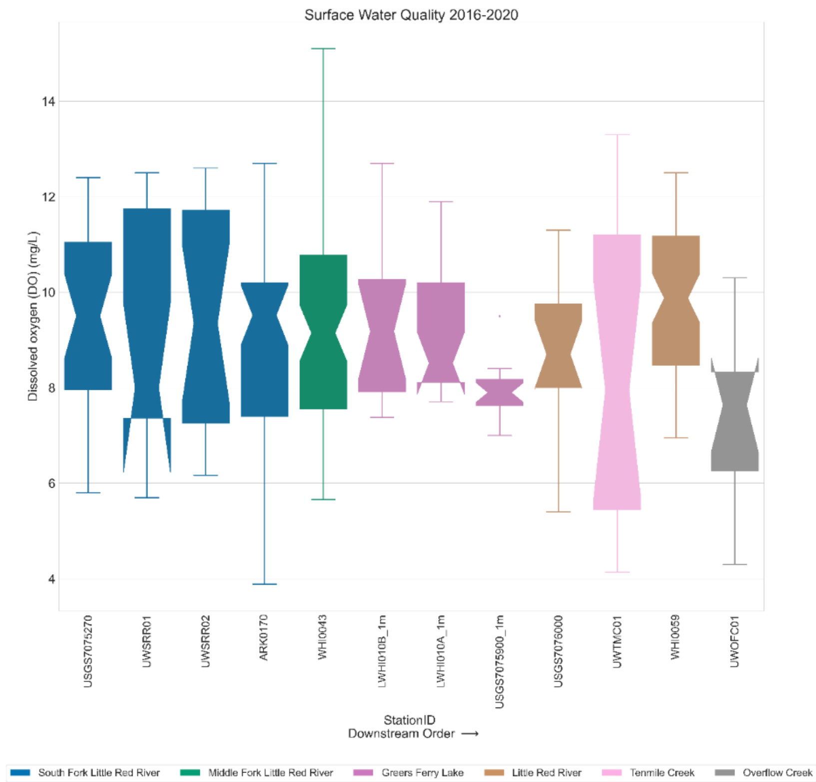

Figure 12. Box and whisker graph of DO measurements from stations with more than 10 values from 2016-2020.

1.6.1 Primary Season

The Primary Season for DO water quality criteria is characterized by lower water temperatures and higher flows. DO concentrations are usually naturally higher during this season. Table 17 lists summary statistics for stream DO measurements from the Primary Season, 2016-2020. Included in Table 17 are listings of the number and percentage of Primary Season DO measurements from 2016-2020 that are less than the Primary Season DO criteria for Little Red River watershed streams. Only three stations had one measurement less than the applicable DO criterion. Overall, Primary Season DO conditions at the monitored stations appear to meet the DO criteria.

Table 17. Summary statistics for Primary Season DO measurements from streams in the Little Red River watershed, 2016-2020 (stations listed in downstream order, first row is farthest upstream station).

Station ID	Stream ID+	Number of measures	Minimum Value, mg/L	Median, mg/L	Mean, mg/L	Maximum Value, mg/L	Criteria, mg/L	Number of Values < Criteria	Percentage of Values < Criteria
07075250	SF	8	8.20	10.0	9.80	11.0	6	0	-*
07075270	SF	22	7.80	10.2	10.3	12.4	6	0	0
UWSRR01	SF	7	10.3	11.9	11.6	12.5	6	0	-
UWSRR02	SF	10	8.70	11.6	11.3	12.6	6	0	0
WHI0195	AF	1	10.4	-	-	-	6	0	-
UWAFK01	AF	3	9.17	10.5	10.8	12.7	6	0	-
ARK0170	SF	31	4.65	10.0	10.1	12.7	5	1	3%
UWMFK01	MF	3	9.2	10.3	10.8	13.0	6	0	-
WHI0177	MF	2	9.3	-	10.2	11.0	6	0	-
WHI0043	MF	47	7.25	10.4	10.3	15.1	6	0	0
WHI0187	TC	2	8.40	-	9.50	10.6	6	0	-
UWBHC01	BF	2	9.48	-	10.2	10.9	6	0	-
07076000	LRR	15	5.40	8.70	8.79	11.3	6	1	7%
UWTMC01	TMC	8	8.26	11.4	11.0	13.3	5	0	-
WHI0059	LRR	62	7.55	9.95	9.98	12.5	5	0	0
UWOFC01	OFC	5	4.30	8.53	8.08	10.3	5	1	-

+ AF = Archey Fork of the Little Red River, BF = Beech Fork, LRR = Little Red River, MF = Middle Fork of the Little Red River, OFC = Overflow Creek, SF = South Fork of the Little Red River, TC = Turkey Creek, TMC = Ten Mile Creek.

* DEQ requires at least 10 samples to evaluate attainment of the DO criteria (DEQ 2019).

Figure 13 shows a box and whisker graph of Primary Season DO measurements from stream stations in the Little Red River watershed with more than 10 Primary Season measurements during 2016-2020. The lowest median primary season DO concentration occurs downstream of Greers Ferry Lake, at the Little Red River station just downstream of the dam (07076000). The median DO concentration at this station is statistically significantly lower than the median concentrations at the other stream stations, though above the DO criterion. The highest median Primary Season DO concentration occurs at station UWSRR02 on the South Fork of the Little Red River. The median DO concentration at UWSRR02 is statistically significantly higher than median concentrations at several of the other stream stations.

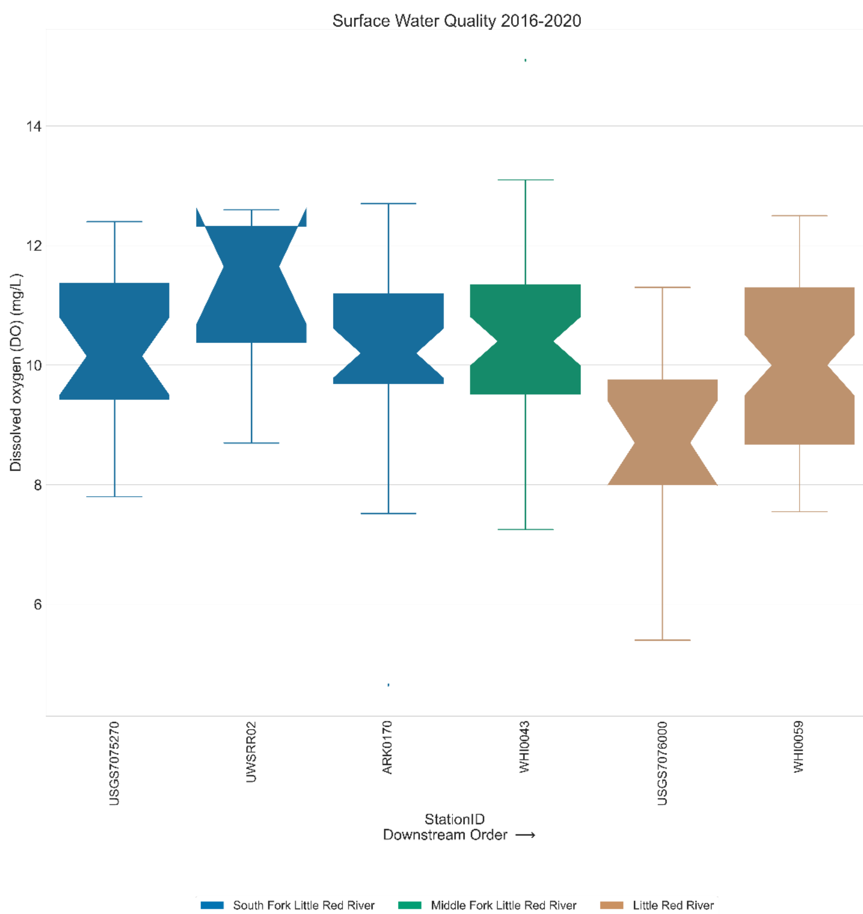

Figure 13. Box and whisker graph of Primary Season DO measurements from stations with more than 10 values from 2016-2020.

1.6.2 Critical Season

The Critical Season for DO water quality criteria is characterized by higher temperatures and lower flows. DO concentrations naturally tend to be lower during this season. Table 18 lists summary statistics for stream DO measurements from the Critical Season, 2016-2020. Included in Table 18 are listings of the number and percentage of Critical Season DO measurements from 2016-2020 that are less than the Critical Season DO criteria for Little Red River watershed streams. At half of the stations, all measurements meet the applicable DO criterion. Four stations had one or more measurement less than the applicable DO criterion. All are located upstream of Greers Ferry Lake. Since only two stations had more than 10 Critical Season DO measurements, these data are not graphed. Note that station 07075270 is located on a stream reach classified as impaired due to low DO during the Critical Season. This is the only waterbody in the watershed classified as impaired due to low DO (DEQ 2020).

Table 18. Summary statistics for Critical Season DO measurements from streams in the Little Red River watershed, 2016-2020 (stations listed in downstream order, first row is farthest upstream station).

Station ID	Stream ID+	Number of measures	Minimum Value, mg/L	Median, mg/L	Mean, mg/L	Maximum Value, mg/L	Criteria, mg/L	Number of Values < Criteria	Percentage of Values < Criteria
07075270	SF	9	5.80	7.28	7.30	9.00	6	1	-*
UWSRR01	SF	8	5.70	7.36	7.05	8.00	6	2	-
UWSRR02	SF	8	6.17	7.14	7.01	7.70	6	0	-
ARK0170	SF	18	3.89	7.14	6.96	8.77	6	2	11%
WHI0043	MF	27	5.66	7.41	7.29	8.07	6	1	4%
UWTMC01	TMC	8	4.14	5.29	5.54	7.64	3	0	-
WHI0059	LRR	6	6.95	8.12	7.88	8.65	5	0	-
UWOFC01	OFC	6	5.68	7.06	6.91	8.14	3	0	-

+ LRR = Little Red River, MF = Middle Fork of the Little Red River, OFC = Overflow Creek, SF = South Fork of the Little Red River, TMC = Ten Mile Creek.

* DEQ requires at least 10 samples to evaluate attainment of DO criteria (DEQ 2019).

It is interesting that there are so few Critical Season DO measurements collected at station WHI0059 during 2016-2020. However, during this period, only six out of 68 water temperature measurements were greater than 22 degrees C (see Figure 14). As a result, only six of the DO measurements are classified as being from the Critical Season. Examination of long-term water temperature records for this station suggests that water temperatures at this station may be decreasing (see Appendix E).

There are also relatively few Critical Season DO measurements from station 07075270, only nine out of 31 measurements were collected when water temperature was greater than 22˚C.

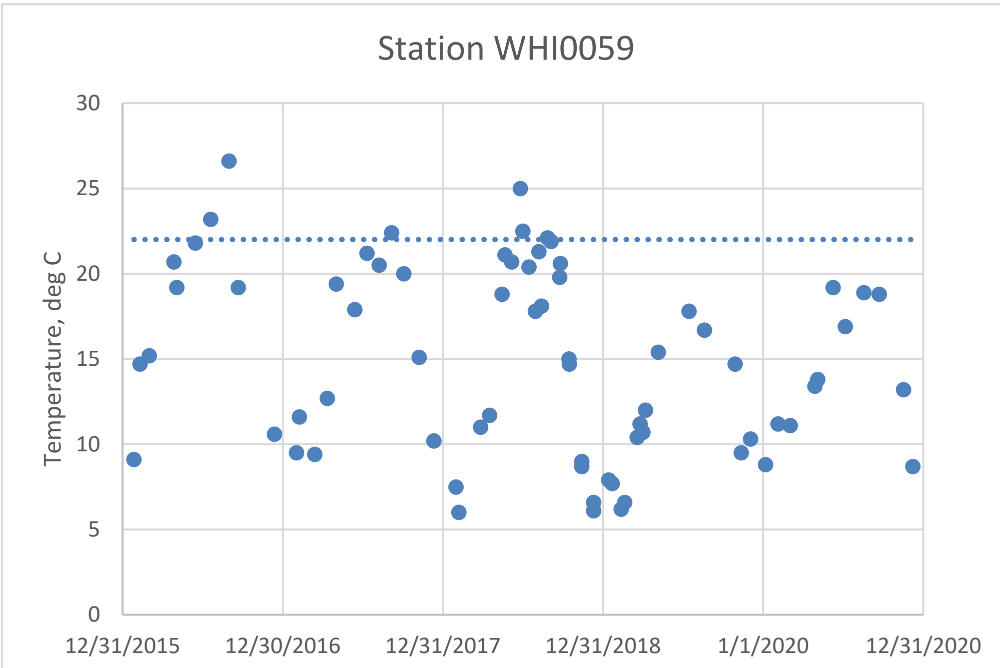

Figure 14. Graph of water temperatures measured at station WHI0059 during 2016-2020, with dotted line at 22˚C.

The lowest median Critical Season DO concentration was from Ten Mile Creek (UWTMC01). The highest median DO concentration was from the farthest downstream station on the Little Red River, near Searcy, WHI0059. At stations UWSRR01, UWSRR02, UWTMC01, and UWOFC01, all of The Critical Season DO measurements are from 2018.

D.6 Percent DO Saturation

Water temperature affects the ability of water to dissolve oxygen. More oxygen can be dissolved in cooler water than in warmer water, i.e., higher maximum DO concentrations are possible in cooler water than in warmer water. Percent DO saturation compares the measured

DO concentration to the maximum possible DO concentration at the measured water temperature. Percent DO saturation values greater than 100% can occur during algae blooms. Table 19 lists summary statistics for stream percent DO saturation values from the period 2016-2020. Table 20 lists summary statistics for Greers Ferry Lake percent DO saturation values from the period 2016-2020. There are several stream stations where DO saturation values greater than 100% occur. DO saturation values greater than 100% also occur in the reservoir. These values indicate relatively high levels of algal activity. Decomposition of large amounts of algae reduce dissolved oxygen levels in water. DO concentrations below the Critical Season criteria occur at stations ARK0170 (South Fork Little Red River) and WHI0043 (Middle Fork Little Red River) (Table 18). These stations also exhibit DO saturation values greater than 100%. This suggests that algae blooms may be occurring at these locations that affect DO levels, making them both high and low. This kind of response may be caused by excessive nutrients stimulating algal growth.

Table 19. Summary statistics for stream DO measurements from 2016-2020 (stations listed in downstream order, first row is farthest upstream station).

Station ID	Stream ID+	Number of measures	Minimum Value, %	25^{th} Percentile, %	Median, %	Mean, %	75^{th} Percentile, %	Maximum Value, %
07075250	SF	7	86.0	86.5	93.0	92.6	97	102
07075270	SF	30	73.0	89.0	96.0	93.4	100.00	106.00
UWSRR01	SF	15	68.5	90.1	95.1	92.6	99.2	100.7
UWSRR02	SF	18	78.6	89.3	94.0	93.7	99.0	108.7
WHI0195	AF	1	-	-	-	99.3	-	-
UWAFK01	AF	3	103.1	-	103.8	103.8	-	104.5
ARK0170	SF	49	48.8	89.3	95.0	92.7	100.5	109.3
UWMFK01	MF	3	98.6	-	98.9	99.3	-	100.2
WHI0177	MF	2	99.8	-	-	103.6	-	107.4
WHI0043	MF	74	70.9	89.6	96.3	94.8	99.7	114.6
WHI0187	TC	2	92.9	-	-	96.1	-	99.2
UWBHC01	BF	2	103.2	-	-	105.1	-	106.9
07076000	LRR	13	65.0	73.0	90.0	85.6	100.00	110
UWTMC01	TMC	16	51.8	67.4	90.9	83.0	98.5	102.0
WHI0059	LRR	70	76.1	90.3	97.4	96.2	100.0	124.1
UWOFC01	OFC	11	47.7	77.3	87.2	85.1	98.2	101.7

+ AF = Archey Fork of the Little Red River, BF = Beech Fork, LRR = Little Red River, MF = Middle Fork of the Little Red River, OFC = Overflow Creek, SF = South Fork of the Little Red River, TC = Turkey Creek, TMC = Ten Mile Creek.

Table 20. Summary statistics for Greers Ferry Lake percent DO saturation values from 2016-2020.

Station ID	**LWHI010A**		**07075900**		**LWHI010B**
Sample Location	**Epilimnion, thermocline, hypolimnion**	**Epilimnion**	**0.4-167 feet**	**0.4-3 feet**	**Epilimnion**
Number of Measures	43	15	430	15	14
Minimum Value, %	4.1	85	1	70	84.2
25th Percentile, %	59.2	90.2	49	21.3	88.6
Median, %	85.4	99.1	70.5	101	93.9
Mean, %	75.6	97.4	70.1	95.5	95.3
75th Percentile, %	97	102.9	93.8	29.2	103.1
Maximum Value, %	109.5	109.2	140	106	106

Figure 15 shows a box and whisker graph of percent DO saturation values from monitoring locations in the Little Red River watershed with more than 10 measurements during the period 2016-2020. The highest median DO saturation occurs in the reservoir near the dam, at station 07075720. The lowest median DO saturation occurs at the station on Overflow Creek (UWOFC01). This is the only monitored location with a median DO saturation less than 90%. However, none of the median DO saturation values are statistically significantly different from each other.

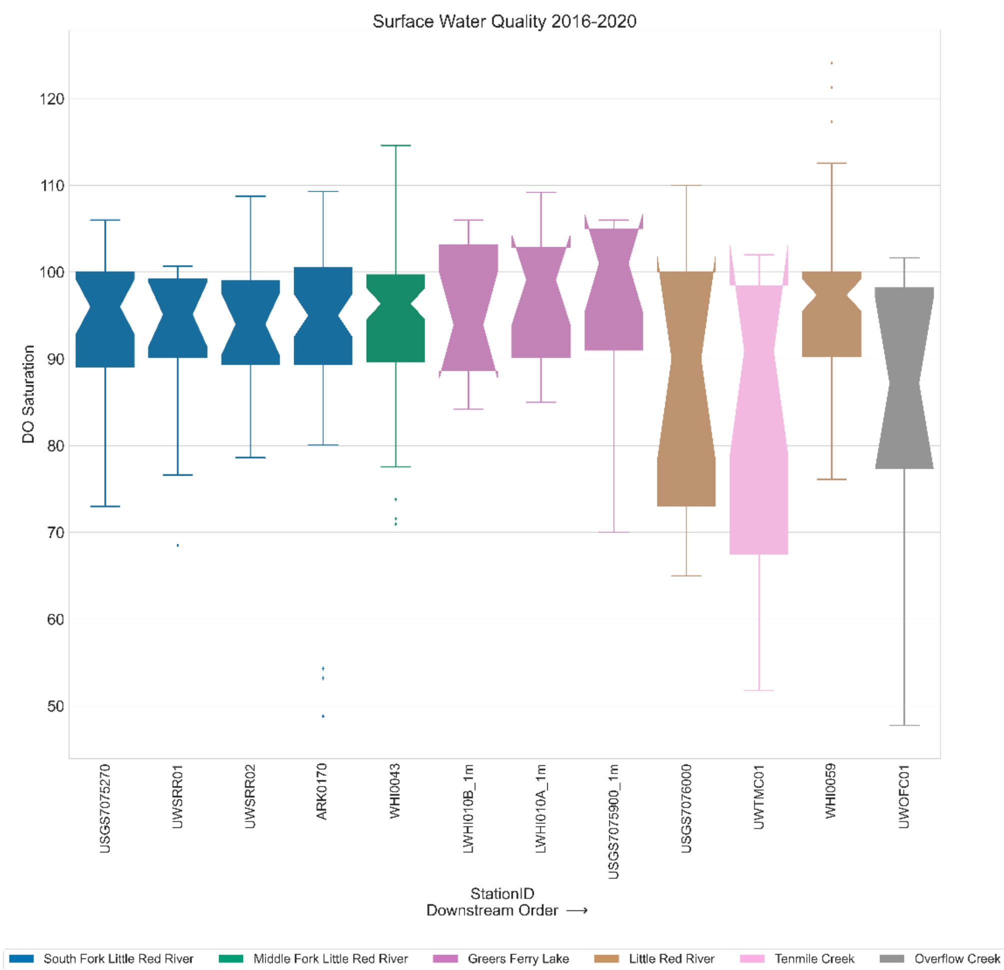

Figure 15. Box and whisker graph of percent DO saturation values from stations with more than 10 values from 2016-2020.

1.7 Biochemical Oxygen Demand

Biochemical Oxygen Demand (BOD) represents the amount of DO needed by aerobic microorganisms to decompose organic matter in a water sample at a specific water temperature. It is an indicator of the level of organic pollution in water, and the likelihood that adequate DO levels can be maintained. BOD was measured at only one station in the Little Red River watershed during 2016-2020, WHI0059 (Little Red River near Searcy). Summary statistics for BOD measurements at WHI0059 are listed in Table 21 There is no numeric water quality criterion for BOD in Arkansas. Because DO and decomposition can be affected by temperature,

Figure 16 shows a graph of BOD concentrations by day of year. In general, BOD appears to be highest in the fall. This may be the result of natural organic matter entering the system as trees drop their leaves and other vegetation dies back. The two BOD values greater than 2 mg/L both occurred in 2017. The cause of these unusually high values is unknown. The Searcy WWTP discharge is a possible source, however, there is no indication of unusually high BOD values in the WWTP discharge during the months when the stream BOD was unusually high (EPA Echo retrieval 12/17/21).

Table 21. Summary statistics for BOD measurements from WHI0059, 2016-2020.

Statistic	**BOD Value**
Number of measures	51
Minimum Value, mg/L	0.10
25^{th} Percentile, mg/L	0.30
Median, mg/L	0.42
Average, mg/L	0.62
75^{th} Percentile, mg/L	0.67
Maximum Value, mg/L	3.18

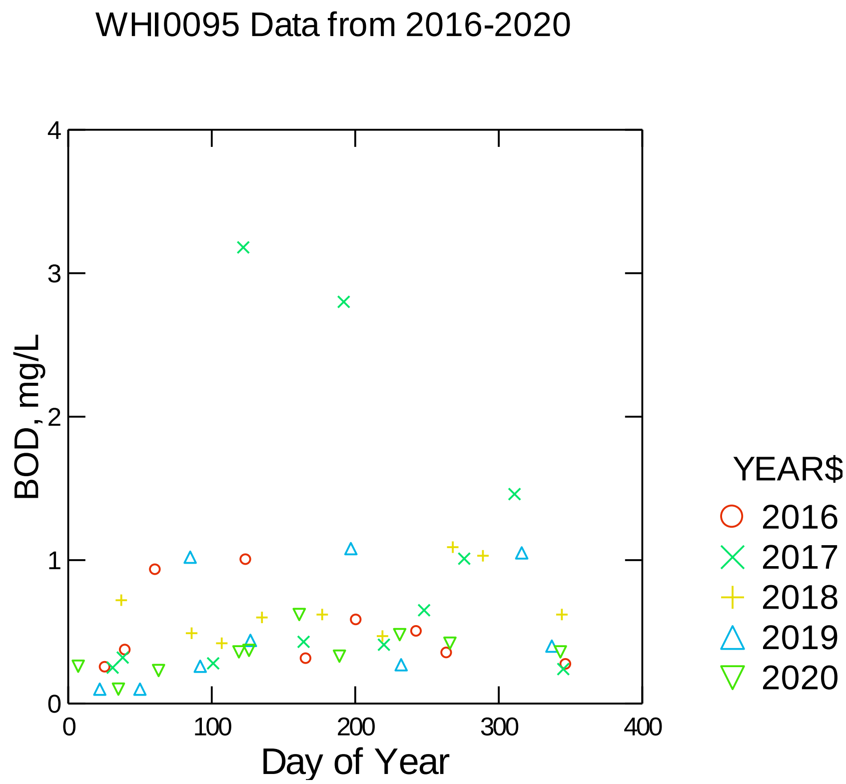

Figure 16. Graph of BOD measurements from WHI0059 during 2016-2020, by day of year.

1.8 Phosphorus

Phosphorus is a nutrient and is not harmful to humans or animals itself. However, it can stimulate algal growth in surface waters. Excessive algal growth has the potential to create conditions that are a nuisance or harmful to humans, aquatic organisms, or livestock, including low DO levels. There are no numeric water quality standards for phosphorus that apply in the Little Red River watershed (Arkansas Pollution Control and Ecology Commisison, 2022), and no impaired waterbodies with phosphorus or nutrients listed as a cause for impairment (DEQ 2020). However, Arkansas is a nutrient reduction target state for the Gulf of Mexico Hypoxia Task Force (Alexander, et al., 2008). Therefore, phosphorus levels are a concern in all Arkansas watersheds.

Table 22 lists summary statistics for total phosphorus measurements collected from streams in the Little Red River watershed during 2016-2020. Table 23 lists summary statistics for total phosphorus measurements collected from Greers Ferry Lake during 2016-2020. Only two measurements from Greers Ferry Lake were above the total phosphorus detection limit. Of the stream stations with more than five measurements during 2016-2020, only one had a maximum value greater than 0.10 mg/L, WHI0059 (the farthest downstream station on the Little Red River). The highest total phosphorus value was measured at an Archey Fork station with only three measurements, UWAFK01 (upstream of Greers Ferry Lake). Two stations located upstream of Greers Ferry Lake, in the Beech Creek tributary watershed, also had a relatively high total phosphorus measurement, UWBHC01 and WHI0187. All three of these high total phosphorus measurements were collected on 4/24/2016. No other stations in this watershed were sampled that date. Overall, it appears that total phosphorus levels in the reservoir are low. Total phosphorus levels in streams tend to be higher than those in the reservoir, and occasionally reach levels close to 1 mg/L.

Table 22. Summary statistics for stream measurements from 2016-2020 for total phosphorus (stations listed in downstream order, first row is farthest upstream station).

Station ID	Stream ID+	Number of measures	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L
07075250	SF	13	0.006	0.009	0.023	0.029	0.041	0.071
07075270	SF	9	0.002	0.008	0.010	0.010	0.011	0.026
UWSRR02	SF	3	<0.020	-	<0.020	<0.020	-	<0.020
WHI0195	AF	1	<0.020	-	-	-	-	-
UWAFK01	AF	3	<0.020	-	<0.020	0.309	-	0.907
ARK0170	SF	48	<0.020	<0.020	0.020	0.021	0.030	0.050
UWMFK01	MF	3	<0.020	-	<0.020	<0.020	-	<0.020
WHI0177	MF	2	<0.020	-	-	<0.020	-	<0.020
WHI0043	MF	55	<0.020	<0.020	0.020	0.023	0.030	0.064
WHI0187	TC	2	<0.020	-	-	0.357	-	0.704
UWBHC01	BF	2	<0.020	-	-	0.387	-	0.764
WHI0059	LRR	52	<0.020	<0.020	0.026	0.036	0.045	0.171

+ AF = Archey Fork of the Little Red River, BF = Beech Fork, LRR = Little Red River, MF = Middle Fork of the Little Red River, SF = South Fork of the Little Red River, TC = Turkey Creek.

Table 23. Summary statistics for Greers Ferry Lake measurements from 2016-2020 for total phosphorus.

Station ID	Sample location	Number of measures	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L
LWHI010A	Epilimnion, thermocline, hypolimnion	47	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
LWHI010A	Epilimnion	24	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
LWHI010B	Epilimnion	13	<0.020	<0.020	<0.020	0.012	<0.020	0.030

Figure 17 shows a box and whisker graph of total phosphorus measurements from 2016-2020 at stations with more than five measurements. Median total phosphorus measurements at the reservoir stations are statistically significantly less than the median values at the stream stations. The lowest median total phosphorus concentration for a stream station occurs at 07075270 (upper South Fork Little Red River). The highest median total phosphorus concentration for a stream station occurs at station WHI0059 (Little Red River near Searcy). None of the median values at the graphed stream stations are statistically significantly different.

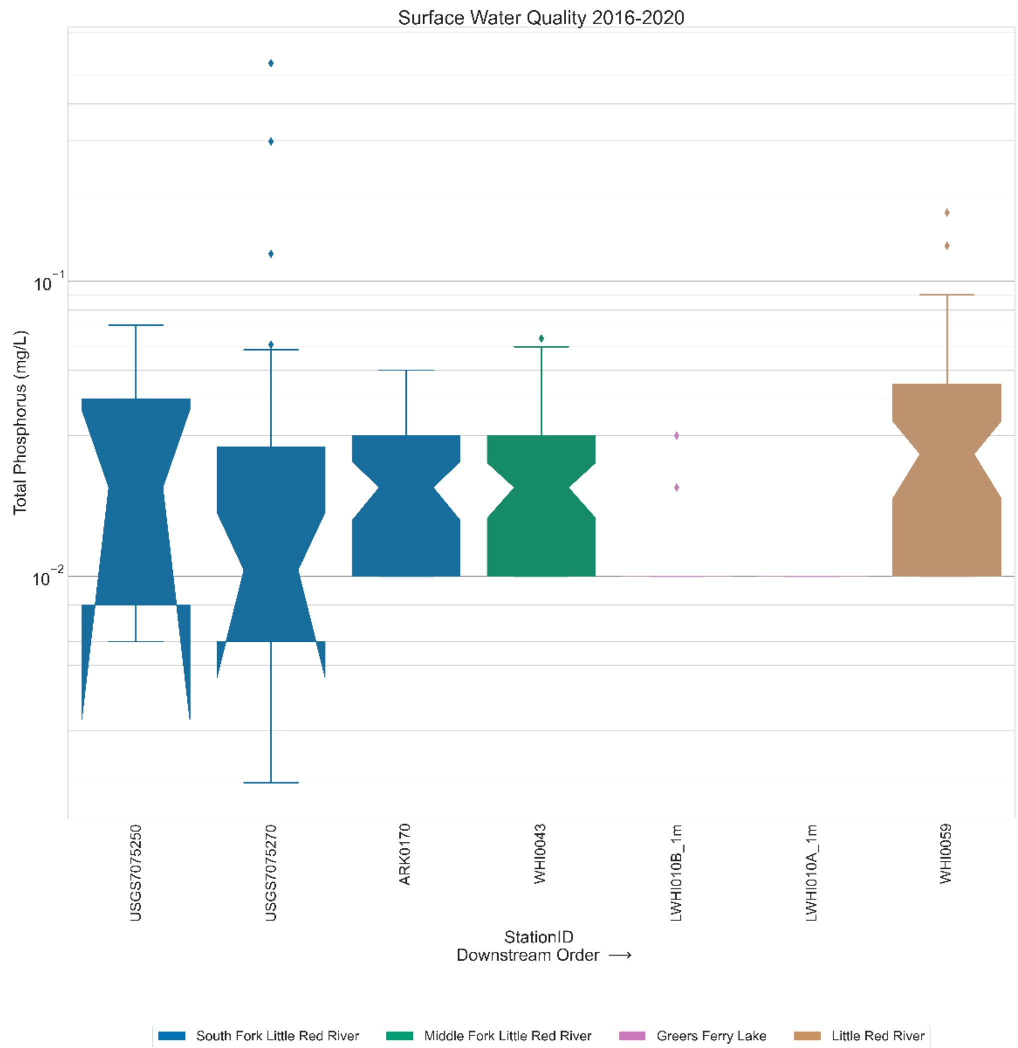

Figure 17. Box and whisker graph of total phosphorus measurements from stations with more than 10 values from 2016-2020.

1.9 Nitrogen

Nitrogen is a nutrient and can stimulate algal growth. Excessive algal growth has the potential to create conditions that are a nuisance or harmful to humans, aquatic organisms, or livestock, including low DO levels. The only numeric water quality standards for nitrogen that are specified in the Arkansas Water Quality Standards23 are the criteria for ammonia nitrogen, which are dependent on temperature and pH (Arkansas Pollution Control and Ecology Commisison, 2022). Additionally, DEQ uses the numeric value of 10 mg/L of nitrate nitrogen as a maximum allowable in-stream value for maintaining the designated use of domestic water supply. Therefore, ammonia nitrogen and nitrate+nitrite nitrogen measurements are evaluated in subsections below.

In addition, total nitrogen measurements are evaluated. There are no numeric water quality standards for total nitrogen that apply in the Little Red River watershed (Arkansas Pollution Control and Ecology Commisison 2022), and no impaired waterbodies with nitrogen or nutrients listed as a cause for impairment (DEQ 2020). However, Arkansas is a nutrient reduction target state for the Gulf of Mexico Hypoxia Task Force. Therefore, total nitrogen levels are a concern in all Arkansas watersheds.

Since 2018, DEQ has been utilizing a laboratory method that produces a direct measurement of total nitrogen, which is more efficient than the traditional procedure of measuring total Kjeldahl nitrogen (TKN) and nitrate + nitrite nitrogen and summing the results to calculate total nitrogen. However, data from the new method are not available prior to May 2018 for water samples collected in the Little Red River watershed. This time period is too short to properly characterize water quality. Therefore, for DEQ stations, evaluation of total nitrogen is conducted on total nitrogen values calculated from nitrate + nitrite nitrogen and TKN measurements.

1.9.1 Ammonia Nitrogen

Under certain conditions of pH and temperature, ammonia nitrogen can be toxic to aquatic life. Ammonia can also reduce dissolved oxygen concentrations in water through bacterial conversion of ammonia to nitrate and encouraging excessive algal or plant growth.

Tables 24 and 25 list summary statistics for ammonia nitrogen measurements from the Little Red River watershed during 2016 -2020. No stream reaches in the Little Red River watershed have been identified as impaired due to ammonia nitrogen (DEQ 2020). Almost all ammonia nitrogen measurements are reported as less than detection. Note that USGS and DEQ have different detection limits for ammonia nitrogen. The detection limit for the USGS data is 0.01 mg/L, and for DEQ the detection limit is 0.03 mg/L. The highest reported ammonia nitrogen concentration during 2016-2020 occurred at the farthest downstream Little Red River station, WHI0059. This station is located just downstream of Searcy. Because the majority of the ammonia nitrogen measurements are reported as less than detection, no graphs of the data are provided.

Table 24. Summary statistics for stream measurements from 2016-2020 for ammonia nitrogen (stations listed in downstream order, first row is farthest upstream station).

Station ID	Stream ID+	Number of measures	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L
07075250	SF	9	<0.010	<0.010	<0.010	<0.010	<0.010	0.020
07075270	SF	9	<0.010	<0.010	<0.010	<0.010	0.010	0.020
UWSRR02	SF	3	<0.030	-	<0.030	<0.030	-	<0.030
WHI0195	AF	1	<0.030	-	-	-	-	-
UWAFK01	AF	3	<0.030	-	<0.030	<0.030	-	<0.030
ARK0170	SF	50	<0.030	<0.030	<0.030	<0.030	<0.030	0.050
UWMFK01	MF	3	<0.030	-	<0.030	<0.030	-	<0.030
WHI0177	MF	2	<0.030	-	-	<0.030	-	<0.030
WHI0043	MF	59	<0.030	<0.030	<0.030	<0.030	<0.030	0.040
WHI0187	TC	2	<0.030	-	-	<0.030	-	<0.030
UWBHC01	BF	2	<0.030	-	-	<0.030	-	<0.030
WHI0059	LRR	52	<0.030	<0.030	<0.030	<0.030	0.030	0.110

+ AF = Archey Fork of the Little Red River, BF = Beech Fork, LRR = Little Red River, MF = Middle Fork of the Little Red River, SF = South Fork of the Little Red River, TC = Turkey Creek.

Table 25. Summary statistics for Greers Ferry Lake measurements from 2016-2020 for ammonia nitrogen.

Station ID	Sample location	Number of measures	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L
LWHI010A	Epilimnion, thermocline, hypolimnion	49	<0.030	<0.030	<0.030	<0.030	<0.030	0.075
LWHI010A	Epilimnion	18	<0.030	<0.030	<0.030	<0.030	<0.030	0.075
LWHI010B	Epilimnion	14	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030

1.9.2 Nitrate + Nitrite Nitrogen

Tables 26 and 27 list summary statistics for nitrate + nitrite nitrogen measurements from the Little Red River watershed during 2016 -2020. All measurements are below the 10 mg/L drinking water criterion. The highest nitrate+nitrite nitrogen value during 2016-2020 was measured in the South Fork Little Red River at station ARK0170. The next highest value was measured at the farthest downstream station on the Little Red River, WHI0059. Both of these stations are located just downstream of towns. However, the seasonal patterns in the nitrate + nitrite measurements from these two stations indicate that nonpoint sources are the greatest influence (because the lowest values occur during the dry season, and the highest values occur during the wet season) (see Figure 18).

Table 26. Summary statistics for stream measurements of nitrate + nitrite nitrogen from 2016-2020 (stations listed in downstream order, first row is farthest upstream station).

Station ID	Stream ID+	Number of measures	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L
07075250	SF	9	0.010	0.040	0.055	0.057	0.070	0.110
07075270	SF	31	<0.010	0.010	0.030	0.043	0.060	0.150
UWSRR02	SF	3	0.101	-	0.113	0.130	-	0.175
WHI0195	AF	1	0.049	-	-	-	-	-
UWAFK01	AF	3	<0.030	-	0.031	0.049	-	0.100
ARK0170	SF	50	<0.030	<0.050	0.060	0.866	0.120	0.665
UWMFK01	MF	2	0.074	-	-	0.089	-	0.103
WHI0177	MF	2	<0.030	-	-	<0.030	-	<0.030
WHI0043	MF	56	<0.030	<0.050	<0.050	<0.050	<0.050	0.310
WHI0187	TC	2	0.180	-	-	0.274	-	0.368
UWBHC01	BF	2	0.053	-	-	0.132	-	0.210
WHI0059	LRR	53	<0.050	0.136	0.170	0.188	0.210	0.490

+ AF = Archey Fork of the Little Red River, BF = Beech Fork, LRR = Little Red River, MF = Middle Fork of the Little Red River, SF = South Fork of the Little Red River, TC = Turkey Creek.

Table 27. Summary statistics for Greers Ferry Lake nitrate + nitrite nitrogen measurements from 2016-2020.

Station ID	Sample location	Number of measures	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L
LWHI010A	Epilimnion, thermocline, hypolimnion	51	<0.030	<0.050	0.110	0.106	0.140	0.272
LWHI010A	Epilimnion	23	<0.050	<0.050	0.089	0.078	0.110	0.236
LWHI010B	Epilimnion	14	<0.030	<0.050	0.062	0.080	0.120	0.190

Data from 2016-2020

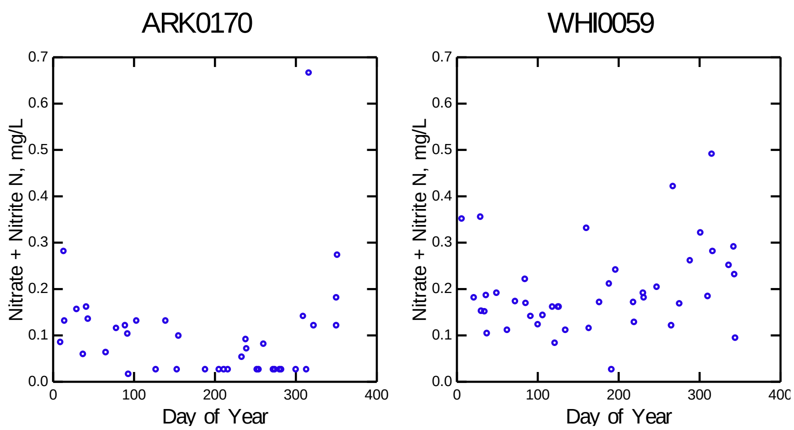

Figure 18. Graphs of nitrate + nitrite nitrogen measurements by day of the year at selected stations to exhibit seasonal patterns.

Figure 19 shows a box and whisker graph of nitrate + nitrite nitrogen measurements from stations with greater than five measurements from the period 2016-2020. The highest median nitrate + nitrite nitrogen value occurs at station WHI0059, the farthest downstream station on the Little Red River. The median value at this station is statistically significantly higher than median values at all the other stations. The lowest median nitrate + nitrite nitrogen value occurs at station WHI0043, on the Middle Fork Little Red River. This median value is statistically significantly lower than the median values at four of the six other stations graphed. Nitrate + nitrite levels in Greers Ferry Lake appear similar to levels in its monitored tributaries.

1.9.3 Total Nitrogen

Tables 28 and 29 list summary statistics for total nitrogen data from the Little Red River watershed during 2016 -2020. The highest maximum total nitrogen value was measured at station 07075270, on the South Fork Little Red River just downstream of the Scott Henderson Gulf Mountain Wildlife Management Area. This is also one of the stations with the lowest minimum total nitrogen values. There is quite a bit of variability in total nitrogen levels at several of the water quality stations.

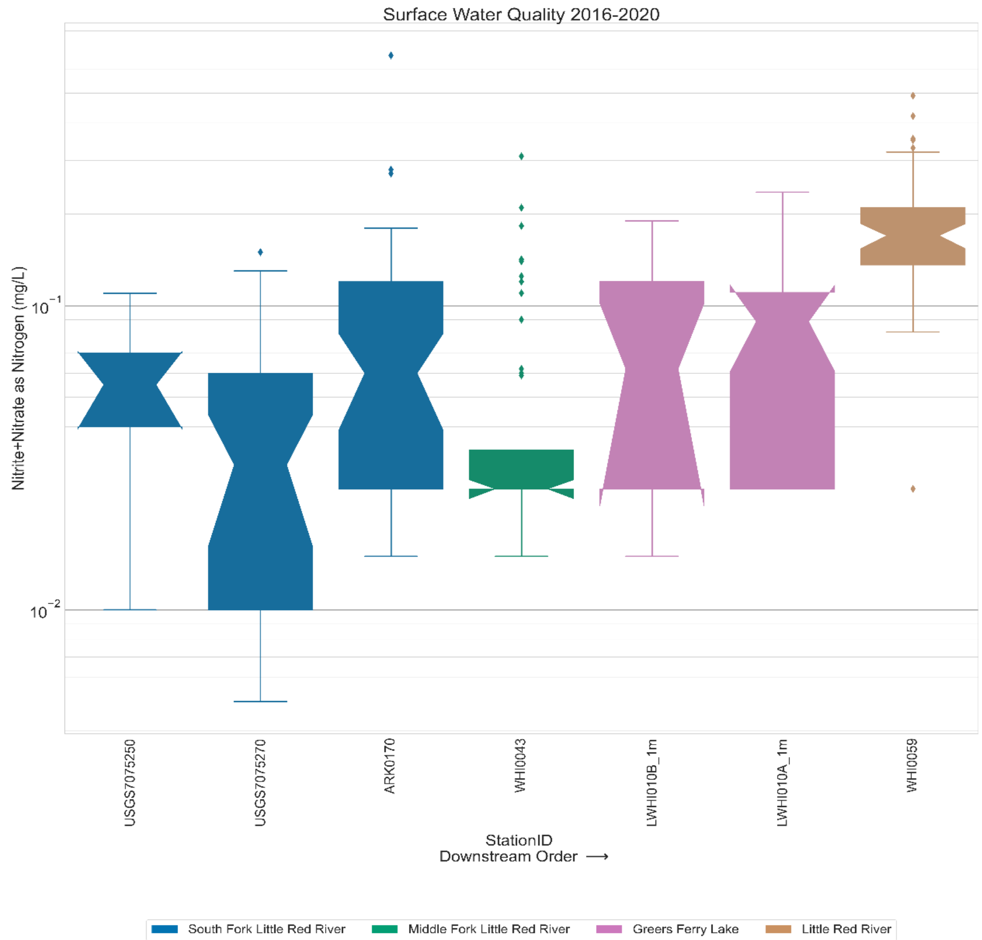

Figure 19. Box and whisker graph of nitrate + nitrite nitrogen measurements from stations with more than five values from 2016-2020.

Figure 20 shows a box and whisker graph of total nitrogen measurements from stations with more than 10 measurements from the period 2016-2020. The highest median total nitrogen concentration occurs at the farthest downstream Little Red River station, WHI0059. This median value is statistically significantly higher than the median values at the rest of the stations. However, higher maximum concentrations occurred at stations 07075270 and ARK0170. The lowest median concentration occurred at station 07075270. Median total nitrogen concentrations in Greers Ferry Lake are similar to median concentrations at the tributary stations closest to the reservoir.

Table 28. Summary statistics for stream values of total nitrogen from 2016-2020 (stations listed in downstream order, first row is farthest upstream station).

Station ID	Stream ID+	Number of measures	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L
07075250	SF	13	0.04	0.09	0.25	0.22	0.32	0.45
07075270	SF	38	0.04	0.05	0.16	0.29	0.38	2.40
UWSRR02	SF	3	0.196	-	0.212	0.222	-	0.257
WHI0195	AF	1	0.089	-	-	-	-	-
UWAFK01	AF	3	0.085	0.112	0.140	0.137	0.162	0.185
ARK0170	SF	49	0.134	0.190	0.255	0.274	0.294	1.165
UWMFK01	MF	2	0.198	-	-	0.218	-	0.237
WHI0177	MF	2	0.161	-	-	0.190	-	0.219
WHI0043	MF	55	0.055	0.170	0.253	0.243	0.288	0.770
WHI0187	TC	2	0.412	-	-	0.458	-	0.503
UWBHC01	BF	2	0.296	-	-	0.310	-	0.323
WHI0059	LRR	52	0.232	0.325	0.400	0.455	0.512	0.980

+ AF = Archey Fork of the Little Red River, BF = Beech Fork, LRR = Little Red River, MF = Middle Fork of the Little Red River, SF = South Fork of the Little Red River, TC = Turkey Creek.

Table 29. Summary statistics for Greers Ferry Lake total nitrogen values from 2016-2020.

Station ID	Sample location	Number of measures	Minimum Value, mg/L	25th Percentile, mg/L	Median, mg/L	Mean, mg/L	75th Percentile, mg/L	Maximum Value, mg/L
LWHI010A	Epilimnion	23	0.180	0.214	0.248	0.256	0.246	0.485
LWHI010B	Epilimnion	14	0.188	0.211	0.268	0.276	0.329	0.421

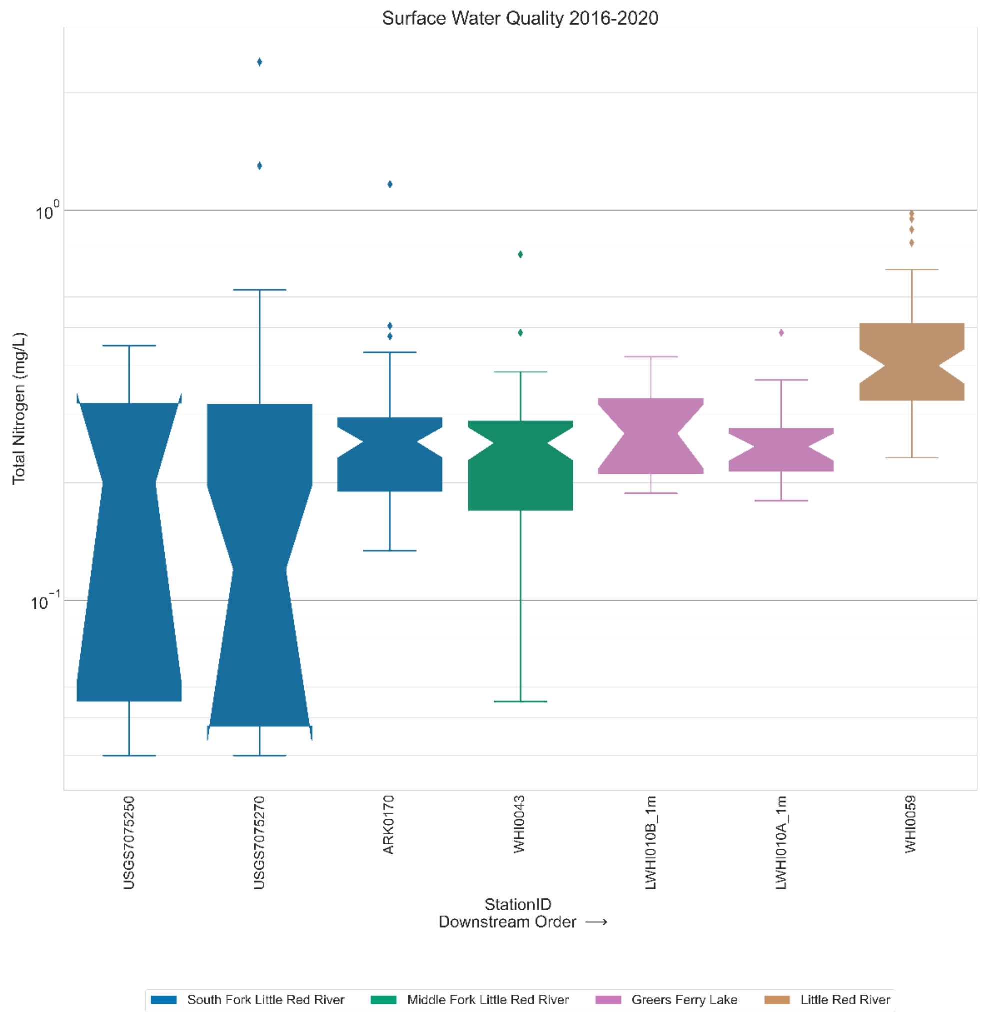

Figure 20. Box and whisker graph of total nitrogen values from stations with more than 10 values from 2016-2020.

