SOUTHWEST MISSOURI WATER QUALITY IMPROVEMENT PROJECT (WQIP)
SPRING RIVER BASIN
WATER QUALITY GAP ANALYSIS

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ACRONYMS AND ABREVIATIONS

ACWI	Advisory Committee on Water Information
BOD	Biochemical Oxygen Demand
CAFO	Concentrated Animal Feeding Operation
CERCLIS	Comprehensive Environmental Response, Compensation and Liability Information System
cfu	colony forming units
cfs	cubic feet per second
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
EPA	U.S. Environmental Protection Agency
EPA STORET	U.S. Environmental Protection Agency STOrage and RETrieval
ERC	Environmental Resources Coalition
FAPRI	Food and Agricultural Policy Research Institute at the University of Missouri
ft.	feet
GIS	Geographic Information System
HUC	Hydrologic Unit Code
KDHE	Kansas Department of Health and the Environment
MDC	Missouri Department of Conservation
MDCB	Methods and Data Comparability Board
MDNR	Missouri Department of Natural Resources
MEC	Midwest Environmental Consultants Water Resources, Inc.
MGD	million gallons per day
MS	Microsoft
MSU	Missouri State University
mi.	mile
NASQAN	National Stream Quality Accounting Network
NAWQA	National Water-Quality Assessment Program
nd	non-detect
NCHD	Newton County Health Department
NO_2	Nitrite
NO_3	Nitrate
NO_3-N	Nitrate expressed as Nitrogen
NH_4	Ammonium
NH_3	Ammonia
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Services
NWIS	National Water Information System
NWQMC	National Water Quality Monitoring Council
OCC	Oklahoma Conservation Commission
Pb	Lead
PSU	Pittsburg State University
QA/QC	Quality Assurance and Quality Control
RTAG	Regional Technical Assistance Group
sq. mi.	square mile

TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TNTC	Too Numerous To Count
TP	Total Phosphorus
TSS	Total Suspended Solids
WBC	Whole Body Contact
WBCR	Whole Body Contact Recreation
WQDE	water quality data elements
WWTF	Wastewater Treatment Facility
WWTP	Wastewater Treatment Plant
µg/L	microgram per liter
mg/L	milligram per liter
mL	milliliter
N_2	Nitrogen gas
N_2O	Nitrous Oxide
NO	Nitric Oxide
UMC	University of Missouri at Columbia
USGS	U.S. Geological Survey
VSS	Volatile Suspended Solids
Zn	zinc

EXECUTIVE SUMMARY

Rapid growth and expansion in southwest Missouri are threatening the water resources this region's population, agriculture, and tourism industry so heavily depend upon. In response to this threat, several watershed groups in southwest Missouri collaborated to secure federal funding for water protection efforts in the region. As a result of this effort, the Environmental Resources Coalition (ERC) received a U.S. Environmental Protection Agency (EPA) grant to develop and manage the Southwest Missouri Water Quality Improvement Project (WQIP), a multi-year, multi-stakeholder effort to address water quality issues in this region. WQIP has initially been tasked with assembling, evaluating, and interpreting existing water quality for several major basins in southwest Missouri. The Spring River basin is the subject of this report.

The Spring River basin is 2,752 square miles and includes the City of Joplin and portions of southeast Kansas and northeast Oklahoma. Major tributaries of the Spring River include Clear, Shoal, Center, Short, and Cow Creeks, as well as the North Fork of the Spring River. Water quality regulatory concerns in the basin include Clean Water Act 303(d) listings for elevated levels of metals from mining activities, sedimentation, nutrient enrichment, bacteria, and low dissolved oxygen.

Water quality data from the Spring River basin were compiled from multiple collection entities including the Missouri Department of Natural Resources, the Food and Agriculture Policy Research Institute at the University of Missouri, the Kansas Department of Health and Environment, the Oklahoma Conservation Commission, EPA, the Newton County Health Department, Pittsburg State University and the U.S. Geological Survey. The data were analyzed for total phosphorus, total nitrogen, nitrate plus nitrite as nitrogen, *Escherichia coli* (*E. coli*), total zinc, dissolved zinc, total lead, and dissolved lead. Phosphorus and nitrogen levels were elevated throughout much of the Spring River basin, but notably so in Clear Creek below Monett and in Turkey Creek near Joplin. *E. coli* geometric means suggest many streams within the Shoal Creek watershed and part of the Spring River are impaired based on Missouri's water quality criteria. EPA metals data indicates significant lead and zinc loading sources exist in the vicinity of the Tri-State Mining District.