1.10 Data Gaps

Several water quality data gaps were identified during inventorying and analyzing recent water quality data. These are discussed in the paragraphs below.

DEQ has collected BOD measurements from only one of their stations in this watershed since 2010, WHI0059. There is one BOD measurement from the stream reach listed as impaired due to low DO, station WHI0189 in 2005. Although the single BOD measurement at this station in 2005 was <10 mg/L, measuring BOD again at this location may be useful. These measurements could be used to help evaluate how much the low DO conditions are influenced by organic matter in the water column (as opposed to organic matter on the stream bottom).

Turbidity data from UWTMC01 resulted in Ten Mile Creek being listed as not meeting turbidity standards. However, turbidity measurements have not been collected at this site since 2003. Turbidity measurements are needed to be able to determine whether this stream is meeting the turbidity water quality criteria.

There are few or no DO measurements from several stations during Critical Season, because water temperatures are rarely or never above 22 deg C.

For many of the DEQ monitoring stations, there are no measurements of lab water quality parameters after 2016.

1.11 Summary

Recent *E. Coli* measurements confirm bacteria impairments. Potential sources of *E. Coli* affecting monitored locations included both point sources and nonpoint sources (developed areas, pasture, septic systems).

Low pH values in the Little Red River watershed appear to be largely a result of low buffering capacity (i.e., alkalinity) in the streams. This is a function of the underlying geology of the areas of the watershed within the Boston Mountains physiographic region, which has little carbonate rock. The Middle Fork Little Red River stations have the highest alkalinity measurements in the watershed, and the highest pH measurements.

For the most part, sediment parameters data from monitored stream locations appear relatively consistent across the watershed. Values in Greers Ferry Lake epilimnion are statistically significantly lower than values in the streams, due to the settling that occurs. Turbidity and TSS values at the downstream Little Red River station, WHI0059, tend to be higher than values from the tributaries upstream of Greers Ferry Lake, suggesting that sediment may be more of an issue downstream of the reservoir.

For the most part, DO levels at monitored locations in the Little Red River watershed are supportive of aquatic life, especially during the Primary Season. DO concentrations at the monitoring location just downstream of Greers Ferry Lake dam reflect DO concentrations in reservoir releases, which tend to be a bit lower than values at other locations.

Phosphorus levels measured in the streams are relatively similar throughout the watershed (where more than 10 measurements were taken). Total phosphorus concentrations in Greers Ferry Lake epilimnion are significantly lower than in the streams. The highest median phosphorus concentration was at station WHI0059 (Little Red River near Searcy), though this median value was not statistically significantly different from the median values for the other stream stations.

Nitrogen concentrations in the Greers Ferry Lake epilimnion are not that different from concentrations measured in the streams. The highest median nitrogen concentrations occurred at station WHI0059, and nitrate + nitrite and total nitrogen median concentrations were statistically significantly higher than median concentrations at other stations.

There are three stations where the recent water quality data indicate high levels of productivity that could become harmful to aquatic life; WHI0043 (Middle Fork Little Red River), ARK0170 (South Fork Little Red River), and WHI0059 (Little Red River near Searcy). DO percent saturation values greater than 100% occur at all three stations, and relatively high pH values also occur at stations WHI0043 and WHI0059. All three stations also have higher maximum nitrogen concentrations than the other stream stations, and WHI0059 also has the highest median total phosphorus concentration. These higher nutrient levels may be fueling the higher productivity.

1.12 References

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APPENDIX E

Evaluation of Long-Term Water Quality Trends

There are 11 stream water quality monitoring locations in the Little Red River watershed with data records of at least 10 years that extend at least into 2016. These data records may be suitable for evaluating long-term trends affecting current water quality. Parameters evaluated for trends were dissolved oxygen (DO), water temperature, pH, turbidity, total suspended solids (TSS), suspended sediment concentration (SSC), total phosphorus, ammonia nitrogen, nitrate + nitrite nitrogen, and total nitrogen.

1.1 Trend Analysis of Data from Continuous Record Stations

Water quality data collected continuously, or with only short data gaps, can be evaluated statistically to see if they exhibit trends. Water quality stations with long records of continuous data are listed in Table 1 (in order from downstream to upstream, see Figure 3.2 in report). These are the only five stations in the Little Red River watershed that have at least 10 years of continuous water quality data records that continue through 2020.

Table 1. Active water quality monitoring stations in Little Red River watershed with continuous data records of at least 10 years, through 2020.

Station ID*	Waterbody	Location	Data period
WHI0059	Little Red R	State Road 367	1990-2020
07076000	Little Red R	Below dam	1945-2020
WHI0043	Middle Fork	State Road 9	1990-2020
ARK0170	South Fork	County Road 23	2011-2020
07075270	South Fork	Near Scotland, AR	2011-2020

*Stations listed in upstream order, i.e., station in the first row is farthest downstream

First, the sampling frequency of the data from these stations was evaluated. Changes in sampling frequency over the analysis period affects the statistical analysis of trends. Adjusting the data sets to create data records with consistent frequency results in a constant variance over time (Meals, Spooner, Dressing, & Harcum, 2011).

The three stations monitored by the Arkansas Department of Energy and the Environment Division of Environmental Quality (DEQ) (WHI0059, WHI0043, ARK0170) were mostly sampled monthly, although for some parameters (usually field parameters), measurements were taken more frequently some years. In those instances, data from only one sampling date per month were used in the trend analyses. The data used were either from the sampling date when a full set of water quality analyses were conducted, or a randomly selected sampling date.

USGS station 07075270 was sampled 9 to 5 months of each year. During some months and on some dates, measurements were collected multiple times. In those instances, data from only one sampling date and time per month were used in the trend analysis. The data used were either from the date and time when samples were collected on which a full set of water quality analyses were conducted, or a random date, or a sampling time around midday.

USGS station 07076000 was sampled monthly to biannually. For the trend analysis, only samples collected in June and the latest month from October through December were used for each year.

Next, we considered the period of the data to analyze. For those stations with data records beginning earlier than 2011, data from the period 2010-2020 were evaluated for trends. Ten years of data is considered adequate for identifying trends (Meals, Spooner, Dressing, & Harcum, 2011).

Characteristics of the data determined what type of statistical trend analysis was appropriate. Data characteristics of concern include the presence of seasonal patterns, whether the data were normally distributed, and whether concentrations appeared to be related to flow rate. Discharge data were not collected with the water quality data from the DEQ stations. Discharge data were collected at the USGS stations, however not during the analysis period, or not during the entire analysis period. Therefore, flow rate was not considered as part of these trend analyses. Relevant characteristics of the data from the analysis period are discussed in the following sections.

1.1.1 Dissolved Oxygen

Figure 1 shows time series graphs of DO concentrations from the five continuous record water quality stations for the period 2010 – 2020. As shown in Figure 2, DO data typically exhibits a seasonal pattern. This is because DO concentrations, and processes that affect DO, are affected by water temperature, which varies seasonally.

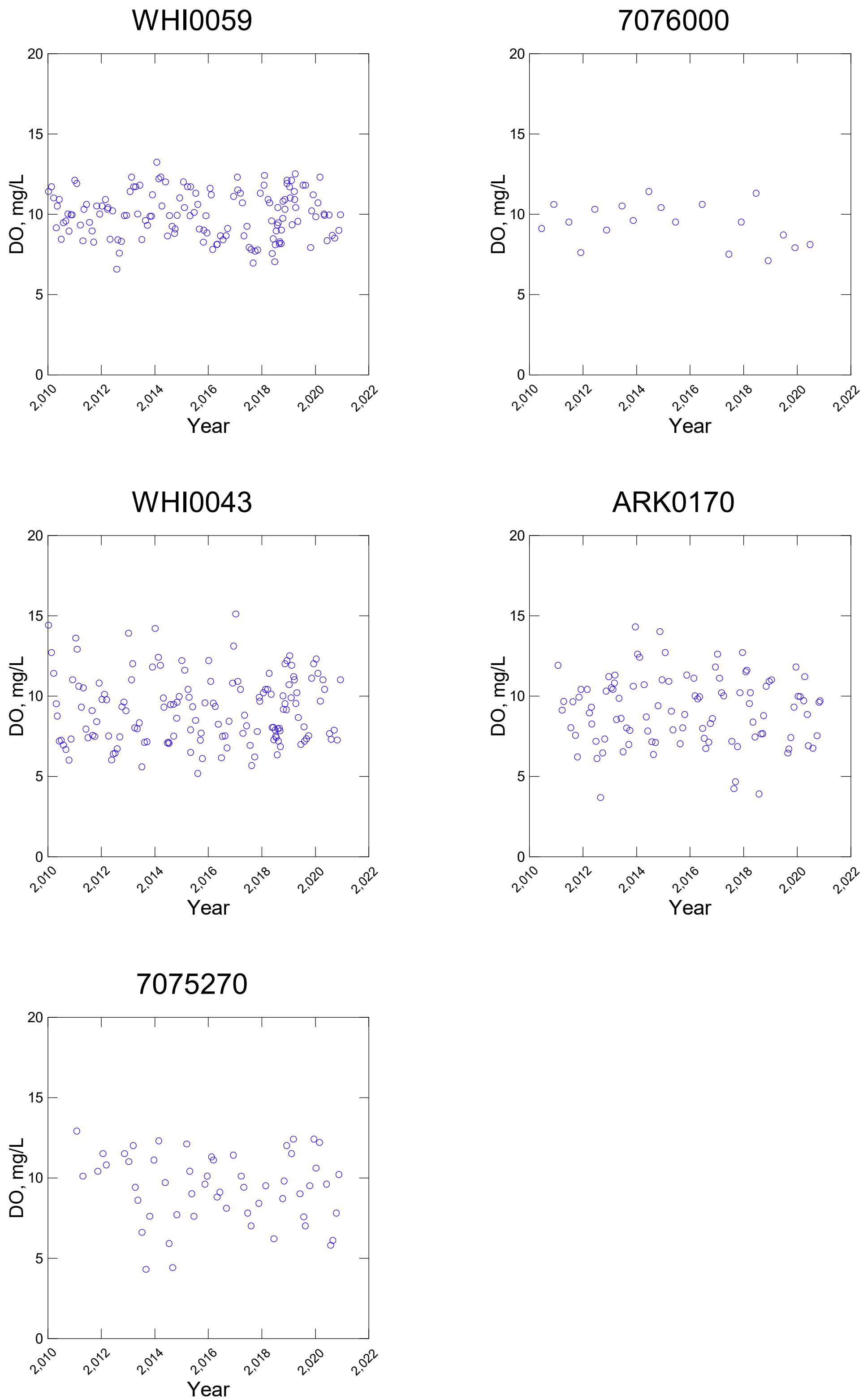


Figure 1. Time series graphs of DO measurements from 2010-2020.

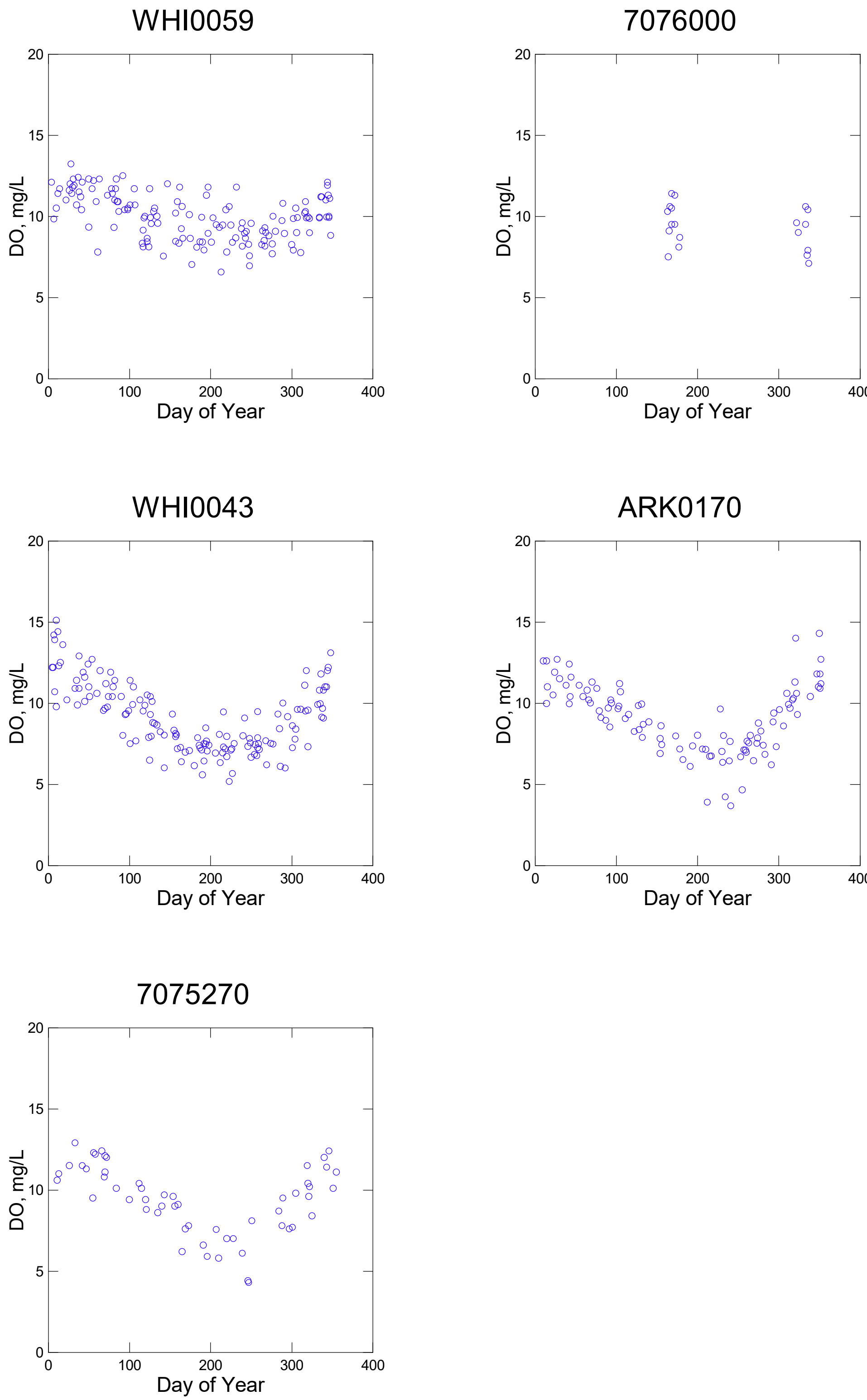


Figure 2. Graphs of DO measurements from 2010-2020 showing seasonal pattern.

Because of the strong seasonality exhibited by the data, the Seasonal Kendall non-parametric statistical test was used to evaluate trends in dissolved oxygen concentrations. The USGS program for the Kendall family of tests was used to run the statistical test (Helsel, Mueller, & Slack, 2006). For all but station 07076000, the program was set up with 12 seasons, i.e., each month was considered a separate season. For station 07076000, the program was set up with two seasons, because there are only two measurements each year. The analyses in this program are based on water years (i.e., October – September). The program input and output are included as Attachment 1. The test results, summarized in Table 2, indicate that there are no statistically significant trends in these data (p-values are all greater than 0.05).

Table 2. Results of Seasonal Kendall test of 2010-2020 DO data.

Station	Stream	Number of Years	S Statistic	Z Statistic	P-Value	Statistically Significant Trend?
WHI0059	Little Red River	12	-29	-0.676	0.499	No
07076000	Little Red River	12	-15	-0.877	0.381	No
WHI0043	Middle Fork Little Red River	12	43	0.984	0.325	No
ARK0170	South Fork Little Red River	11	15	0.456	0.649	No
07075270	South Fork Little Red River	11	8	0.515	0.606	No

1.1.2 Water Temperature

The monitored streams in the Little Red River watershed all meet applicable water temperature criteria. However, water temperature is a concern in the designated trout streams in the watershed. Also, as noted in Appendix D (Section D.5.2), it appears that water temperatures at station WHI0059 may be decreasing. Therefore, water temperature data from the long-term stations were evaluated for trends. Figure 3 shows time series graphs of water temperatures at all five of the stations from 2010 to 2020. Maximum water temperatures at Station WHI0059 appear to be decreasing during this period. There may also be an increasing trend in water temperatures at station 07076000. The abrupt change in maximum water temperatures at station 07075270 is most likely the result of the fact that water temperatures were not collected during the summer at this station during 2011 and 2012.

As shown in Figure 4, water temperatures typically exhibit a seasonal pattern. Water temperatures at station 07076000 do not vary as much during the year as at the other stations, due to the influence of releases from Greers Ferry Lake reservoir.

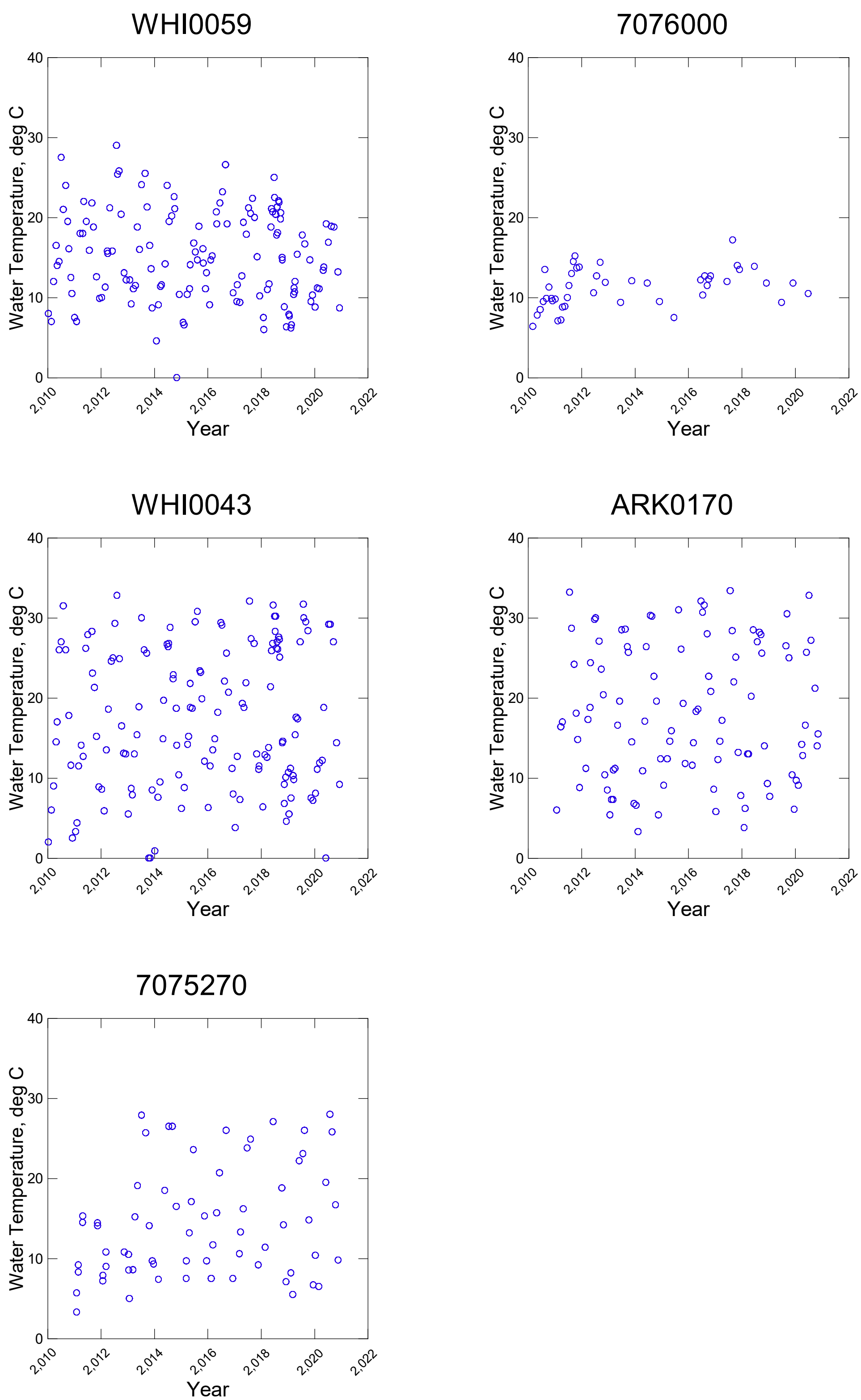


Figure 3. Time series graphs of stream water temperature measurements from 2010-2020.

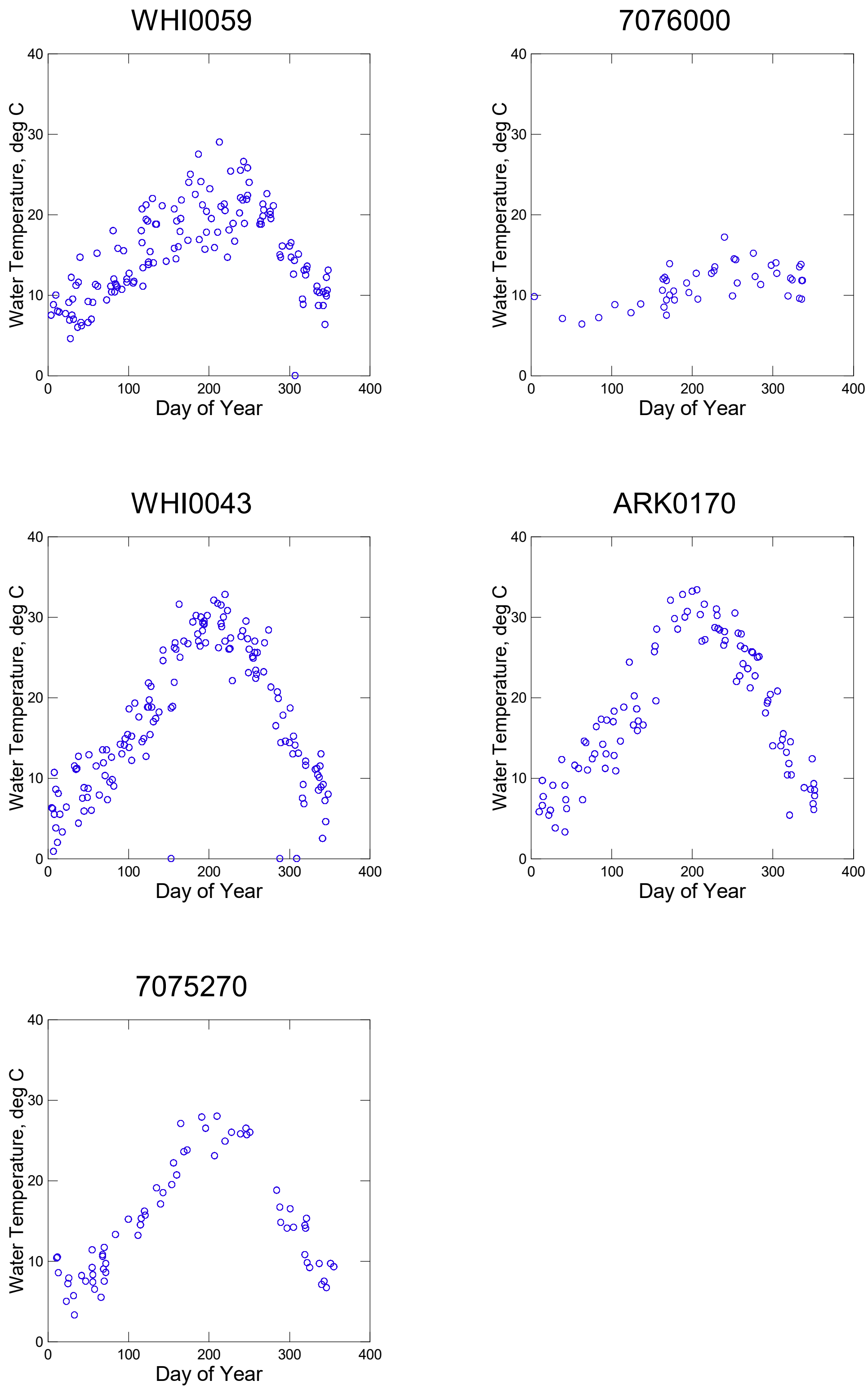


Figure 4. Graphs of stream water temperature measurements from 2010-2020 showing seasonal pattern.

Because of the strong seasonality exhibited by the data, the Seasonal Kendall non-parametric statistical test was used to evaluate trends in water temperature. The USGS program for the Kendall family of tests was used to run the statistical test (Helsel, Mueller, & Slack, 2006). The input data was prepared the same as for dissolved oxygen (see Section 1.1.1). The program input and output are included as Attachment 2. The test results, summarized in Table 3, indicate a statistically significant decreasing trend in water temperature at station WHI0059, but not at any of the other stations.

Table 3. Output from Seasonal Kendall test of water temperature data from 2010-2020, from selected monitoring stations.

Station	Stream	Number of Years	S Statistic	Z Statistic	P-value	Adjusted P-value	Statistically Significant Trend?
WHI0059	Little Red River	12	-99	-2.39	0.017	0.169	Yes, decreasing
07076000	Little Red River	11	21	1.45	0.147	0.151	No
WHI0043	Middle Fork Little Red River	12	81	1.88	0.061	0.162	No
ARK0170	South Fork Little Red River	11	-7	-0.19	0.847	0.878	No
07075270	South Fork Little Red River	11	-3	-0.17	0.866	0.889	No

1.1.3 pH

Figure 5 shows graphs of pH from the selected long-term water quality stations for the period 2010 – 2020. The graphs include a dashed line highlighting the 6 su pH ambient water quality standard. Measurements from three of the stations have periods when there was a higher incidence of values less than 6 su. At stations WHI0059 and WHI0043, this appears to be about a two-year period beginning around 2018. At station 07075270, the period is longer, about four years, starting around 2014.

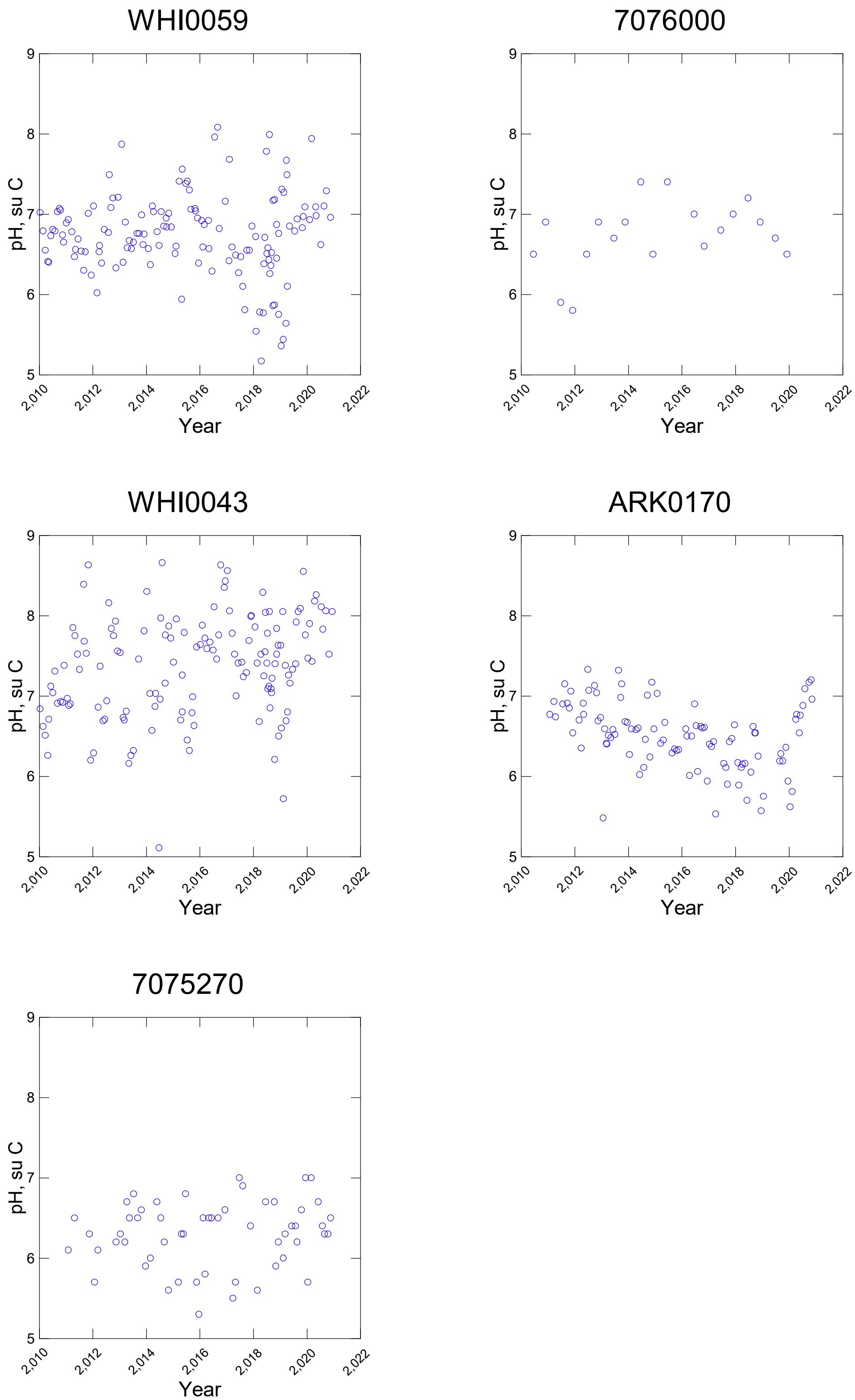


Figure 5. Time series graphs of stream pH measurements from 2010-2020.

Figure 6 shows graphs of pH data by day of year to evaluate data seasonality. Data from the South Fork Little Red River stations (ARK0170 and 07075270) appear to exhibit some seasonality. Data from station 07076000 might also exhibit seasonality. Notched box and whisker graphs of these data by month and quarter show that the median values from the two seasons are not statistically significantly different (Figure 7).

The data were tested for normal distribution using the Shaprio-Wilk and Anderson-Darling statistics. The statistics results are given in Table 4. Three of the data sets exhibit normal distribution. Table 5 summarizes the methods used for trend analysis based on the data characteristics.

Table 4. Normality test results for 2010-2020 pH data from long term stations.

Station	Number of Measures	Shapiro-Wilk Statistic	Shapiro-Wilk p-value	Anderson-Darling Statistic	Anderson-Darling p-value	Normal Data Distribution?
WHI0059	139	0.975	0.011	1.261	<0.01	No
07076000	19	0.930	0.172	0.512	>0.15	Yes
WHI0043	142	0.985	0.116	0.445	>0.15	Yes
ARK0170	101	0.984	0.281	0.334	>0.15	Yes
07075270	55	0.962	0.080	0.770	0.042	Unclear

Table 5. Trend analysis approach based on data characteristics.

Station	Seasonality	Normality	Analysis
WHI0059	No	No	Mann Kendall
07076000	No	Yes	Linear regression
WHI0043	No	Yes	Linear regression
ARK0170	Maybe	Yes	Linear regression
07075270	Yes	Unclear	Seasonal Kendall

The Mann-Kendal and Seasonal Kendall analyses were performed using the USGS program for the Kendall family of tests (Helsel, Mueller, & Slack, 2006). The input data was prepared the same as for DO (see Section 1.1.1). The program input and output are included as Attachment 3. Results from these analyses are listed in Table 6. They indicate a statistically significant increasing trend in the data from station WHI0059 and no trend in data from station 07075270.

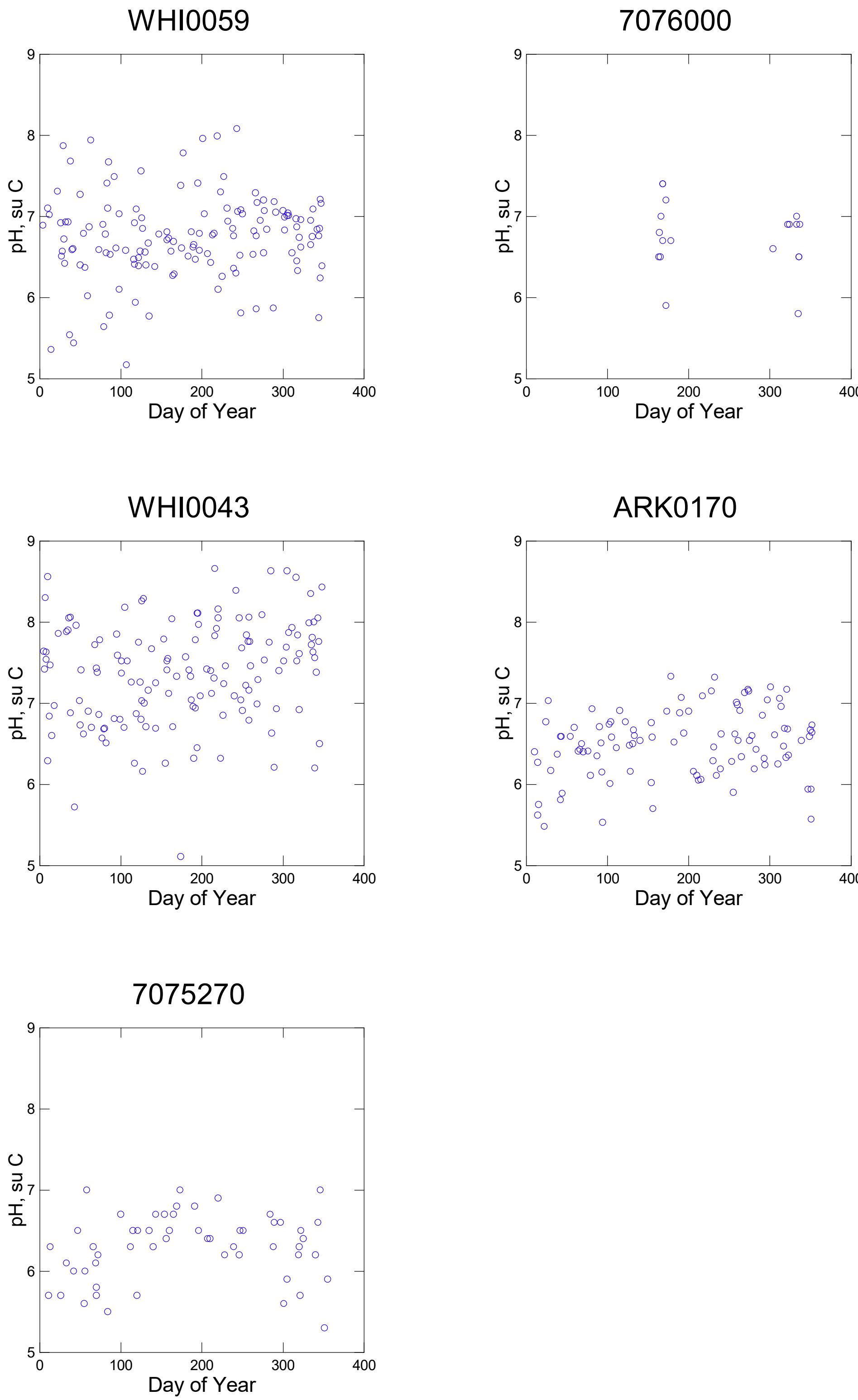


Figure 6. Graphs of stream pH measurements from 2010-2020 to evaluate seasonal patterns.

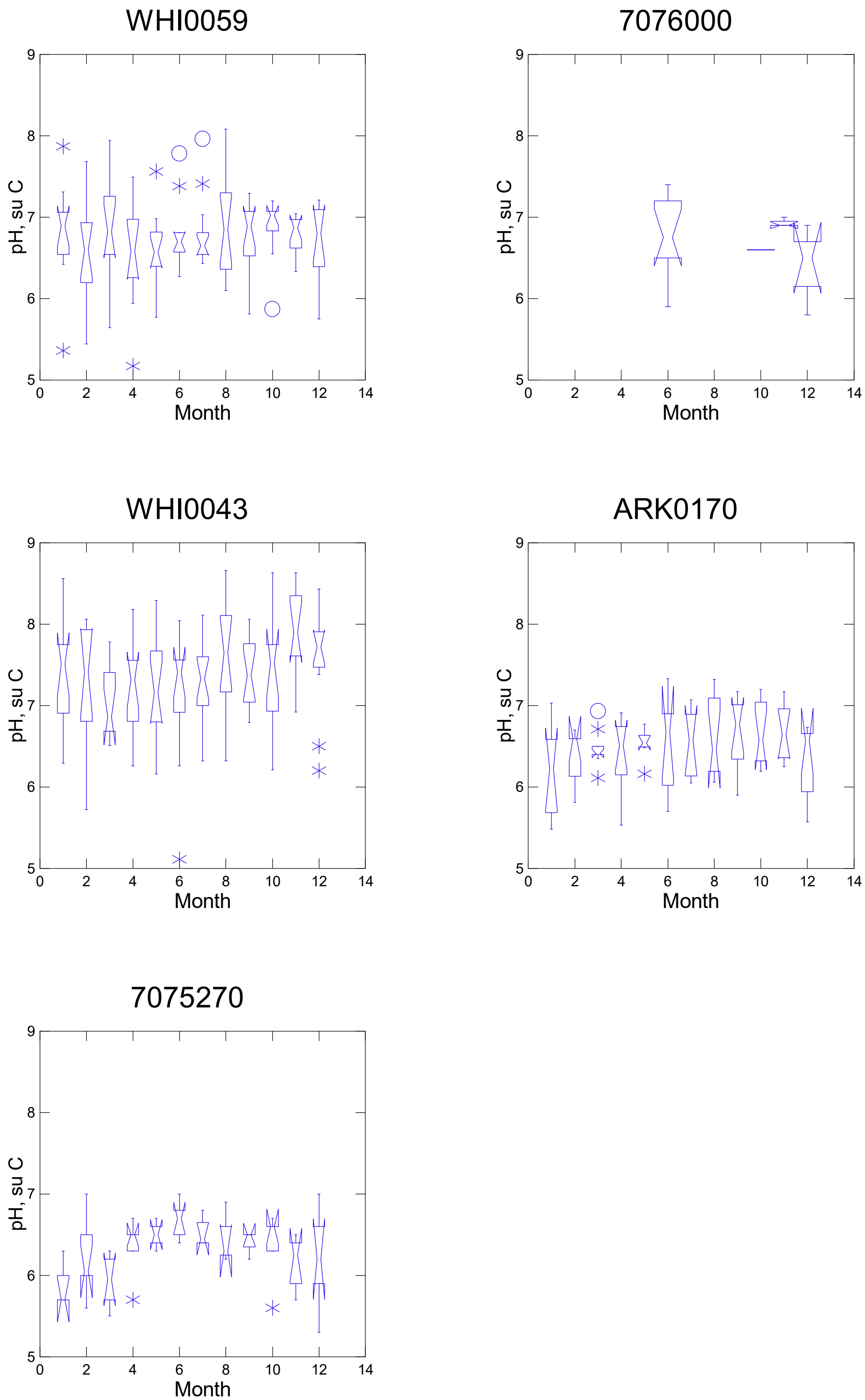


Figure 7. Box and whisker graphs of stream pH measurements from 2010-2020 to evaluate seasonal patterns.

Table 6. Results of Kendall tests on 2010-2020 pH data from selected stream water quality stations.

Station	Stream	Number of Years	S Statistic	Z Statistic	P-value	Statistically Significant Trend?
WHI0059*	Little Red River	-	988	2.21	0.027	Yes, increasing
07075270+	S. Fork Little Red River	11	8	0.52	0.61	No

* Mann-Kendall analysis results
+ Seasonal Kendall analysis results

The linear regression analysis was performed using the Systat statistical program (Version 12.02.00, 2007). In this analysis, pH was regressed against decimal year. The results from the linear regression trend analyses are listed in Table 7. This analysis confirms a statistically significant increasing trend in pH values from station WHI0043, but not in the pH values from station 07076000. The increasing trend at station WHI0043 appears to be the result, of higher minimum pH values. Maximum pH values do not appear to be changing over time (Figure 5).

Table 7. Results of linear regression of pH data from selected stream water quality stations.

Station	Stream	Number of Values	Constant	Slope	P-value	Statistically Significant Trend?
07076000	Little Red River	19	-94.2	0.05	0.127	No
WHI0043	Middle Fork Little Red River	142	-111.2	0.06	0.000	Yes, increasing
ARK0170	South Fork Little Red River	101	111.2	-0.05	0.000	Yes, decreasing

This analysis also confirms a statistically significant decreasing trend in pH at station ARK0170, visible in the time series graph (Figure 5). Low pH levels at this station have resulted in the listing of the associated reach of the South Fork Little Red River as impaired. However, during 2020 pH values at this station appear to have increased to 2010 levels (Figure 5). The minimum pH value measured at this station after 2020 (through April 2022) is 6.02 su, and the average of the measurements during this period is 6.72 su. This suggests that pH conditions at this station have improved. The reason for this change is unknown.

1.1.4 Turbidity

Turbidity measurements were collected only at the DEQ water quality stations in the Little Red River watershed during the period 2010-2020. Figure 8 shows time series graphs of turbidity measurements from the DEQ long-term stream water quality stations for the period 2010 – 2020. Prior to 2012, the data at all three stations show more variability and/or higher maximum values than the rest of the period of interest. This is more apparent in box graphs of the data by year (Figure 9). This pattern may influence the trend analysis. Therefore, turbidity data from 2010 and 2011 are excluded from this trend analysis.

Figure 10 shows graphs of turbidity data by day of year to evaluate data seasonality. There is no readily apparent seasonal pattern. This is surprising, as stream turbidity is often correlated with flow, which does exhibit a seasonal pattern in the streams on which these stations are located (Section 3.3.2).

The data were tested for normal distribution using the Shaprio-Wilk and Anderson-Darling statistics. The statistics results are given in Table 8. None of the data sets exhibit normal distribution.

Table 8. Normality test results for 2010-2020 turbidity data from long term stations.

Station	Number of Measures	Shapiro-Wilk Statistic	Shapiro-Wilk p-value	Anderson-Darling Statistic	Anderson-Darling p-value	Normal Data Distribution?
WHI0059	122	0.542	0.000	16.185	<0.01	No
WHI0043	133	0.388	0.000	24.420	<0.01	No
ARK0170	101	0.539	0.000	14.436	<0.01	No

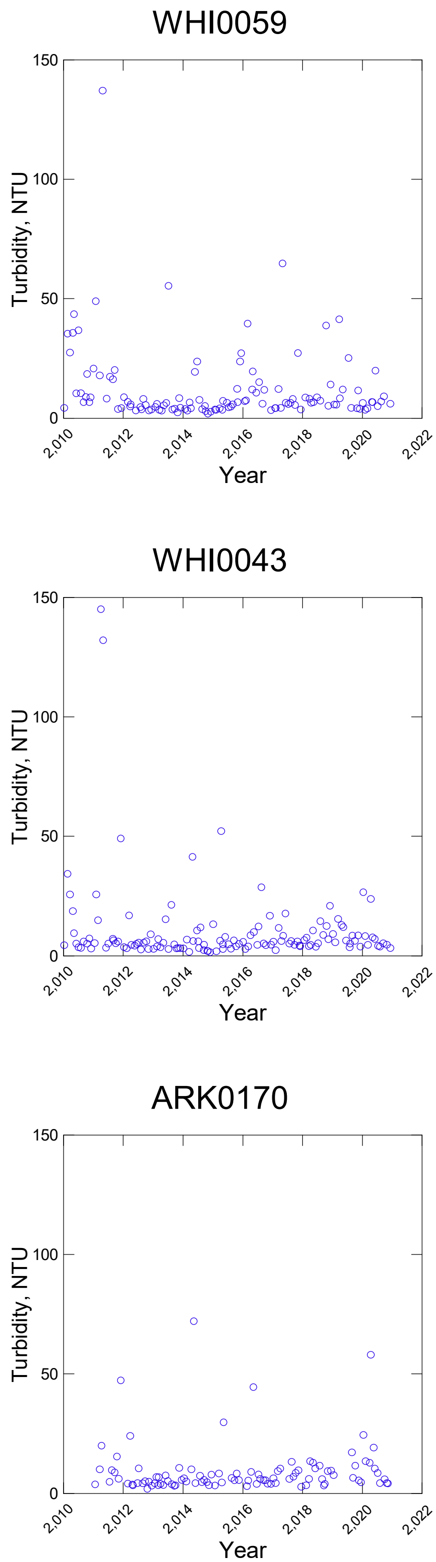


Figure 8. Time series graphs of stream turbidity measurements from 2010-2020.

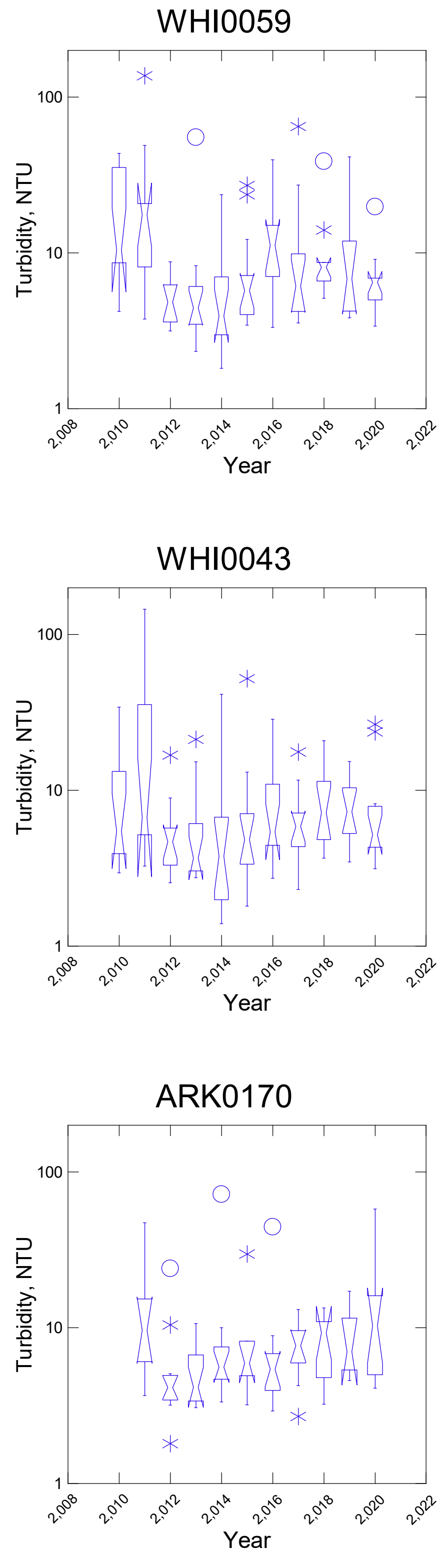


Figure 9. Box and whisker graphs of stream turbidity measurements from 2010-2020.

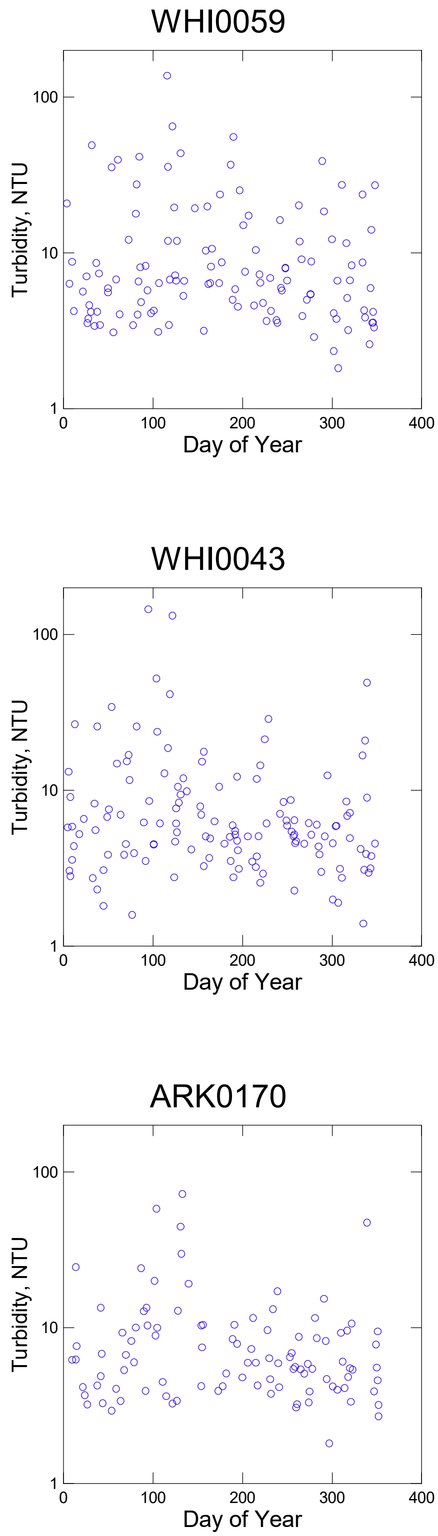


Figure 10. Graphs of stream turbidity measurements to evaluate seasonal patterns.

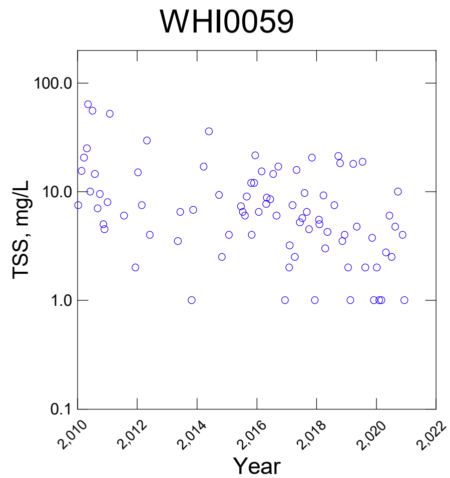
The Mann-Kendall nonparametric trend test was performed on these data, using the USGS program for the Kendall family of tests (Helsel, Mueller, & Slack, 2006). The program input and output are included as Attachment 4. The test results indicated statistically significant increasing trends in turbidity levels at all three stations (Table 9).

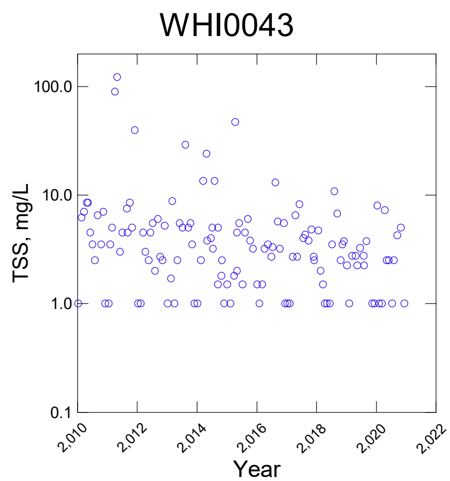
Table 9. Results of Mann-Kendal tests on 2012-2020 turbidity data.

Station	Stream	Tau correlation coefficient	S Statistic	Z Statistic	P-value	Statistically Significant Trend?
WHI0059	Little Red River	0.203	986	2.98	0.003	Yes, increasing
WHI0043	Middle Fork Little Red River	0.159	886	2.42	0.016	Yes, increasing
ARK0170	S. Fork Little Red River	0.240	983	3.37	0.001	Yes, increasing

1.1.5 Total Suspended Solids

Total suspended solids (TSS) measurements were collected only at the DEQ water quality stations in the Little Red River watershed during the period 2010-2020. Figure 11 shows time series graphs of TSS from the selected water quality stations for the period 2010 – 2020. During the period 2011-2015, 23 of the 60 TSS measurements from station WHI0059 did not meet DEQ quality assurance criteria. These measurements were excluded from the analysis data set, resulting in a period of sparse data. Less than detection values were reported in the data sets at all three stations, using detection levels of 1.0 mg/L and 2.0 mg/L. Since only 15% or less of the TSS measurements collected during 2010-2020 were reported as less than detection, half the detection value was used in the data sets used for statistical trend. To prevent the variation in the detection limits from influencing the trend analysis, all less than detection values were set to 0.5 mg/L in the analysis data set tests (Kayhanian, Singh, & Meyer, 2002) (Helsel, 2005) (Helsel, 2019).





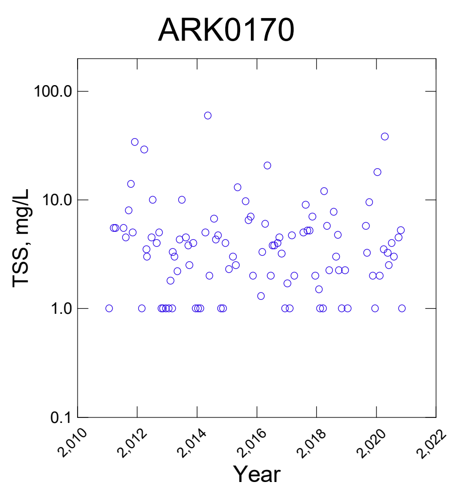


Figure 11. Time series graphs of stream TSS measurements from 2010-2020.

Figure 12 shows graphs of TSS data by day of year to evaluate data seasonality. These graphs do seem to show seasonal patterns in the data. TSS in streams is often correlated to flow, which would be expected to exhibit a seasonal pattern at these stations. However, TSS concentrations are usually higher in the fall and winter, when flows are higher, and lower in the summer, when flows are lower. At these stations, the opposite appears to be true.

The data were tested for normal distribution using the Shaprio-Wilk and Anderson-Darling statistics. The statistics results are given in Table 10. None of the data sets exhibit normal distribution. Natural log transformed data from station WHI0059 exhibited normal distribution. Natural log transformed data from the other two stations were not normally distributed.

Table 10. Normality test results for 2010-2020 TSS data from long-term stations.

Station	Number of Measures	Shapiro-Wilk Statistic	Shapiro-Wilk p-value	Anderson-Darling Statistic	Anderson-Darling p-value	Normal Data Distribution?
WHI0059	86	0.683	0.000	7.521	<0.01	No
WHI0043	132	0.317	0.000	29.47	<0.01	No
ARK0170	102	0.515	0.000	14.81	<0.01	No

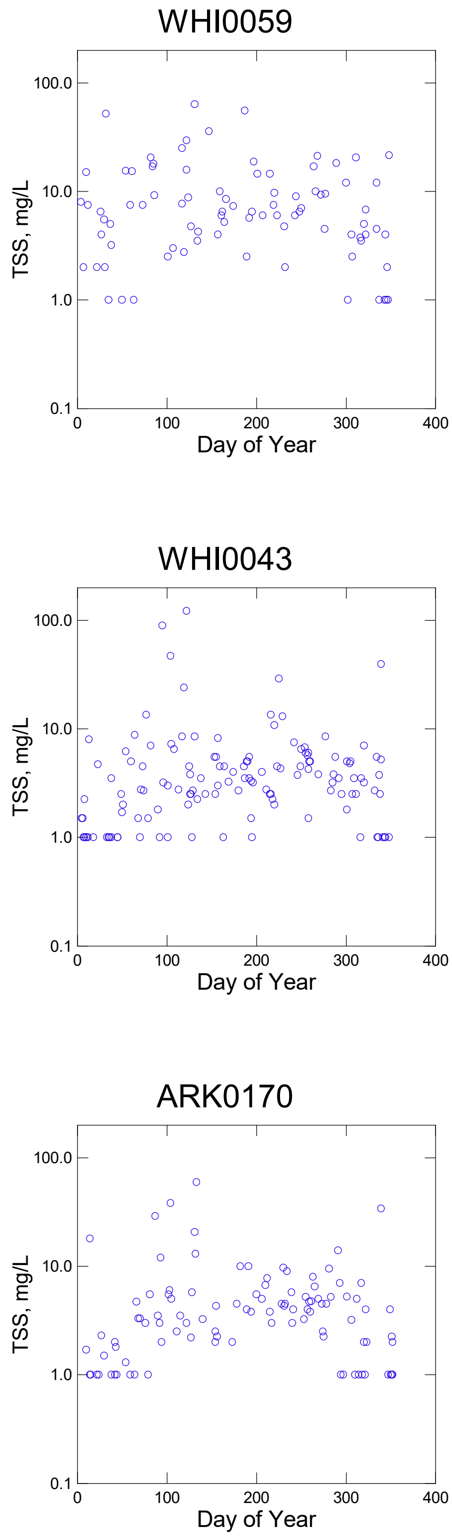


Figure 12. Graphs of stream TSS measurements to evaluate seasonal patterns.

The Seasonal Kendall nonparametric trend test was run on these data. The USGS program for the Kendall family of tests was used to run the statistical test (Helsel, Mueller, & Slack, 2006). The input data was prepared the same as for DO (see Section 1.1.1). The program input and output are provided in Attachment 5. The results of the test indicate a statistically significant decreasing trend in TSS at station WHI0059 on the Little Red River, and at WHI0043 on the Middle Fork Little Red River (Table 11). It is surprising to find decreasing trends in TSS since increasing trends in turbidity were identified at these stations. Appendix D graphs of turbidity versus TSS indicated positive relationships between these two parameters (Appendix D Figure 10).

Table 11. Results of Seasonal Kendall tests on 2010-2020 TSS data from long-term stations.

Station	Stream	Number of Years	S Statistic	Z Statistic	P-value	Statistically Significant Trend?
WHI0059	Little Red River	12	-81	-3.47	0.0005	Yes, decreasing
WHI0043	Middle Fork Little Red River	12	-142	-3.03	0.010	Yes, decreasing
ARK0170	S. Fork Little Red River	11	-33	-1.04	0.298	No

1.1.6 Suspended Sediment

USGS measures suspended sediment concentration (SSC) at station 07075270 instead of TSS. Figure 13 shows a time series graph of suspended sediment concentrations for the period 2010 – 2020. Figure 14 shows a graph of suspended sediment concentrations to evaluate seasonal patterns. The data do seem to exhibit a seasonal pattern. Anderson-Darling and Shapiro-Wilks statistics indicate that both untransformed and natural log transformed suspended sediment measurements are not normally distributed. Therefore, the Seasonal Kendall test was performed to evaluate these data for trends. The result of this test does not indicate the presence of a trend (Attachment 6).

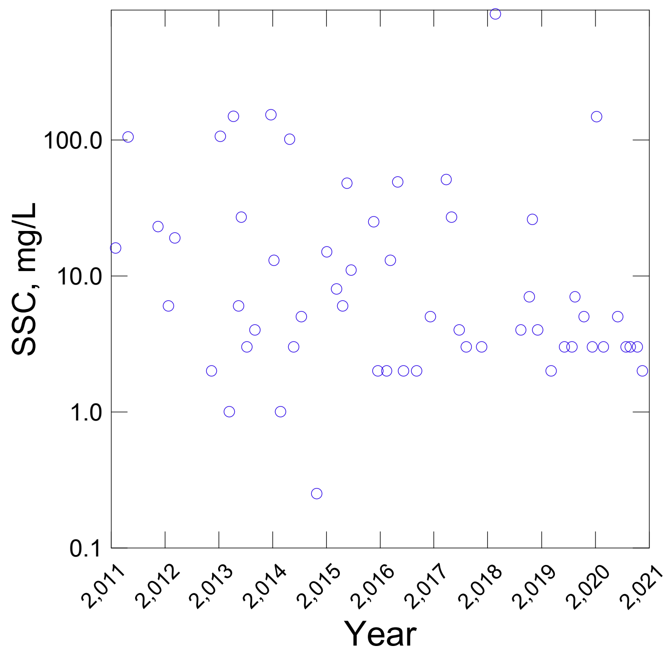


Figure 13. Time series graph of 07075270 SSC measurements from 2010-2020.

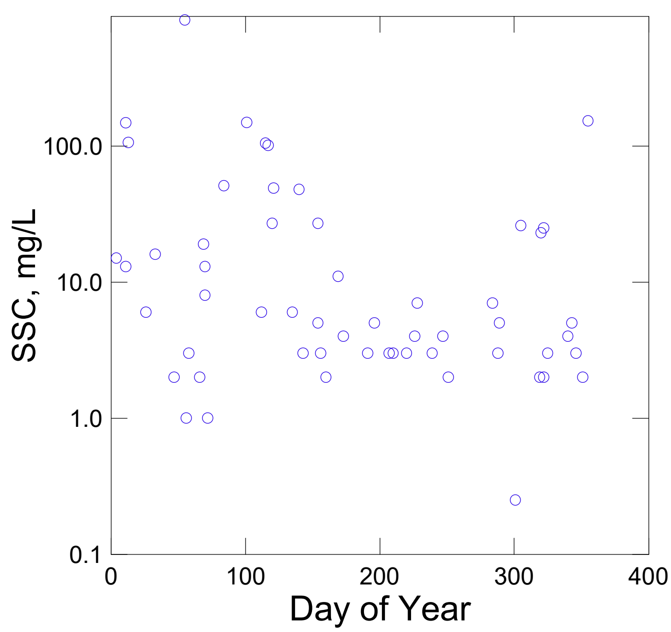


Figure 14. Graph of 07075270 SSC measurements to evaluate seasonal pattern.

1.1.7 Total Phosphorus

Figure 15 shows time series graphs of total phosphorus data from the selected water quality stations for the period 2010-2020. A log10 vertical scale is used to better display the data. Over 15% of measurements from stations ARK0170 (30 of 99), WHI0043 (45 of 128), and WHI0059 (32 of 121) were reported as less than detection. Replacing that many data points with half of the detection level will bias the data set (Helsel, 2019). Therefore, these data sets were not analyzed for trends. However, the total phosphorus data from station 07075270 was suitable for our trend analysis.

Shaprio-Wilk and Anderson-Darling statistics for these data indicate they were not normally distributed, even when log-transformed. Therefore, Mann-Kendall analysis was used to evaluate these data for a trend. The result of this test does not indicate the presence of a trend in total phosphorus concentrations at station 07075270 during the period 2010-2020 (Attachment 7).

1.1.8 Ammonia Nitrogen

Figure 16 shows graphs of ammonia nitrogen measurements from the selected water quality stations for the period 2010-2020. The majority of the measurements from all of the stations were reported as less than detection. As a result, ammonia nitrogen data from the long-term stations are judged not suitable for evaluation of trends.

1.1.9 Nitrate + Nitrite Nitrogen

Figure 17 shows graphs of nitrate + nitrite nitrogen data from the selected water quality stations for the period 2010-2020. A log10 vertical scale is used to better display the data. Over 15% of measurements from stations ARK0170 (35 of 102), WHI0043 (87 of 130), and 07075270 (11 Of 54) were reported as less than detection. In addition, the DEQ detection levels changed during the analysis period. As a result, the nitrate + nitrite nitrogen data from these three stations is not suitable for evaluation of trends. However, the nitrate + nitrite nitrogen data from station WHI0059 is suitable

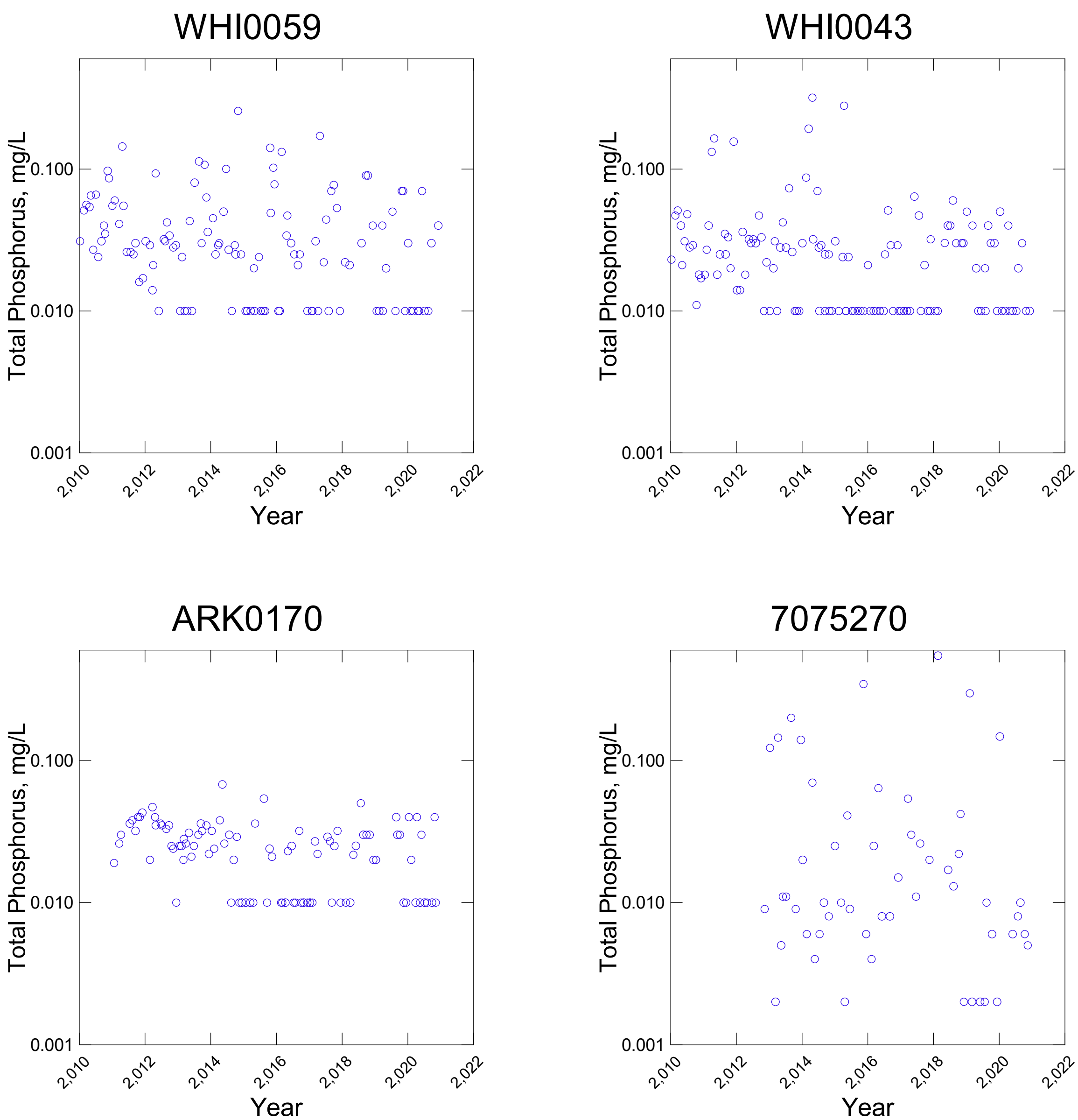


Figure 15. Time series graphs of stream total phosphorus measurements from 2010-2020.

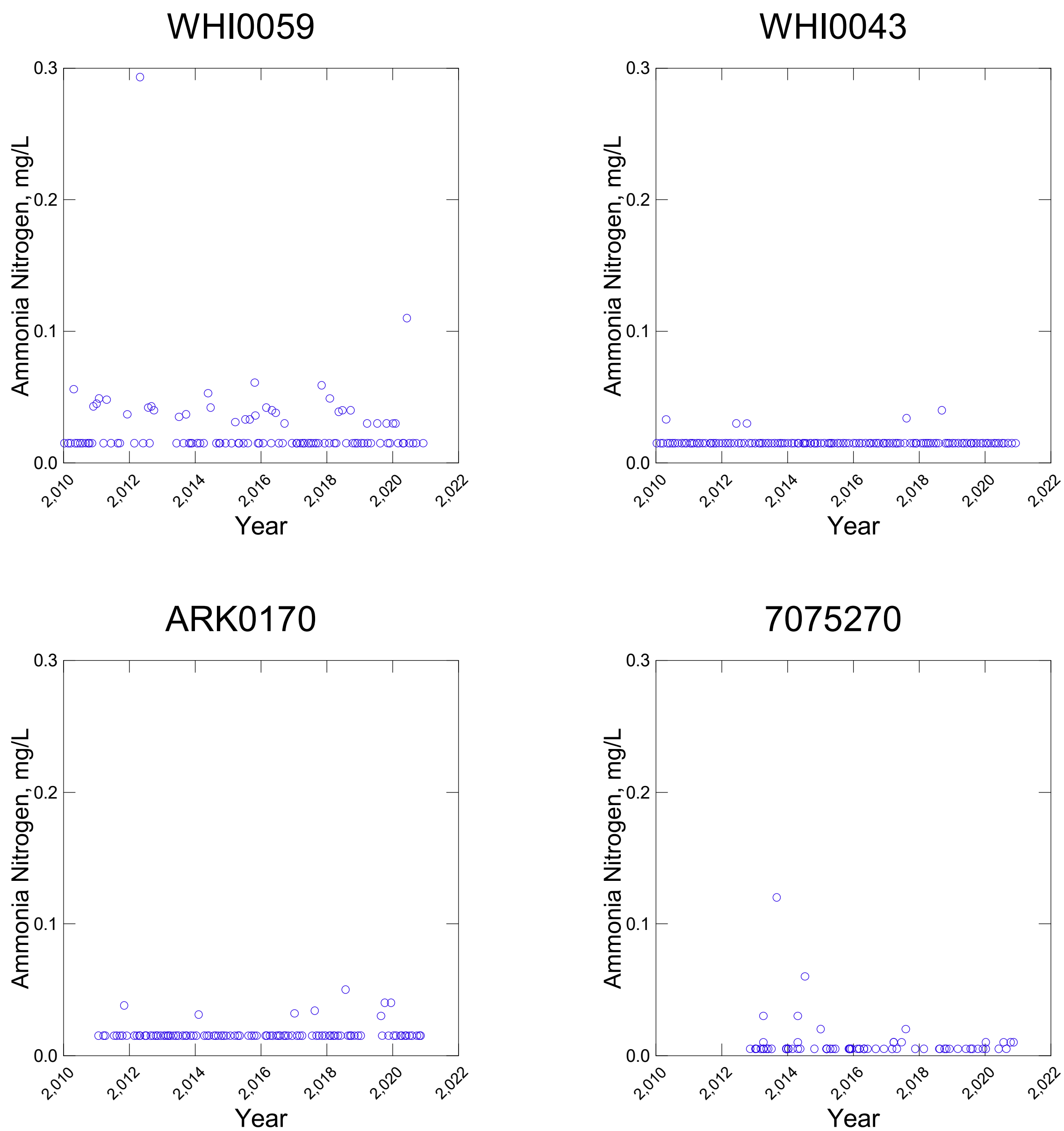


Figure 16. Time series graphs of stream ammonia nitrogen measurements from 2010-2020.

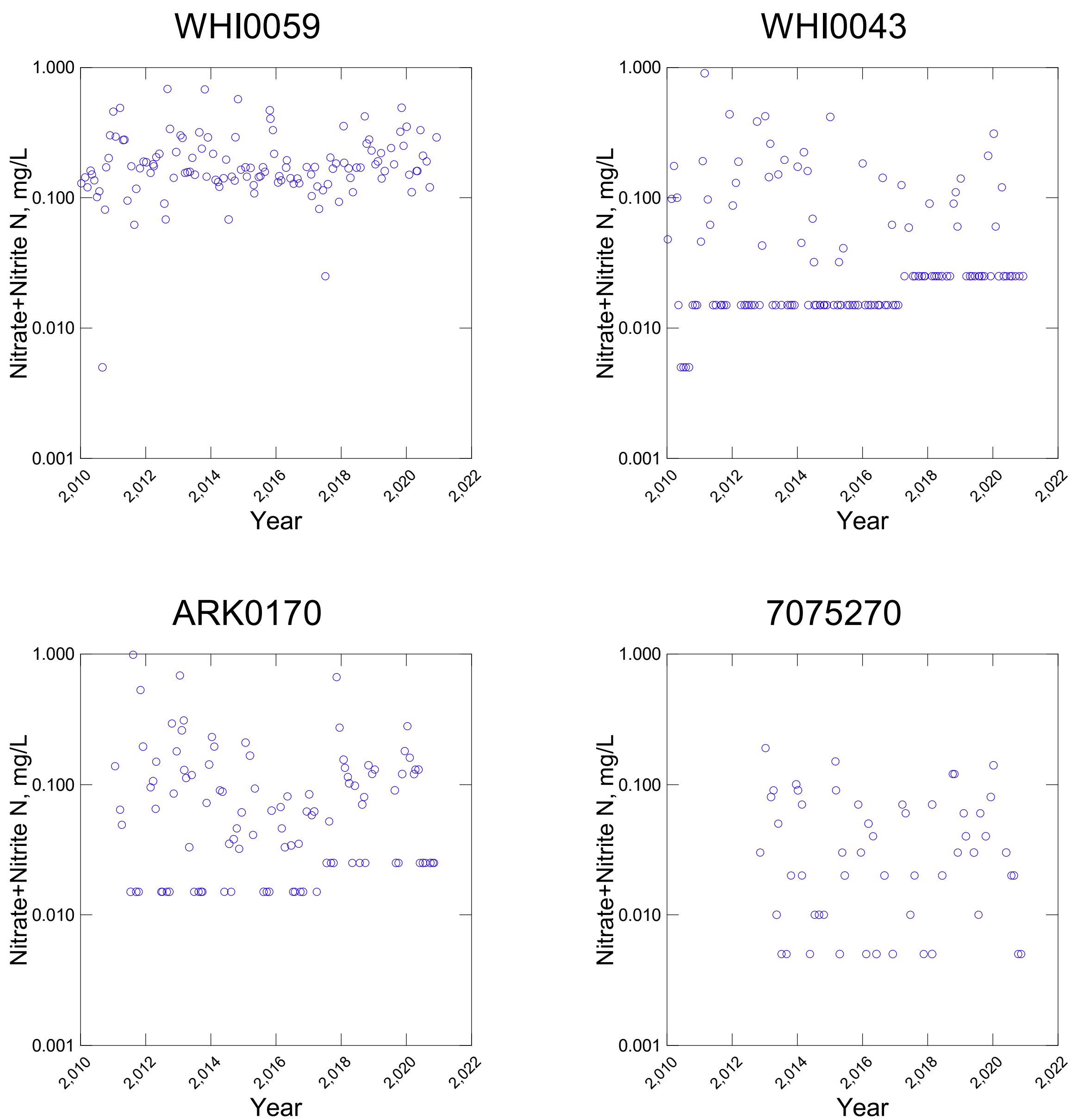


Figure 17. Time series graphs of stream nitrate+nitrite nitrogen measurements from 2010-2020.

Nitrate + nitrite nitrogen data from station WHI0059 may exhibit a seasonal pattern. Shaprio-Wilk and Anderson-Darling statistics for these data indicate they are not normally distributed, even when log-transformed. Therefore, Seasonal Kendall analysis was used to evaluate these data for a trend. The USGS program for the Kendall family of tests was used to run the statistical test (Helsel, Mueller, & Slack, 2006). The input data was prepared the same as for DO (see Section 1.1.1). The results of this analysis indicate no trend over the 2010-2020 period (Attachment 8).

1.1.10 Total Nitrogen

Total nitrogen values were reported by USGS at station 07075270. As noted in report Section 3.1.3.7, DEQ has reported total nitrogen values for its stations only since May 2018. Therefore, for the DEQ stations, total nitrogen values were calculated by adding measured TKN to nitrate + nitrite nitrogen. Figure 18 shows time series graphs of total nitrogen values from the period 2010-2020 at the long-term monitoring stations. A log10 vertical scale is used to better display the data. Figure 18 shows graphs of total nitrogen concentrations to evaluate seasonal patterns. Except at station WHI0059, the data appear to exhibit seasonal patterns.

Since the total nitrogen data from station WHI0059 do not appear to exhibit a trend, nor seasonal pattern, no further analyses were performed on the data from this station. The Seasonal Kendall nonparametric trend test was run on total nitrogen data from the other three water quality stations. The USGS program for the Kendall family of tests was used to run the statistical test (Helsel, Mueller, & Slack, 2006). The input data was prepared the same as for DO (see Section 1.1.1). The program input and output are provided in Attachment 9. The results of the test indicate a statistically significant decreasing trend in total nitrogen at station WHI0043 (Middle Fork Little Red River) (see Table 12).

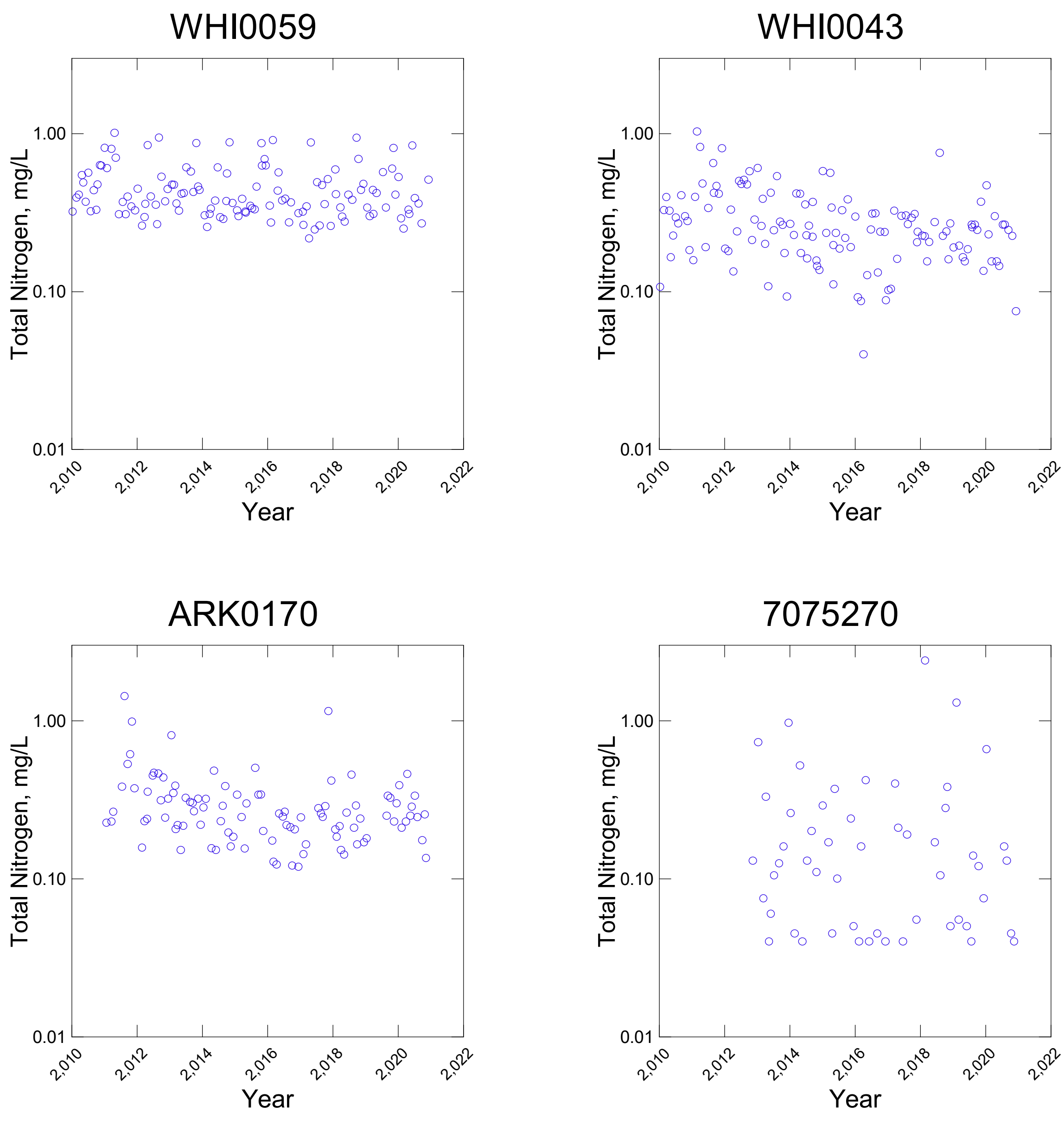


Figure 18. Time series graphs of stream total nitrogen data from 2010-2020.

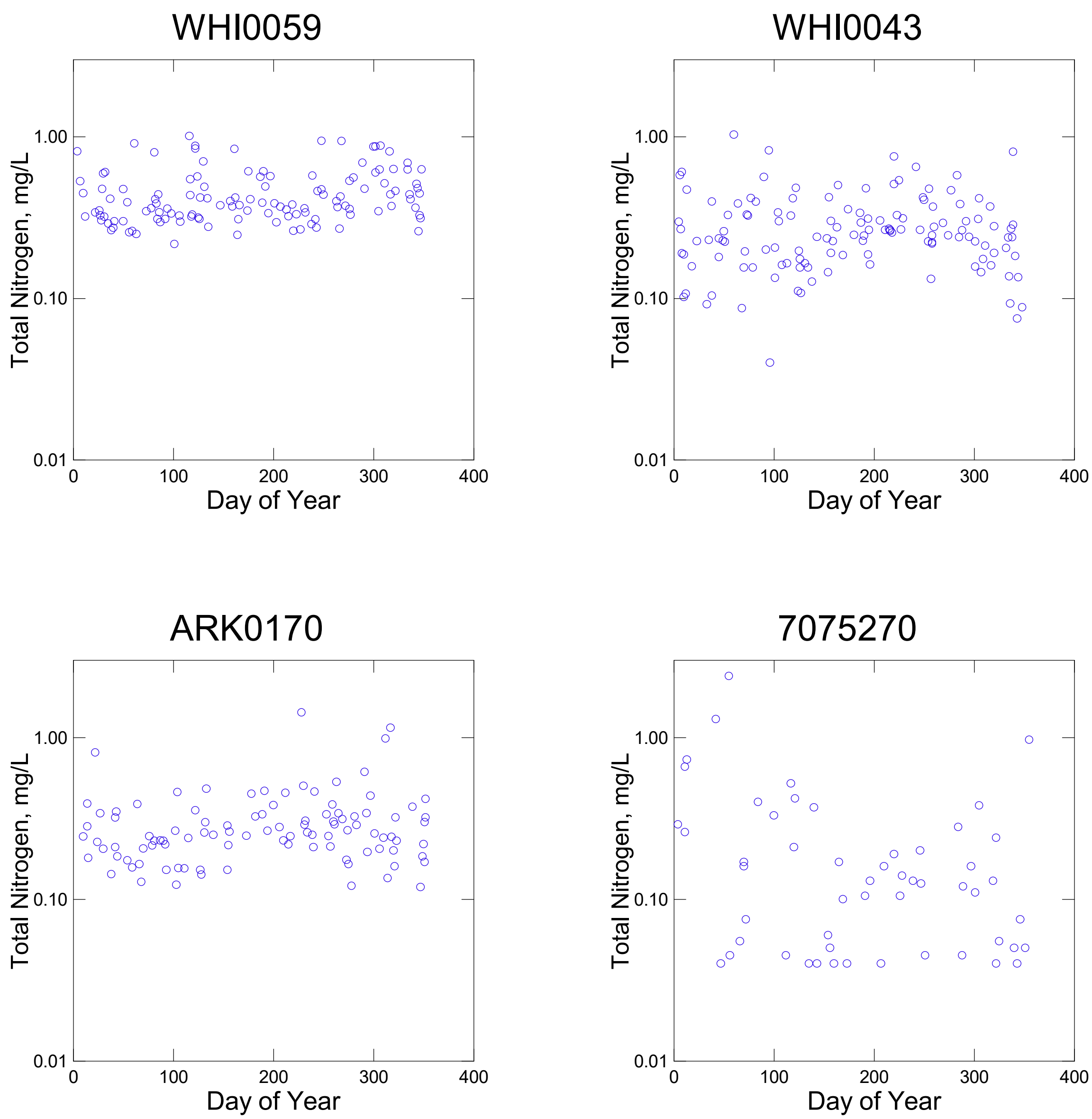


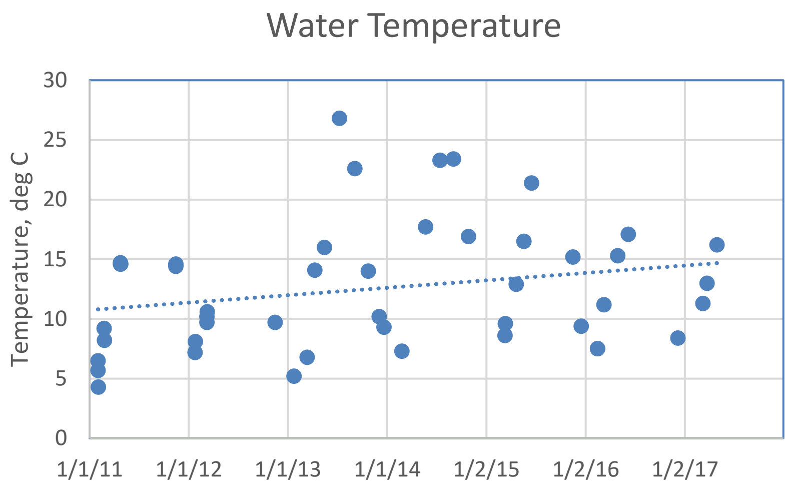
Figure 19. Time series graphs of stream total nitrogen data to evaluate seasonal patterns.

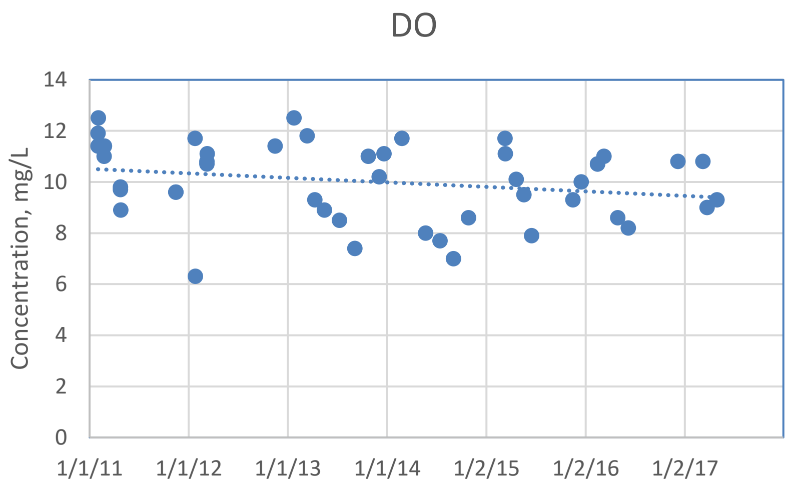
Table 12. Results of Seasonal Kendall tests on TN data.

Station	Stream	Number of Years	S Statistic	Z Statistic	P-Value	Statistically Significant Trend?
WHI0043	Middle Fork Little Red River	12	-163	-3.84	0.000	Yes, decreasing
ARK0170	S. Fork Little Red River	11	-41	1.61	0.107	No
07075270	South Fork Little Red River	9	-6	-0.41	0.683	No

1.2 Station 07075250

Note that, although the data does not meet our criteria for trend evaluation (data record too short and ends too early), measurements of some parameters at station 07075250 appear to exhibit trends (see Figure 20). Of particular concern are possible decreasing trends in pH and DO and possible increasing trends in water temperature and total phosphorus. Possible decreasing trends in nitrate + nitrite nitrogen, total nitrogen and *E. coli* are also of interest. These data patterns suggest that it may be useful to continue monitoring water quality at this station in the future.





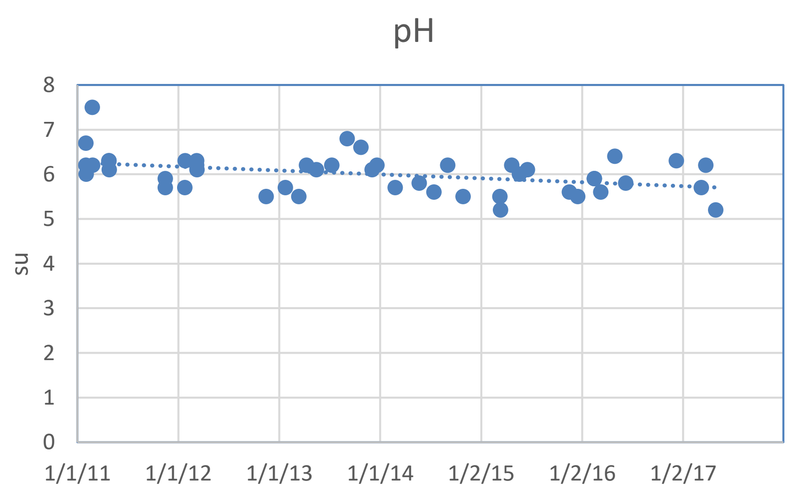
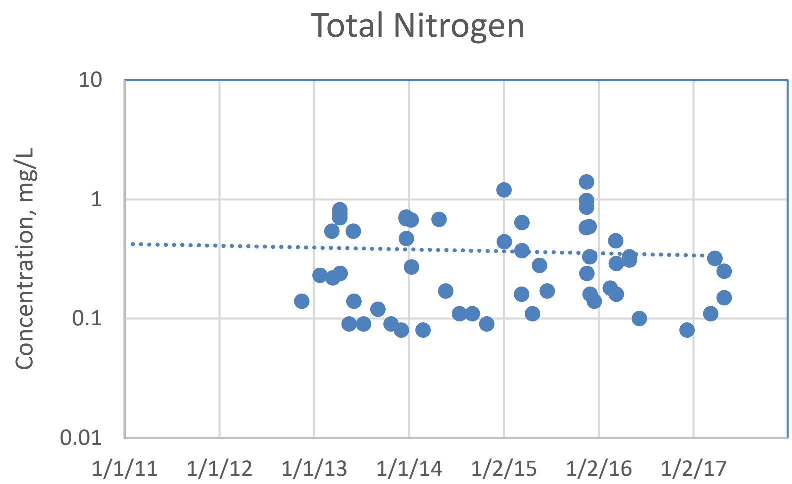
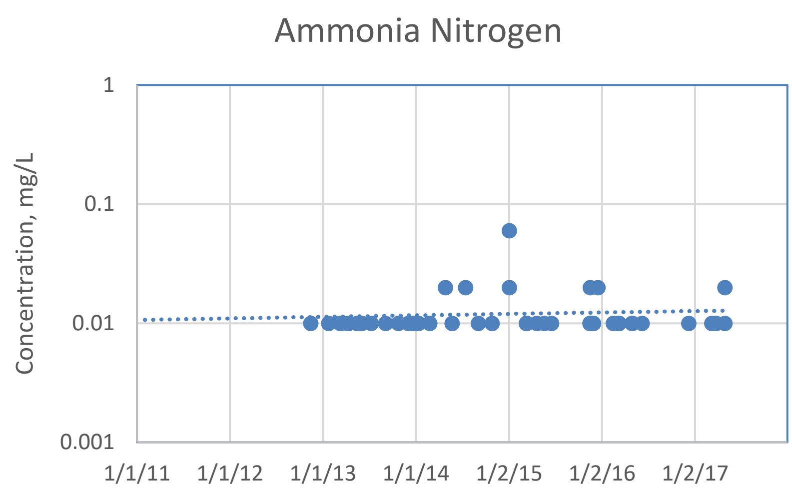
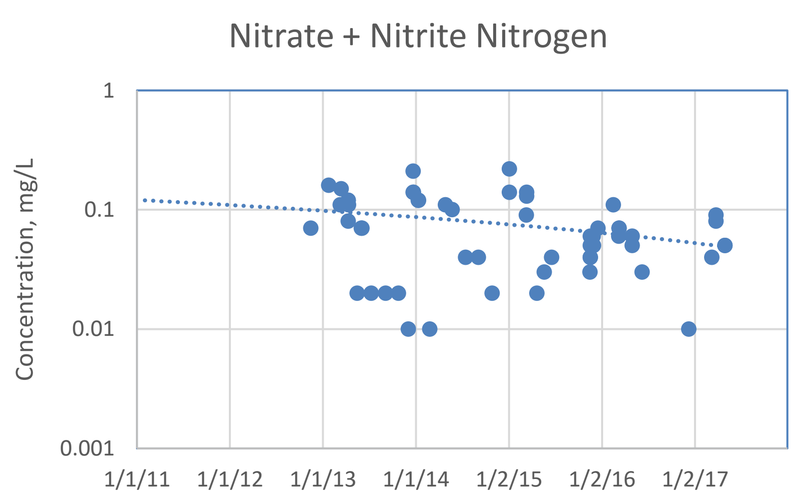


Figure 20. Time series graphs of measurements of parameters of interest from station 07075250 period of record (2011-2017).







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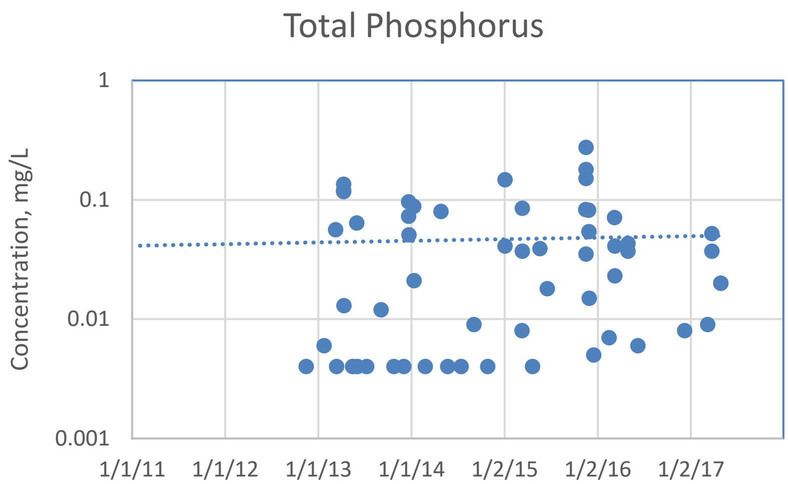

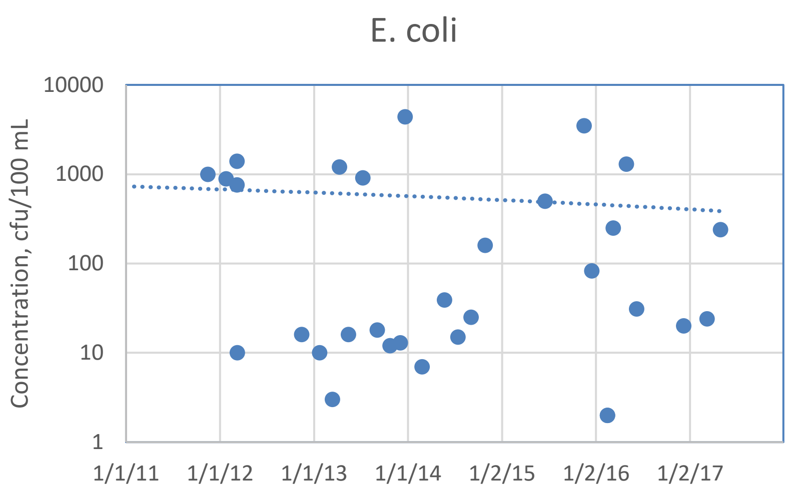

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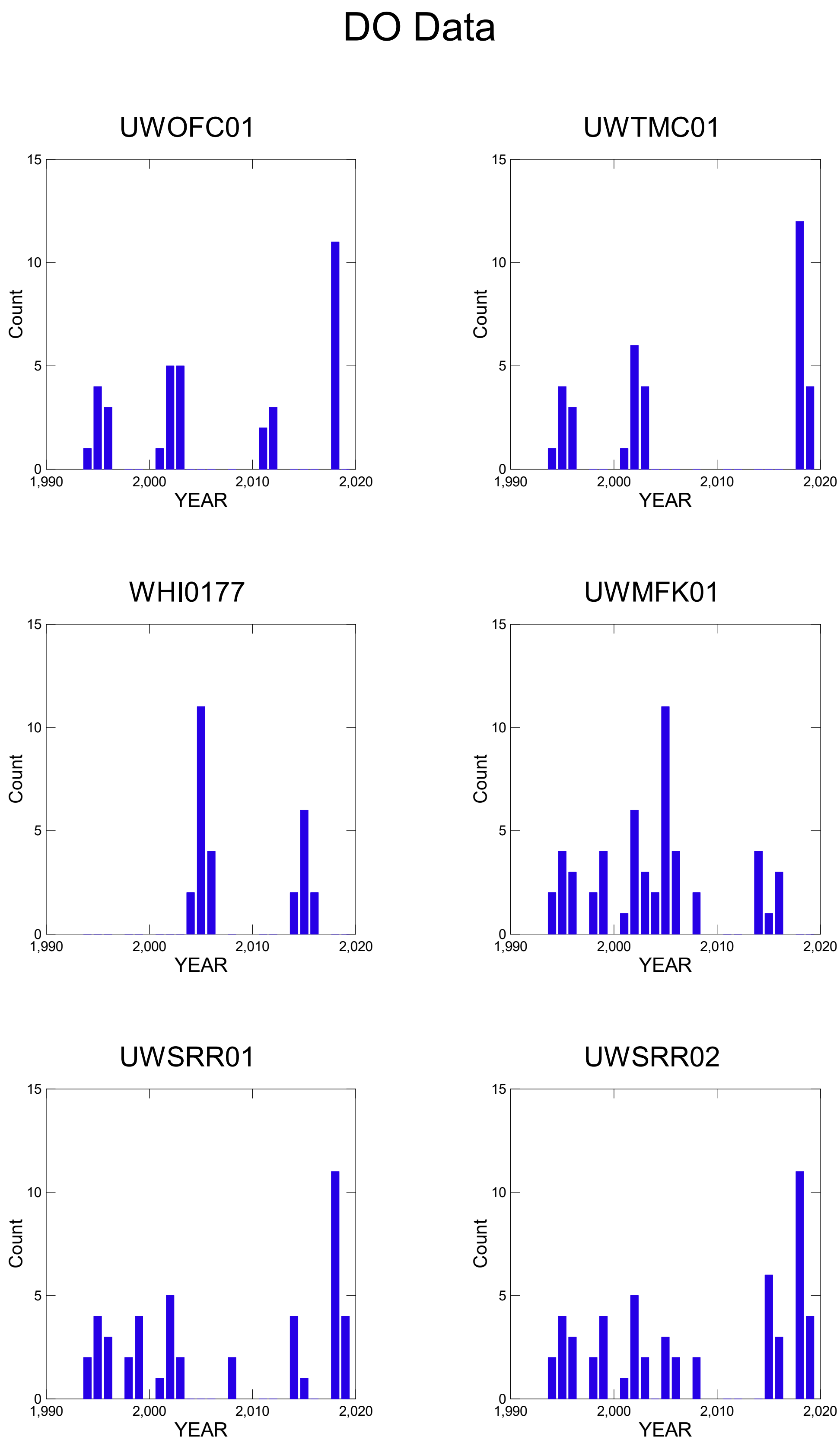


Figure 21. Number of DO measurements by year at selected stations.