Based on a data gap analysis of the existing water quality data in the Spring River basin, several recommendations were made for WQIP. Formation of a monitoring coordinating board could benefit all the stakeholder entities in WQIP by standardizing sampling designs, quality assurance programs, metadata requirements, and by developing a centralized database to facilitate the sharing of water quality data. Current and historical water quality data are insufficient to fully address the goals of WQIP; therefore, a new comprehensive water quality monitoring network needs to be designed. The network should include long-term stations to monitor trends where EPA data suggests elevated levels of metals occur. Further data analysis and potential special storm water studies are also recommended to better understand non-point source loading issues. Also, WQIP stakeholders are encouraged to participate in the development of regional stream nutrient criteria through stakeholder involvement and further water quality studies. Finally, efforts should be made to incorporate additional existing water quality data into the WQIP database that were not populated at the time of the database's creation.

I. INTRODUCTION

One of the most important physical and economic attributes of southwestern Missouri is its abundant supply of high quality water resources. A rapidly expanding population, the growing needs of agriculture, and a billion dollar tourism industry are simultaneously highly dependent on these resources and present the greatest threats to the sustained quality of these resources.

The Environmental Resources Coalition (ERC) received a federal grant to develop and manage the Southwest Missouri Water Quality Improvement Project (WQIP), a multi-year, multi-stakeholder effort to address water quality issues in this region. The overall purpose of WQIP is to improve water quality while also protecting rural economic development and agricultural interests by providing factual information to facilitate sound regulatory and policy decision making.

ERC selected MEC Water Resources, Inc. (MEC) to assist with the technical aspects of WQIP. One of the first major components of WQIP was to assemble existing water quality data. These data have been collected for various reasons during many years, at many locations, by many different entities. Once compiled, these data would be evaluated and interpreted to determine possible data gaps. The database developed through this compilation would also serve as an invaluable resource for future research efforts.

MEC assembled an expert team, including the Ozarks Environmental and Water Resources Institute (OEWRI) and the University Missouri-Columbia to perform the WQIP Data Gap Analysis. This report presents the data gap analysis for the Spring River basin (hydrologic unit 11070207). The data gap analysis for the Spring River basin includes a compilation and evaluation of existing data and highlights data gaps to be filled to allow for sound technical and policy decisions to address WQIP objectives.

This report is organized into seven major sections including this introduction:

Section 2. Study Area Description – a summary of the key characteristics of the Spring River basin including land use and demographics, point and nonpoint wastewater discharges, climate, geology, mining history, and surface water hydrology

Section 3. Methods – describes from who and how the data were collected, how the data were managed, and how the data were assessed for use in the data gap analysis.

Section 4. Water Quality Summaries and Statistics – provides a summary of the most common water quality parameters of interest including nutrients and bacteria. Various statistical analyses are presented to allow interpretation of the data and to put the data into context.

Section 5. Biological Monitoring – provides a summary of the biological indices and fisheries data that has been collected in the Spring River basin.

Section 6. Data Gaps – provides an assessment of where data gaps exist in terms of spatial, temporal, hydrological, chemical, and biological coverage of the study area.

Section 7. Recommendations – provides highlights of the key findings of the data gap analysis.

References are also provided. The complete data set is available through ERC by special request.

II. STUDY AREA

The study area description of the Spring River basin provided below describes the basin characteristics, population and land use, point sources and permitted discharges, mining history, geology and soils, and climate and hydrology.

2.1. Basin Characteristics

The Spring River basin (2,752 mi^2) is located mostly in southwest Missouri. The upper portion of the basin extends into southeast Kansas and northeast Oklahoma draining portions of Crawford and Cherokee Counties in Kansas, and Ottawa County in Oklahoma where it reaches its confluence with the Neosho River. The basin also drains Jasper County, and portions of Barry, Barton, Lawrence, and Newton Counties in Missouri. The headwaters begin in southeastern Lawrence County, Missouri (≈ 1,300 feet asl) flowing 100 miles before reaching its confluence with the Lower Neosho River and Grand Lake O' The Cherokees in northeast Oklahoma. Major tributary drainage areas include Center, Cow and Shoal Creeks (Figure 1).

Joplin, Missouri is the largest metropolitan area within the basin. Located in southern Jasper County and Northern Newton County, the City of Joplin is one of Missouri's larger cities with a population of near 48,000. The north end of the metropolitan area is drained from east to west by Center Creek and the south end is drained from east to west by Shoal Creek. Other communities of significant size that are located within the drainage basin are: Carthage, Carytown, Granby, Monett, and Neosho. It should be noted that all thematic data in this report are confined to the Spring River basin in Missouri as defined by the goals of the gap analysis.