1.3 Stations with Intermittent Sampling

There are six DEQ stream water quality monitoring stations with data records covering at least 10 years where sampling was intermittent, rather than continuous (Table 13). Five of these stations were established as part of the DEQ "roving" water quality monitoring program (those with station IDs beginning with "UW"). Figure 21 illustrates the variation in the intermittent sampling programs at these stream stations. A review of the data from these six stations identified five periods when around 10 samples were collected during a two to three-year period, from at least three of the stations (see Table 14).

Table 13. Active water quality monitoring stations in Little Red River watershed with intermittent data records spanning at least 10 years.

Station ID*	Waterbody	Location	Data period
UWOFC01	Overflow Creek	Huntsman Rd, SE of Judsonia, AR	1993-2018
UWTMC01	Ten Mile Creek	Sunny Dale Rd N of Province, AR	1993-2019
WHI0177	Middle Fork Little Red River	South of Leslie, AR	2004-2016
UWMFK01	Middle Fork Little Red River	Highway 65	1994-2016
UWSRR01	South Fork Little Red River	Highway 95 near Scotland, AR	1994-2019
UWSRR02	South Fork Little Red River	Highway 65	1994-2019

*Stations listed in upstream order, i.e., the station in the first row is farthest downstream

DO Data

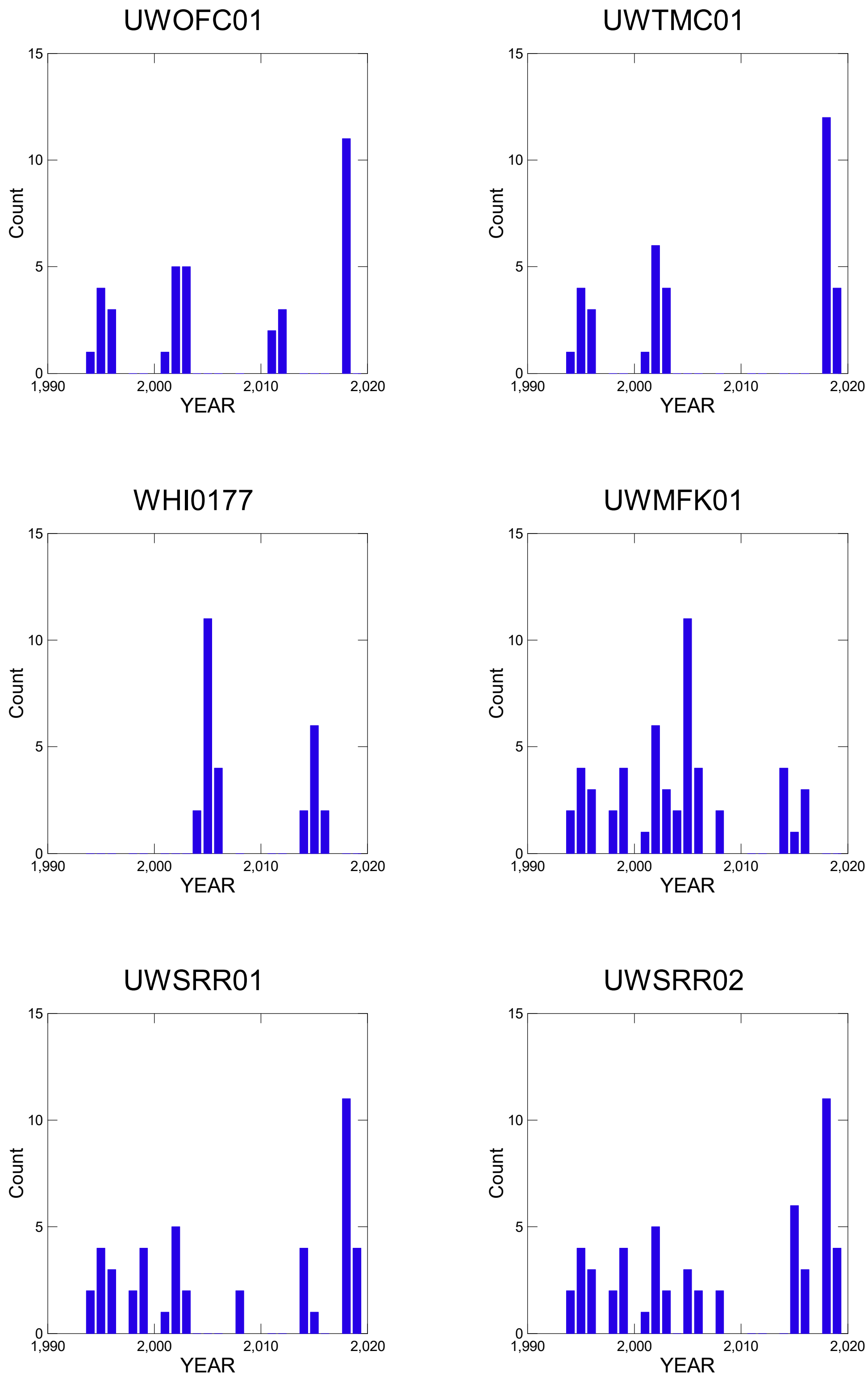


Figure 21. Number of DO measurements by year at selected stations.

Table 14. Number of DO measurements collected at each station during identified sampling periods.

Station ID	Sampling Periods				
	1994-1996	2001-2003	2004-2006	2014-2016	2018-2019
UWMFK01 (Middle Fork Little Red River)	9	10	17	8	0
WHI0177 (Middle Fork Little Red River)	0	0	17	10	0
UWSRR01 (South Fork Little Red River)	9	8	0	5	15
UWSRR02 (South Fork Little Red River)	9	8	5	9	15
UWTM01 (Ten Mile Creek)	8	11	0	0	16
UWOFC01 (Overflow Creek)	8	11	0	0	11

Nonparametric tests were used to compare the measurements from each sampling period. Notched box and whisker graphs were used to compare the data visually, and the Kruskal-Wallis test was performed to confirm whether there are statistically significant differences between the data sets from each period. The results of these analyses are presented below for each of the parameters of interest.

Elements of the notched box and whisker graphs used in this analysis are illustrated in Figure 22. Median values are considered statistically significantly different when their confidence intervals (i.e., notches) do not overlap.

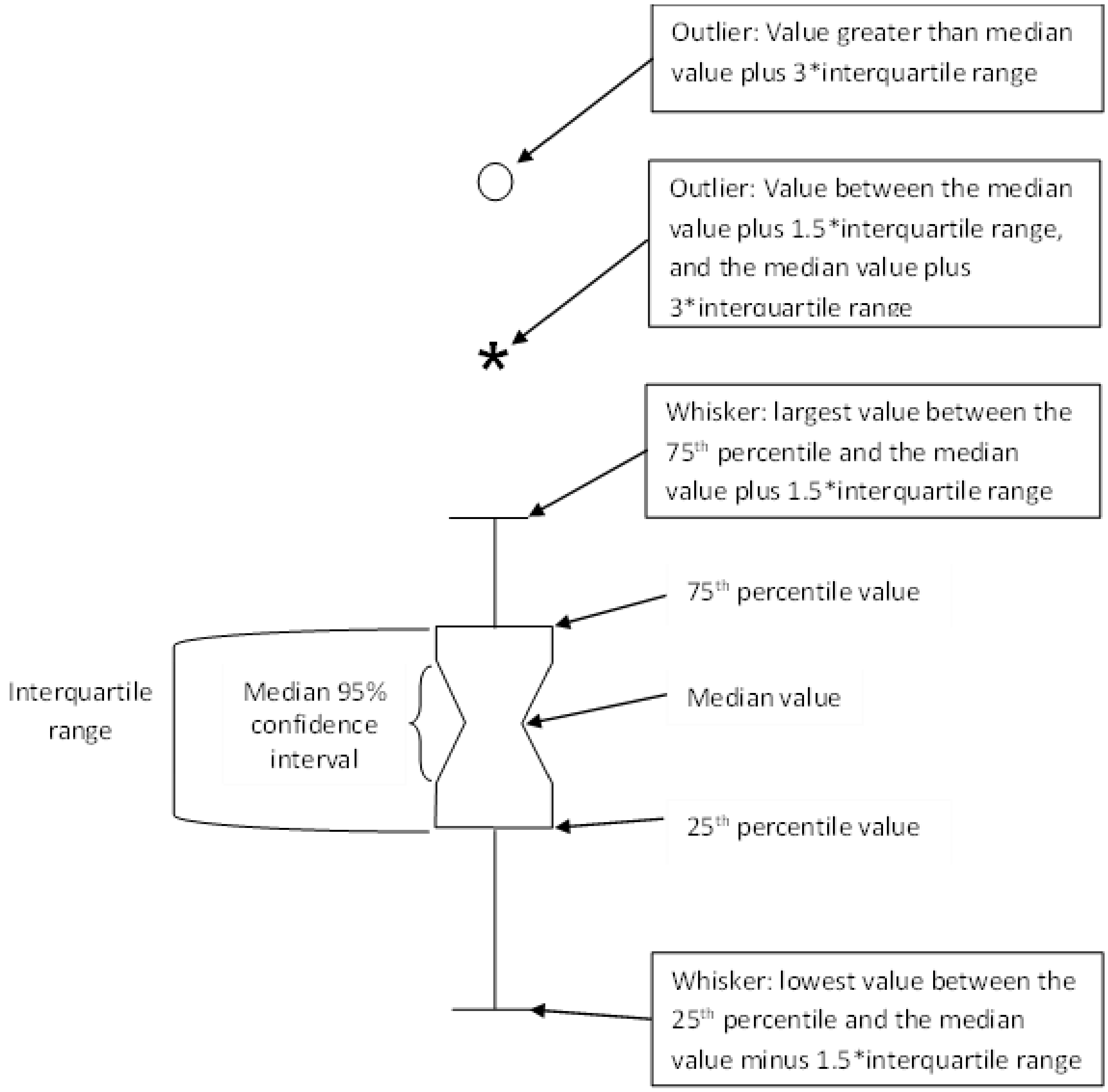


Figure 22. Illustration of elements of box and whisker graphs used to analyze intermittent data records.

1.3.1 Dissolved Oxygen

Figure 23 shows time series graphs of DO measurements from the six long term water quality stations where sampling has been intermittent. Figure 24 shows box and whisker graphs comparing DO measurements from these water quality stations during the five sampling periods. These graphs indicate that there may have been changes in DO concentrations over time at some of the stations. However, these changes in DO concentrations are not statistically significant (Table 15). Note that continuously monitored stations on Middle Fork and South Fork Little Red River did not exhibit trends in DO concentrations (see Section 1.1.1).

Table 15. Results from Kruskal-Wallis test of DO data from sampling periods at selected long-term stream water quality stations.

Station ID	Stream	Kruskal-Wallis p-value	Statistically significant?
UWOFC01	Overflow Creek	0.706	No
UWTMC01	Ten Mile Creek	0.309	No
WHI0177	Middle Fork Little Red River	0.900	No
UWMFK01	Middle Fork Little Red River	0.719	No
UWSRR01	South Fork Little Red River	0.958	No
UWSRR02	South Fork Little Red River	0.853	No

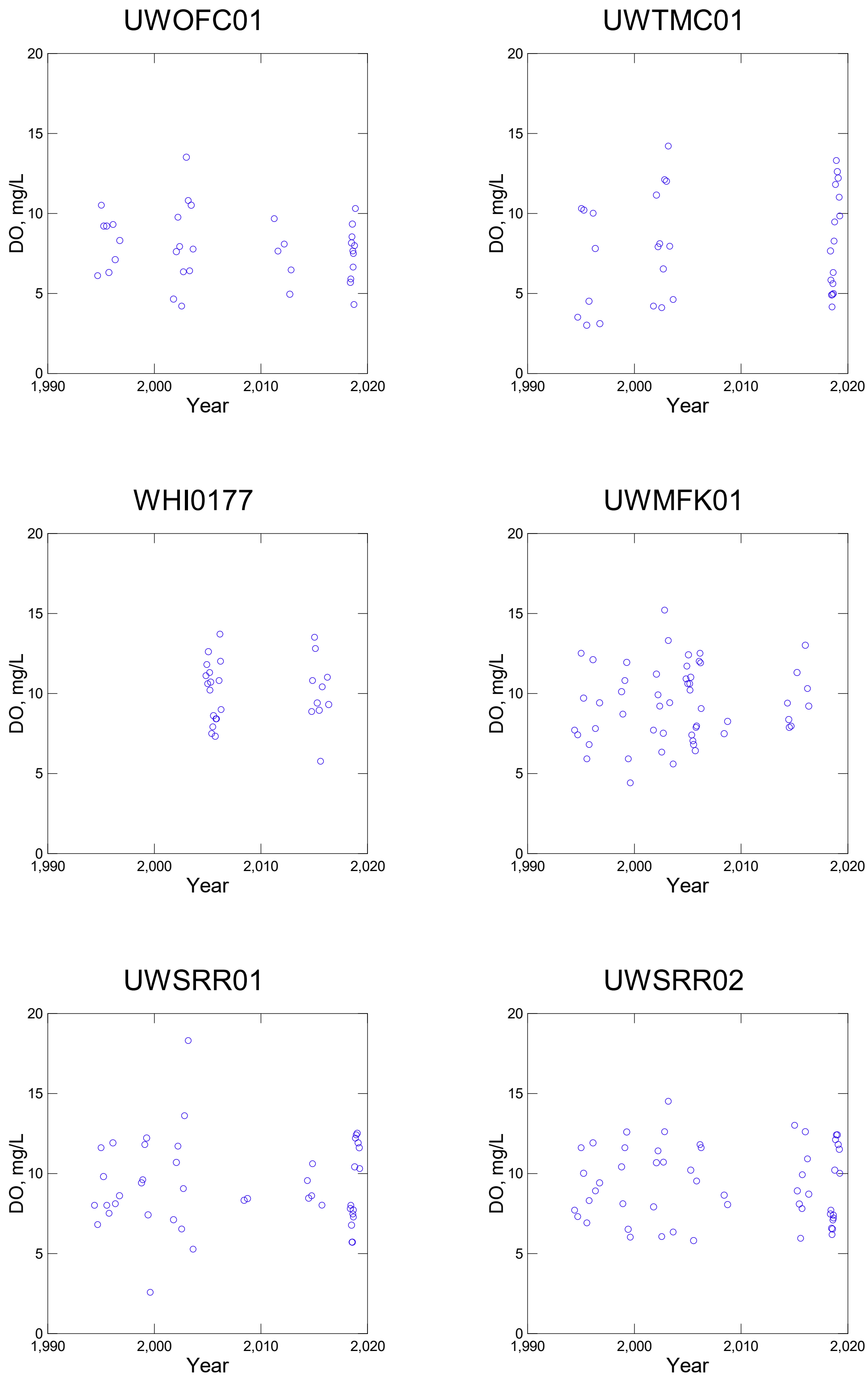


Figure 23. Time series graphs of DO measurements from intermittent stations.

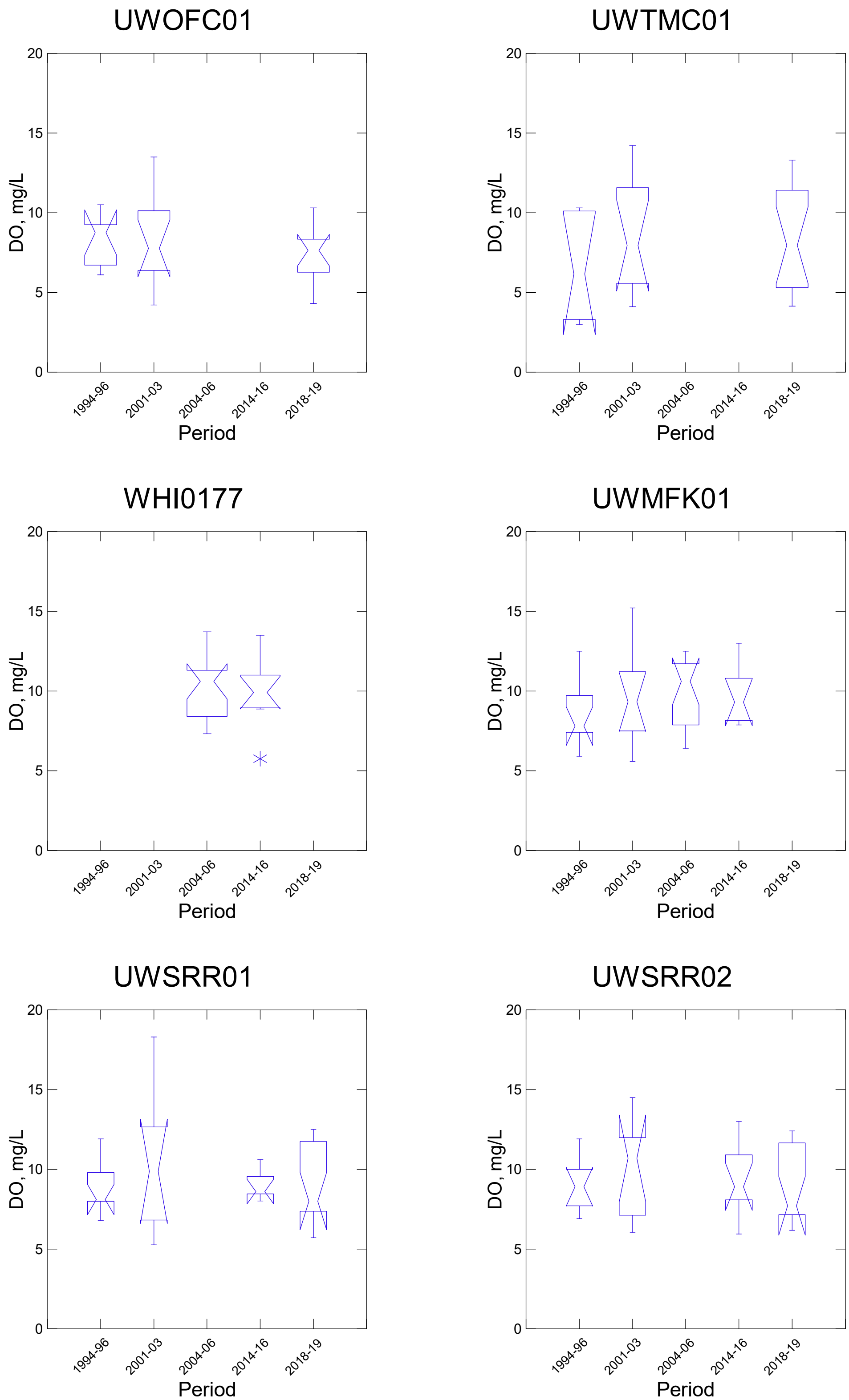


Figure 24. Box and whisker graphs of DO measurements from selected periods.

1.3.2 Water Temperature

Figure 25 shows time series graphs of water temperature measurements from the six long term water quality stations where sampling has been intermittent. Figure 26 shows box and whisker graphs comparing water temperature measurements from the five sampling periods at these water quality stations. Relative changes in the median water temperatures between sampling periods appear to be similar at all of the stations. For example, median water temperatures from period 2001-2003 are lower than the median of water temperatures from the period 1994-1996, and median water temperature from the period 2018-2019 is higher than the median water temperatures from 1994-1995 and from 2001-2003. None of the median values appear statistically significantly different. Kruskal-Wallis test confirms that there are no statistically significant differences in the water temperatures from the different sampling periods (Table 16). Overall, there is no indication of a consistent long-term trend in water temperatures at these stations. The Continuous record monitoring stations on the Middle Fork Little Red River and South Fork Little Red River also did not exhibit trends (Section 1.1.2).

Table 16. Results from Kruskal-Wallis test of water temperature measurements from sampling periods at selected long-term stream water quality stations.

Station ID	Stream	Kruskal-Wallis p-value	Statistically significant?
UWOFC01	Overflow Creek	0.066	No
UWTMC01	Ten Mile Creek	0.580	No
WHI0177	Middle Fork Little Red River	0.598	No
UWMFK01	Middle Fork Little Red River	0.541	No
UWSRR01	South Fork Little Red River	0.888	No
UWSRR02	South Fork Little Red River	0.970	No

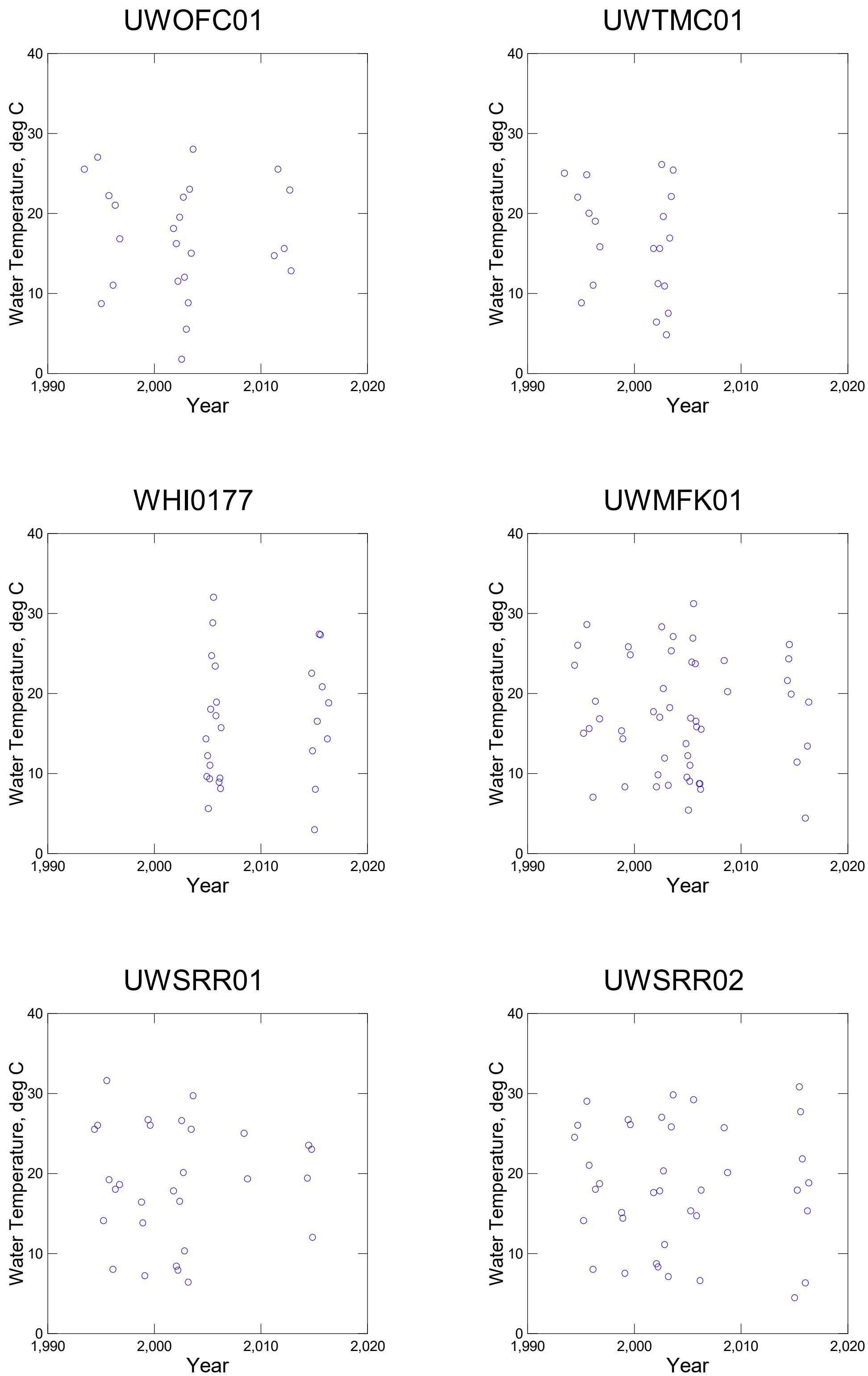


Figure 25. Time series graphs of water temperature measurements from intermittent stations.

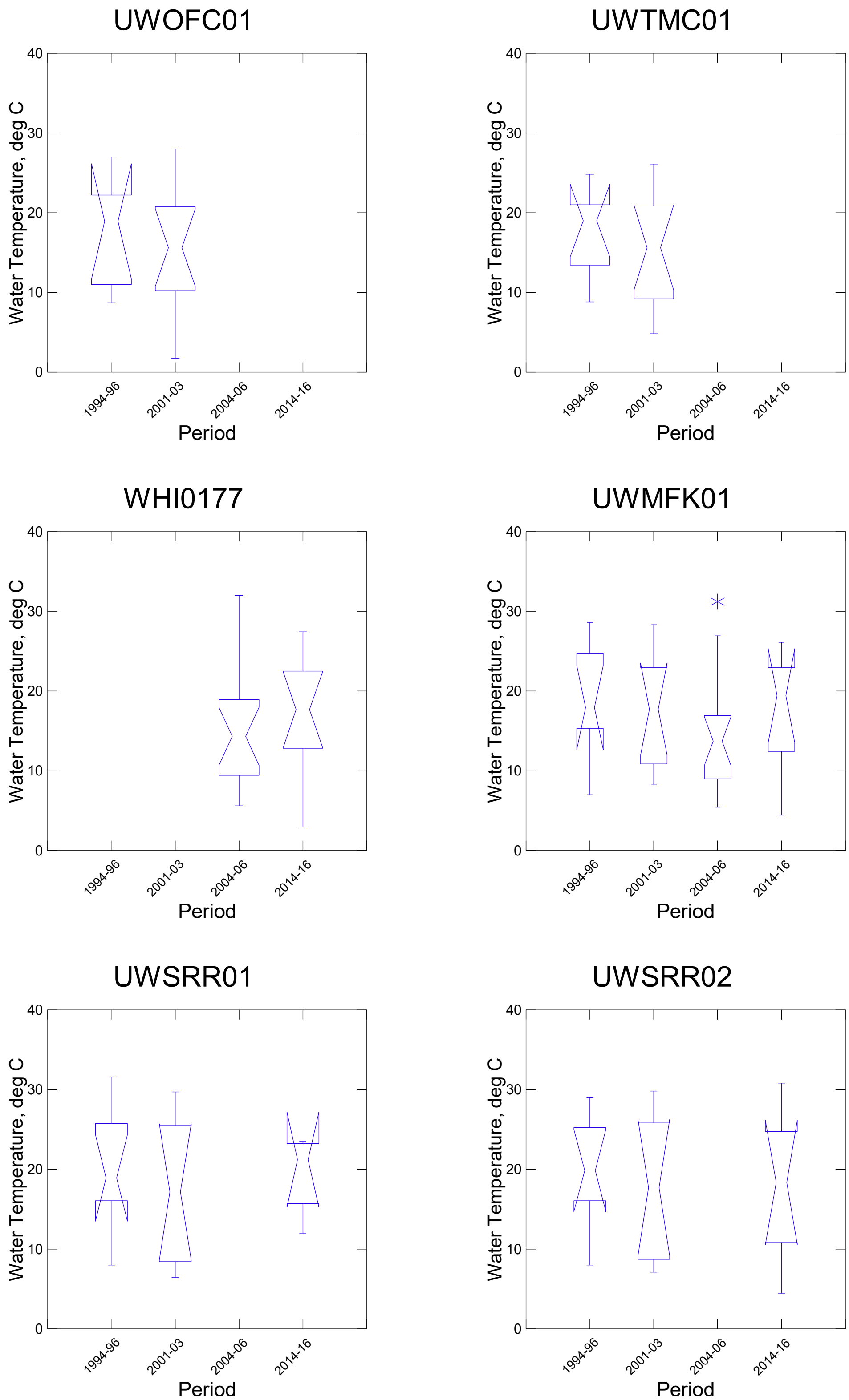


Figure 26. Box and whisker graphs of water temperature measurements from selected periods.

1.3.3 pH

Figure 27 shows time series graphs of pH measurements from the six long term water quality stations where sampling has been intermittent. Figure 28 shows box and whisker graphs comparing pH measurements from the five sampling periods at these water quality stations. These graphs show median pH values decreasing between sampling periods at several of the stations. At most of these stations, the change in pH levels over time has been statistically significant (Table 17). The continuous data station located downstream of the UWSRR stations on the South Fork of the Little Red River (ARK0170) also had a statistically significant decreasing trend in pH (see Section 1.1.3). Note that though median pH values at the UWSRR stations from more recent sampling periods are lower than those from the earliest sampling periods, they appear to have stabilized.

Median pH values at UWMFK01 are decreasing, as at the other tributary stream stations. However, downstream of Leslie, at WHI0177, median pH values may be increasing. Farther downstream, at the continuous data station on the Middle Fork of the Little Red River (WHI0043), pH exhibited a statistically significant increasing trend (see Section 1.1.3).

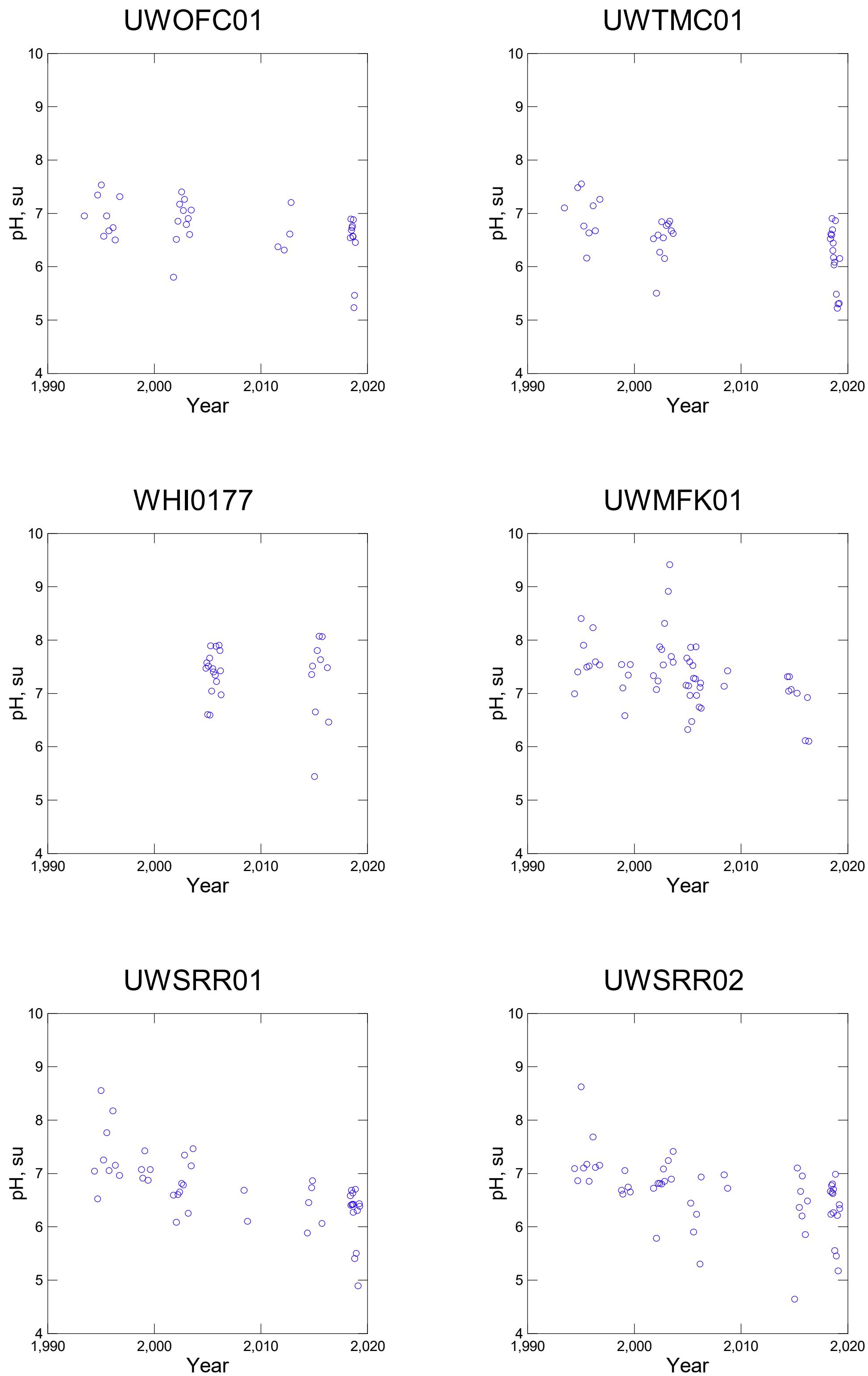


Figure 27. Time series graphs of pH measurements from intermittent stations.

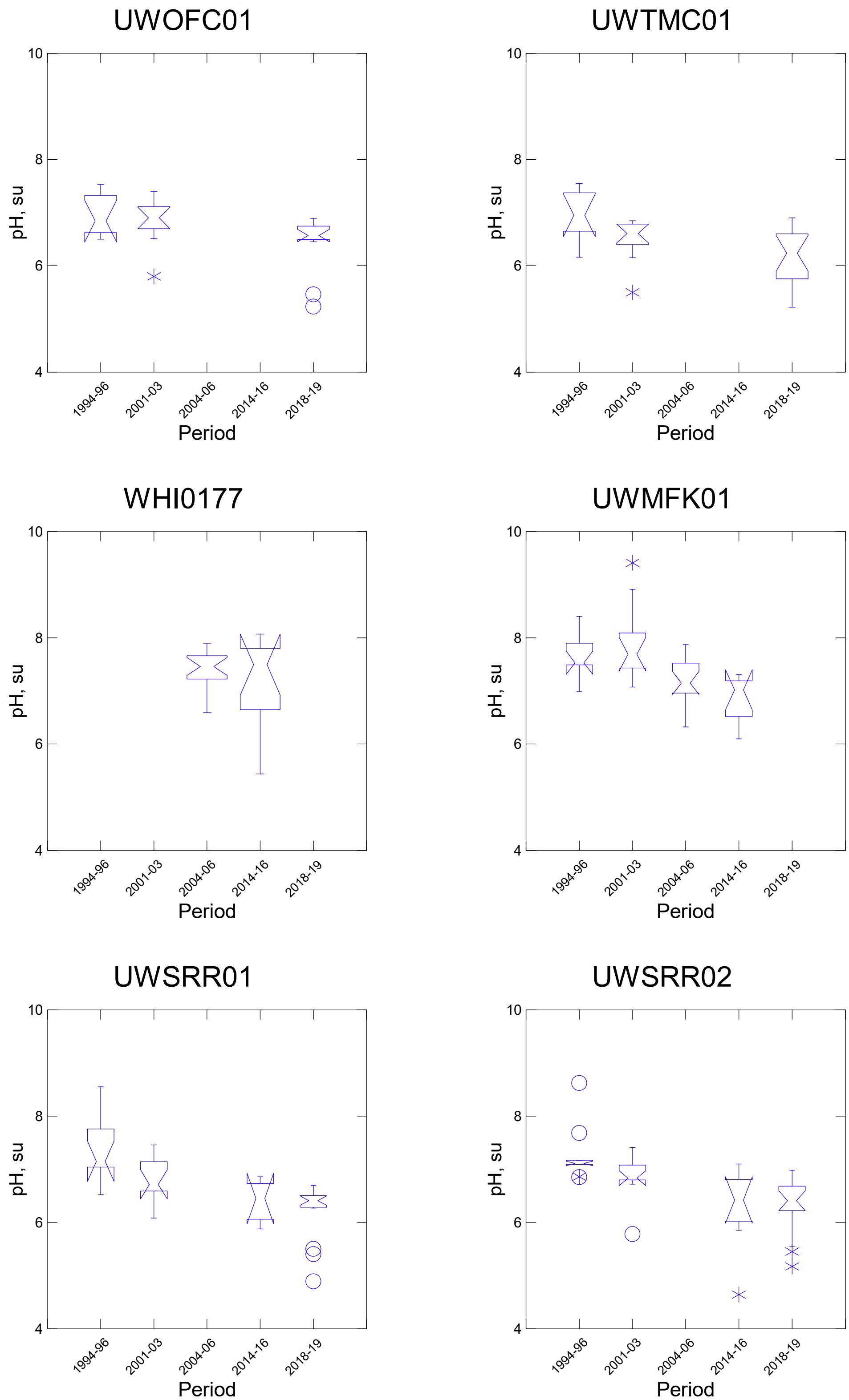


Figure 28. Box and whisker graphs of pH measurements from selected periods.

Table 17. Results from Kruskal-Wallis test of pH data from sampling periods at selected long-term stream water quality stations.

Station ID	Stream	Kruskal-Wallis p-value	Statistically significant?
UWOFC01	Overflow Creek	0.052	No
UWTMC01	Ten Mile Creek	0.007	Yes
WHI0177	Middle Fork Little Red River	0.880	No
UWMFK01	Middle Fork Little Red River	0.001	Yes
UWSRR01	South Fork Little Red River	0.000	Yes
UWSRR02	South Fork Little Red River	0.000	Yes

1.3.4 Turbidity

Figure 29 shows time series graphs of turbidity measurements from the six long term water quality stations where sampling has been intermittent. Figure 30 shows box and whisker graphs comparing turbidity measurements from four sampling periods at these water quality stations (no data turbidity measurements were collected at these stations during the 2018-2019 sampling period). Some stations do not really have enough of a data record to decide if there is a long-term trend. Both stations on the Middle Fork Little Red River (UWMFK01 and WHI0177) show a decrease in turbidity between the 2004-2006 and the 2014-2016 sampling periods. However, at UWMFK01, the median values from earlier sampling periods appear to be increasing. Kruskal-Wallis test results confirm that the change in turbidity between the 2004-2006 and the 2014-2016 sampling periods at station WHI0177 is a statistically significant decrease (Table 18). At the downstream continuous monitoring station, WHI0043, turbidity measurements from 2010-2020 exhibited a statistically significant increasing trend (see Section 1.1.4). So, there may be an increasing trend at UWMFK01, and the decrease at WHI0177 may not indicate a trend.

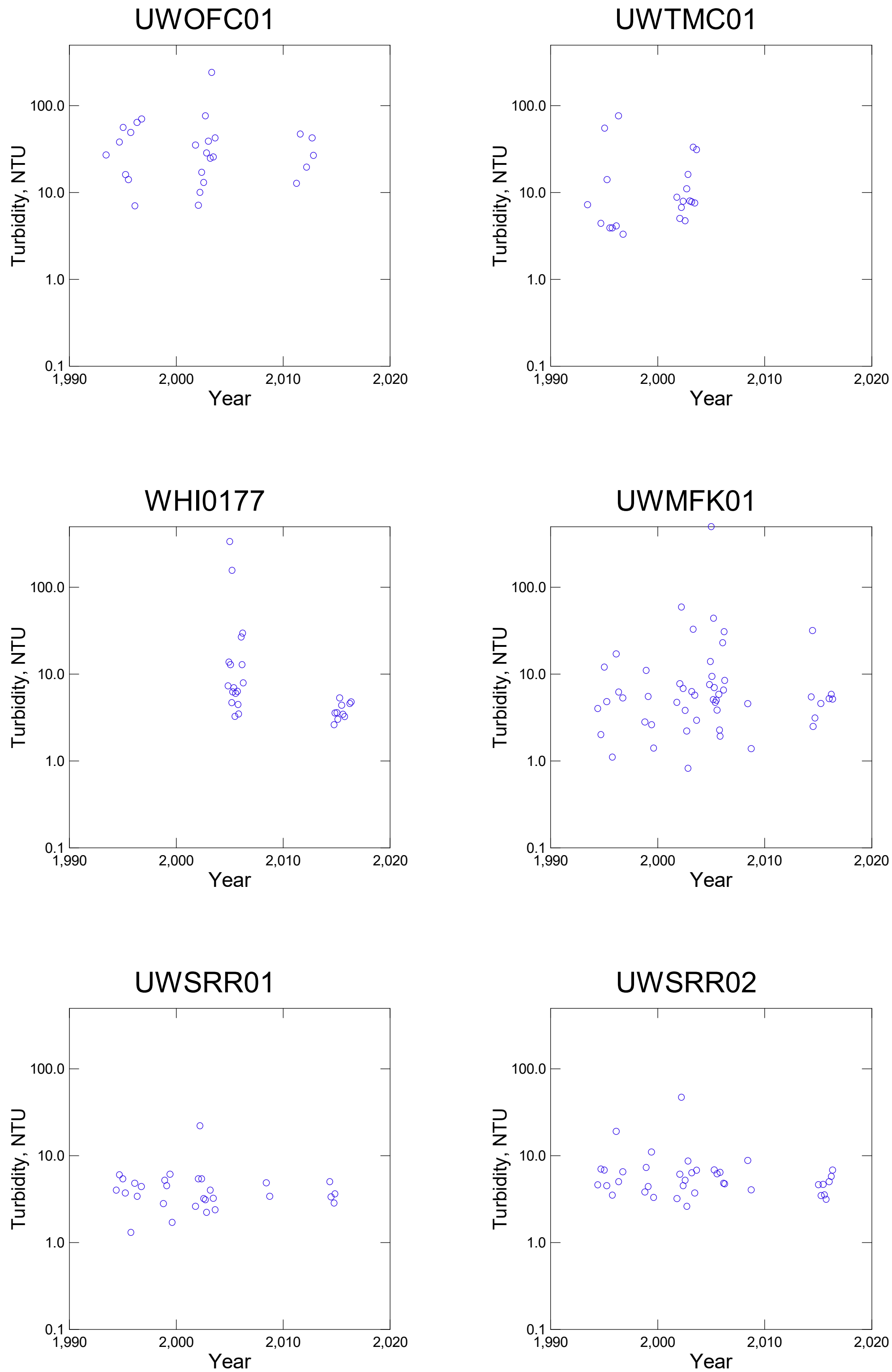


Figure 29. Time series graphs of turbidity measurements from intermittent stations.

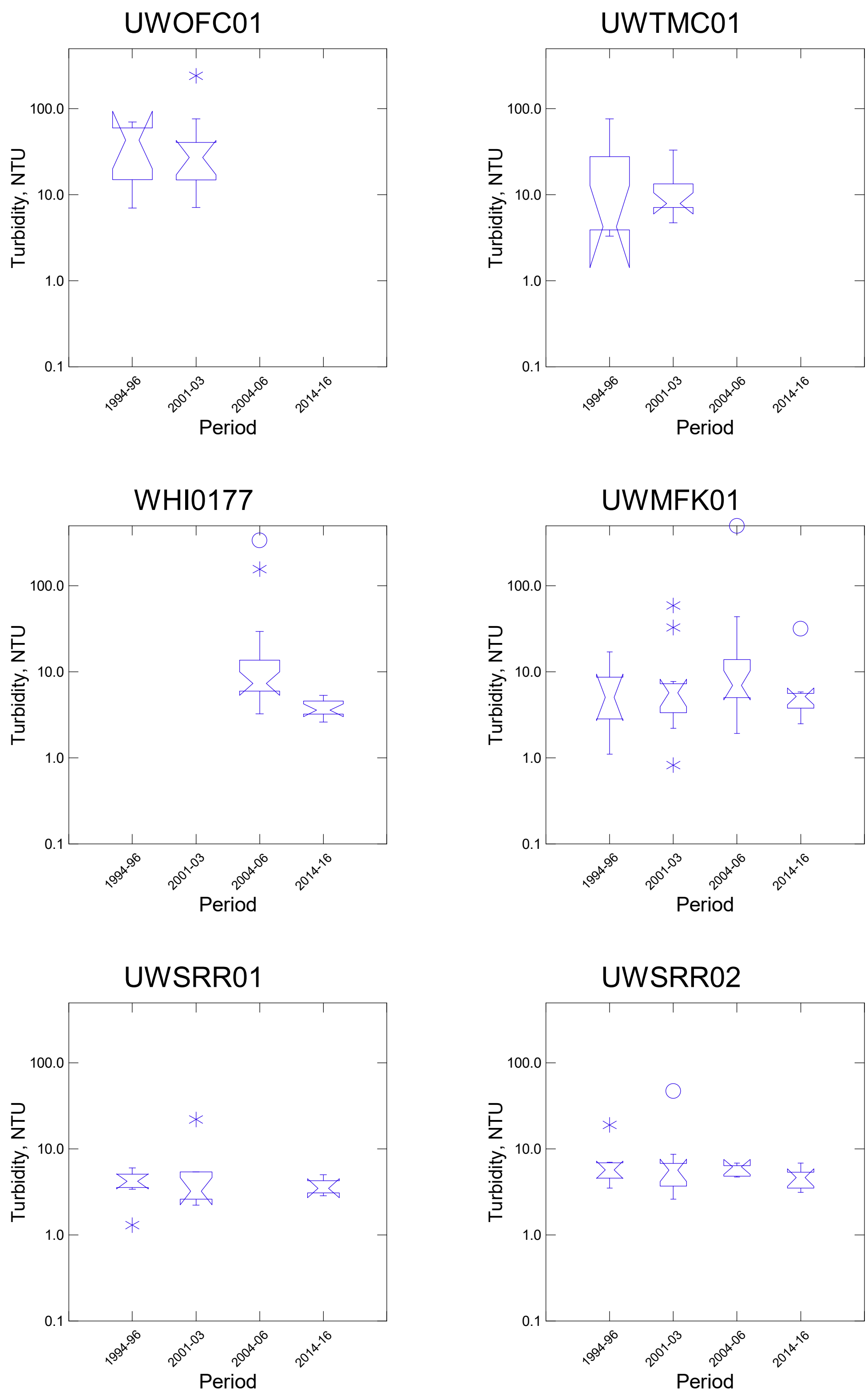


Figure 30. Box and whisker graphs of turbidity measurements from selected periods.

Table 18. Results from Kruskal-Wallis test of turbidity data from sampling periods at selected long-term stream water quality stations.

Station ID	Stream	Kruskal-Wallis p-value	Statistically significant?
UWOFC01	Overflow Creek	0.643	No
UWTMC01	Ten Mile Creek	0.247	No
WHI0177	Middle Fork Little Red River	0.001	Yes
UWMFK01	Middle Fork Little Red River	0.430	No
UWSRR01	South Fork Little Red River	0.570	No
UWSRR02	South Fork Little Red River	0.440	No

Sampling period median values at the South Fork Little Red River stations (UWSRR01 and UWSRR02) look like they may be consistently decreasing, but median values are not statistically significantly different from each other, and Kruskall-Wallis test results confirm no statistically significant change over time (Table 18). At the downstream continuous monitoring station, ARK0170, turbidity measurements from 2010-2020 exhibited a statistically significant increasing trend (see Section 1.1.4).

1.3.5 TSS

Figure 31 shows time series graphs of TSS measurements at the six long term water quality stations sampled intermittently. Note that no TSS measurements were collected at these stations after 2016. There appears to be a high incidence of less than detection values at some of these stations. Data sets with more than 15% of values at less than detection are not appropriate for evaluation of trends (Table 19). Therefore, only TSS measurements at stations UWOFC01 and UWTMC01 were evaluated.

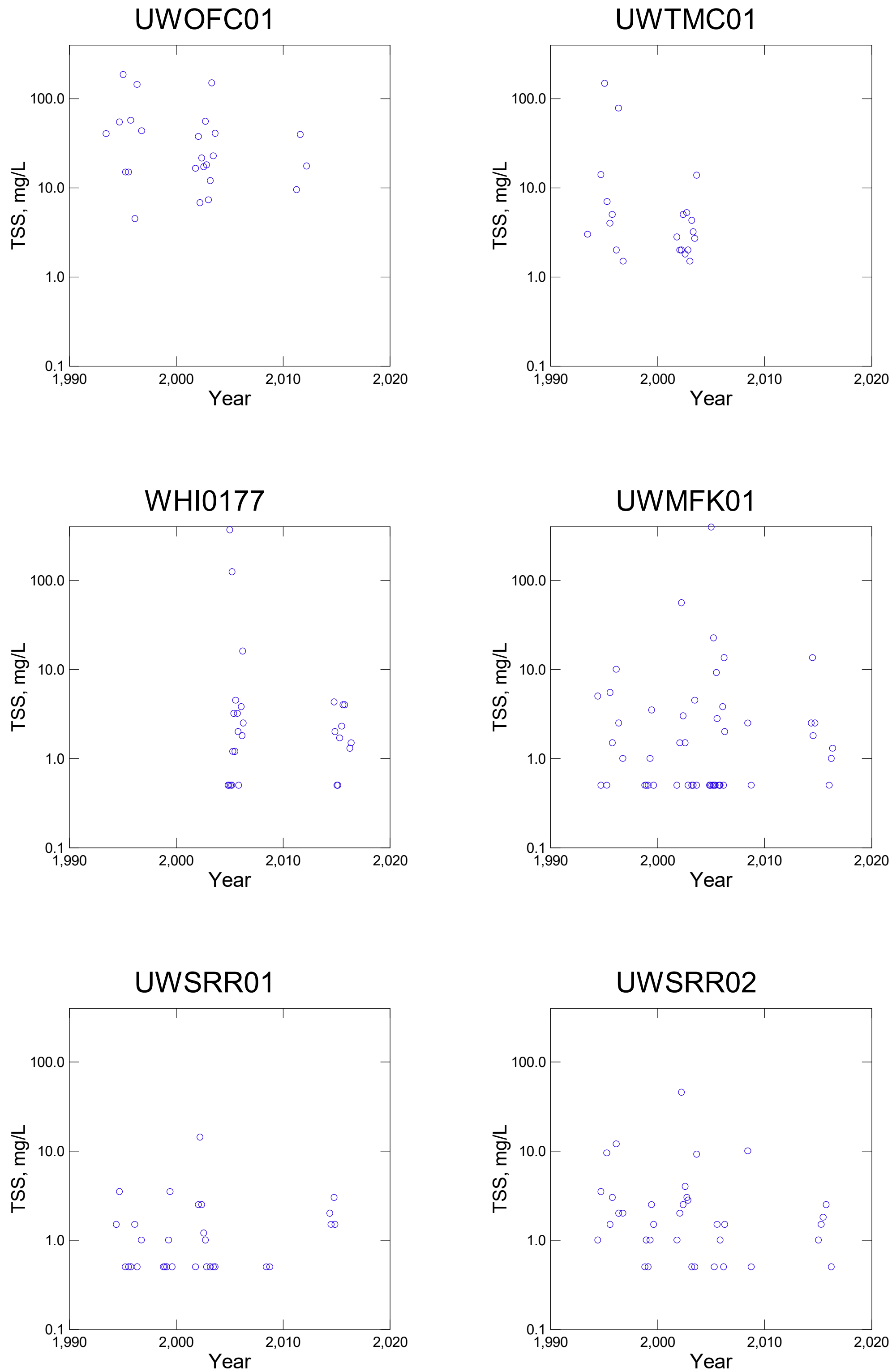
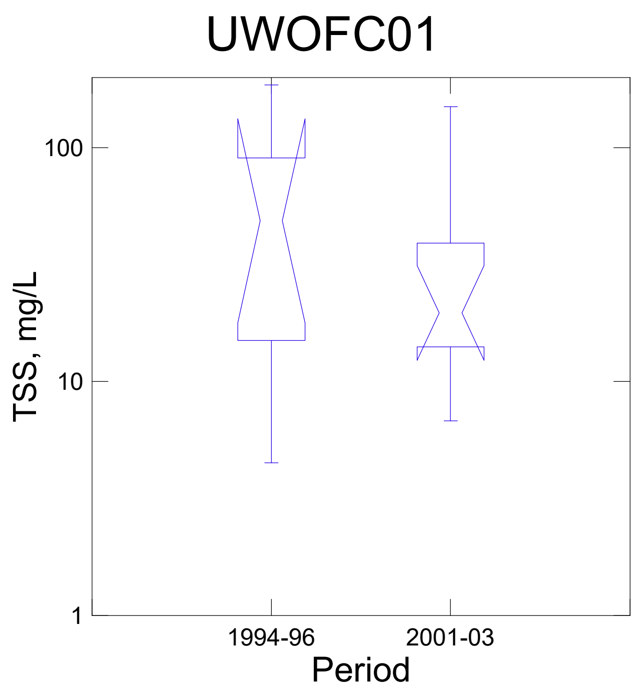


Figure 31. Time series graphs of TSS measurements from intermittent stations.

Table 19. Number and percentage of TSS less than detection measurements from selected long-term water quality stations in Little Red River watershed.

Station ID	Number of measurements	Number of measurements less than detection	Percent of measurements less than detection
UWOFC01	24	0	0
UWTMC01	21	0	0
WHI0177	27	7	26%
UWMFK01	50	23	46%
UWSRR01	30	15	50%
UWSRR02	36	8	22%

Figure 32 shows box and whisker graphs comparing TSS measurements from four sampling periods at the two stations with suitable data sets. As there are data from only the two earliest of our target sampling periods, it is not possible to evaluate long term trends in TSS at these two stations.



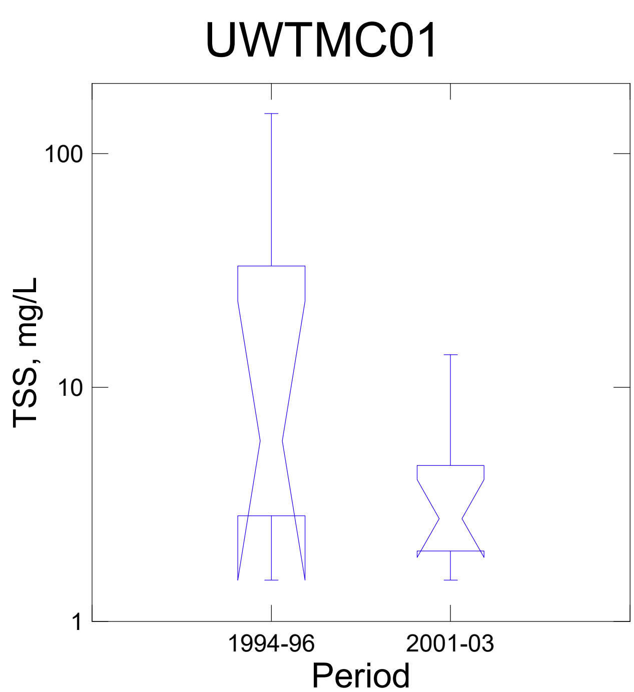


Figure 32. Box and whisker graphs of stream TSS measurements from selected periods.

1.3.6 Total Phosphorus

Figure 33 shows time series graphs of total phosphorus measurements from the six long term water quality stations with intermittent sampling. Note that no total phosphorus measurements were collected at these stations after 2016. Some of these stations have a number measurements reported as less than detection (Table 20). Data sets with more than 15% of values at less than detection were not evaluated for trends. The two stations with less than 15% less than detection values, have data from only the earliest two sampling periods. There is not enough information to decide if there is a long-term decreasing trend in total phosphorus at these stations. Therefore, no trend analysis was conducted on total phosphorus data from the intermittently sampled stations.

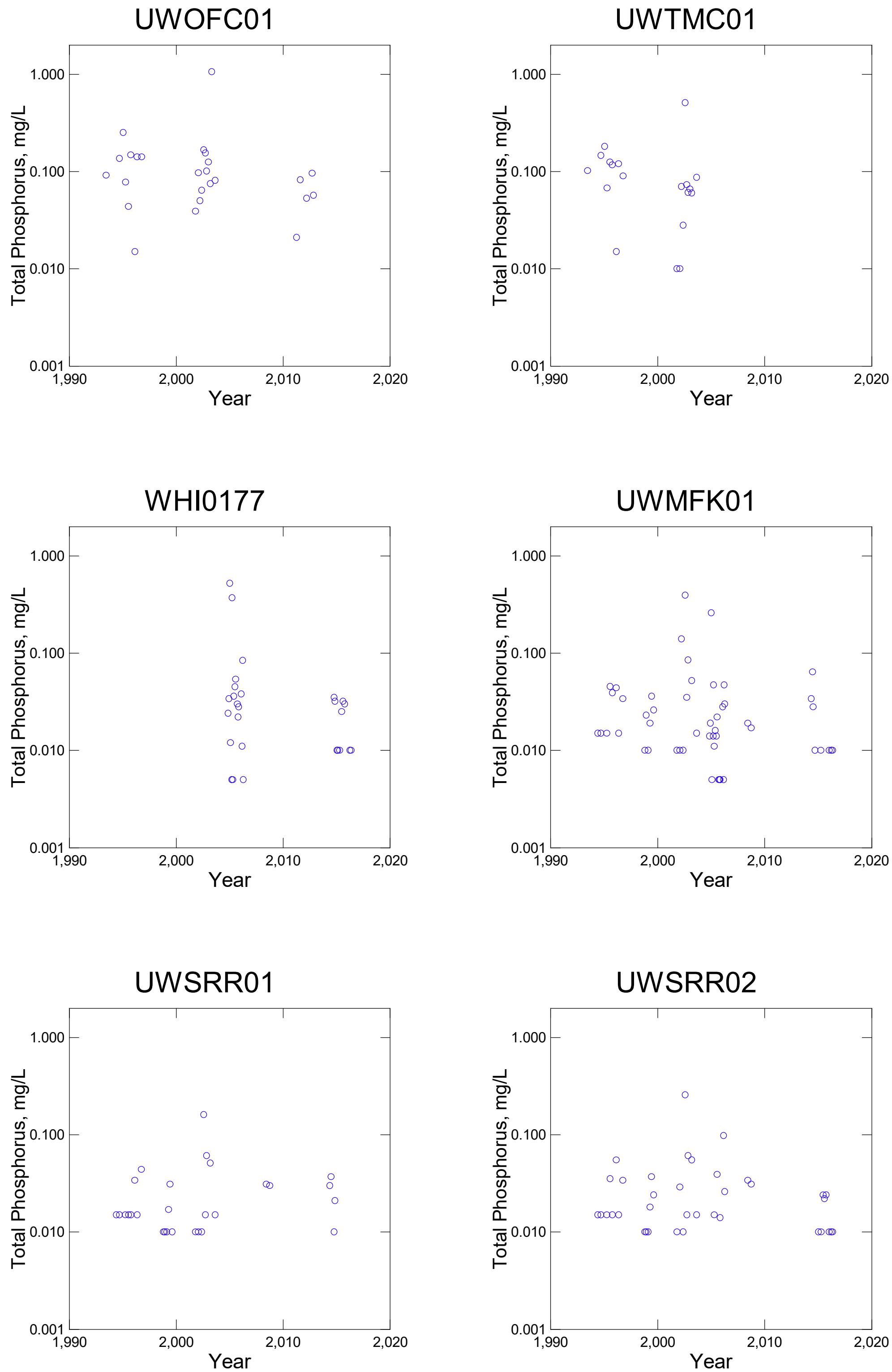


Figure 33. Time series graphs of total phosphorus measurements from intermittent stations.

Table 20. Number and percentage of total phosphorus less than detection measurements from selected long-term water quality stations in Little Red River watershed.

Station ID	Number of measurements	Number of measurements less than detection	Percent of measurements less than detection
UWOFC01	25	1	4%
UWTMC01	19	3	16%
WHI0177	27	8	30%
UWMFK01	50	20	40%
UWSRR01	28	16	57%
UWSRR02	37	17	46%

1.3.7 Ammonia Nitrogen

Figure 34 shows time series graphs of ammonia nitrogen measurements from the six long term water quality stations with intermittent sampling. Note that no ammonia nitrogen measurements were collected at these stations after 2016. It is evident from these graphs that most values are reported as less than detection. Therefore, these data are not suitable for evaluation of trends.

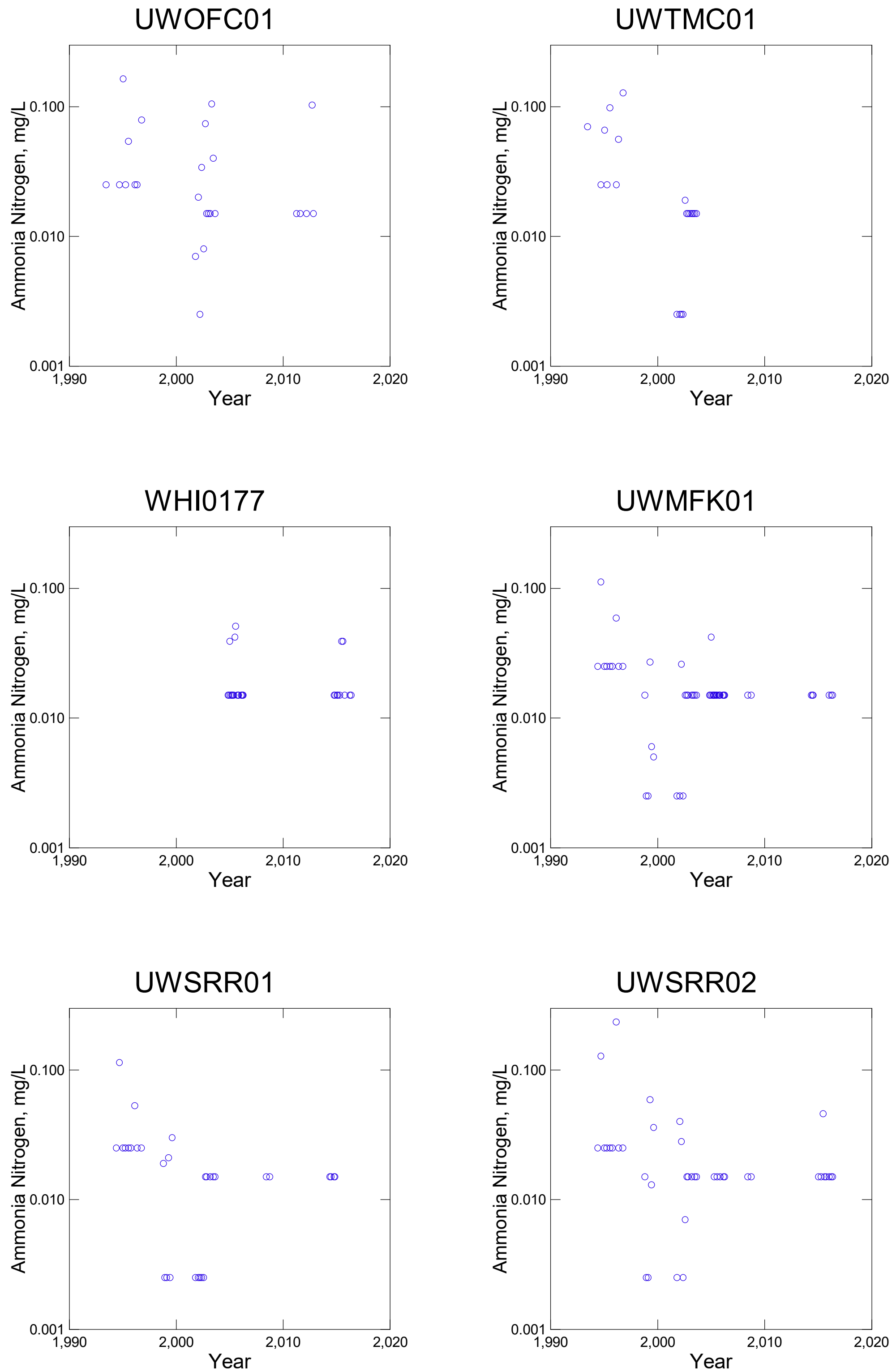


Figure 34. Time series graphs of ammonia measurements from intermittent stations.

1.3.8 Nitrate + Nitrite Nitrogen

Figure 35 shows time series graphs of nitrate + nitrite nitrogen measurements from the six long term water quality stations with intermittent sampling. Note that no nitrate + nitrite nitrogen measurements were collected at these stations after 2016. Some of these stations have measurements reported as less than detection (Table 21). Data sets with more than 15% of values at less than detection are not suitable for trend evaluation. Therefore, the data sets from stations WHI0177 and UWSRR02 were not evaluated.

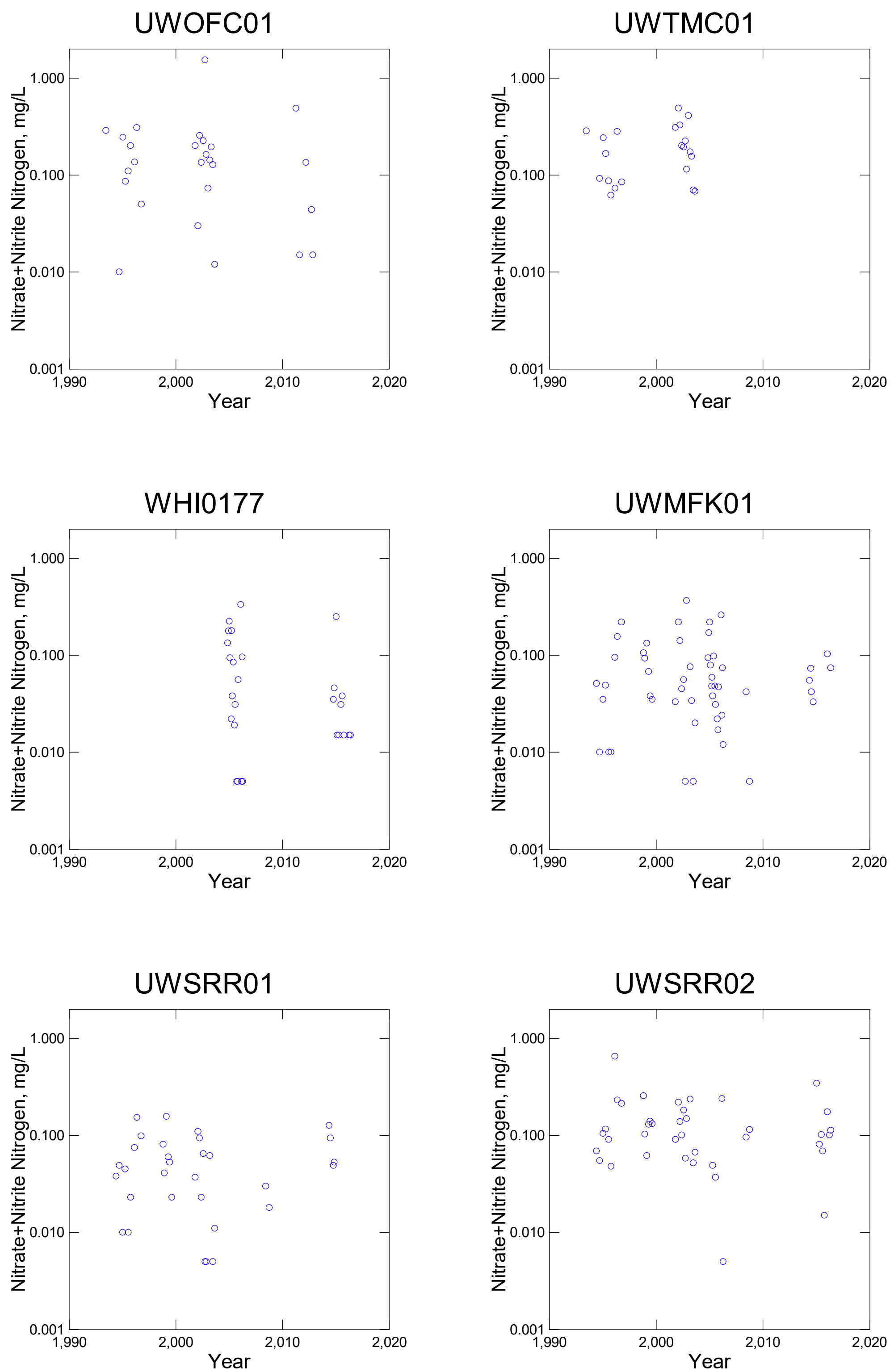


Figure 35. Time series graphs of nitrate+nitrite measurements from intermittent stations.

Table 21. Number and percentage of nitrate + nitrite nitrogen less than detection measurements from selected long-term water quality stations in Little Red River watershed.

Station ID	Number of measurements	Number of measurements less than detection	Percent of measurements less than detection
UWOFC01	26	3	12%
UWTMC01	21	0	0
WHI0177	27	9	33%
UWMFK01	51	6	12%
UWSRR01	31	5	16%
UWSRR02	39	2	5%

Figure 36 shows box and whisker graphs comparing median nitrate + nitrite nitrogen values from four sampling periods at the long-term water quality stations with suitable data. The results of the Kruskal-Wallis test confirm that there has not been a statistically significant change in nitrate + nitrite nitrogen levels at any of these stations over time (Table 22).

Table 22. Results from Kruskal-Wallis test of nitrate + nitrite data from sampling periods at selected long-term stream water quality stations.

Station ID	Stream	Kruskal-Wallis p-value	Statistically significant?
UWMFK01	Middle Fork	0.864	No
UWOFC01	Overflow Creek	0.541	No
UWSRR01	South Fork	0.119	No
UWSRR02	South Fork	0.646	No
UWTMC01	Ten Mile Creek	0.201	No

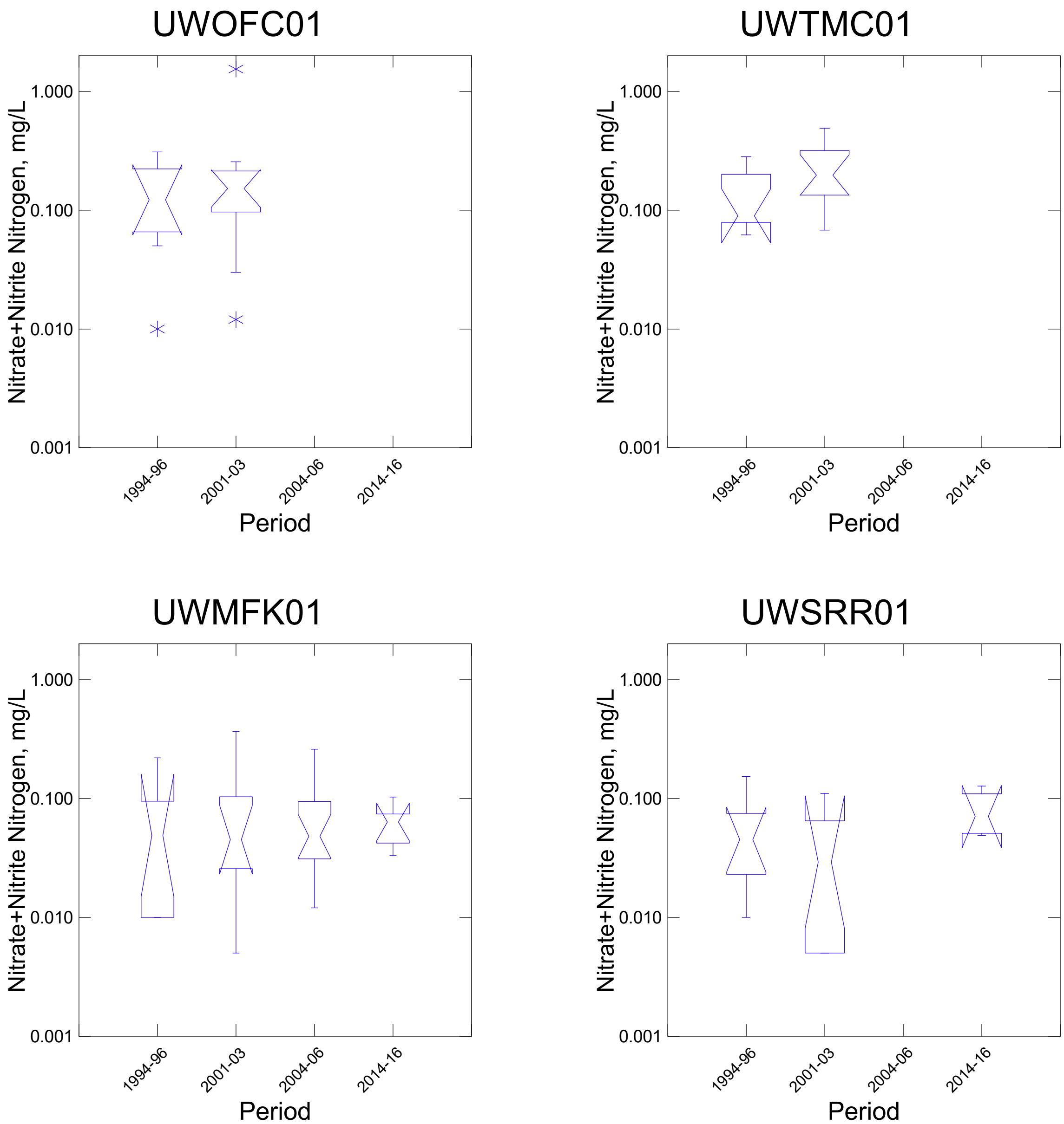


Figure 36. Box and whisker graphs of nitrate + nitrite measurements selected periods.

1.3.9 Total Nitrogen

Figure 37 shows time series plots of total nitrogen values calculated from TKN and nitrate + nitrite nitrogen measurements at the six water quality stations where sampling was intermittent. Total nitrogen values were not calculated if both TKN and nitrate + nitrite were not both measured. TKN was not reported for all samples collected from these stations. As a result, note that there are no total nitrogen values prior to 2008 nor after 2016, and there are fewer total nitrogen values for these stations than nitrate + nitrite nitrogen values. As can be seen in Figure 37, total nitrogen values are available for only one sampling period at some of the water quality stations.

Figure 38 shows box and whisker graphs comparing median total nitrogen values from four sampling periods at the long-term water quality stations with suitable data. There are variations in the median values for each of the sampling periods, but no consistent increases or decreases and none of the median values for the sampling periods are statistically significantly different.

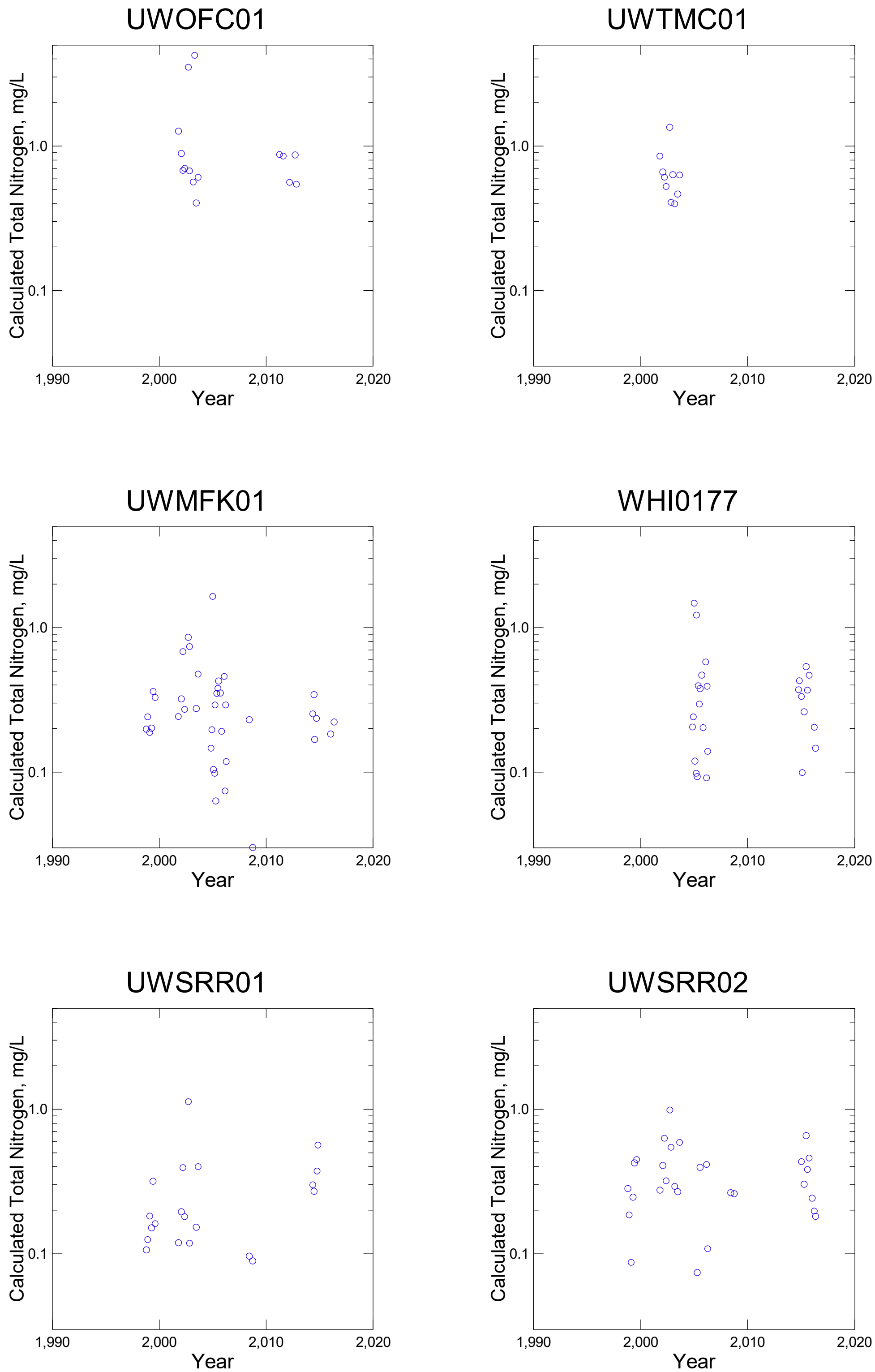


Figure 37. Time series graphs of total nitrogen measurements from intermittent stations.

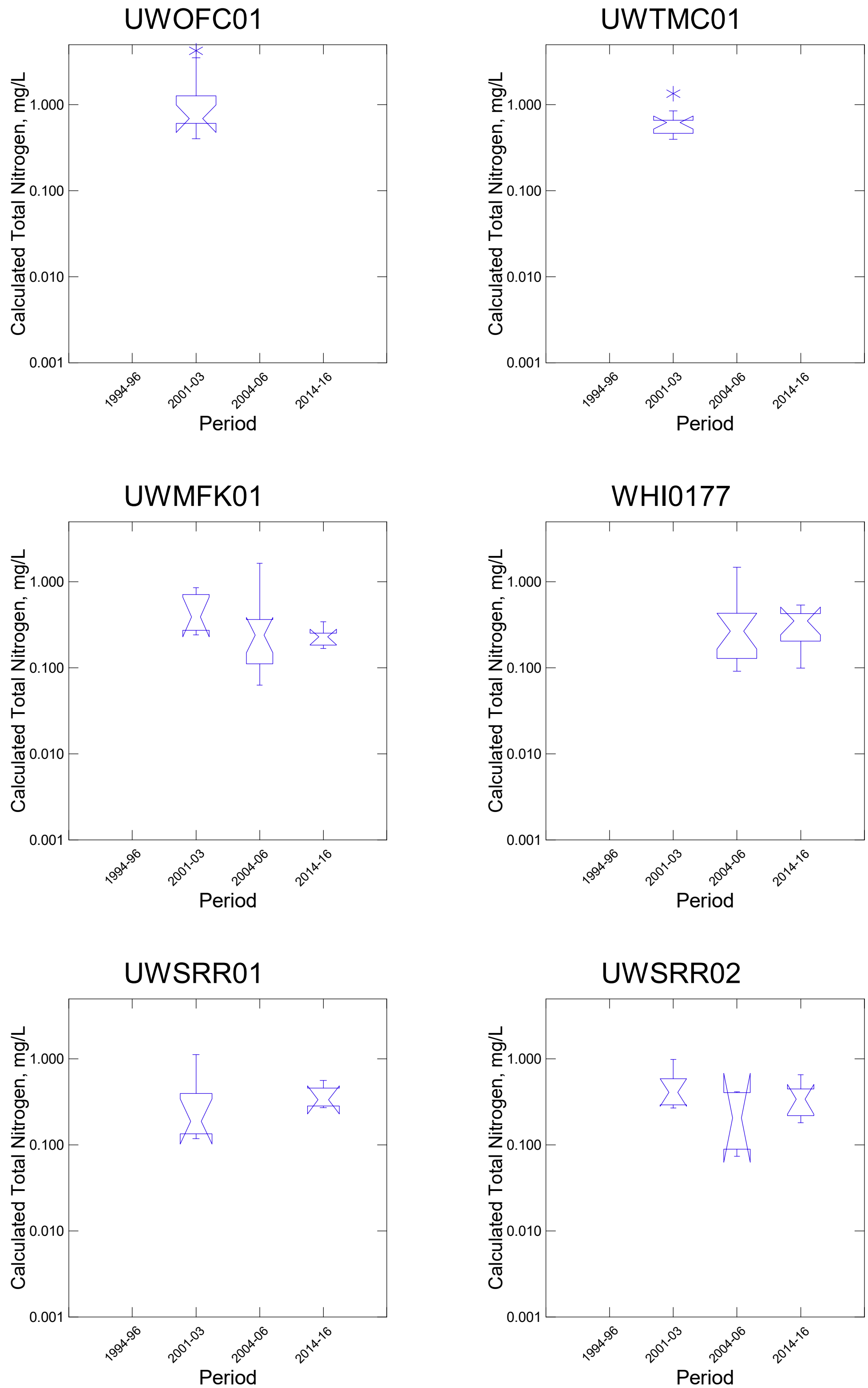


Figure 38. Box and whisker graphs of total nitrogen values for selected periods.

1.3.10 Bacteria

Bacteria sampling has occurred intermittently in the Little Red River watershed. Figure 39 shows time series graphs of *E. coli* measurements at long-term stations in the Little Red River watershed. Only four stations were sampled recently and frequently enough to consider evaluating long term changes in E. coli; WHI0043, WHI0059, UWTM01, and UWOFC01 (Table 23).

Table 23. Number of *E. coli* measurements collected at each station during sampling periods. Values in parentheses indicate number of measurements used in analysis data sets.

Station ID		Sampling Periods				
	1991-94	2003	2005-2006	2011-12	2015	2018-19
UWMFK01 (Middle Fork Little Red River)	0	4	6	0	0	0
WHI0177 (Middle Fork Little Red River)	0	0	0	0	0	0
WHI0043 (Middle Fork Little Red River)*	0	0	7 (6)	0	1	15 (7)
UWSRR01 (South Fork Little Red River)	0	3	0	0	1	15
UWSRR02 (South Fork Little Red River)	0	3	0	0	1	15
WHI0059 (Little Red River)*	14 (5)	0	8 (5)	0	0	16 (5)
UWTM01 (Ten Mile Creek)*	0	5	0	0	0	16 (5)
UWOFC01 (Overflow Creek)*	0	5	0	6	0	11 (6)

*stations evaluated for trends

To improve the comparability of the data sets from the different time periods, one sample per month was included in the analysis data sets. Sample dates closest to the 15th were used. Where there was still quite a difference in the number of samples, only samples from the same months as the smaller data set(s) were included. Sampling periods with fewer than five samples were excluded from the analysis. The number of samples from each sampling period and station used in the analysis is shown in parentheses in Table 23. Box plots of the analysis data are shown in Figure 40. Given the variability in *E. coli* measurements and the small number of measurements from each sampling period, there is no statistically significant change in *E. coli* levels over time at any of the stations evaluated.

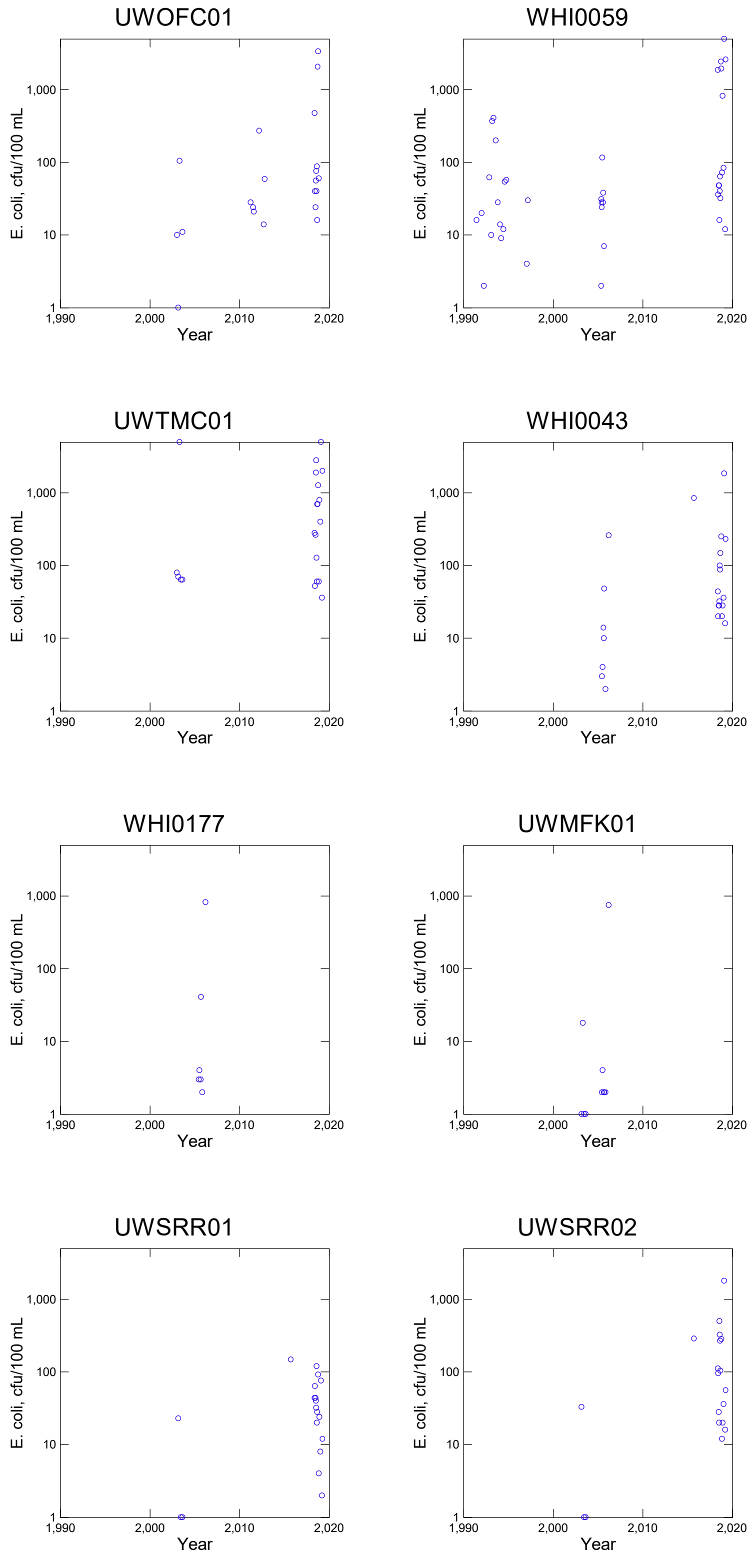


Figure 39. Time series graphs of E. coli measurements from intermittent stations.

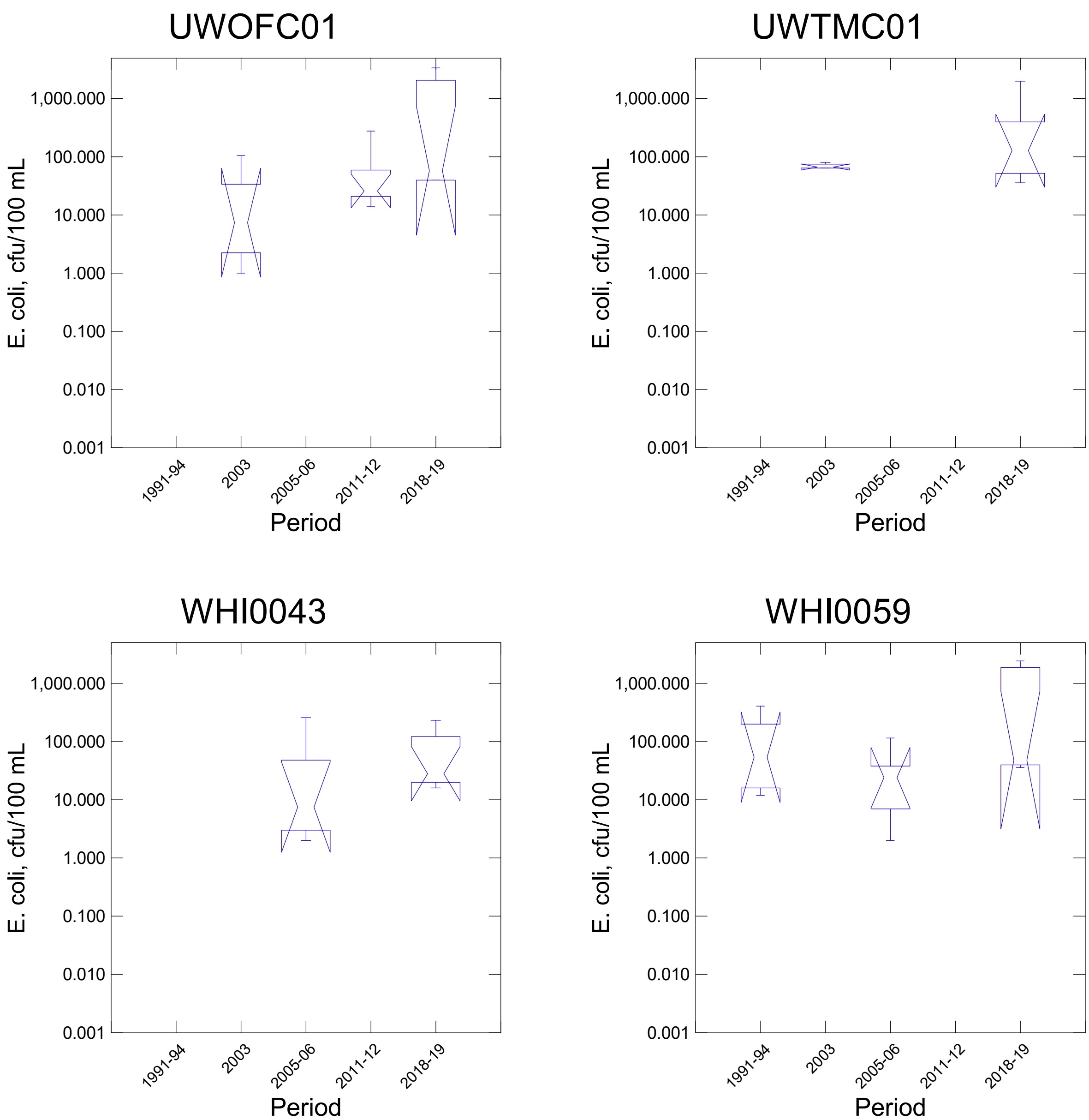


Figure 40. Box and whisker graphs of E.coli measurements from selected periods.

1.4 Summary

There are 11 stream monitoring locations in the Little Red River watershed with long data records that were suitable for evaluation of trends, for several parameters of interest for this watershed. Data for DO, water temperature, pH, turbidity, TSS, suspended sediment, and total nitrogen data from these stations are suitable for evaluation of trends. Total phosphorus, ammonia nitrogen, and nitrate + nitrite nitrogen data records at several stations have too many less than detection results to be evaluated for trends. Five stream monitoring locations have long term continuous data records. These data records were evaluated for trends primarily using the Seasonal Kendall test. Six stream monitoring locations have been sampled periodically over a long period. For these locations, data sets from selected sampling periods were compared using the Kruskal-Wallis test to determine if concentrations from the different sampling periods were statistically different.

Table 24 lists the monitoring locations and parameters for which statistically significant trends were identified. Decreasing pH trends at several of the stations suggest low pH will continue to be an issue in some streams. Increasing pH, with decreasing trends in TSS and total nitrogen at station WHI0043 suggest water quality in the lower Middle Fork Little Red River may be improving.

Table 24. Monitoring locations and parameters for which statistically significant trends were identified.

Station	Stream	Parameter	Trend direction
WHI0059	Little Red R	pH	Increasing
		Temperature	Decreasing
		Turbidity	Increasing
		TSS	Decreasing
UWTMC01	Ten Mile Cr	pH	Decreasing
WHI0177	Middle Fork	Turbidity	Decreasing
UWMFK01	Middle Fork	pH	Decreasing
WHI0043	Middle Fork	pH	Increasing
		Turbidity	Increasing
		TSS	Decreasing
		Total nitrogen	Decreasing
UWSRR01	South Fork	pH	Decreasing
UWSRR02	South Fork	pH	Decreasing
ARK0170	South Fork	pH*	Decreasing
		Turbidity	Increasing

*pH measurements after 2019 have increased above the minimum pH criterion.

1.5 References

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Attachment 1

DO Kendall Trend Analysis Program (Helsel, Mueller, & Slack, 2006) Inputs and Output

Station WHI0059 DO Seasonal Kendall Input File

2 0 DO WHI0059 2010-2020
2010 1 11.4
2010 2 11.7
2010 3 11.0
2010 4 9.14
2010 5 10.5
2010 6 10.9
2010 7 8.43
2010 8 9.46
2010 9 9.56
2010 10 8.94
2010 11 9.96
2011 1 12.1
2011 2 11.9
2011 3 9.31
2011 4 8.33
2011 5 10.3
2011 6 10.6
2011 7 9.48
2011 8 8.95
2011 9 8.25
2011 11 10.5
2011 12 10.0
2012 1 10.5
2012 2 10.9
2012 3 10.3
2012 4 10.4
2012 5 8.43
2012 6 10.2
2012 7 6.56
2012 8 8.39
2012 9 7.56
2012 10 8.29
2012 11 9.90
2012 12 9.92
2013 1 11.4
2013 2 12.3
2013 3 11.7
2013 4 11.7
2013 5 10.0
2013 6 11.8
2013 7 8.41

2013	8	9.60
2013	9	9.29
2013	10	9.86
2013	11	9.87
2013	12	11.2
2014	1	13.2
2014	2	12.2
2014	3	12.3
2014	4	10.5
2014	5	12.0
2014	6	8.63
2014	7	9.90
2014	8	9.23
2014	9	8.79
2014	10	9.07
2014	11	9.92
2014	12	11.0
2015	1	12.0
2015	2	10.4
2015	3	11.7
2015	4	9.89
2015	5	11.7
2015	6	10.1
2015	7	11.3
2015	8	10.6
2015	9	9.06
2015	10	8.25
2015	11	9.89
2015	12	8.82
2016	1	11.6
2016	2	11.2
2016	3	7.79
2016	4	8.11
2016	5	8.12
2016	6	8.64
2016	7	8.40
2016	8	8.65
2016	9	9.10
2016	12	11.1
2017	1	12.3
2017	2	11.5
2017	3	11.3
2017	4	10.7
2017	5	8.64
2017	6	9.23
2017	7	7.92
2017	8	7.80
2017	9	6.95

2017 10 7.69
2017 11 7.76
2017 12 11.3
2018 1 11.8
2018 2 12.4
2018 3 10.9
2018 4 10.7
2018 5 9.57
2018 6 7.03
2018 7 8.95
2018 8 10.4
2018 9 9.00
2018 10 10.8
2018 11 10.3
2018 12 11.9
2019 1 11.0
2019 2 9.33
2019 3 10.9
2019 4 12.5
2019 5 9.54
2019 7 11.8
2019 8 11.8
2019 10 7.91
2019 11 10.2
2019 12 11.2
2020 1 9.83
2020 2 10.7
2020 3 12.3
2020 4 10.0
2020 5 9.92
2020 6 8.34
2020 7 9.94
2020 8 8.67
2020 9 8.50
2020 11 8.98
2020 12 9.96

Station WHI0059 DO Seasonal Kendall Output

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: O WHI0059 2010-2020

The record is 12 complete water years with 12 seasons per year
beginning in water year 2010.

The tau correlation coefficient is -0.049
S =   -29.

z = -0.676
p = 0.4989
p = 0.6419 adjusted for correlation among seasons
(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

Y =   10.08   + -0.2000E-01 * Time

where Time = Year (as a decimal) - 2009.75
(beginning of first water year)

Station 07076000 DO Seasonal Kendall Input File

```
2 0	DO 07076000 2010-2020
2010 2 9.1
2010 1 10.6
2011 2 9.5
2011 1 7.6
2012 2 10.3
2012 1 9
2013 2 10.5
2013 1 9.6
2014 2 11.4
2014 1 10.4
2015 2 9.5
2016 2 10.6
2016 1 9.5
2017 2 7.5
2017 1 9.5
2018 2 11.3
2018 1 7.1
2019 2 8.7
2019 1 7.9
2020 2 8.1
```

Station 07076000 DO Seasonal Kendall Output

```
    Seasonal Kendall Test for Trend
      US Geological Survey, 2009

 Data set:  DO 07076000 2010-2020

 The record is 12 complete water years with   2 seasons per year
   beginning in water year 2010.

 The tau correlation coefficient is -0.165
    S =    -15.
    z =  -0.877
    p =  0.3806
    p =  0.4457 adjusted for correlation among seasons
              (such as serial dependence)
 The adjusted p-value should be used only for data with
   more than 10 annual values per season.

 The estimated trend may be described by the equation:

   Y =   10.10     +  -0.1000     * Time

   where Time = Year (as a decimal) - 2009.75
                          (beginning of first water year)
```

Station WHI0043 DO Seasonal Kendall Input File

2 0 DO WHI0043 2010-2020
2010 1 14.40
2010 2 12.70
2010 3 11.40
2010 4 9.51
2010 5 8.74
2010 6 7.19
2010 7 7.23
2010 8 6.94
2010 9 6.66
2010 10 6.00
2010 11 7.31
2010 12 11.00
2011 1 13.60
2011 2 12.90
2011 3 10.60
2011 4 9.30
2011 5 10.50
2011 6 7.93
2011 7 7.39
2011 8 9.08
2011 9 7.54
2011 10 7.47
2011 11 8.39
2011 12 10.80
2012 1 9.78
2012 2 10.10
2012 3 9.76
2012 4 7.50
2012 5 6.01
2012 6 6.38
2012 7 6.43
2012 8 6.71
2012 9 7.45
2012 10 9.32
2012 11 9.62
2012 12 9.07
2013 1 13.90
2013 2 11.00
2013 3 12.00
2013 4 8.01
2013 5 7.96
2013 6 8.32
2013 7 5.58
2013 8 7.11
2013 9 7.14
2013 12 11.80

2014	1	14.20
2014	2	12.40
2014	3	11.90
2014	4	9.87
2014	5	9.29
2014	6	7.07
2014	7	7.11
2014	8	9.46
2014	9	7.49
2014	10	8.61
2014	11	9.61
2014	12	9.96
2015	1	12.20
2015	2	11.60
2015	3	10.40
2015	4	9.91
2015	5	7.88
2015	6	9.32
2015	7	8.47
2015	8	5.17
2015	9	7.24
2015	9	7.68
2015	10	6.10
2015	11	9.56
2016	1	12.20
2016	2	10.90
2016	3	9.54
2016	4	9.34
2016	5	8.23
2016	6	6.14
2016	7	7.48
2016	8	7.51
2016	9	6.76
2016	10	8.42
2016	11	10.80
2016	12	13.10
2017	1	15.10
2017	2	10.90
2017	3	10.40
2017	4	7.67
2017	5	8.79
2017	6	8.13
2017	7	6.92
2017	8	5.66
2017	9	6.20
2017	10	7.78
2017	11	9.91
2017	12	9.67

2018 1 10.20
2018 2 10.40
2018 3 10.40
2018 4 11.40
2018 5 10.10
2018 6 7.27
2018 7 7.50
2018 8 7.95
2018 9 6.84
2018 10 9.16
2018 11 9.51
2018 12 12.20
2019 1 10.70
2019 2 9.88
2019 3 11.20
2019 4 10.20
2019 5 8.65
2019 6 6.97
2019 7 8.07
2019 8 7.18
2019 9 7.33
2019 10 7.52
2019 11 11.10
2019 12 12.00
2020 1 12.30
2020 2 11.40
2020 3 9.67
2020 4 11.00
2020 5 10.40
2020 6 8.94
2020 7 7.65
2020 8 7.30
2020 9 7.87
2020 10 7.25
2020 12 11.00

Station WHI0043 DO Seasonal Kendall Output

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: O WHI0043 2010-2020

The record is 12 complete water years with 12 seasons per year
beginning in water year 2010.

The tau correlation coefficient is 0.069
S =   43.
z =   0.984

p = 0.3249
p = 0.5222 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 9.052 + 0.2889E-01 * Time

where Time = Year (as a decimal) - 2009.75
(beginning of first water year)

Station ARK0170 DO Seasonal Kendall Input File

2 0 DO ARK0170 2011-2020
2011 1 11.9
2011 3 9.11
2011 4 9.65
2011 7 8.02
2011 8 9.63
2011 9 7.55
2011 10 6.20
2011 11 9.92
2011 12 10.4
2012 2 10.4
2012 3 8.94
2012 4 9.29
2012 5 8.25
2012 6 7.17
2012 7 6.10
2012 8 3.67
2012 9 6.45
2012 10 7.31
2012 11 10.3
2012 12 11.2
2013 1 10.5
2013 2 10.4
2013 3 11.3
2013 4 8.53
2013 5 9.85
2013 6 8.60
2013 7 6.52
2013 8 8.00
2013 9 6.97
2013 10 7.85
2013 11 10.6
2013 12 14.3
2014 1 12.6
2014 2 12.4
2014 4 10.7
2014 5 8.69
2014 6 7.81
2014 7 7.14
2014 8 6.35
2014 9 7.10
2014 10 9.38
2014 11 14.0
2014 12 11.0
2015 1 12.7
2015 3 10.9
2015 4 9.04

2015	5	7.88
2015	8	7.02
2015	9	8.01
2015	10	8.84
2015	11	11.3
2016	2	11.1
2016	3	10.0
2016	4	9.81
2016	5	9.94
2016	6	7.97
2016	7	7.36
2016	8	6.72
2016	9	7.12
2016	10	8.28
2016	11	8.59
2016	12	11.8
2017	1	12.6
2017	2	11.1
2017	3	10.2
2017	4	10.0
2017	7	7.17
2017	8	4.22
2017	9	4.65
2017	10	6.84
2017	11	10.2
2017	12	12.7
2018	1	11.5
2018	2	11.6
2018	3	9.52
2018	4	10.2
2018	5	8.37
2018	6	7.44
2018	7	3.89
2018	8	7.63
2018	9	7.65
2018	10	8.77
2018	11	10.6
2018	12	10.9
2019	1	11.0
2019	8	6.44
2019	9	6.69
2019	10	7.40
2019	11	9.29
2019	12	11.8
2020	1	9.97
2020	2	9.96
2020	3	9.70
2020	4	11.2

2020 5 8.84
2020 6 6.89
2020 8 6.74
2020 9 7.52
2020 10 9.60
2020 11 9.69

Station 07076000 DO Seasonal Kendall Output

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: DO ARK0170 2011-2020

The record is 11 complete water years with 12 seasons per year
beginning in water year 2011.

The tau correlation coefficient is 0.040
S =   15.
z =   0.456
p = 0.6487
p = 0.7680 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y =   9.111   +   0.1614E-01 * Time

where Time = Year (as a decimal) - 2010.75
(beginning of first water year)

Station 07075270 DO Seasonal Kendall Input File

2 0 DO 07075270 2011-2020
2011 2 12.9
2011 4 10.1
2011 11 10.4
2012 1 11.5
2012 3 10.8
2012 11 11.5
2013 1 11
2013 3 12
2013 4 9.4
2013 5 8.6
2013 7 6.6
2013 9 4.3
2013 10 7.6
2013 12 11.1
2014 2 12.3
2014 5 9.7
2014 7 5.9
2014 9 4.4
2014 10 7.7
2015 3 12.1
2015 4 10.4
2015 5 9
2015 6 7.6
2015 11 9.6
2015 12 10.1
2016 2 11.3
2016 3 11.1
2016 4 8.8
2016 6 9.1
2016 9 8.1
2016 12 11.4
2017 3 10.1
2017 4 9.4
2017 6 7.8
2017 8 7
2017 11 8.4
2018 2 9.5
2018 6 6.2
2018 10 8.7
2018 11 9.8
2018 12 12
2019 2 11.5
2019 3 12.4
2019 6 9
2019 7 7.56
2019 8 7

2019 10 9.5
2019 12 12.4
2020 1 10.6
2020 2 12.2
2020 6 9.6
2020 7 5.8
2020 8 6.1
2020 10 7.8
2020 11 10.2

Station 07075270 DO Seasonal Kendall Output

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: DO 07075270 2011-2020

The record is 11 complete water years with 12 seasons per year
beginning in water year 2011.

The tau correlation coefficient is 0.074
S =   8.
z =   0.515
p = 0.6065
p = 0.6562 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y =   9.279   +   0.5833E-01 * Time

where Time = Year (as a decimal) - 2010.75
(beginning of first water year)

Attachment 2

Water Temperature Kendall Trend Analysis Program (Helsel, Mueller, & Slack, 2006) Inputs and Output

Station WHI0059 Water Temperature Seasonal Kendall Input File

2 0 Temperature WHI0059 2010-2020
2010 1 8.0
2010 2 7.0
2010 3 12.0
2010 4 16.5
2010 5 14.0
2010 6 14.5
2010 7 27.5
2010 8 21.0
2010 9 24.0
2010 10 16.1
2010 11 12.5
2011 1 7.5
2011 2 7.0
2011 3 18.0
2011 4 18.0
2011 5 22.0
2011 6 19.5
2011 7 15.9
2011 8 21.8
2011 9 18.8
2011 11 12.6
2011 12 9.9
2012 1 10.0
2012 2 11.3
2012 3 15.8
2012 4 15.5
2012 5 21.2
2012 6 15.8
2012 7 29.0
2012 8 25.4
2012 9 25.8
2012 10 20.4
2012 11 13.1
2012 12 12.2
2013 1 12.2
2013 2 9.2
2013 3 11.1
2013 4 11.5
2013 5 18.8
2013 6 16.0

2013	7	24.1
2013	8	25.5
2013	9	21.3
2013	10	16.5
2013	11	13.6
2013	12	8.7
2014	1	4.6
2014	2	9.1
2014	3	11.4
2014	4	11.6
2014	5	14.2
2014	6	24.0
2014	7	19.5
2014	8	20.2
2014	9	22.6
2014	10	21.1
2014	12	10.4
2015	1	6.9
2015	2	6.6
2015	3	10.4
2015	4	11.1
2015	5	14.1
2015	6	16.8
2015	7	15.7
2015	8	14.7
2015	9	18.9
2015	10	16.1
2015	11	11.1
2015	12	13.1
2016	1	9.1
2016	2	14.7
2016	3	15.2
2016	4	20.7
2016	5	19.2
2016	6	21.8
2016	7	23.2
2016	8	26.6
2016	9	19.2
2016	12	10.6
2017	1	9.5
2017	2	11.6
2017	3	9.4
2017	4	12.7
2017	5	19.4
2017	6	17.9
2017	7	21.2
2017	8	20.5
2017	9	22.4

2017 10 20.0
2017 11 15.1
2017 12 10.2
2018 1 7.5
2018 2 6.0
2018 3 11.0
2018 4 11.7
2018 5 18.8
2018 6 25.0
2018 7 20.4
2018 8 21.3
2018 9 20.6
2018 10 14.7
2018 11 9.0
2018 12 6.6
2019 1 7.7
2019 2 6.6
2019 3 11.2
2019 4 10.7
2019 5 15.4
2019 7 17.8
2019 8 16.7
2019 10 14.7
2019 11 9.5
2019 12 10.3
2020 1 8.8
2020 2 11.2
2020 3 11.1
2020 4 13.4
2020 5 13.8
2020 6 19.2
2020 7 16.9
2020 8 18.9
2020 9 18.8
2020 11 13.2
2020 12 8.7

Station WHI0059 Water Temperature Seasonal Kendall Output

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: emperature WHI0059 2010-2020

The record is 12 complete water years with 12 seasons per year
beginning in water year 2010.

The tau correlation coefficient is -0.170
S =   -99.

z = -2.392
p = 0.0168
p = 0.1691 adjusted for correlation among seasons
(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 15.62 + -0.1528 * Time

where Time = Year (as a decimal) - 2009.75
(beginning of first water year)

Station 07076000 Water Temperature Seasonal Kendall Input File

2 0 Temperature 07076000 2010-2020
2010 1 8.5
2010 2 9.6
2011 1 10
2011 2 13.8
2012 1 10.6
2012 2 11.9
2013 1 9.4
2013 2 12.1
2014 1 11.8
2014 2 9.5
2015 1 7.5
2016 1 12.2
2016 2 12.7
2017 1 12
2017 2 13.5
2018 1 13.9
2018 2 11.8
2019 19.4
2019 2 11.8
2020 1 10.5

Station 07076000 Water Temperature Seasonal Kendall Output

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: Temperature 07076000 2010-2020

The record is 11 complete water years with 19 seasons per year
beginning in water year 2010.

The tau correlation coefficient is 0.288
S = 21.
z = 1.450
p = 0.1471
p = 0.1514 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 10.15 + 0.3000 * Time

where Time = Year (as a decimal) - 2009.75
(beginning of first water year)

Station WHI0043 Water Temperature Seasonal Kendall Input File

2 0 Temperature WHI0043 2010-2020
2010 1 2.0
2010 2 6.0
2010 3 9.0
2010 4 14.5
2010 5 17.0
2010 6 26.0
2010 7 27.0
2010 8 31.5
2010 9 26.0
2010 10 17.8
2010 11 11.6
2010 12 2.5
2011 1 3.3
2011 2 4.4
2011 3 11.5
2011 4 14.1
2011 5 12.7
2011 6 26.2
2011 7 27.9
2011 8 28.3
2011 9 23.1
2011 10 21.3
2011 11 15.2
2011 12 8.9
2012 1 8.6
2012 2 5.9
2012 3 13.5
2012 4 18.6
2012 5 24.6
2012 6 25.0
2012 7 29.3
2012 8 32.8
2012 9 24.9
2012 10 16.5
2012 11 13.1
2012 12 13.0
2013 1 5.5
2013 2 8.7
2013 3 7.9
2013 4 13.0
2013 5 15.4
2013 6 18.9
2013 7 30.0
2013 8 26.0
2013 9 25.6

2013 12 8.5
2014 1 0.9
2014 2 7.6
2014 3 9.5
2014 4 14.9
2014 5 19.7
2014 6 26.7
2014 7 26.4
2014 8 28.8
2014 9 22.9
2014 10 18.7
2014 11 14.1
2014 12 10.4
2015 1 6.2
2015 2 8.8
2015 3 14.2
2015 4 15.2
2015 5 18.8
2015 6 18.7
2015 7 29.5
2015 8 30.8
2015 9 23.4
2015 10 19.9
2015 11 12.1
2016 1 6.3
2016 2 11.5
2016 3 13.5
2016 4 14.9
2016 5 18.2
2016 6 29.4
2016 7 29.1
2016 8 22.1
2016 9 25.6
2016 10 20.7
2016 11 11.2
2016 12 8.0
2017 1 3.8
2017 2 12.7
2017 3 7.3
2017 4 19.3
2017 5 18.8
2017 6 21.9
2017 7 32.1
2017 8 27.4
2017 9 26.8
2017 10 13.0
2017 11 11.1
2017 12 11.5

2018 1 6.4
2018 2 12.9
2018 3 12.6
2018 4 13.8
2018 5 21.4
2018 6 31.6
2018 7 28.3
2018 8 27.0
2018 9 25.1
2018 10 14.6
2018 11 9.2
2018 12 4.6
2019 1 10.7
2019 2 11.2
2019 3 10.3
2019 4 17.6
2019 5 17.4
2019 6 27.0
2019 7 31.7
2019 8 30.0
2019 9 29.5
2019 10 28.4
2019 11 7.5
2019 12 7.2
2020 1 8.1
2020 2 11.1
2020 3 11.9
2020 4 12.2
2020 5 18.8
2020 6 23.6
2020 7 29.2
2020 8 29.2
2020 9 27.0
2020 10 14.4
2020 12 9.2

Station WHI0043 Water Temperature Seasonal Kendall Output

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: Temperature WHI0043 2010-2020

The record is 12 complete water years with 12 seasons per year beginning in water year 2010.

The tau correlation coefficient is 0.130
S =   81.
z =   1.875

p = 0.0608
p = 0.1618 adjusted for correlation among seasons
(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 14.30 + 0.1667 * Time

where Time = Year (as a decimal) - 2009.75
(beginning of first water year)

Station ARK0170 Water Temperature Seasonal Kendall Input File

2 0 Temperature ARK0170 2012-2020
2011 1 6.0
2011 3 16.4
2011 4 17.0
2011 7 33.2
2011 8 28.7
2011 9 24.2
2011 10 18.1
2011 11 14.8
2011 12 8.8
2012 2 11.2
2012 3 17.3
2012 4 18.8
2012 5 24.4
2012 6 29.8
2012 7 30.0
2012 8 27.1
2012 9 23.6
2012 10 20.4
2012 11 10.4
2012 12 8.5
2013 1 5.4
2013 2 7.3
2013 3 11.0
2013 4 11.2
2013 5 16.6
2013 6 19.6
2013 7 28.5
2013 8 28.6
2013 9 26.4
2013 10 25.7
2013 11 14.5
2013 12 6.8
2014 1 6.6
2014 2 3.3
2014 4 10.9
2014 5 17.1
2014 6 26.4
2014 7 30.3
2014 8 30.2
2014 9 22.7
2014 10 19.6
2014 11 5.4
2014 12 12.4
2015 1 9.1
2015 3 12.4

2015	4	14.6
2015	5	15.9
2015	8	31.0
2015	9	26.1
2015	10	19.3
2015	11	11.8
2016	2	11.6
2016	3	14.4
2016	4	18.3
2016	5	18.6
2016	6	32.1
2016	7	30.7
2016	8	31.6
2016	9	28.0
2016	10	22.7
2016	11	20.8
2016	12	8.6
2017	1	5.8
2017	2	12.3
2017	3	14.6
2017	4	17.2
2017	7	33.4
2017	8	28.4
2017	9	22.0
2017	10	25.1
2017	11	13.2
2017	12	7.8
2018	1	3.8
2018	2	6.2
2018	3	13.0
2018	4	13.0
2018	5	20.2
2018	6	28.5
2018	7	27.0
2018	8	28.2
2018	9	27.9
2018	10	25.6
2018	11	14.0
2018	12	9.3
2019	1	7.7
2019	8	26.5
2019	9	30.5
2019	10	25.0
2019	11	10.4
2019	12	6.1
2020	1	9.7
2020	2	9.1
2020	3	14.2

2020 4 12.8
2020 5 16.6
2020 6 25.7
2020 7 32.8
2020 8 27.2
2020 9 21.2
2020 10 14.0
2020 11 15.5

Station ARK0170 Water Temperature Seasonal Kendall Output

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: emperature ARK0170 2012-2020

The record is 11 complete water years with 12 seasons per year
beginning in water year 2011.

The tau correlation coefficient is -0.018
S =   -7.
z = -0.193
p = 0.8471
p = 0.8781 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y =   17.42   + -0.4000E-01 * Time

where Time = Year (as a decimal) - 2010.75
(beginning of first water year)

Station 07075270 Water Temperature Seasonal Kendall Input File

2 0 Temperature 07075270 2011-2020
2011 2 3.3
2011 4 14.2
2011 11 14.1
2012 1 7.9
2012 3 9.0
2013 1 8.2
2013 3 8.6
2013 4 15.2
2013 5 19.1
2013 7 27.9
2013 9 25.7
2013 12 9.3
2014 2 7.4
2014 5 18.5
2014 7 26.5
2014 10 16.5
2015 3 7.5
2015 4 13.2
2015 5 17.1
2015 6 23.6
2015 11 15.3
2015 12 9.7
2016 2 7.5
2016 3 11.7
2016 4 15.7
2016 6 20.7
2016 9 26.0
2016 12 7.5
2017 3 13.3
2017 4 16.2
2017 6 23.8
2017 8 24.9
2017 11 9.2
2018 2 11.4
2018 10 18.8
2018 11 14.2
2018 12 7.1
2019 3 5.5
2019 6 22.2
2019 7 23.1
2019 8 26.0
2019 10 14.8
2019 12 6.7
2020 1 10.4
2020 2 6.5

2020 6 19.5
2020 7 28.0
2020 8 25.8
2020 10 16.7
2020 11 9.8

Station 07075270 Water Temperature Seasonal Kendall Output

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: Temperature 07075270 2011-2020

The record is 11 complete water years with 12 seasons per year
beginning in water year 2011.

The tau correlation coefficient is -0.034
S =   -3.
z = -0.168
p = 0.8662
p = 0.8889 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y =   15.60   + -0.2000   * Time

where Time = Year (as a decimal) - 2010.75
(beginning of first water year)

Attachment 3

pH Kendall Trend Analysis Program (Helsel, Mueller, & Slack, 2006) Inputs and Output

Station WHI0059 pH Mann-Kendall Input File

```
2 0      pH WHI0059 2010-2020
2010 1  7.02
2010 2  6.79
2010 3  6.55
2010 4  6.41
2010 5  6.40
2010 6  6.73
2010 7  6.81
2010 8  6.79
2010 9  7.03
2010 10 7.05
2010 11 6.74
2011 1  6.89
2011 2  6.93
2011 3  6.78
2011 4  6.47
2011 5  6.56
2011 6  6.69
2011 7  6.54
2011 8  6.30
2011 9  6.53
2011 11 7.01
2011 12 6.24
2012 1  7.10
2012 2  6.02
2012 3  6.53
2012 4  6.61
2012 5  6.39
2012 6  6.81
2012 7  6.77
2012 8  7.49
2012 9  7.08
2012 10 7.20
2012 11 6.33
2012 12 7.21
2013 1  7.87
2013 2  6.40
2013 3  6.90
2013 4  6.58
2013 5  6.67
2013 6  6.57
2013 7  6.65
```

2013 8 6.76
2013 9 6.76
2013 10 6.99
2013 11 6.62
2013 12 6.75
2014 1 6.57
2014 2 6.37
2014 3 7.10
2014 4 7.03
2014 5 6.78
2014 6 6.61
2014 7 7.03
2014 8 6.85
2014 9 6.95
2014 10 6.84
2014 11 7.01
2014 12 6.84
2015 1 6.51
2015 2 6.60
2015 3 7.41
2015 4 5.94
2015 5 7.56
2015 6 7.38
2015 7 7.41
2015 8 7.30
2015 9 7.06
2015 10 7.07
2015 11 6.95
2015 12 6.39
2016 1 6.92
2016 2 6.59
2016 3 6.87
2016 4 6.92
2016 5 6.57
2016 6 6.29
2016 7 7.96
2016 8 8.08
2016 9 6.82
2016 12 7.16
2017 1 6.42
2017 2 7.68
2017 3 6.59
2017 5 6.49
2017 6 6.27
2017 7 6.47
2017 8 6.10
2017 9 5.81
2017 10 6.55

2017 11 6.55
2017 12 6.85
2018 1 6.72
2018 2 5.54
2018 3 5.78
2018 4 5.17
2018 5 5.77
2018 5 6.38
2018 6 7.78
2018 7 6.51
2018 7 6.58
2018 7 6.43
2018 8 7.99
2018 9 7.17
2018 10 7.18
2018 11 6.87
2018 12 6.76
2019 1 7.31
2019 2 7.27
2019 3 7.67
2019 4 7.49
2019 5 6.85
2019 7 6.79
2019 8 6.94
2019 10 6.83
2019 11 6.97
2019 12 7.09
2020 2 6.93
2020 3 7.94
2020 4 7.09
2020 5 6.98
2020 7 6.62
2020 8 7.10
2020 9 7.29
2020 11 6.96

Station WHI0059 pH Mann-Kendall Output

Station 07075270 pH Seasonal Kendall Input File

2 0 pH 07075270 2011-2020
2011 2 12.9
2011 4 10.1
2011 11 10.4
2012 1 11.5
2012 3 10.8
2012 11 11.5
2013 1 11
2013 3 12
2013 4 9.4
2013 5 8.6
2013 7 6.6
2013 9 4.3
2013 10 7.6
2013 12 11.1
2014 2 12.3
2014 5 9.7
2014 7 5.9
2014 9 4.4
2014 10 7.7
2015 3 12.1
2015 4 10.4
2015 5 9
2015 6 7.6
2015 11 9.6
2015 12 10.1
2016 2 11.3
2016 3 11.1
2016 4 8.8
2016 6 9.1
2016 9 8.1
2016 12 11.4
2017 3 10.1
2017 4 9.4
2017 6 7.8
2017 8 7
2017 11 8.4
2018 2 9.5
2018 6 6.2
2018 10 8.7
2018 11 9.8
2018 12 12
2019 2 11.5
2019 3 12.4
2019 6 9
2019 7 7.56

2019 8 7
2019 10 9.5
2019 12 12.4
2020 1 10.6
2020 2 12.2
2020 6 9.6
2020 7 5.8
2020 8 6.1
2020 10 7.8
2020 11 10.2

Station 07075270 pH Seasonal Kendall Output

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: pH 07075270 2011-2020

The record is 11 complete water years with 12 seasons per year
beginning in water year 2011.

The tau correlation coefficient is 0.074
S =   8.
z =   0.515
p = 0.6065
p = 0.6562 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y =   9.279   +   0.5833E-01 * Time

where Time = Year (as a decimal) - 2010.75
(beginning of first water year)

Attachment 4

Turbidity Kendall Trend Analysis Program (Helsel, Mueller, & Slack, 2006) Inputs and Output

Station WHI0059 Turbidity Mann-Kendall Input File

4 0 Turbidity WHI0059 2012-2020
2012.027 8.73
2012.161 6.73
2012.238 4.81
2012.257 5.73
2012.429 3.15
2012.582 4.57
2012.620 3.64
2012.678 7.93
2012.754 5.43
2012.869 3.18
2012.945 3.55
2013.079 4.60
2013.137 5.90
2013.213 3.42
2013.290 3.10
2013.366 5.27
2013.443 6.28
2013.519 55.30
2013.653 3.54
2013.730 3.91
2013.825 2.33
2013.880 8.28
2013.918 4.26
2014.077 3.77
2014.153 3.08
2014.230 6.52
2014.268 4.09
2014.402 19.30
2014.478 23.60
2014.555 7.54
2014.650 3.68
2014.743 4.99
2014.765 2.87
2014.839 1.81
2014.934 2.58
2015.074 3.53
2015.112 3.43
2015.227 4.00
2015.322 3.43
2015.342 7.15
2015.475 6.37

2015.533 4.49
2015.609 4.75
2015.667 5.71
2015.820 12.20
2015.913 23.60
2015.951 27.10
2016.071 7.03
2016.109 7.35
2016.167 39.50
2016.320 11.90
2016.339 19.50
2016.454 10.60
2016.549 15.00
2016.664 5.94
2016.721 11.80
2016.948 3.31
2017.085 4.16
2017.104 4.17
2017.199 12.10
2017.276 4.24
2017.333 64.70
2017.448 6.38
2017.525 5.83
2017.601 6.40
2017.678 8.00
2017.754 5.39
2017.850 27.20
2017.943 3.54
2018.101 8.58
2018.235 8.06
2018.292 6.37
2018.369 6.59
2018.484 8.67
2018.598 7.24
2018.732 27.30
2018.790 38.70
2018.866 5.11
2018.940 14.00
2019.060 5.62
2019.137 5.56
2019.232 41.30
2019.251 8.23
2019.347 11.90
2019.538 25.10
2019.634 4.22
2019.825 4.08
2019.863 11.50
2019.921 3.83

2020.019 6.32
2020.096 3.38
2020.172 4.02
2020.325 6.72
2020.344 6.60
2020.440 19.80
2020.516 4.98
2020.631 6.88
2020.727 9.07
2020.937 5.92

Station WHI0059 Turbidity Mann-Kendall Output

Kendall's tau Correlation Test
US Geological Survey, 2009

Data set: Turbidity WHI0059 2012-2020

The tau correlation coefficient is 0.203
S = 986.
z = 2.978
p = 0.0029

The relation may be described by the equation:

Y = -701.59 + 0.3509 * X

Station WHI0043 Turbidity Mann-Kendall Input File

4 0 turb WHI0043 2012-2020
2012.027 3.56
2012.123 3.06
2012.199 16.80
2012.276 4.46
2012.391 4.15
2012.448 4.89
2012.525 5.46
2012.601 2.54
2012.697 5.41
2012.773 6.00
2012.850 2.73
2012.926 8.93
2013.022 2.80
2013.137 3.84
2013.175 6.93
2013.251 3.50
2013.347 5.36
2013.423 15.20
2013.519 2.75
2013.615 21.20
2013.710 4.70
2013.787 2.98
2013.844 3.12
2013.918 3.08
2014.019 3.03
2014.134 6.71
2014.210 1.58
2014.325 41.30
2014.344 6.10
2014.475 10.50
2014.516 5.93
2014.590 11.80
2014.708 4.55
2014.822 1.98
2014.839 1.89
2014.915 1.39
2015.016 13.10
2015.123 1.80
2015.246 6.19
2015.284 52.10
2015.339 2.75
2015.418 7.85
2015.530 4.73
2015.609 2.91
2015.705 6.40

2015.781 3.86
2015.874 4.91
2016.014 5.76
2016.090 2.72
2016.186 3.84
2016.262 8.51
2016.377 9.83
2016.492 4.52
2016.530 12.20
2016.626 28.60
2016.702 5.07
2016.779 4.34
2016.913 16.70
2016.951 4.53
2017.027 5.83
2017.104 2.30
2017.202 11.60
2017.295 6.11
2017.352 8.31
2017.429 17.60
2017.563 5.04
2017.620 6.11
2017.735 4.52
2017.831 5.87
2017.907 4.18
2017.923 3.89
2018.063 6.53
2018.139 7.51
2018.216 3.93
2018.276 4.50
2018.350 10.50
2018.445 3.66
2018.525 5.18
2018.601 14.40
2018.694 8.63
2018.806 12.40
2018.866 6.82
2018.921 20.80
2019.022 9.02
2019.098 5.53
2019.194 15.30
2019.309 12.80
2019.366 11.90
2019.462 6.30
2019.577 3.47
2019.596 5.05
2019.672 8.39
2019.749 6.14

2019.863 8.45
2019.940 3.77
2020.036 26.50
2020.096 8.18
2020.191 4.50
2020.287 23.70
2020.344 7.63
2020.421 6.94
2020.533 4.11
2020.590 3.75
2020.705 5.17
2020.822 4.55
2020.937 3.14

Station WHI0043 Turbidity Mann-Kendall Output

Kendall's tau Correlation Test
US Geological Survey, 2009

Data set: turb WHI0043 2012-2020

The tau correlation coefficient is 0.159
S = 886.
z = 2.416
p = 0.0157

The relation may be described by the equation:

Y = -539.94 + 0.2705 * X

Station ARK0170 Turbidity Mann-Kendall Input File

4 0 turb ARK0170 2012-2020
2012.161 4.04
2012.238 24.0
2012.314 3.62
2012.333 3.25
2012.486 4.19
2012.522 10.4
2012.658 4.13
2012.735 5.06
2012.811 1.80
2012.869 4.81
2012.962 3.18
2013.060 4.14
2013.117 6.77
2013.191 6.67
2013.251 3.91
2013.347 3.38
2013.423 7.45
2013.497 5.07
2013.634 3.75
2013.710 3.06
2013.749 3.30
2013.880 10.6
2013.956 5.53
2014.038 6.23
2014.115 4.86
2014.287 9.97
2014.363 72.0
2014.421 4.20
2014.574 7.28
2014.631 4.65
2014.708 5.59
2014.803 4.66
2014.877 3.33
2014.954 7.77
2015.074 3.20
2015.208 8.20
2015.303 4.47
2015.361 29.7
2015.628 6.35
2015.724 5.39
2015.801 8.20
2015.874 5.48
2016.148 2.92
2016.186 5.32
2016.281 8.88

2016.358 44.4
2016.473 3.91
2016.530 7.85
2016.587 5.93
2016.702 5.41
2016.760 5.43
2016.836 3.98
2016.948 3.89
2017.027 6.19
2017.104 4.24
2017.180 9.25
2017.257 10.3
2017.563 5.93
2017.639 13.1
2017.697 6.86
2017.773 8.54
2017.866 9.55
2017.962 2.69
2018.120 3.26
2018.216 5.98
2018.254 13.4
2018.350 12.8
2018.426 10.4
2018.579 11.5
2018.656 5.89
2018.713 3.22
2018.751 3.88
2018.847 9.24
2018.959 9.43
2019.041 7.60
2019.653 17.1
2019.691 6.45
2019.768 11.5
2019.883 5.36
2019.959 4.57
2020.038 24.4
2020.115 13.4
2020.246 12.7
2020.284 57.9
2020.383 19.1
2020.421 10.3
2020.516 8.43
2020.593 4.24
2020.746 5.84
2020.822 4.18
2020.858 4.09

Station ARK0170 Turbidity Mann-Kendall Output

Kendall's tau Correlation Test
US Geological Survey, 2009

Data set: turb ARK0170 2012-2020

The tau correlation coefficient is 0.240
S =   983.
z =   3.367
p = 0.0008

The relation may be described by the equation:

Y = -885.03   +   0.4418   * X

Attachment 5

TSS Kendall Trend Analysis Program (Helsel, Mueller, & Slack, 2006) Inputs and Output

Station WHI0059 TSS Seasonal Kendall Input File

2 0 TSS WHI0059 2010-2020
2010 1 7.50
2010 2 15.50
2010 3 20.50
2010 4 25.00
2010 5 63.50
2010 6 10.00
2010 7 55.50
2010 8 14.50
2010 9 7.00
2010 10 9.50
2010 11 5.00
2011 1 8.00
2011 2 52.00
2011 7 6.00
2011 12 2.00
2012 1 15.00
2012 2 7.50
2012 5 29.50
2012 6 4.00
2013 5 3.50
2013 6 6.50
2013 10 1.00
2014 3 17.00
2014 5 35.80
2014 9 9.30
2014 11 2.50
2015 1 4.00
2015 6 7.30
2015 7 6.50
2015 8 6.00
2015 9 9.00
2015 10 12.00
2015 11 12.00
2015 12 21.50
2016 1 6.50
2016 3 15.30
2016 4 7.70
2016 5 8.80
2016 6 8.50
2016 7 14.50
2016 8 6.00

2016 9 17.00
2016 12 0.50
2017 1 2.00
2017 2 3.20
2017 3 7.50
2017 4 2.50
2017 5 15.80
2017 6 5.20
2017 7 5.70
2017 8 9.70
2017 9 6.50
2017 10 4.50
2017 11 20.50
2017 12 0.50
2018 1 5.50
2018 2 5.00
2018 3 9.20
2018 4 3.00
2018 5 4.25
2018 8 7.50
2018 9 21.20
2018 10 18.20
2018 11 3.50
2018 12 4.00
2019 1 2.00
2019 2 0.50
2019 3 18.00
2019 5 4.75
2019 7 18.80
2019 8 2.00
2019 11 3.75
2019 12 0.50
2020 1 2.00
2020 2 0.50
2020 3 0.50
2020 4 2.75
2020 6 6.00
2020 7 2.50
2020 8 4.75
2020 9 10.00
2020 11 4.00
2020 12 0.50

Station WHI0059 TSS Seasonal Kendall Output

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: TSS WHI0059 2010-2020

The record is 12 complete water years with 12 seasons per year
beginning in water year 2010.

The tau correlation coefficient is -0.321
S = -81.
z = -3.472
p = 0.0005
p = 0.0510 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 10.56 + -0.6762 * Time

where Time = Year (as a decimal) - 2009.75
(beginning of first water year)

Station WHI0043 TSS Seasonal Kendall Input File

2 0 tss WHI0043 2010-2020
2010 1 0.5
2010 2 6.2
2010 3 7.0
2010 4 8.5
2010 5 8.5
2010 6 4.5
2010 7 3.5
2010 8 2.5
2010 9 6.5
2010 10 3.5
2010 11 7.0
2010 12 0.5
2011 1 0.5
2011 2 3.5
2011 3 5.0
2011 4 89.5
2011 5 122.
2011 6 3.0
2011 7 4.5
2011 8 7.5
2011 9 4.5
2011 10 8.5
2011 11 5.0
2011 12 39.5
2012 1 1.0
2012 2 0.5
2012 3 4.5
2012 4 3.0
2012 5 2.5
2012 6 4.5
2012 7 5.5
2012 8 2.0
2012 9 6.0
2012 10 2.7
2012 11 2.5
2012 12 5.2
2013 1 0.5
2013 2 1.7
2013 3 8.8
2013 4 1.0
2013 5 2.5
2013 6 5.5
2013 7 5.0
2013 8 29.0
2013 9 5.0

2013	10	5.5
2013	11	3.5
2013	12	0.5
2014	1	0.5
2014	2	2.5
2014	3	13.5
2014	4	24.0
2014	5	3.8
2014	6	4.0
2014	7	5.0
2014	8	13.5
2014	9	5.0
2014	10	1.8
2014	11	2.5
2014	12	0.5
2015	1	1.5
2015	2	1.0
2015	3	1.8
2015	4	47.0
2015	5	2.0
2015	6	5.5
2015	7	1.5
2015	8	4.5
2015	9	6.0
2015	10	3.8
2015	11	3.2
2016	1	1.5
2016	2	0.5
2016	3	1.5
2016	4	3.2
2016	5	3.5
2016	6	2.7
2016	7	3.3
2016	8	13.0
2016	9	5.7
2016	10	3.2
2016	11	5.5
2016	12	0.5
2017	1	0.5
2017	2	0.5
2017	3	2.7
2017	4	6.5
2017	5	2.7
2017	6	8.2
2017	7	4.0
2017	8	4.3
2017	9	3.8
2017	10	4.8

2017 11 2.7
2017 12 2.5
2018 1 4.7
2018 2 2.0
2018 3 1.5
2018 4 0.5
2018 5 0.5
2018 6 0.5
2018 7 3.5
2018 8 10.8
2018 9 6.8
2018 10 2.5
2018 11 3.5
2018 12 3.8
2019 1 2.3
2019 2 0.5
2019 3 2.8
2019 4 2.8
2019 5 2.3
2019 6 3.3
2019 7 2.8
2019 8 2.3
2019 9 3.8
2019 10 4.5
2019 11 0.5
2019 12 0.5
2020 1 8.0
2020 2 0.5
2020 3 0.5
2020 4 7.3
2020 5 2.5
2020 6 2.5
2020 7 0.5
2020 8 2.5
2020 9 4.3
2020 10 5.0
2020 12 0.5

Station WHI0043 TSS Seasonal Kendall Output

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: tss WHI0043 2010-2020

The record is 12 complete water years with 12 seasons per year
beginning in water year 2010.

The tau correlation coefficient is -0.222

S =   -142.
z = -3.303
p = 0.0010
p = 0.0097 adjusted for correlation among seasons
(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

Y =   4.600   + -0.2000   * Time

where Time = Year (as a decimal) - 2009.75
(beginning of first water year)

Station ARK0170 TSS Seasonal Kendall Input File

2 0 tss ARK0170 2011-2020
2011 1 1.0
2011 3 5.5
2011 4 5.5
2011 7 5.5
2011 8 4.5
2011 9 8.0
2011 10 14.0
2011 11 5.0
2011 12 34.0
2012 2 1.0
2012 3 29.0
2012 4 3.5
2012 5 3.0
2012 6 4.5
2012 7 10.0
2012 8 4.0
2012 9 5.0
2012 10 0.5
2012 11 1.0
2012 12 0.5
2013 1 0.5
2013 2 1.8
2013 3 3.3
2013 4 3.0
2013 5 2.2
2013 6 4.3
2013 7 10.0
2013 8 4.5
2013 9 3.8
2013 10 2.5
2013 11 4.0
2013 12 0.5
2014 1 0.5
2014 2 0.5
2014 4 5.0
2014 5 59.5
2014 6 2.0
2014 7 6.7
2014 8 4.3
2014 9 4.7
2014 10 0.5
2014 11 0.5
2014 12 4.0
2015 1 2.3
2015 3 3.0

2015	4	2.5
2015	5	13.0
2015	8	9.7
2015	9	6.5
2015	10	7.0
2015	11	2.0
2016	2	1.3
2016	3	3.3
2016	4	6.0
2016	5	20.7
2016	6	2.0
2016	7	3.8
2016	8	3.8
2016	9	4.0
2016	10	4.5
2016	11	3.2
2016	12	0.5
2017	1	1.7
2017	2	1.0
2017	3	4.7
2017	4	2.0
2017	7	5.0
2017	8	9.0
2017	9	5.2
2017	10	5.2
2017	11	7.0
2017	12	2.0
2018	1	1.5
2018	2	1.0
2018	3	0.5
2018	4	12.0
2018	5	5.8
2018	6	2.3
2018	7	7.8
2018	8	3.0
2018	9	4.8
2018	10	2.3
2018	11	0.5
2018	12	2.3
2019	1	0.5
2019	8	5.8
2019	9	3.3
2019	10	9.5
2019	11	2.0
2019	12	0.5
2020	1	18.0
2020	2	2.0
2020	3	3.5

2020 4 38.2
2020 5 3.3
2020 6 2.5
2020 7 4.0
2020 8 3.0
2020 9 4.5
2020 10 5.3
2020 11 0.5

Station ARK0170 TSS Seasonal Kendall Output

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: tss ARK0170 2011-2020

The record is 11 complete water years with 12 seasons per year
beginning in water year 2011.

The tau correlation coefficient is -0.086
S =   -33.
z = -1.042
p = 0.2976
p = 0.3073 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y =   4.144   + -0.6250E-01 * Time

where Time = Year (as a decimal) - 2010.75
(beginning of first water year)

Attachment 6

Suspended Sediment Kendall Trend Analysis Program (Helsel, Mueller, & Slack, 2006) Inputs and Output

Station 07075270 Suspended Sediment Seasonal Kendall Input File

```
2 0	SS 07075270 2011-2020
2011 2  16
2011 4  105
2011 11 23
2012 1  6
2012 3  19
2012 11 2
2013 1  106
2013 3  1
2013 4  149
2013 5  6
2013 6  27
2013 7  3
2013 9  4
2013 12 153
2014 1  13
2014 2  1
2014 4  101
2014 5  3
2014 7  5
2014 10 0.25
2015 1  15
2015 3  8
2015 4  6
2015 5  48
2015 6  11
2015 11 25
2015 12 2
2016 2  2
2016 3  13
2016 4  49
2016 6  2
2016 9  2
2016 12 5
2017 3  51
2017 4  27
2017 6  4
2017 8  3
2017 11 3
2018 2  843
2018 8  4
```

2018 10 7
2018 11 26
2018 12 4
2019 3 2
2019 6 3
2019 7 3
2019 8 7
2019 10 5
2019 12 3
2020 1 148
2020 2 3
2020 6 5
2020 7 3
2020 8 3
2020 10 3
2020 11 2

Station 07075270 Suspended Sediment Seasonal Kendall Output

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: SS 07075270 2011-2020

The record is 11 complete water years with 12 seasons per year
beginning in water year 2011.

The tau correlation coefficient is -0.080
S =   -9.
z = -0.583
p = 0.5599
p = 0.4034 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y =   7.017   + -0.3667   * Time

where Time = Year (as a decimal) - 2010.75
(beginning of first water year)

Attachment 7

Total Phosphorus Kendall Trend Analysis Program (Helsel, Mueller, & Slack, 2006) Inputs and Output

Station 07075270 Total Phosphorus Mann-Kendall Input File

```
4 0     TP 07075270 2011-2020
2012.869 0.009
2013.033 0.123
2013.200 0.002
2013.275 0.145
2013.372 0.005
2013.422 0.011
2013.525 0.011
2013.675 0.2
2013.814 0.009
2013.972 0.14
2014.028 0.02
2014.150 0.006
2014.322 0.07
2014.394 0.004
2014.539 0.006
2014.672 0.01
2014.825 0.008
2015.008 0.025
2015.194 0.01
2015.308 0.002
2015.386 0.041
2015.464 0.009
2015.878 0.346
2015.961 0.006
2016.125 0.004
2016.192 0.025
2016.331 0.064
2016.436 0.008
2016.683 0.008
2016.936 0.015
2017.233 0.054
2017.331 0.03
2017.475 0.011
2017.603 0.026
2017.889 0.02
2018.147 0.549
2018.453 0.017
2018.619 0.013
2018.778 0.022
2018.833 0.042
2018.931 0.002
```

2019.111 0.298
2019.183 0.002
2019.428 0.002
2019.569 0.002
2019.625 0.01
2019.792 0.006
2019.947 0.002
2020.028 0.148
2020.419 0.006
2020.575 0.008
2020.653 0.01
2020.786 0.006
2020.878 0.005

Station 07075270 Total Phosphorus Mann-Kendall Output

Kendall's tau Correlation Test
US Geological Survey, 2009

Data set: TP 07075270 2011-2020

The tau correlation coefficient is -0.110
S = -157.
z = -1.167
p = 0.2432

The relation may be described by the equation:

Y = 1.1479 + -0.5643E-03 * X

Attachment 8

Nitrate + Nitrite Kendall Trend Analysis Program (Helsel, Mueller, & Slack, 2006) Inputs and Output

Station WHI0059 Nitrate + Nitrite Seasonal Kendall Input File

```
2 0     TP WHI0059 2010-2020
2010 1  0.031
2010 2  0.051
2010 3  0.056
2010 4  0.054
2010 5  0.065
2010 6  0.027
2010 7  0.066
2010 8  0.024
2010 9  0.031
2010 10 0.035
2010 11 0.097
2011 1  0.055
2011 2  0.060
2011 3  0.041
2011 4  0.144
2011 5  0.055
2011 6  0.026
2011 7  0.026
2011 8  0.025
2011 9  0.030
2011 11 0.016
2011 12 0.017
2012 1  0.031
2012 2  0.029
2012 3  0.014
2012 4  0.021
2012 5  0.093
2012 6  0.010
2012 7  0.032
2012 8  0.031
2012 9  0.042
2012 10 0.034
2012 11 0.028
2012 12 0.029
2013 1  0.010
2013 2  0.024
2013 3  0.010
2013 4  0.010
2013 5  0.043
2013 6  0.010
2013 7  0.080
```

2013	8	0.113
2013	9	0.030
2013	10	0.107
2013	11	0.063
2013	12	0.036
2014	1	0.045
2014	2	0.025
2014	3	0.029
2014	4	0.030
2014	5	0.050
2014	6	0.100
2014	7	0.027
2014	8	0.010
2014	9	0.029
2014	10	0.025
2014	11	0.256
2014	12	0.025
2015	1	0.010
2015	2	0.010
2015	3	0.010
2015	4	0.020
2015	5	0.010
2015	6	0.024
2015	7	0.010
2015	8	0.010
2015	9	0.010
2015	10	0.141
2015	11	0.102
2015	12	0.078
2016	1	0.010
2016	2	0.010
2016	3	0.132
2016	4	0.034
2016	5	0.047
2016	6	0.030
2016	7	0.025
2016	8	0.021
2016	9	0.025
2016	12	0.010
2017	1	0.010
2017	2	0.010
2017	3	0.031
2017	4	0.010
2017	5	0.171
2017	6	0.022
2017	7	0.044
2017	8	0.010
2017	9	0.070

2017 10 0.077
2017 11 0.053
2017 12 0.010
2018 2 0.022
2018 3 0.021
2018 4 0.036
2018 5 0.027
2018 6 0.070
2018 8 0.030
2018 9 0.090
2018 10 0.090
2018 11 0.030
2018 12 0.040
2019 1 0.010
2019 2 0.010
2019 3 0.040
2019 4 0.010
2019 5 0.020
2019 7 0.050
2019 8 0.010
2019 10 0.070
2019 11 0.070
2019 12 0.010
2020 1 0.030
2020 2 0.010
2020 3 0.010
2020 4 0.010
2020 5 0.010
2020 6 0.070
2020 7 0.010
2020 8 0.010
2020 9 0.030
2020 12 0.040

Station WHI0059 Total Phosphorus Seasonal Kendall Output

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: P WHI0059 2010-2020

The record is 12 complete water years with 12 seasons per year
beginning in water year 2010.

The tau correlation coefficient is -0.204
S =   -115.
z = -2.913
p = 0.0036
p = 0.0675 adjusted for correlation among seasons

(such as serial dependence)
The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 0.3782E-01 + -0.1387E-02 * Time

where Time = Year (as a decimal) - 2009.75
(beginning of first water year)

Attachment 9

Total Nitrogen Kendall Trend Analysis Program (Helsel, Mueller, & Slack, 2006) Inputs and Output

Station WHI0043 Total Nitrogen Seasonal Kendall Input File

2 0 tn WHI0043 2010-2020
2010 1 0.107
2010 2 0.328
2010 3 0.396
2010 4 0.325
2010 5 0.165
2010 6 0.226
2010 7 0.294
2010 8 0.270
2010 9 0.407
2010 10 0.300
2010 11 0.279
2010 12 0.183
2011 1 0.158
2011 2 0.397
2011 3 1.030
2011 4 0.823
2011 5 0.482
2011 6 0.191
2011 7 0.338
2011 8 0.650
2011 9 0.421
2011 10 0.466
2011 11 0.415
2011 12 0.807
2012 1 0.187
2012 2 0.180
2012 3 0.330
2012 4 0.134
2012 5 0.240
2012 6 0.501
2012 7 0.479
2012 8 0.509
2012 9 0.476
2012 10 0.577
2012 11 0.212
2012 12 0.285
2013 1 0.605
2013 2 0.260
2013 3 0.386
2013 4 0.200
2013 5 0.108

2013	6	0.422
2013	7	0.244
2013	8	0.537
2013	9	0.277
2013	10	0.264
2013	11	0.175
2013	12	0.093
2014	1	0.268
2014	2	0.228
2014	3	0.417
2014	4	0.415
2014	5	0.175
2014	6	0.356
2014	7	0.227
2014	8	0.261
2014	9	0.369
2014	10	0.157
2014	11	0.145
2014	12	0.137
2015	1	0.578
2015	2	0.235
2015	3	0.563
2015	4	0.340
2015	5	0.111
2015	6	0.235
2015	7	0.187
2015	8	0.327
2015	9	0.218
2015	10	0.383
2015	11	0.191
2016	1	0.298
2016	2	0.092
2016	3	0.087
2016	4	0.040
2016	5	0.127
2016	6	0.247
2016	7	0.311
2016	8	0.312
2016	9	0.132
2016	10	0.239
2016	11	0.238
2016	12	0.088
2017	1	0.102
2017	2	0.104
2017	3	0.325
2017	4	0.161
2017	6	0.301
2017	7	0.303

2017 8 0.267
2017 9 0.293
2017 10 0.310
2017 11 0.205
2017 12 0.239
2018 1 0.226
2018 2 0.224
2018 3 0.155
2018 4 0.206
2018 5 0.132
2018 6 0.275
2018 8 0.755
2018 9 0.225
2018 10 0.240
2018 11 0.160
2018 12 0.270
2019 1 0.190
2019 3 0.195
2019 4 0.165
2019 5 0.155
2019 6 0.185
2019 7 0.265
2019 8 0.255
2019 9 0.265
2019 10 0.245
2019 11 0.370
2019 12 0.135
2020 1 0.470
2020 2 0.230
2020 3 0.155
2020 4 0.300
2020 5 0.155
2020 6 0.145
2020 7 0.265
2020 8 0.265
2020 9 0.245
2020 10 0.225
2020 12 0.075

Station WHI0043 Total Nitrogen Seasonal Kendall Output

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: tn WHI0043 2010-2020

The record is 12 complete water years with 12 seasons per year
beginning in water year 2010.

The tau correlation coefficient is -0.267
S =   -163.
z = -3.843
p = 0.0001
p = 0.0120 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 0.3217   + -0.1245E-01 * Time

where Time = Year (as a decimal) - 2009.75
(beginning of first water year)

Station ARK0170 Total Nitrogen Seasonal Kendall Input File

2 0 tn ARK0170 2011-2020
2011 1 0.226
2011 3 0.230
2011 4 0.265
2011 7 0.382
2011 8 1.430
2011 9 0.531
2011 10 0.613
2011 11 0.987
2011 12 0.373
2012 2 0.157
2012 3 0.231
2012 4 0.239
2012 5 0.355
2012 6 0.449
2012 7 0.468
2012 8 0.463
2012 9 0.313
2012 10 0.437
2012 11 0.243
2012 12 0.321
2013 1 0.808
2013 2 0.348
2013 3 0.206
2013 4 0.218
2013 5 0.152
2013 6 0.216
2013 7 0.325
2013 8 0.306
2013 9 0.302
2013 10 0.267
2013 11 0.321
2013 12 0.219
2014 1 0.282
2014 2 0.320
2014 4 0.156
2014 5 0.482
2014 6 0.152
2014 7 0.231
2014 8 0.289
2014 9 0.385
2014 10 0.196
2014 11 0.160
2014 12 0.184
2015 1 0.340
2015 3 0.245

2015	4	0.155
2015	5	0.299
2015	8	0.503
2015	9	0.340
2015	10	0.341
2015	11	0.200
2016	2	0.174
2016	3	0.128
2016	4	0.123
2016	5	0.258
2016	6	0.247
2016	7	0.265
2016	8	0.218
2016	9	0.212
2016	10	0.121
2016	11	0.205
2016	12	0.119
2017	1	0.244
2017	2	0.143
2017	3	0.165
2017	4	
2017	7	
2017	8	
2017	9	
2017	10	
2017	11	
2017	12	
2018	1	
2018	2	
2018	3	
2018	4	
2018	5	
2018	6	
2018	7	
2018	8	
2018	9	
2018	10	
2018	11	
2018	12	
2019	1	
2019	8	
2019	9	
2019	10	
2019	11	
2019	12	
2020	1	
2020	2	
2020	3	

2020 4
2020 5
2020 6
2020 7
2020 8
2020 9
2020 10
2020 11

Station ARK0170 Total Nitrogen Seasonal Kendall Output

Station 07075270 Total Nitrogen Seasonal Kendall Input File

2 0 Total nitrogen 07075270 2011-2020
2012 11 0.13
2013 1 0.73
2013 3 0.08
2013 4 0.33
2013 5 0.04
2013 6 0.06
2013 7 0.11
2013 9 0.13
2013 10 0.16
2013 12 0.97
2014 1 0.26
2014 2 0.05
2014 4 0.52
2014 5 0.04
2014 7 0.13
2014 9 0.20
2014 10 0.11
2015 1 0.29
2015 3 0.17
2015 4 0.05
2015 5 0.37
2015 6 0.10
2015 11 0.24
2015 12 0.05
2016 2 0.04
2016 3 0.16
2016 4 0.42
2016 6 0.04
2016 9 0.05
2016 12 0.04
2017 3 0.40
2017 4 0.21
2017 6 0.04
2017 8 0.19
2017 11 0.06
2018 2 2.40
2018 6 0.17
2018 8 0.11
2018 10 0.28
2018 11 0.38
2018 12 0.05
2019 2 1.30
2019 3 0.06
2019 6 0.05
2019 7 0.04

2019 8 0.14
2019 10 0.12
2019 12 0.08
2020 1 0.66
2020 7 0.16
2020 8 0.13
2020 10 0.05
2020 11 0.04

Station 07075270 Total Nitrogen Seasonal Kendall Output

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: Total nitrogen 07075270 2011-2020

The record is 9 complete water years with 12 seasons per year
beginning in water year 2013.

The tau correlation coefficient is -0.063
S =   -6.
z = -0.407
p = 0.6838
p = 0.5954 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 0.1450   + -0.3333E-02 * Time

where Time = Year (as a decimal) - 2012.75
(beginning of first water year)

APPENDIX F

Evaluation of Current Groundwater Quality

Measurements of selected parameters of concern collected during 2016-2020 by DEQ and USGS are summarized below. The data used for this summary were downloaded in February2022 from online databases managed by DEQ and USGS (DEQ 2020a, USGS 2020). Regarding human health, the primary water quality parameters of concern are nitrate, nitrite, and toxics. We also looked at pH in groundwater as a possible source of low pH inputs to surface water.

F.1 Nitrate and Nitrite in Groundwater

Nitrite was not measured at any of the monitoring wells during 2016-2020. Nitrate + nitrite nitrogen was measured once in the DEQ monitoring wells during 2016-2020, in the fall of 2018. All nitrate + nitrite nitrogen measurement results from this DEQ sampling event were reported as less than detection. Nitrate + nitrite nitrogen was measured once by USGS in a well during 2019. All nitrate + nitrite nitrogen measurements from DEQ and USGS wells collected from the Little Red River watershed were less than the 10 mg/L drinking water standard (DEQ 2021b, USGS 2021).

F.2 pH

All of the groundwater pH measurements from 2018 and 2019 were between 7.0 su and 8.0 su. At the DEQ monitoring locations, historically (2010-2018), measured pH values ranged from 6.99 su to 8.25 su, all within the surface water quality criteria range of 6 su to 9su. These data suggest that groundwater is not contributing to low pH conditions in surface waters.

F.3 Toxics

DEQ and USGS measured metals concentrations in wells during the period 2016-2020. They did not measure organic chemical concentrations in wells during this period. EPA has established drinking water Maximum Contaminant Levels (MCL) for many of the metals measured in the groundwater in Little Red River watershed. These MCLs are intended to protect human health. Table 1 lists the metals drinking water MCLs with levels reported in the wells sampled during 2016-2020. Metals concentrations in the DEQ wells do not exceed the drinking water MCLs. The USGS well, which takes water from the Mississippi River Valley Alluvial aquifer, reported a barium measurement greater than the MCL. Water from this aquifer is sometimes used as private a drinking water source, so this may be a health concern. Barium is not a metal that has been much discussed or studied in Arkansas groundwater (Kresse, et al., 2014). In Arkansas, USGS has measured a barium concentration greater than the MCL in only one other groundwater sample, which was from the Nacatoch Sand aquifer (USGS, 2021).

Table 1. Drinking water MCLs for metals compared to reported concentrations.

Metal	Drinking water MCL, mg/L	DEQ reported total recoverable values 2010-2020, mg/L	USGS measurement, mg/L (dissolved)
Antimony	0.006	<0.010	<0.0003
Arsenic	0.01	-	0.001
Barium	2	0.104-0.212	6.34
Beryllium	0.004	<0.0005	<0.00005
Cadmium	0.005	<0.001	<0.00015
Chromium	0.1	<0.001	<0.0025
Copper	1.3	<0.001	<0.002
Fluoride	4.0	-	0.35
Lead	0.015	<0.001	<0.0001
Selenium	0.05	<0.002	<0.00025
Thallium	0.002	<0.0025	<0.0002

APPENDIX G

Trend Analysis of Flows

Monthly average flows downstream of Greers Ferry Lake were evaluated for evidence of trends. Monthly average releases from Greers Ferry Lake for January 1990 through December 2019 were provided by US Army Corps of Engineers for the SWAT modeling portion of this project. Monthly average flows at USGS gage 07076517, Little Red River near Dewey, Arkansas, for January 1990 through December 2019 were retrieved from the USGS National Water Information System online database. The Seasonal Kendall non-parametric statistical test was used to evaluate trends in these flow data for the period 2010-2019. The USGS program for the Kendall family of tests was used to run the statistical test (Helsel, Mueller, & Slack, 2006). The input files for the program were set up with 12 seasons, i.e., each month was considered a separate season. The Seasonal Kendall test was run on all the data and on the data from just the low flow season-June through October. The program input and output are included as attachments. The results of the analyses are summarized in Tables 1 and 2. The analyses indicate that flows downstream of Greers Ferry Lake reservoir have been stable during the period 2010-2019, though flows appear to have increased since 1990 (see Figure 3.14 in text).

Table 1. Results of Seasonal Kendall test of 2010-2019 monthly average flow data, full year.

Station	Stream	Number of Years	S Statistic	Z Statistic	Adjusted P-Value	Statistically Significant Trend?
NA	Reservoir releases	11	78	1.99	0.142	No
07076517	Little Red River	11	122	3.12	0.057	No

Table 2. Results of Seasonal Kendall test of 2010-2019 monthly average flow data, June-October.

Station	Stream	Number of Years	S Statistic	Z Statistic	Adjusted P-Value	Statistically Significant Trend?
NA	Reservoir releases	11	37	1.44	0.111	No
07076517	Little Red River	11	53	2.08	0.051	No

Attachment 1

Kendall Trend Analysis Program (Helsel, Mueller, & Slack, 2006) Inputs and Output

Greers Ferry Lake (GFL) Reservoir Monthly Average Releases Seasonal Kendall Input File (full year)

2 0 month avg GFL outflow 2010-2019
2010 1 179.18
2010 2 116.80
2010 3 65.32
2010 4 53.17
2010 5 71.81
2010 6 54.55
2010 7 34.70
2010 8 26.87
2010 9 9.13
2010 10 3.53
2010 11 1.21
2010 12 1.61
2011 1 11.21
2011 2 18.22
2011 3 31.95
2011 4 25.97
2011 5 72.21
2011 6 97.68
2011 7 112.76
2011 8 86.37
2011 9 26.54
2011 10 23.49
2011 11 33.24
2011 12 155.96
2012 1 103.17
2012 2 64.37
2012 3 113.88
2012 4 119.92
2012 5 22.89
2012 6 17.04
2012 7 10.02
2012 8 14.94
2012 9 11.08
2012 10 3.58
2012 11 2.86
2012 12 7.00
2013 1 34.29
2013 2 82.52
2013 3 87.80
2013 4 67.38
2013 5 33.71

2013	6	97.16
2013	7	19.76
2013	8	22.28
2013	9	15.74
2013	10	7.14
2013	11	2.39
2013	12	31.93
2014	1	61.35
2014	2	41.24
2014	3	51.05
2014	4	69.14
2014	5	90.45
2014	6	73.73
2014	7	41.48
2014	8	32.65
2014	9	10.86
2014	10	4.20
2014	11	2.70
2014	12	3.73
2015	1	40.83
2015	2	43.05
2015	3	70.17
2015	4	98.93
2015	5	81.76
2015	6	92.66
2015	7	90.56
2015	8	65.82
2015	9	30.30
2015	10	15.13
2015	11	32.70
2015	12	131.79
2016	1	152.43
2016	2	165.40
2016	3	69.92
2016	4	44.12
2016	5	23.08
2016	6	28.94
2016	7	24.16
2016	8	31.94
2016	9	59.19
2016	10	21.39
2016	11	30.00
2016	12	40.28
2017	1	30.01
2017	2	16.47
2017	3	40.01

2017 4 63.61
2017 5 69.40
2017 6 83.54
2017 7 80.73
2017 8 27.21
2017 9 20.21
2017 10 13.51
2017 11 6.61
2017 12 15.29
2018 1 16.57
2018 2 18.77
2018 3 159.48
2018 4 82.03
2018 5 34.08
2018 6 22.19
2018 7 28.00
2018 8 21.27
2018 9 18.01
2018 10 15.67
2018 11 88.32
2018 12 97.60
2019 1 97.86
2019 2 81.81
2019 3 114.79
2019 4 137.06
2019 5 79.62
2019 6 83.55
2019 7 94.52
2019 8 91.42
2019 9 23.69
2019 10 8.82
2019 11 15.84
2019 12 38.40

GFL Releases (full year) Seasonal Kendall Output

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: month avg GFL outflow 2010-2019

The record is 11 complete water years with 12 seasons per year
beginning in water year 2010.

The tau correlation coefficient is 0.144
S =   78.
z =   1.988

p = 0.0468
p = 0.1423 adjusted for correlation among seasons
(such as serial dependence)

The adjusted p-value should be used only for data with more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 28.37 + 1.114 * Time

where Time = Year (as a decimal) - 2009.75
(beginning of first water year)

Attachment 2

Kendall Trend Analysis Program (Helsel, Mueller, & Slack, 2006) Inputs and Output

USGS Gage 07076517 Monthly Average Flows Seasonal Kendall Input File (full year)

2 0 month avg LRR flow @ Dewey 2010-2019
2010 1 5960.00
2010 2 4247.50
2010 3 2536.84
2010 4 2055.73
2010 5 2895.16
2010 6 1938.90
2010 7 1199.06
2010 8 1008.00
2010 9 464.67
2010 10 221.26
2010 11 108.59
2010 12 130.15
2011 1 429.46
2011 2 1004.18
2011 3 1581.06
2011 4 1789.47
2011 5 3890.55
2011 6 3053.67
2011 7 3565.48
2011 8 2855.52
2011 9 960.27
2011 10 798.63
2011 11 1807.35
2011 12 5863.23
2012 1 3579.26
2012 2 2521.00
2012 3 4285.00
2012 4 4277.70
2012 5 860.87
2012 6 649.63
2012 7 383.03
2012 8 570.26
2012 9 466.10
2012 10 210.95
2012 11 180.05
2012 12 391.05
2013 1 1685.13
2013 2 2946.21
2013 3 3011.16
2013 4 2387.53
2013 5 1452.29
2013 6 3423.67

2013	7	794.87
2013	8	912.84
2013	9	581.50
2013	10	308.93
2013	11	150.81
2013	12	1642.19
2014	1	2413.90
2014	2	1705.75
2014	3	2216.39
2014	4	3240.67
2014	5	3817.74
2014	6	3186.97
2014	7	1709.90
2014	8	1249.52
2014	9	440.80
2014	10	228.66
2014	11	169.81
2014	12	219.19
2015	1	1670.16
2015	2	1717.89
2015	3	3566.94
2015	4	4304.33
2015	5	3937.74
2015	6	3530.67
2015	7	3420.00
2015	8	2385.48
2015	9	1087.37
2015	10	554.11
2015	11	2054.31
2015	12	6092.58
2016	1	5424.84
2016	2	5848.62
2016	3	3499.03
2016	4	2020.90
2016	5	1047.13
2016	6	1239.40
2016	7	904.48
2016	8	1399.06
2016	9	2265.53
2016	10	833.13
2016	11	1152.27
2016	12	1715.27
2017	1	1113.19
2017	2	966.61
2017	3	1987.39
2017	4	3410.87

2017 5 3470.32
2017 6 3237.00
2017 7 3120.23
2017 8 1130.87
2017 9 784.60
2017 10 524.70
2017 11 326.29
2017 12 663.14
2018 1 739.48
2018 2 2917.39
2018 3 6940.32
2018 4 3721.73
2018 5 1409.19
2018 6 897.13
2018 7 1109.84
2018 8 879.10
2018 9 786.43
2018 10 906.61
2018 11 4483.63
2018 12 5096.45
2019 1 4622.90
2019 2 5450.36
2019 3 5355.16
2019 4 6436.00
2019 5 4128.71
2019 6 3150.33
2019 7 3664.84
2019 8 3824.32
2019 9 942.10
2019 10 432.16
2019 11 768.64
2019 12 1680.00

USGS Gage 07076517 (full year) Seasonal Kendall Output

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: month avg LRR flow @ Dewey 2010-2019

The record is 11 complete water years with 12 seasons per year
beginning in water year 2010.

The tau correlation coefficient is 0.226
S =   122.
z =   3.124
p = 0.0018
p = 0.0574 adjusted for correlation among seasons

(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

$$Y = 1362. + 62.87 * \text{Time}$$

where Time = Year (as a decimal) - 2009.75
(beginning of first water year)

Attachment 3

Kendall Trend Analysis Program (Helsel, Mueller, & Slack, 2006) Inputs and Output

Greers Ferry Lake (GFL) Reservoir Monthly Average Releases Seasonal Kendall Input File (June-October)

2 0 month avg GFL outflow 2010-2019
2010 6 54.55
2010 7 34.70
2010 8 26.87
2010 9 9.13
2010 10 3.53
2011 6 97.68
2011 7 112.76
2011 8 86.37
2011 9 26.54
2011 10 23.49
2012 6 17.04
2012 7 10.02
2012 8 14.94
2012 9 11.08
2012 10 3.58
2013 6 97.16
2013 7 19.76
2013 8 22.28
2013 9 15.74
2013 10 7.14
2014 6 73.73
2014 7 41.48
2014 8 32.65
2014 9 10.86
2014 10 4.20
2015 6 92.66
2015 7 90.56
2015 8 65.82
2015 9 30.30
2015 10 15.13
2016 6 28.94
2016 7 24.16
2016 8 31.94
2016 9 59.19
2016 10 21.39
2017 6 83.54
2017 7 80.73
2017 8 27.21
2017 9 20.21
2017 10 13.51
2018 6 22.19

2018 7 28.00
2018 8 21.27
2018 9 18.01
2018 10 15.67
2019 6 83.55
2019 7 94.52
2019 8 91.42
2019 9 23.69
2019 10 8.82

GFL Releases (June-October) Seasonal Kendall Output

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: month avg GFL outflow 2010-2019

The record is 11 complete water years with 10 seasons per year
beginning in water year 2010.

The tau correlation coefficient is 0.164
S =   37.
z =   1.440
p = 0.1499
p = 0.1115 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y =   19.55   +   1.055   * Time

where Time = Year (as a decimal) - 2009.75
(beginning of first water year)

Attachment 4

Kendall Trend Analysis Program (Helsel, Mueller, & Slack, 2006) Inputs and Output

USGS Gage 07076517 Monthly Average Flows Seasonal Kendall Input File (June-October)

```
2 0	month avg LRR flow @ Dewey 2010-2019
2010 6  1938.90
2010 7  1199.06
2010 8  1008.00
2010 9  464.67
2010 10 221.26
2011 6  3053.67
2011 7  3565.48
2011 8  2855.52
2011 9  960.27
2011 10 798.63
2012 6  649.63
2012 7  383.03
2012 8  570.26
2012 9  466.10
2012 10 210.95
2013 6  3423.67
2013 7  794.87
2013 8  912.84
2013 9  581.50
2013 10 308.93
2014 6  3186.97
2014 7  1709.90
2014 8  1249.52
2014 9  440.80
2014 10 228.66
2015 6  3530.67
2015 7  3420.00
2015 8  2385.48
2015 9  1087.37
2015 10 554.11
2016 6  1239.40
2016 7  904.48
2016 8  1399.06
2016 9  2265.53
2016 10 833.13
2017 6  3237.00
2017 7  3120.23
2017 8  1130.87
2017 9  784.60
2017 10 524.70
2018 6  897.13
2018 7  1109.84
```

2018 8 879.10
2018 9 786.43
2018 10 906.61
2019 6 3150.33
2019 7 3664.84
2019 8 3824.32
2019 9 942.10
2019 10 432.16

USGS Gage 07076517 (June-October) Seasonal Kendall Output

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: month avg LRR flow @ Dewey 2010-2019

The record is 11 complete water years with 10 seasons per year
beginning in water year 2010.

The tau correlation coefficient is 0.236
S =   53.
z =   2.080
p = 0.0375
p = 0.0513 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y =   671.9   +   50.77   * Time

where Time = Year (as a decimal) - 2009.75
(beginning of first water year)

APPENDIX H

Approach for Identifying Recommended HUC12 Subwatersheds

To identify HUC12 subwatersheds to recommend for additional management of nonpoint source pollution under this plan, available information was used to rank all of the HUC12 subwatersheds of the Little Red River watershed in terms of water quality and habitat concerns. Thirteen water quality-related criteria were assessed and used to rank each of the HUC12 subwatersheds. The following information was used to rank the HUC12 subwatersheds:

- Water quality impairment;
- Water quality risk, including loads and natural resource concerns; and
- Aquatic communities and habitat, including habitat resource concern, condition of threatened and endangered species, and predicted stream biotic condition.

1.1 Water Quality Impairment

Over 130 miles of streams in the Little Red River watershed were classified as impaired on the 2018 and 2020 Arkansas 303(d) lists. For ranking, HUC12 subwatersheds containing stream reaches classified as impaired by low dissolved oxygen (DO), pathogen indicator bacteria, or turbidity were assigned a value of one. A value of one was assigned for each pollutant. So, stream reaches with more than one pollutant exceeding criteria receive a higher rank. All other HUC12 subwatersheds were assigned a value of zero. Locations of impaired stream reaches and the associated HUC12 subwatersheds are shown on Figure 1. Figure 2 summarizes the water quality impairment ranking of the Little Red River HUC12 subwatersheds.

Impairments due to low pH and mercury, and the mercury fish consumption advisory were not used to rank the HUC12 subwatersheds. There is no evidence that low pH conditions in the watershed are due to local nonpoint sources of pollution. Atmospheric deposition may contribute, but there is little that can be done locally to reduce causes of low pH. The mercury TMDL study of South Fork Little Red River identified atmospheric deposition of mercury from global sources as the principal source of mercury to the watershed (FTN Associates 2002). Thus, there appears to be little that can be done locally to affect mercury bioaccumulation.

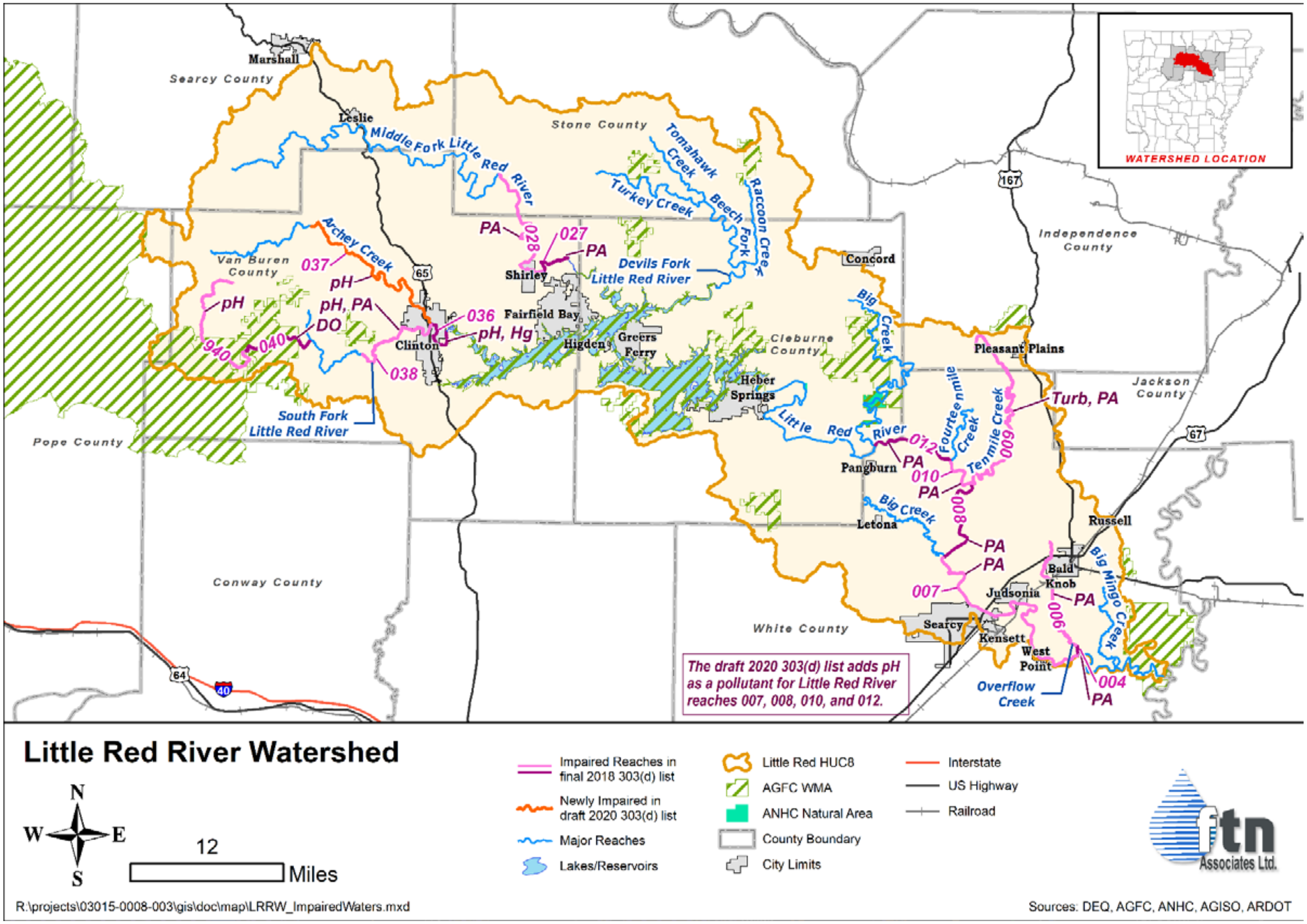

Figure 1. Impaired waterbodies of the Little Red River watershed (DEQ 2020).

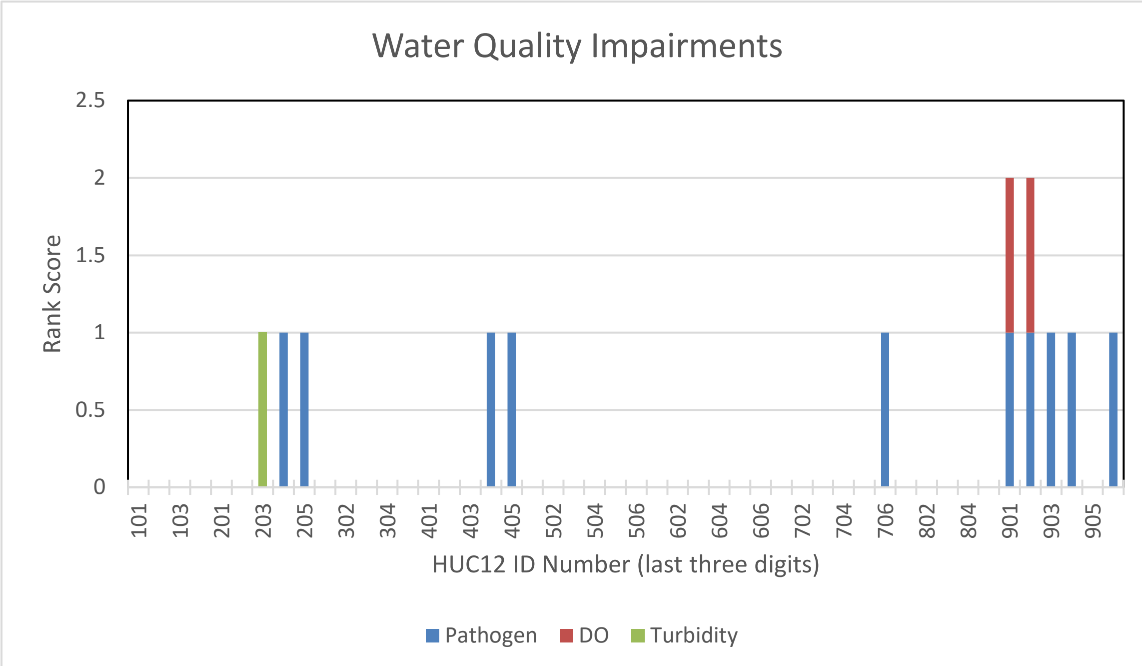

Figure 2. Summary of HUC12 ranking based on final 2018 water quality impairments.

1.2 Water Quality Risk

Measurements of water quality were available from around 30 of the 48 Little Red River HUC12 subwatersheds. Recent water quality data (from 2012 – 2021) were available from 18 of the HUC12 subwatersheds (Figure 3). Overall, the available water quality measurements were not considered appropriate for identifying recommended HUC12 subwatersheds. Modeled areal loads (SWAT model) and NRCS water quality degradation resource concerns information were available for all the HUC12 subwatersheds, so this information was used to rank the HUC12 subwatersheds.

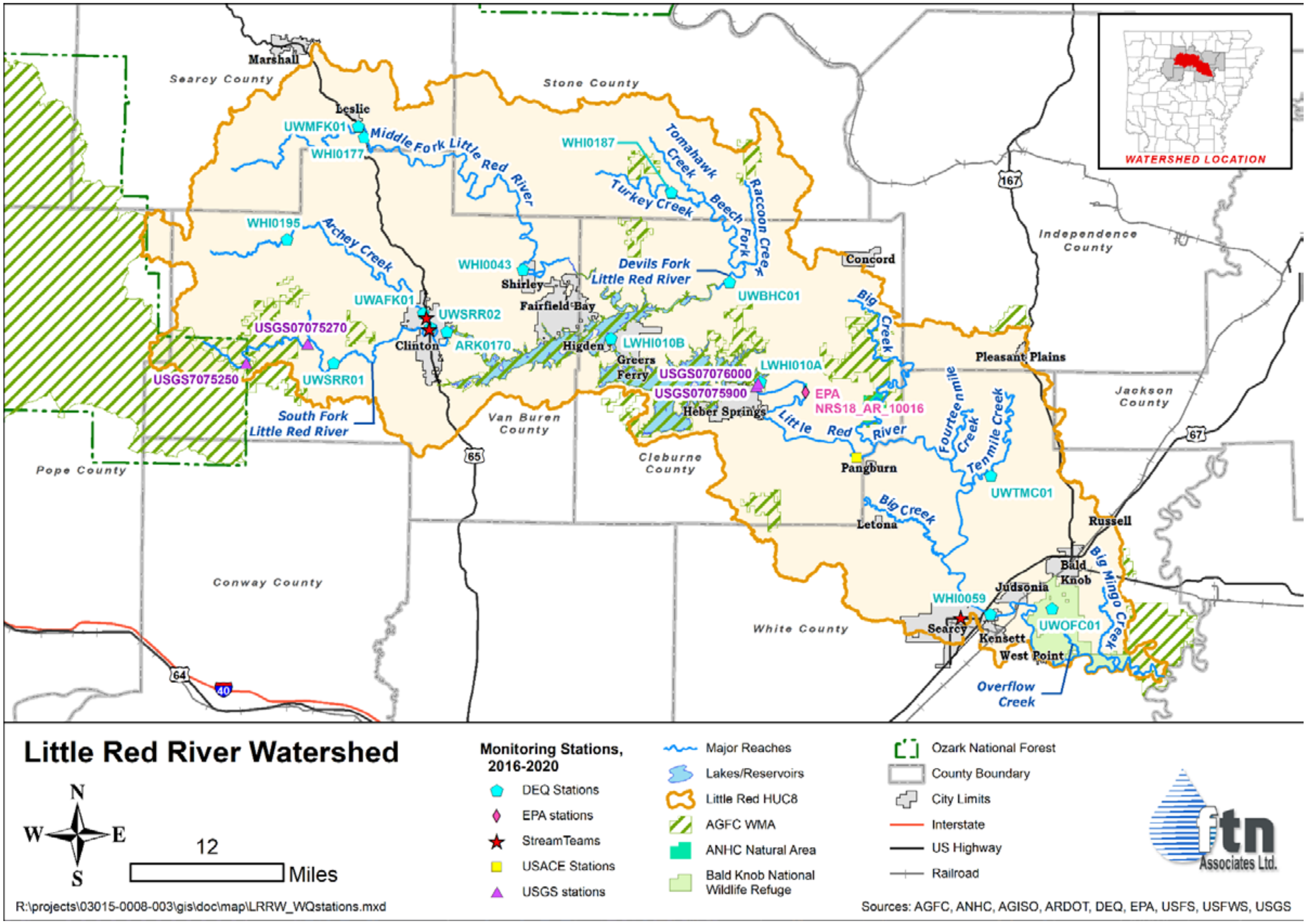

Figure 3. Locations of water quality monitoring 2012-2021, by HUC12.

1.2.1 Modeled Loads

A recent SWAT modeling project of the Little Red River watershed estimated areal loads (loads per unit of watershed area) of total nitrogen, total phosphorus, and sediment from each of the HUC12 subwatersheds (FTN Associates, Ltd. 2021). The modeled loads for the HUC12s were ranked from highest loads to lowest. Separate ranking values were assigned to the HUC12 subwatersheds for nitrogen, phosphorus, and sediment loads. For each parameter, the 10 HUC12 subwatersheds with the highest modeled load (representing the upper quintile) were assigned a value of one. All other HUC12 subwatersheds were assigned a value of zero for that parameter load. Figure 4 summarizes the load rankings of the Little Red River HUC12 subwatersheds. There are several subwatersheds where more than one constituent load was in the top 10, and one subwatershed where all three loads were in the top 10.

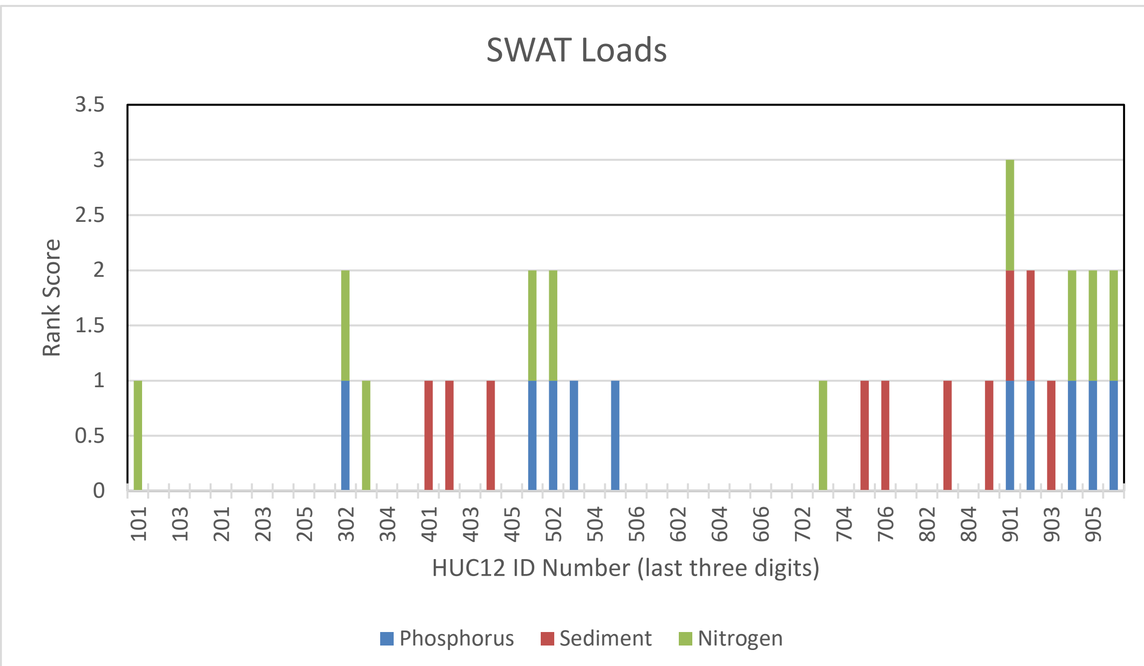

Figure 4. Summary of HUC12 ranking based on modeled loads of nutrients and sediment.

1.2.2 Natural Resources Concerns

Area-weighted risks assigned to HUC12 subwatersheds for water quality degradation resource concerns in the US Natural Resources Conservation Service (NRCS) 2015 Arkansas State Resource Assessment were also ranked from highest to lowest. Separate ranking values (one or zero) were assigned to the HUC12 subwatersheds for each of the following water quality degradation natural resource concerns:

- Excess nutrients in surface water and groundwater;
- Excess sediment in surface water;
- Petroleum, heavy metals, and other pollutants transported to receiving water sources;
- Pesticides and herbicides transported to surface water and groundwater; and
- Excess pathogens and chemicals from manure, biosolids, or compost applications.

For each resource concern, the 10 HUC12 subwatersheds (representing the upper quintile) with the highest area-weighted risks were assigned a value of one. All other HUC12 subwatersheds were assigned a value of zero for that resource concern. Figure 5 summarizes the water resource concern rankings of the Little Red River HUC12 subwatersheds. None of the HUC12 subwatersheds were in the top 10 of area-weighted risk for all five water quality resource concerns, but several subwatersheds were in the top 10 for four of the resource concerns.

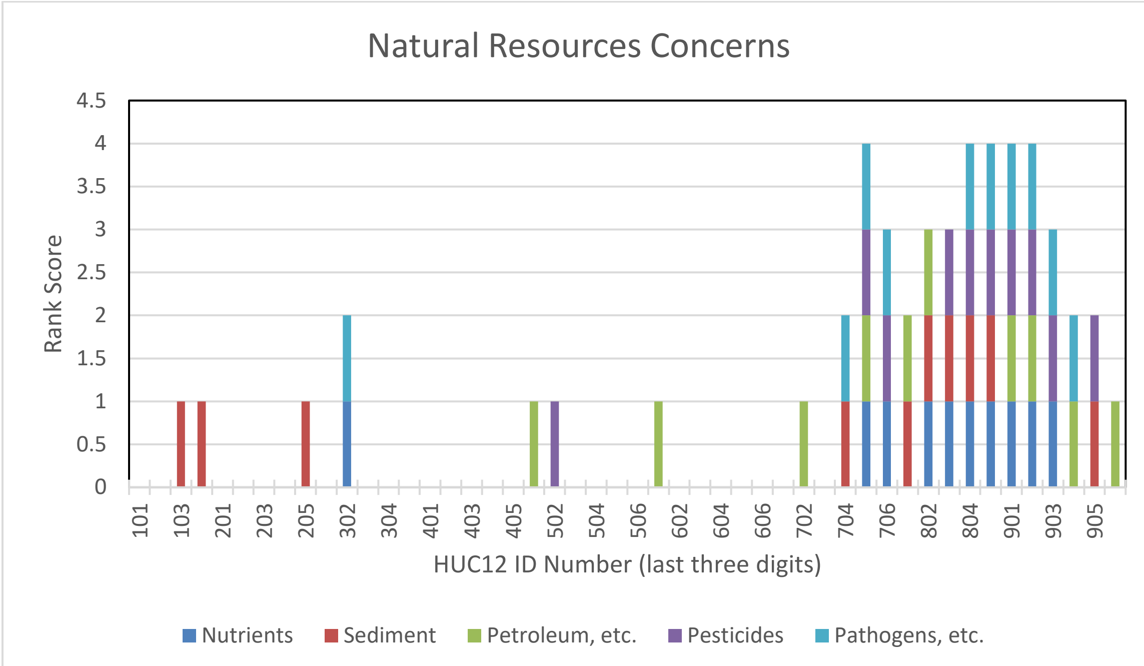

Figure 5. Summary of HUC12 ranking based on NRCS water quality resource concerns risks.

Interestingly, the State Resource Assessment approach classified HUC12 subwatersheds downstream of Greers Ferry Lake as having greater risk of water quality resource concerns. Note that the NRCS risk assessment scoring for several of the water quality resource concerns includes consideration of the presence of impaired waterbodies from the 2016 impaired waters (303(d)) list (NRCS 2016). The DO impairment on the 2018 impaired waters (303(d)) list was not on the 2016 list (DEQ 2017).

1.3 Aquatic Communities and Habitat

Recent surveys of aquatic communities and/or habitat found for only a few HUC12 subwatersheds and for only a few species. To address concerns about aquatic communities and aquatic habitats in the Little Red River watershed we used information about the condition of threatened and endangered aquatic species in the watershed, along with estimates of risk of inadequate habitat from the State Resource Assessment, and predicted biotic condition of streams.

1.3.1 Condition of Populations of Threatened and Endangered Species

There are populations of endangered and threatened aquatic species within the Little Red River watershed. The status of populations of Yellowcheek Darter (endangered), and Rabbitsfoot (threatened) and Speckled Pocketbook (endangered) mussels have been recently evaluated. Darter populations were characterized as stable (Bussell, Driver and Justus 2020). Some of the listed mussel species populations, however, were characterized as declining (USFWS 2020, 2021). This information was used to identify HUC12 subwatersheds of interest. Using information presented in FWS 5-year reviews of these mussel species, HUC12 subwatersheds were identified where populations of endangered mussel species have been characterized as declining. These HUC12 subwatersheds were assigned a value of 1. HUC12 subwatersheds were scored separately for each species. As a result, a subwatershed with declining populations of both mussel species would rank higher than a subwatershed with declining populations of just one species. If a HUC12 subwatershed contained stream reaches designated as Critical Habitat for Rabbitsfoot mussel, and a declining Rabbitsfoot population, it was assigned a value of 2. All other HUC12 subwatersheds were assigned a value of zero for this characteristic.

1.3.2 Inadequate Habitat Resource Concern

Area-weighted risk of inadequate habitat for fish and wildlife assigned to HUC12 subwatersheds in the 2016 State Resource Assessment was also used to identify subwatersheds of interest. As with the water quality resource concerns from the State Resource Assessment, the area-weighted risk of inadequate habitat assigned to the HUC12 subwatershed of the Little Red River were ranked from highest to lowest. The HUC12 subwatersheds ranked 1-10 were assigned a value of one. All other HUC12 subwatersheds were assigned a value of zero for this element. Note that the assessment of risk of inadequate habitat considers the presence of streams classified as Extraordinary Resource Waters and Ecologically Sensitive Waterbodies. Therefore, these characteristics will not be used to score the HUC12 subwatersheds.

1.3.3 Predicted Stream Biotic Condition

EPA researchers developed a landscape model to predict stream biological condition, nationwide, using information from the 2008-2009 National Rivers and Streams Assessment (Hill, et al. 2017). The researchers used this model to predict biological condition for many of the stream segments in the National Hydrographic Dataset (NHD). From this work, biological condition was predicted for approximately one-third of the NHD stream segments in the Little Red River watershed (1,173 of 3,120). For each HUC12 subwatershed, the length of stream segments predicted to have good, fair, or poor condition was calculated, along with the total length of NHD stream segments. HUC12 subwatersheds where biological condition was predicted for at least 25% of the stream length, and the majority of the stream length for which biological condition was predicted to have poor biological condition, were assigned a value of one. All other HUC12 subwatersheds were assigned a value of zero.

1.3.4 Summary

Figure 6 summarizes the HUC12 ranking scores for the aquatic communities and habitat characteristics considered.

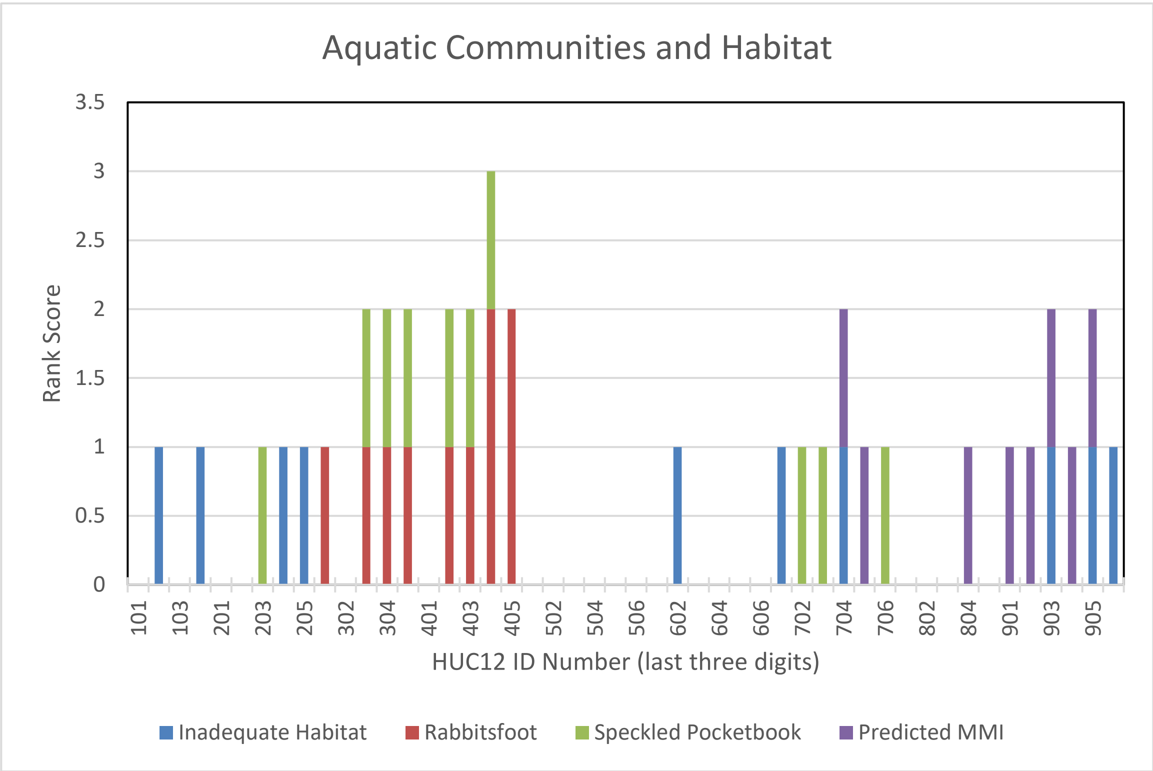

Figure 6. Summary of HUC12 ranking based on aquatic communities and habitat characteristics.

1.4 Ranking of HUC12 Subwatersheds

Scores for all of the ranking characteristics were summed to identify HUC12 subwatersheds with the greatest number of water quality concerns. Figure 7 summarizes the total ranking scores for the Little Red River HUC12 subwatersheds. There are few HUC12 subwatersheds with a score of zero. Four of these are HUC12s associated with Greers Ferry Lake. The HUC12 subwatersheds downstream of Greers Ferry Lake have the highest rank scores.

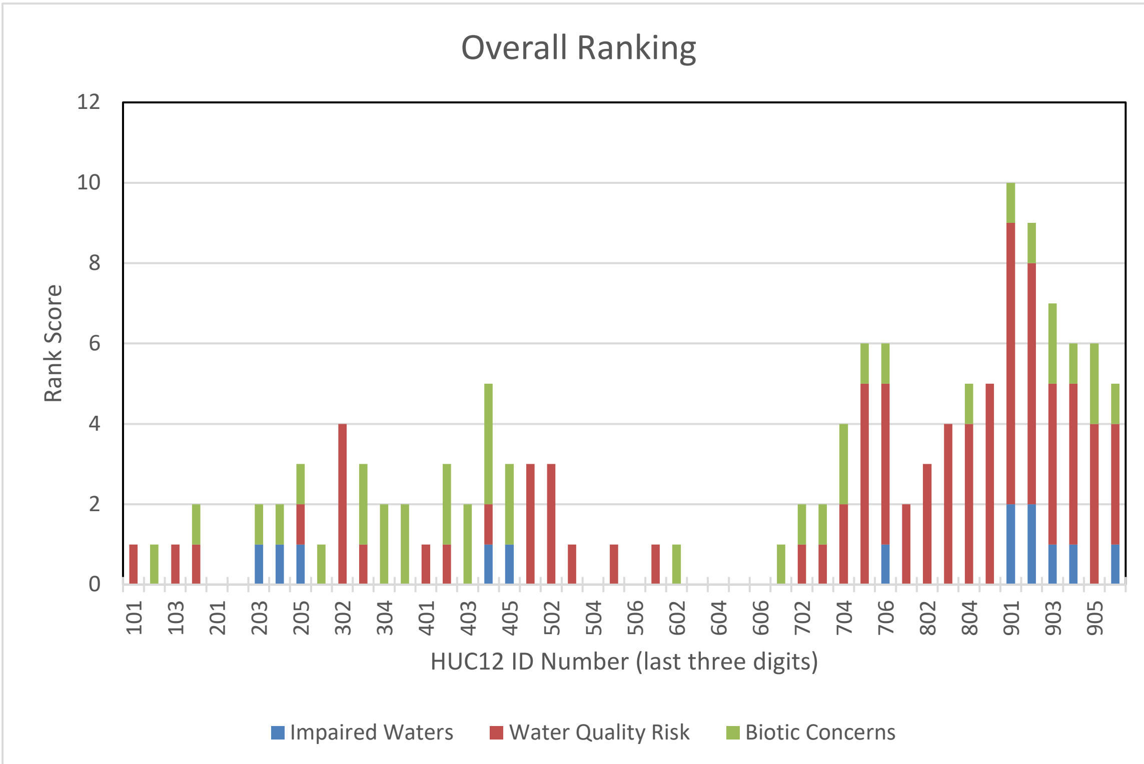

Figure 7. Overall ranking of HUC12 subwatersheds of Little Red River.

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APPENDIX I

Estimation of Potential Pollutant Load Reductions Through Use of BMPs

1.1 Assumptions

Some assumptions are made for any estimate of future conditions. Assumptions made in calculating estimates of load reductions from implementing BMPs are discussed below.

Table 1 (all tables located at the end of this document) lists the load reductions assumed to result from use of selected BMPs. These are the values used in the calculations to estimate the potential load reductions from implementing BMPs.

For the load reduction calculations, 100% of the pollutant loads are assumed to be coming from the source being treated by a BMP, and 100% of the source is assumed to be treated. Thus, the estimated load reductions represent the maximum potential load reduction resulting from use of a practice, which is the value from Table 1. Actual reductions from implementing the BMPs may be less than the estimates presented here, especially if other sources are contributing significantly to the pollutant load.

1.2 Potential Load Reductions

The estimated load reduction results are discussed and summarized for each of the recommended subwatersheds in the subsections below.

1.2.1 Fourteen Mile Creek

There are no load reduction targets for this subwatershed. Potential reductions in nitrogen, phosphorus, sediment, and *E. coli* loads from implementing pasture and unpaved road BMPs, as well as maintaining and/or repairing onsite wastewater treatment systems were estimated. While these sources are not specifically targeted for management in this plan, they are sources of pollutants that could be contributing to water quality concerns that are likely to exist in this subwatershed. Estimated potential load reductions from implementing selected BMPs are presented in Table 2.

1.2.2 Little Red River-Cedar Branch

There is a total phosphorus load reduction target of 36% for this subwatershed. Since the Little Red River in this subwatershed is listed as impaired due to *E. coli*, though 2018 data indicate a zero target load reduction, this pollutant is also targeted. Potential reductions in phosphorus, *E. coli*, nitrogen and sediment loads from implementing pasture and unpaved road BMPs, as well as maintaining and/or repairing onsite wastewater treatment systems, were estimated. Estimated potential load reductions from implementing selected BMPs are presented in Table 3. Note that while this is the least populated of the recommended subwatersheds, it does include residences located along the Little Red River, which are served by onsite wastewater treatment systems. The proximity of these systems to the river makes it imperative that they operate effectively.

1.2.3 Headwaters Ten Mile Creek and Outlet Ten Mile Creek

There is a 41% load reduction target for *E. coli*, 23% load reduction target for total nitrogen, and 78% load reduction target for total phosphorus in these subwatersheds. Since Ten Mile Creek in these subwatersheds is listed as impaired due to turbidity, though the turbidity TMDL does not indicate a need for load reduction, sediment is also targeted. Potential reductions in *E. coli*, nitrogen, phosphorus, and sediment loads from implementing pasture and unpaved road BMPs, as well as maintaining and/or repairing onsite wastewater treatment systems were estimated. Estimated potential load reductions from implementing selected BMPs are presented in Table 4. Given that the BMPs in Table 4 are all assumed to reduce *E. coli* loads by more than 41%, it should be possible to achieve this load reduction target using these practices. The *E. coli* section of Table 4 includes a listing of the percentage of a source to treat to achieve the 41% target *E. coli* load reduction. This value was calculated by dividing the target reduction (41%) by the practice reduction efficiency.

Expected nutrient load reductions from the BMPs in Table 4 are mostly less than the load reduction targets for total nitrogen and total phosphorus. Therefore, it may be difficult to achieve the nutrient load reduction targets for these subwatersheds.

1.2.4 Little Red River-Alder Creek

There is a total phosphorus load reduction target of 36% for this subwatershed. Since the Little Red River in this subwatershed is listed as impaired due to *E. coli*, though 2018 data do not indicate a need for load reduction, this pollutant is also targeted. Potential reductions in phosphorus, *E. coli*, nitrogen and sediment loads from implementing pasture, development, and unpaved road BMPs, as well as maintaining and/or repairing onsite wastewater treatment systems were estimated. Estimated potential load reductions from implementing selected BMPs are presented in Table 5. Given the assumed phosphorus reduction efficiencies for these BMPs, it could be possible to achieve the total phosphorus reduction target for this subwatershed.

1.2.5 Overflow Creek

There are no load reduction targets for this subwatershed. Since the Overflow Creek in this subwatershed is listed as impaired due to *E. coli*, though 2018 data do not indicate a need for load reduction, this pollutant is targeted. Potential reductions in *E. coli*, nitrogen, phosphorus, and sediment loads from implementing pasture and development BMPs, as well as maintaining and/or repairing onsite wastewater treatment systems were estimated. Croplands in the subwatershed are not assumed to be a significant source of *E. coli*. Estimated potential load reductions from implementing selected BMPs are presented in Table 6.

1.2.6 Big Mingo Creek

There is a total nitrogen load reduction target of 71% for this subwatershed. Potential reductions in nitrogen, *E. coli*, phosphorus, and sediment loads from implementing cropland BMPs, as well as maintaining and/or repairing onsite wastewater treatment systems were estimated. Estimated potential load reductions from implementing selected BMPs are presented in Table 7. Note that croplands are assumed to not be a significant source of *E. coli*. Therefore, it is assumed that there are no *E. coli* load reductions associated with application of BMPs on croplands. Given the assumed nitrogen reduction efficiencies of the BMPS, it may be difficult to achieve the total nitrogen load reduction target for this subwatershed.

Table 1. Load reduction values used to calculate potential load reductions from implementing management practices.

Land use	Practice	*E. coli* reduction[a]	TN reduction[a]	TP reduction[a]	Sediment reduction[a]
pasture	Bank stabilization w/ fence	0.45[b]	0.75	0.75	0.75
Pasture	Access control	0.45	0.10	0.15	0.60
Pasture	Prescribed grazing	0.65	0.10	0.15	0.30
Pasture	Alternate water source	0.70	0.10	0.15	0.30
Pasture, hayland	Riparian buffer (forested or herbaceous)	0.50	0.35	0.35	0.60
pasture	Grassed buffer	0.50	0.35	0.35	0.60
Pasture	Pasture management suite	0.70[b]	0.45	0.65	0.60[b]
Pasture, hayland, developed, crop	Nutrient mgt plan	No data found	0.10	0.15	0.60
Developed	Stormwater retention pond	0.65	0.25	0.50	0.75
Developed	Bioretention	0.45	0.25	0	0.75
Pasture, developed	Filter strip	0.60	0.15	0	0.50
Pasture, hayland, developed	Streambank stabilization	No data found	0.15	0.20	0.60
Residential	Fix failing septic systems	0.90	0.25[c]	0.90[c]	0
Unpaved road	Environmentally Sensitive Management	None expected	No data found	No data found	0.80
Crop	Conservation till	No data found	0.10	0.20	0.65
Crop	Cover crops	No data found	0.25	0.30	0.75
Crop	Nutrient mgt plan	No data found	0.10	0.15	0.60
Crop	Forested buffer	No data found	0.30	0.45	0.60
Crop	Grassed buffer	No data found	0.20	0.45	0.60
Crop	Conservation till + cover crop	No data found	0.50	0.55	0.75[b]
Crop	Soil nutrient mgt suite	No data found	0.15	0.25	0.60
Crop	Tailwater recovery suite	No data found	0.50	0.35	0.75
Crop	Irrigation management suite	No data found	0.55	0.40	0.75[b]

a Purple = based on default values used in STEPL version 4.4b
Blue = values from 2019 Arkansas Nutrient Reduction Framework (FTN Associates, Ltd., 2019)
Orange = based on values from multiple sources, see Table 4.24
Green = based on values from International Stormwater BMP Database (Clary, Jones, Leisenring, Hobson, & Strecker, 2020)
b set to highest value from the practices that make up this suite
c based on Table 3.17 of (US EPA Office of Water, 2002)

Table 2. Estimated potential load reductions from BMPs in Fourteen Mile Creek subwatershed.

Potential Sources	Location	BMPs	Estimated potential load reductions (target load reduction)			
			E. coli (none)	Total N (none)	Total P (none)	Sediment (none)
Livestock	Pasture	Access control	45%	10%	15%	60%
		Prescribed grazing	65%	10%	15%	30%
		Alternate water source	70%	10%	15%	30%
Poultry litter	Pasture and haylands	Nutrient management plan	Unknown	10%	15%	60%
Fertilizer	Pasture and haylands	Nutrient management plan	0	10%	15%	60%
Runoff from pasture and hayland	Pasture and haylands	Pasture management suite	70%	45%	65%	60%
Onsite wastewater treatment systems	Within 100 feet of surface water	Maintenance or replacement	90%	25%	90%	0
Poor quality riparian buffers	Pasture and haylands within 100 feet of streams	Restore riparian buffer	50%	35%	35%	60%
Unpaved roads	Stream crossings and within 100 feet of surface water	Environmentally sensitive management	0	0	Unknown	80%
Sheet and rill erosion	Pasture and haylands	Filter strip	60%	15%	0	50%
Gully erosion	Pasture and haylands	Heavy use area protection	90%	10%	15%	80%
Streambank erosion	Streams in pasture and haylands	Streambank stabilization	Unknown	15%	20%	60%

Table 3. Estimated potential load reductions from BMPs in Little Red River-Cedar Creek subwatershed.

Target Sources	Location	BMP	Estimated potential load reductions (target load reduction)			
			E. coli (0)	Total N (none)	Total P (36%)	Sediment (none)
Livestock	Pasture	Access control	45%	10%	15%	60%
		Prescribed grazing	65%	10%	15%	30%
		Alternate water source	70%	10%	15%	30%
Poultry litter	Pasture and haylands	Nutrient management plan	Unknown	10%	15%	60%
Fertilizer	Pasture and haylands	Nutrient management plan	0	10%	15%	60%
Runoff from pasture and hayland	Pasture and haylands	Filter strip	60%	15%	0	50%
		Pasture management suite	70%	45%	65%	60%
Onsite wastewater treatment systems	Within 100 feet of surface water	Maintenance or replacement	90%	25%	90%	0
Poor quality riparian buffers	Pasture and haylands within 100 feet of streams	Restore riparian buffer	50%	35%	35%	60%

Table 4. Estimated potential load reductions from BMPs in Little Red River-Cedar Branch subwatershed.

Target Source	Location	BMP	Estimated potential load reductions (target load reduction)			
			E. coli (0)	Total N (23%)	Total P (78%)	Sediment (0)
Livestock	Pasture	Prescribed grazing	65%	10%	15%	30%
Poultry litter	Pasture and haylands	Nutrient management plan	Unknown	10%	15%	60%
Runoff from pasture and hayland	Pasture and haylands	Pasture management suite	70%	45%	65%	60%
On-site wastewater treatment systems	Within 100 feet of surface water	Maintenance or replacement	90%	25%	90%	0
Poor quality riparian buffers	Pasture and haylands within 100 feet of streams	Restore riparian buffer	50%	35%	35%	60%
Fertilizer	Pasture and haylands	Nutrient management plan	0	10%	15%	60%
Sheet and rill erosion	Pasture and haylands	Filter strip	60%	15%	0	50%
Streambank erosion	Streams in pasture and haylands	Streambank stabilization	Unknown	15%	20%	60%
Channel erosion	Streams	Access control	45%	10%	15%	60%
		Alternate water source	70%	10%	15%	30%
Unpaved roads	Stream crossings and within 100 feet of surface water	Environmentally sensitive management	0	0	Unknown	80%

Table 5. Estimated potential load reductions from BMPs in Little Red River-Alder Creek subwatershed.

Target Source	Location	BMP	Estimated potential load reductions (target load reduction)			
			E. coli (0)	Total N (none)	Total P (36%)	Sediment (none)
Livestock	Pasture	Access control	45%	10%	15%	60%
		Prescribed grazing	65%	10%	15%	30%
		Alternate water source	70%	10%	15%	30%
poultry litter	Pasture and haylands	Nutrient management plan	Unknown	10%	15%	60%
Runoff from pasture and hayland	Pasture and haylands	Filter strip	60%	15%	0	50%
		Pasture management suite	70%	45%	65%	60%
On-site wastewater treatment systems	Within 100 feet of surface water, particularly Little Red River	Maintenance or replacement	90%	25%	90%	0
Poor quality riparian buffers	Development and pasture and haylands within 100 feet of streams	Restore riparian buffer	50%	35%	35%	60%
Runoff from developed areas	Searcy, development along Little Red River	Stormwater retention pond	65%	25%	50%	75%
		Bioretention	45%	25%	0	75%
Fertilizer	Residential areas, pasture, and haylands	Nutrient management plan	0	10%	15%	60%

Table 6. Estimated potential load reductions from BMPs in Overflow Creek subwatershed.

Target Source	Location	BMP	Estimated potential load reductions (target load reduction)			
			E. coli (0)	Total N (none)	Total P (none)	Sediment (none)
Livestock	Pasture	Access control	45%	10%	15%	60%
		Prescribed grazing	65%	10%	15%	30%
		Alternate water source	70%	10%	15%	30%
poultry litter	Pasture and haylands	Nutrient management plan	Unknown	10%	15%	60%
Runoff from pasture and hayland	Pasture and haylands	Filter strip	60%	15%	0	50%
		Pasture management suite	70%	45%	65%	60%
On-site wastewater treatment systems	Within 100 feet of surface water	Maintenance or replacement	90%	25%	90%	0
Poor quality riparian buffers	Development, cropland, pasture, and haylands within 100 feet of streams	Restore riparian buffer	50%	35%	35%	60%
Runoff from developed areas	Bald Knob	Stormwater retention pond	65%	25%	50%	75%
		Bioretention	45%	25%	0	75%

Table 7. Estimated potential load reductions from BMPs in Big Mingo Creek subwatershed.

Target Source	Location	BMP	Estimated potential load reductions (target load reduction)			
			E. coli (none)	Total N (71%)	Total P (none)	Sediment (none)
Runoff from cropland	Cropland	Filter strip	0	15%	0	50%
		Cover crop	0	25%	30%	75%
		Conservation till	0	10%	20%	65%
		Conservation till + cover crop	0	50%	55%	75%
		Soil nutrient management suite	0	15%	25%	60%
		Tailwater recovery suite	0	50%	35%	75%
Fertilizer	Cropland	Nutrient management plan	0	10%	15%	60%
On-site wastewater treatment systems	Within 100 feet of surface water	Maintenance or replacement	90%	25%	90%	0
Poor quality riparian buffers	Cropland within 100 feet of streams	Restore forested riparian buffer	0	30%	45%	60%
		Restore grassed riparian buffer	0	20%	45%	60%

1.3 References

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APPENDIX J

Examples of Education and Outreach Activities in the Little Red River Watershed

1.1 US Army Corps of Engineers

Information and education activities of USACE Little Rock District related to the Little Red River include operating the William Carl Garner visitor center at Greers Ferry Lake. Information about natural resources on USACE lands in the watershed, and their management, is also available on the USACE Greers Ferry Lake website (https://www.swl.usace.army.mil/Missions/Recreation/Lakes/Greers-Ferry-Lake/). USACE Little Rock District also provides information on several social media platforms, including Facebook, Twitter, YouTube, and Instagram.

1.2 US Fish and Wildlife Service

Information and education activities of the USFWS in the Little Red River watershed include offering tours of the Greers Ferry Lake National Fish Hatchery. Youth Conservation Corps opportunities are also provided at this hatchery. USFWS is a sponsor of the annual Little Red River Youth Fish Camp Program. USFWS also provides information about Arkansas wildlife and habitat issues and management, including endangered species, through their website (https://www.fws.gov/office/arkansas-ecological-services), and a variety of social media platforms, including Facebook, Instagram, Twitter, Flickr, and YouTube.

1.3 Natural Resources Conservation Service

Information and education activities of the NRCS include participation in field days and farm demonstrations, soil and water stewardship materials, and informational and training programs at county offices, in addition to information posted on their website (https://www.nrcs.usda.gov/wps/portal/nrcs/ar/home/), Twitter, and YouTube. Through these activities, NRCS provides information and education on a wide range of topics related to agriculture in the state, including benefits, implementation, and maintenance of agricultural practices to protect or improve water quality so water quality standards are met.

1.4 University of Arkansas Division of Agriculture

The UofA Division of Agriculture is a research and information support agency for the agricultural sector in Arkansas. The Division of Agriculture provides information and education through the Cooperative Extension Service. Information and education activities of the Cooperative Extension Service include the Arkansas Watershed Steward program, displays and presentations at fairs and festivals, Little Red River Forage Conference, participation in field days and farm demonstrations, informational and training programs at county offices, newsletters, publications on a variety of topics including feral hog management, and short and long-term agricultural methods that protect water quality so water quality standards are met. A website (https://www.uaex.edu/), and Facebook, Twitter, Instagram, and YouTube accounts provide access to information about programs and resources, and copies of informational publications and videos. The Division of Agriculture also sponsors the annual Most Crop per Drop Irrigation contest.

The Arkansas Cooperative Extension Service also provides information on protecting water quality for non-agricultural landowners and residents in developed areas, through their website and social media. In addition, they are working with NRD to offer the Arkansas Watershed Steward Program.

1.5 County Conservation Districts

Information and education activities of the County Conservation Districts include displays and presentations at fairs and festivals, participation in field days and farm demonstrations, soil and water stewardship materials, informational and training programs at county offices, and support of Arkansas Envirothon, in addition to social media like Facebook and Twitter. Through these activities, County Conservation Districts provide information and education on a wide range of topics related to agriculture and rural life, including benefits, implementation, and maintenance of agricultural practices to protect water quality so water quality standards are met.

1.6 Arkansas Natural Resource Agencies

Arkansas natural resource agencies, including AGFC, Arkansas Natural Heritage Commission, Arkansas Department of Agriculture Forestry Division, DEQ and the NRD, all have information and education programs aimed at increasing public interest, understanding, and stewardship of the natural resources of our state, including protecting water quality to achieve water quality standards. Examples of agency programs relevant to the target nonpoint pollution sources in the recommended subwatersheds include the NRD Unpaved Roads Program and nonpoint source pollution program, AGFC Stream Habitat Program and annual Little Red River Youth Fish Camp, and DEQ Watershed Outreach and Education Program. Arkansas natural resources agencies use a variety of methods to reach Arkansans, including websites (https://www.agfc.com/en/, https://www.arkansasheritage.com/arkansas-natural-heritage/anhc-home, https://www.agriculture.arkansas.gov/natural-resources/, https://www.adeq.state.ar.us/poa/watershed/); social media (e.g., https://www.youtube.com/c/ArkansasGameandFishCommission, https://www.facebook.com/arnaturalheritage/, https://twitter.com/ARDeptofAgricul); newsletters; presentations and displays at meetings, fairs, and festivals; news media stories; and hosting volunteer and training events.

1.7 The Nature Conservancy

The Nature Conservancy assists with outreach and education through a variety of programs. This organization has been most active in the Little Red River watershed upstream of Greers Ferry Lake. The Bluffton Preserve on the Archey Fork of the Little Red River includes educational signage and examples of practices to stabilize stream channels and protect water quality. The Nature Conservancy conducts education and outreach through their website and social media, as well as through articles in newspapers and magazines.

1.8 Arkansas Soil Health Alliance

The Arkansas Soil Health Alliance is a nonprofit organization of farmers for the purpose of educating farmers about soil health and practices that improve soil health, such as cover crops and reduced tillage. Information and education activities of this organization include participation in conferences and field days, and a Facebook page (https://www.facebook.com/Arsoilhealth/).

1.9 Other Nonprofit Interest Groups

There are several other nonprofit groups with interests in the Bayou Meto watershed. These include the Arkansas Cattlemen's Association, Arkansas Farm Bureau, Audubon Arkansas, Save Greers Ferry Lake Inc., Little Red River Foundation, Friends of the Little Red River, Ducks Unlimited, Trout Unlimited, Greers Ferry Chamber of Commerce, Quail Forever, and Greers Ferry Lake & Little Red River Tourism Association. These organizations provide information and education to their members and the public through a variety of methods including, websites; social media; newsletters; visitor guides; presentations and displays at schools, meetings, conferences, fairs, and festivals; teacher resources; river and lake clean up events; workshops; mailings; and news media stories. Many of these organizations already provide information and education about how to protect and improve water quality so that state water quality standards are met. Some of these organizations, e.g., Arkansas Cattlemen's Association, Trout Unlimited, Quail Forever, and Ducks Unlimited, focus their efforts only in select areas of the Little Red River watershed.

1.10 South Fork Nature Center

The South Fork Nature Center provides information and education programs related to conservation of the natural resources of the Greers Ferry Lake shoreline and local history. The center includes an herbarium documenting native plants of the area. Information about the center and local native plants is available on the South Fork Nature Center website (https://southforknaturecenter.org/).

APPENDIX K

Estimation of Costs for Implementing BMPs in Recommended Subwatersheds

1.0 BMP COST ESTIMATION APPROACH

Potential relative costs for implementation of management practices were estimated by multiplying the cost of a practice (see Sections 1.2 and 1.3) by the extent over which the practice could be implemented (see Section 1.4). The extents could be expressed in a variety of units, but for our examples were expressed in acres, feet, or operation (i.e., farm). The extents used in estimating the costs reported in Tables 6.2 and 6.3 were estimates of the currently untreated areas in the recommended subwatersheds. Cost estimates were not calculated for Fourteen Mile Creek or Overflow Creek subwatersheds because no load reduction targets are set for these subwatersheds in this plan.

1.1 Estimating Currently Untreated Areas in Recommended HUC12 Subwatersheds

Information is readily available that allows us to generate estimates of some of the sources of NPS pollution that are targeted in this plan (see Section 4.6). These include numbers of failing septic systems, acreage of pasture, miles of poor riparian buffer, number of livestock operations without nutrient management plans, and acres of row crops where cover crops are not used and conventional tillage is used. Therefore, cost estimates are calculated only for implementing BMPs that address the target pollutants from these sources. The methods for estimating the extent of these sources in the recommended subwatersheds are described in the subsections below.

1.1.1 Failing Septic Systems

Table 1 lists estimated numbers of septic systems in the recommended subwatersheds from Section 4.6.8. The estimated number of failing systems is based on the assumption that 3% of systems in these subwatersheds are failing (TetraTech, EPA, 2013).

Table 1. Estimated numbers of failing septic systems in recommended subwatersheds (TetraTech, EPA, 2013).

HUC12 ID	Subwatershed Name	Estimated number of septic systems	Estimated number of failing septic systems (3%)
110100140901	Headwaters Ten Mile Creek	338	10
110100140902	Outlet Ten Mile Creek	381	11
110100140903	Little Red River – Alder Cr	2,273	68
110100140904	Overflow Creek	891	27
110100140905	Big Mingo Creek	202	6
110100140705	Fourteen Mile Creek	325	10
110100140706	Little Red River – Cedar Br	130	4

1.1.2 Pasture Acreage and Operations Without Prescribed Grazing

The 2017 Arkansas Census of Agriculture reports the number of grazing operations and number of operations using prescribed grazing by county. These numbers were used to calculate percentage of operations using prescribed grazing in White and Independence Counties, which account for most of the area in the recommended HUC12 subwatersheds. These data and calculations are provided in Table 2.

Table 2. 2017 prescribed grazing information for Independence and White Counties (USDA National Agricultural Statistics Service, 2017).

Information	Independence County	White County
Number of grazing operations	579	817
Number of operations using prescribed grazing	129	186
Percentage of operations using prescribed grazing	22%	23%

This percentage was then multiplied by the acres of pasture within the recommended subwatersheds (from NLCD 2019), except Big Mingo subwatershed, to estimate the acres of pasture with prescribed grazing. This estimation method assumes that all grazing operations have the same number of acres, and that prescribed grazing is used on all pasture within an operation. To estimate the pasture area not being treated with prescribed grazing, the estimated pasture area with prescribed grazing was subtracted from the total subwatershed pasture area. Estimated pasture areas in the recommended subwatersheds not already treated using prescribed grazing are listed in Table 3.

Table 3. Estimated pasture area in recommended subwatersheds not being treated using prescribed grazing.

Information	Little Red River – Cedar Br (110100140706)	Headwaters Ten Mile Creek (110100140901)	Outlet Ten Mile Creek (110100140902)	Little Red River - Alder Cr (110100140903)	Overflow Creek (110100140904)
Pasture, acres	5,419	8,979	11,860	10,502	9,078
Assumed percentage with prescribed grazing	23%	22%	23%	23%	23%
Estimated pasture with prescribed grazing, acres	1,246	1,975	2,728	2,415	2,088
Estimated pasture without prescribed grazing, acres	4,173	7,004	9,132	8,087	6,990
Estimated number of operations without prescribed grazing	43	72	94	83	72
Watering facilities	139	233	304	269	233

The number of livestock operations without prescribed grazing was also estimated. To estimate this number, we assumed that, on average, livestock operations in the recommended subwatersheds had 96.9 acres of pasture (see Section 1.1.4). The number of operations without prescribed grazing was calculated by dividing the number of acres in each subwatershed without prescribed grazing by 96.9 and rounding to the nearest whole number. These estimates are listed in Table 3.

The number of watering facilities needed for prescribed grazing programs was estimated based on assuming one watering facility for every 30 acres. The number of watering facilities was calculated by dividing the estimated acres of pasture without prescribed grazing by 30. These estimates are listed in Table 3.

1.1.3 Miles of Poor Riparian Buffer

The EPA StreamCat database lists square kilometers of the area within 100 meters of stream lines that are classified as agricultural or developed land uses (Hill, Weber, Leibowitz, Olsen, & Thornbrugh, 2016). This information was compiled for the recommended subwatersheds using GIS. The reported areas were converted to stream miles by dividing by 100 meters and converting from metric to miles. The results of these calculations are listed in Table 4.

Table 4. Miles of streamlines with agricultural or developed land uses within a 100 meter riparian buffer (Hill, Weber, Leibowitz, Olsen, & Thornbrugh, 2016).

Subwatershed Name	HUC12 ID Number	miles of 100m riparian buffer in land use		
		Agricultural	Developed	Agriculture + Developed
Headwaters Ten Mile Creek	110100140901	37.8	4.8	42.6
Outlet Ten Mile Creek	110100140902	47.4	7.0	51.4
Little Red River – Alder Cr	110100140903	55.1	26.3	81.4
Overflow Creek	110100140904	111.6	18.6	130.2
Big Mingo Creek	110100140905	39.1	4.6	43.7
Little Red River – Cedar Br	110100140706	34.0	4.9	38.9

1.1.4 Livestock Operations Without Nutrient Management Plans

Poultry/livestock operations where poultry litter is applied using a nutrient management plan report poultry litter production and usage to NRD. NRD compiles this information by county and year. In 2021 and 2020 11 farms in White County reported poultry litter production and use to NRD (NRD, 2022). We therefore assumed that only 11 livestock operations in White County had nutrient management plans. Using information reported in the 2017 Census of Agriculture for White County, if we assume that pastureland of all types in White County (110,384 acres) is distributed equally among all of the farms with pastureland of any type in the county (1,139 farms), then each farm would be assumed to have 96.9 acres of pasture. We can then estimate the number of livestock operations in each recommended subwatershed by dividing the acres of pasture from NLCD 2019 by 96.9 acres/operation and rounding to a whole number. If we assume there is one livestock operation in each recommended subwatershed, except Big Mingo, with a nutrient management plan, then we assume the rest of the livestock operations in the recommended subwatersheds has the potential to develop and implement nutrient management plans.

Table 5. Estimated number of livestock operations in recommended subwatersheds.

Subwatershed Name	HUC12 ID Number	2019 Acres of Pasture	Estimated number of livestock operations 2019
Headwaters Ten Mile Creek	110100140901	8,979	93
Outlet Ten Mile Creek	110100140902	11,860	122
Little Red River – Alder Cr	110100140903	10,502	108
Overflow Creek	110100140904	9,078	94
Little Red River – Cedar Br	110100140706	5,419	56

1.1.5 Acreage of Row Crops Without Cover Crop

The 2017 Arkansas Census of Agriculture reports acres of cover crops and acres of cropland by county. These numbers were used to calculate percentage of row crop acres with cover crops for White County (Table 6). It was assumed that cover crops were grown after any crop but rice (producers in the Delta have reported that traditional cover crops often don’t do well in soils best suited for rice). Data from the 2019 NASS Cropland Data Layer, clipped to the Big Mingo subwatershed boundary, was used to calculate the acreage of cropland within the subwatershed not planted in rice, 3,594 acres. The area of non-rice crops was then multiplied by 0.02 to estimate the acres in the subwatershed using cover crops, 72 acres. This value was subtracted from the total acres of non-rice crops in the subwatershed to determine the row crop acres where cover crops could be added, 3,522 acres.

Table 6. 2017 Census of Agriculture Cover Crop Information for White County (USDA National Agricultural Statistics Service, 2017).

Information	White County
Acres of cropland	153,217
Acres idle	32,621
Acres of rice (harvested)	10,857
Acres of non-rice crop (cropland – idle – rice)	109,739
Acres of cover crop	2,191
Percentage of non-rice cropland with cover crop	2%

1.1.6 Acreage of Row Crops Where Conventional Tillage is Used

The 2017 Arkansas Census of Agriculture reported acreages for conventional tillage, conservation tillage, and no-till by county. These data were used to calculate the percentage of cropland in the Big Mingo subwatershed on which conventional tillage practices were used. Because the sum of the acreages for conventional tillage, conservation tillage, and no-till was less than the total county cropland acreage, the percentage of conventional tillage was calculated by dividing the acres for conventional tillage by the sum of the acreages reported for conventional tillage, conservation tillage, and no-till. These calculations are summarized in Table 7. Row crops are targeted for management only in Big Mingo Creek subwatershed. The estimated acres of cropland in Big Mingo subwatersheds under conventional tillage (3,797 acres) in 2019 was calculated by multiplying the total 2019 cropland acreage for the subwatershed (9,040 acres) by 0.42.

Table 7. 2017 tillage information for White County (USDA National Agricultural Statistics Service, 2017).

Information	White County
Acres conventional tillage	24,360
Acres conservation tillage	12,228
Acres no-till	21,666
Sum of acres with reported tillage	58,254
Percentage of conventional tillage	42%

1.1.7 Croplands Without Nutrient Management Plans

Between 2016 and 2020 an average of 32 acres per year of nutrient management (NRCS practice number 590) was funded in White County through EQIP or CSP (Christianson, 2021). Nutrient management plans (practice numbers 102 or 104) were not reported, so nutrient management (practice number 590) was used as a surrogate. The average of the acres with funded nutrient management (32) was divided by the 2017 acres of cropland reported for White County in the Census of agriculture (153,217) to calculate a percentage of cropland with nutrient management (<1%). Based on this calculation, we assumed that none of the cropland in the Big Mingo Creek subwatersheds is managed using a nutrient management plan.

The 2017 Census of Agriculture reports that there were 789 farms with cropland in White County and 108,846 acres of cropland were harvested in White County in 2017. Dividing the number of acres harvested by the number of farms, we estimate that, on average, crop farms in White County have 138 acres of cropland. Dividing the 2019 acres of cropland in Big Mingo Creek subwatershed (9,040 acres) by 138 acres/farm, we estimate that there are 66 crop farms in the Big Mingo Creek subwatershed where nutrient management plans could be implemented.

1.2 Unit Costs

BMP unit costs used to estimate cost for implementing BMPs in the recommended subwatersheds are listed in Table 8. The Cost for Estimation values in Table 8 were primarily derived from unit costs identified for the Arkansas Environmental Quality Incentives Program (EQIP) for 2023 75% allowance for non-historically underserved (HU) producers (NRCS, 2022). The cost used for estimation was derived by dividing the EQIP unit cost by 0.75, i.e., assuming the EQIP allowance is 75% of the actual cost for implementation. The result of this calculation was then rounded to one or two significant digits.

For some of the practices the units for the EQIP allowance would be difficult to characterize for estimating implementation costs, for example, for ponds and ditches the EQIP allowance was based on cubic yards of dirt moving. Where possible, the Cost for Estimation for these practices was derived from the average of reported EQIP funds distributed for the practice in Arkansas during the period 2008-2020 (Christianson, 2021). As with the EQIP allowance, the reported funds distributed were assumed to represent 60% of the cost of implementation (the

EQIP program paid 60% of cost 2008-2020). The values given in Table 8 were calculated by dividing the average of the reported funding by 0.6 and then rounding up to one or two significant digits. The pasture management suite of BMPs is a combination of eight BMPs. See Table 9 for an explanation of how the unit cost for this suite of BMPs was derived.

Table 8. Unit costs used to estimate implementation costs for BMPs in recommended subwatersheds.

BMP	Unit cost for estimation	Units	2023 EQIP practice	2023 EQIP 75% allowance (no HU)	Average EQIP & CSP funding per unit 2008-2020 Little Red River
Nutrient Management plan (pasture)	$5,100	Operation	102	$3,841.80	-
Nutrient management plan (cropland)	$3,200	Operation	157	$2,433.38	-
Fence (access control)	$4.30	Feet	382	$3.22	-
Watering facility	$1,200	Number	614	$980.47	$603.55
Prescribed grazing	$40	Acres	528	$31.00	$15.45
Pasture management suite	$33,000	Operation	See Table	See Table	-
Forest riparian buffer	$800	Acres	391	$601.50	-
Herbaceous riparian buffer	$280	Acres	390	$209.10	-
Septic tank remediation	$11,000	Systems	NA	NA	NA
Cover crop	$100	Acres	340	$75.31	$11.39
Conservation tillage	$25	Acres	329, 345	$19.00	$3.08
Conservation tillage + cover crop	$120	Acres	340 + 329	$75.31 + $15.38	-

Table 9. Pasture management suite cost per operation estimate.

BMP	2023 EQIP practice ID	Assumed cost/unit	Assumptions	Cost/operation
Nutrient management plan	102	$5,100/operation	None	$5,1000
Soil testing	590	$37/acre	97 acres/operation	$3,600
Arkansas phosphorus index				
Nutrient management (4R nutrient stewardship)				
Stream exclusion or access control	382	$4.30/foot	100 feet of stream access/operation	
Watering facility	614	$1,200 facility	3 facilities/ operation	
Heavy use area protection	561	$4/square foot	0.1 acre/operation or 4356 square feet	$17,000
Prescribed grazing	528	$40/acre	97 acres/ operation	$3,900
Total cost/ operation				**$32,900**

1.3 Cost Estimates to Achieve Load Reduction Targets

There are no load reduction targets set for the Fourteen Mile Creek or Overflow Creek recommended subwatersheds, so no cost estimates are presented for these subwatersheds. However, it is expected that BMPs will be implemented in these subwatershed that reduce bacteria, nutrient, and sediment loads, as well as improving aquatic habitat for mussel species of concern. The cost estimates for the remaining recommended subwatersheds give an indication of costs to implement BMPs in Fourteen Mile Creek and Overflow Creek subwatersheds.

Cost estimates for implementing BMPs to achieve load reduction targets for the other recommended subwatersheds are discussed in the subsections below, by subwatershed. The area to be treated is estimated based on the assumption that 100% of the pollutant load is coming from the source being treated, the estimated untreated areas from Section K.1, and the BMP reduction efficiency assumed in Appendix I. Where the BMP reduction efficiency is greater than the target reduction, the portion of the source to treat is calculated by dividing the target reduction by the BMP reduction efficiency. For example, when the target reduction is 36% and the BMP reduction efficiency is 0.65, we assume that 0.36/0.65 or 0.55 of the source would need to be treated to achieve the 36% load reduction. When the BMP reduction efficiency is less than the target reduction we assume that all of the untreated source is treated.

The cost is then estimated by multiplying the estimated area to be treated by the unit cost from Table 8. The resulting cost estimates are reported only to two significant digits.

1.3.1 Little Red River-Cedar Branch

The target pollutant for this subwatershed is total phosphorus, with a load reduction target of 36%. Estimated costs for reducing total phosphorus up to 36% are listed in Table 10.

Table 10. Cost estimates for reducing Little Red River-Cedar Branch total phosphorus load 36%.

Source	Untreated extent of source	BMP	BMP total phosphorus reduction efficiency	Amount of BMP assumed for cost estimate	Unit cost	Cost estimate
Onsite wastewater treatment systems (failing)	4 systems	Septic system remediation	0.90	1 or 2	$11,000	$11,000-$22,000
Poor quality riparian buffer	38.9 miles * 100 m = 1,546 acres	Forested riparian buffer	0.35	1,546 acres	$800	$1,200,000
		Herbaceous riparian buffer	0.35	1,546 acres	$280	$430,000
Runoff from pasture and hayland	43 operations without prescribed grazing	Pasture management suite	0.65	24 operations	$32,900	$790,000
Poultry litter and fertilizer	55 operations without nutrient management plans	Nutrient management plan	0.15	43 plans	$3,200	$180,000
Livestock	38.9 miles poor quality buffer	Access control (fence)	0.15	38.9 miles = 205,392 feet	$4.30	$880,000
	4,173 acres without prescribed grazing	Prescribed grazing	0.15	4,173 acres	$40	$170,000
		Alternate water source	0.15	139 facilities	$1,200	$170,000

1.3.2 Ten Mile Creek

Target pollutants for the Ten Mile Creek subwatersheds are *E. Coli*, total nitrogen, total phosphorus, and sediment. The load reduction targets for these pollutants are listed in Tables 11 and 12. Estimated costs for reducing these pollutants in the Ten Mile Creek Headwaters subwatershed are listed in Table 11, and in the Ten Mile Creek Outlet subwatershed are listed in Table 12. In calculating the cost estimates in these tables, the load reduction targets for *E. Coli*, total nitrogen, total phosphorus, and sediment were all considered. Cost estimates were calculated using the largest portion of the source needed to meet any of the load reduction targets. There are several BMPs listed in these tables where the reduction efficiency for one or more of these parameters is less than the parameter load reduction target. For example, the reduction efficiency for phosphorus for prescribed grazing is 15%, which is less than the phosphorus reduction target of 78%. If the reduction efficiency for the BMP is greater than at least one of the load reduction targets, the cost estimate is based on treating the amount of the source to achieve that load reduction target. For example, phosphorus and nitrogen reduction efficiencies for prescribed grazing are less than their load reduction targets, but the *E. Coli* load reduction efficiency is greater than the *E. Coli* load reduction target. Therefore, the cost estimate for prescribed grazing is based on the pasture area treated to achieve the *E. Coli* load reduction target. If BMP reduction efficiencies for all three target pollutants is less than the load reduction targets, then the cost estimate is based on treating all of the source.

Table 11. Cost estimates for reducing target pollutants in Ten Mile Creek Headwaters subwatershed.

Source	Untreated extent of source	BMP	Total phosphorus reduction efficiency	Source portion to treat to achieve 78% total phosphorus reduction (0.78/reduction)*extent	Total nitrogen reduction efficiency	Source portion to treat to achieve 23% total nitrogen reduction (0.23/reduction)*extent	E. coli reduction efficiency	Source portion to treat to achieve 41% E. coli reduction (0.41/reduction)*extent	Amount of BMP for cost estimate	unit cost	total cost
runoff from pastures and hayland	72 livestock operations	pasture management suite	0.65	-	0.45	0.51	0.7	0.59	42 operations Implementing Pasture Management suite	$32,900	$1,400,000
Poor quality riparian buffers	42.6 miles * 100 m = 1,694 acres	forested riparian buffer	0.35	-	0.35	0.66	0.5	0.82	1,389 acres	$800	$1,100,000
		herbaceous riparian buffer	0.35	-	0.35	0.66	0.5	0.82	1,389 acres	$280	$390,000
Onsite wastewater treatment systems (failing)	10 failing systems	Septic remediation	0.9	0.87	0.25	0.92	0.9	0.46	9 systems	$11,000	$100,000
poultry litter & fertilizer	92 livestock operations	nutrient management plan	0.15	-	0.10	-	-	-	92 plans	$3,200	$290,000
Livestock	37.8 miles Poor quality Riparian buffer	access control (fence)	0.15	-	0.1	-	0.45	0.91	34 miles = 179,520 feet	$4.30	$770,000
Livestock	7,004 acres Without Prescribed grazing	prescribed grazing	0.15	-	0.1	-	0.65	0.63	4,418 acres	$40	$180,000
		alternate water source	0.15	-	0.1	-	0.7	0.59	147 watering Facilities	$1,200	$180,000

Table 12. Cost estimates for reducing target pollutants in Ten Mile Creek Outlet subwatershed.

Source	Untreated extent of source	BMP	Total phosphorus reduction efficiency	Source portion to treat to achieve 78% total phosphorus reduction (0.78/reduction)*extent	Total nitrogen reduction efficiency	Source portion to treat to achieve 23% total nitrogen reduction (0.23/reduction)*extent	E. coli reduction efficiency	Source portion to treat to achieve 41% E. coli reduction (0.41/reduction)*extent	Amount of BMP for cost estimate	Unit cost	Total cost
runoff from pastures and hayland	94 livestock operations	pasture management suite	0.65	-	0.45	0.51	0.7	0.59	55 operations implementing pasture management suite	$32,900	$1,800,000
Poor quality riparian buffers	51.4 miles * 100 m = 2,044 acres	forested riparian buffer	0.35	-	0.35	0.66	0.5	0.82	1,676 acres	$800	$1,300,000
		herbaceous riparian buffer	0.35	-	0.35	0.66	0.5	0.82	1,676 acres	$280	$470,000
Onsite wastewater treatment systems (failing)	11 failing systems	Septic remediation	0.9	0.87	0.25	0.92	0.9	0.46	10 systems	$11,000	$110,000
poultry litter & fertilizer	121 livestock operations	nutrient management plan	0.15	-	0.10	-	-	-	121 plans	$3,200	$390,000
livestock	51.4 miles poor quality buffer	access control (fence)	0.15	-	0.1	-	0.45	0.91	43 miles = 227,040 feet	$4.30	$980,000
Livestock	9,132 acres without prescribed grazing	prescribed grazing	0.15	-	0.1	-	0.65	0.63	5,760 acres	$40	$230,000
		alternate water source	0.15	-	0.1	-	0.7	0.59	192 watering facilities	$1,200	$230,000

1.3.3 Little Red River-Alder Creek

The target pollutant for this subwatershed is total phosphorus, with a load reduction target of 36%. Estimated costs for reducing total phosphorus up to 36% are listed in Table 13.

Table 13. Cost estimates for reducing Little Red River-Alder Creek total phosphorus load 36%.

Source	Untreated extent of source	BMP	BMP total phosphorus reduction efficiency	Portion of source to treat	Amount of BMP assumed for cost estimate	Unit cost	Cost estimate
Onsite wastewater treatment systems (failing)	68 systems	Septic system remediation	0.90	0.55	27 systems	$11,000	$300,000
Poor quality riparian buffer	81.4 miles * 100 m = 3,236 acres	Forested riparian buffer	0.35	1	3,236 acres	$800	$2,600,000
		Herbaceous riparian buffer	0.35	1	3,236 acres	$280	$910,000
Runoff from pasture and hayland	83 operations without prescribed grazing	Pasture management suite	0.65	0.40	46 operations	$32,900	$790,000
Poultry litter and fertilizer	107 operations without nutrient management plans	Nutrient management plan	0.15	1	107 plans	$3,200	$340,000
Livestock	55.1 miles poor quality buffer	Access control (fence)	0.15	1	55.1 miles = 290,928 feet	$4.30	$1,200,000
	8,087 acres without prescribed grazing	Prescribed grazing	0.15	1	8,087 acres	$40	$320,000
		Alternate water source	0.15	1	270 facilities	$1,200	$320,000

1.3.4 Big Mingo Creek

The target pollutant for this subwatershed is total nitrogen, with a load reduction target of 71%. Estimated costs for reducing total nitrogen are listed in Table 14. Because nitrogen reduction efficiencies of none of these BMPs is greater than 71%, all of the cost estimates are based on the assumption that all currently untreated area is treated.

Table 14. Cost estimates for reducing Big Mingo Creek total nitrogen load.

Source	Untreated extent of source	BMP	BMP total nitrogen reduction efficiency	Amount of BMP assumed for cost estimate	Unit cost	Cost estimate
Onsite wastewater treatment systems (failing)	6 systems	Septic system remediation	0.25	6 systems	$11,000	$66,000
Poor quality riparian buffer	43.7 miles * 100 m = 1,737 acres	Forested riparian buffer	0.30	1,737 acres	$800	$1,400,000
		Herbaceous riparian buffer	0.20	1,737 acres	$280	$490,000
Fertilizer	66 operations without nutrient management plans	Nutrient management plan	0.10	66 plans	$3,200	$210,000
Croplands	3,522 acres without cover crops	Cover crop	0.25	3,522 acres	$100	$350,000
	3,797 acres without conservation tillage	Conservation tillage	0.10	3,797 acres	$20	$76,000
	3,522 acres without cover crops	Cover crop + conservation tillage	0.50	3,522 acres	$120	$420,000