2.2. Population and Land Use

Population data from the 2000 census show the highest population density (>5,000 persons per mi^2) in the basin occurs in Joplin (Figure 2), with the next highest densities (2,000 – 5,000 persons per mi^2) occurring in Aurora and Neosho. A majority of the basin, however, has a density of <40 persons per mi^2. The high density areas in and around Joplin occupy both Jasper and Newton Counties and are primarily drained by Joplin Creek to the North and Shoal Creek to the South.

An analysis of population change in the basin between 1990 and 2000 shows the highest percentage of change (20% to 50% increase) to occur in the more rural regions of the basin (Figure 3), most notably in Barton and Newton Counties. Much of Barton County is drained by the North Fork and the Little North Fork of the Spring River and the majority of the Newton County area is drained by Shoal Creek. A negative trend (-15% to 0%) was shown to occur in the most populated area in and around the city of Joplin in Jasper County.

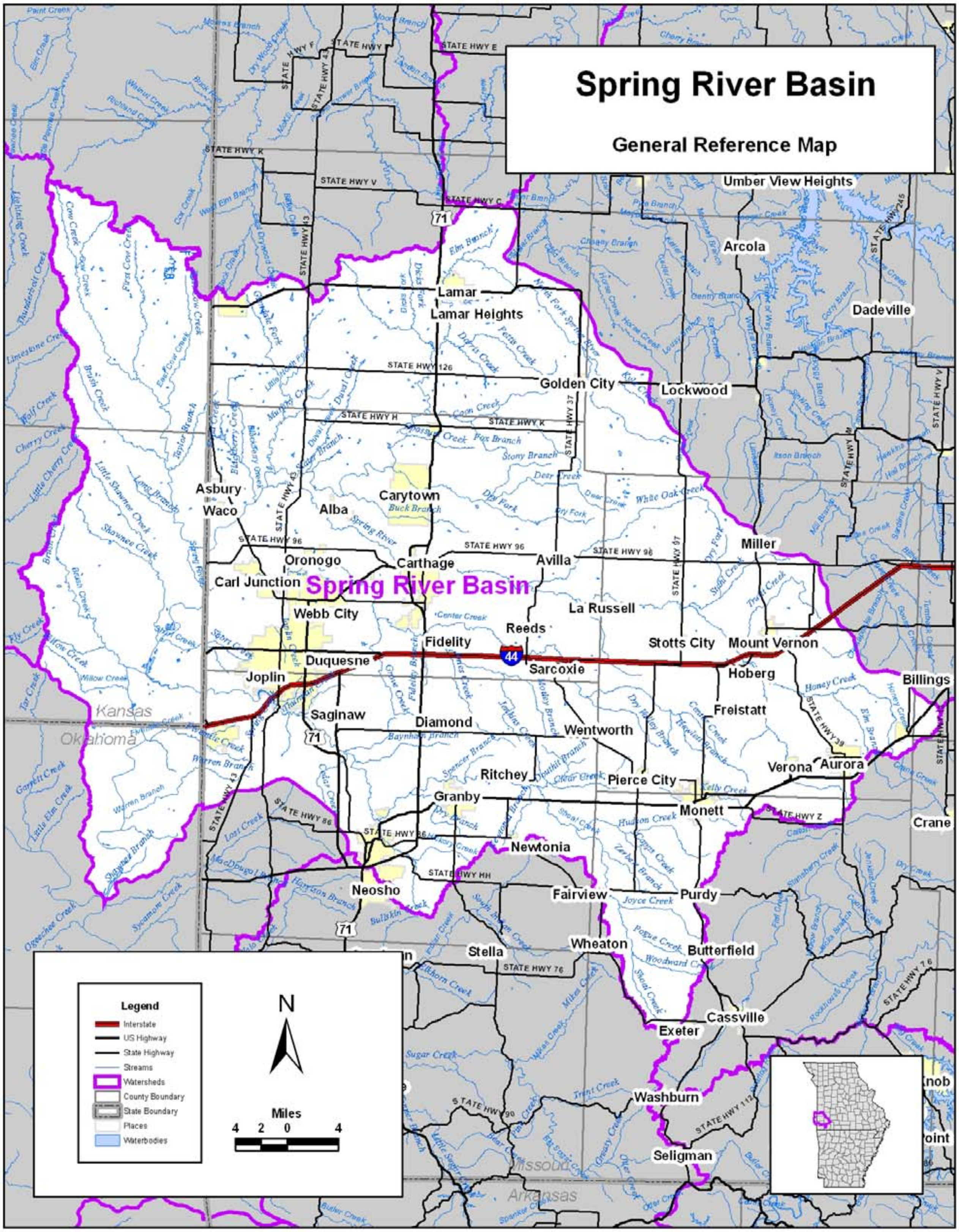

FIGURE 1. Spring River Basin – General Reference

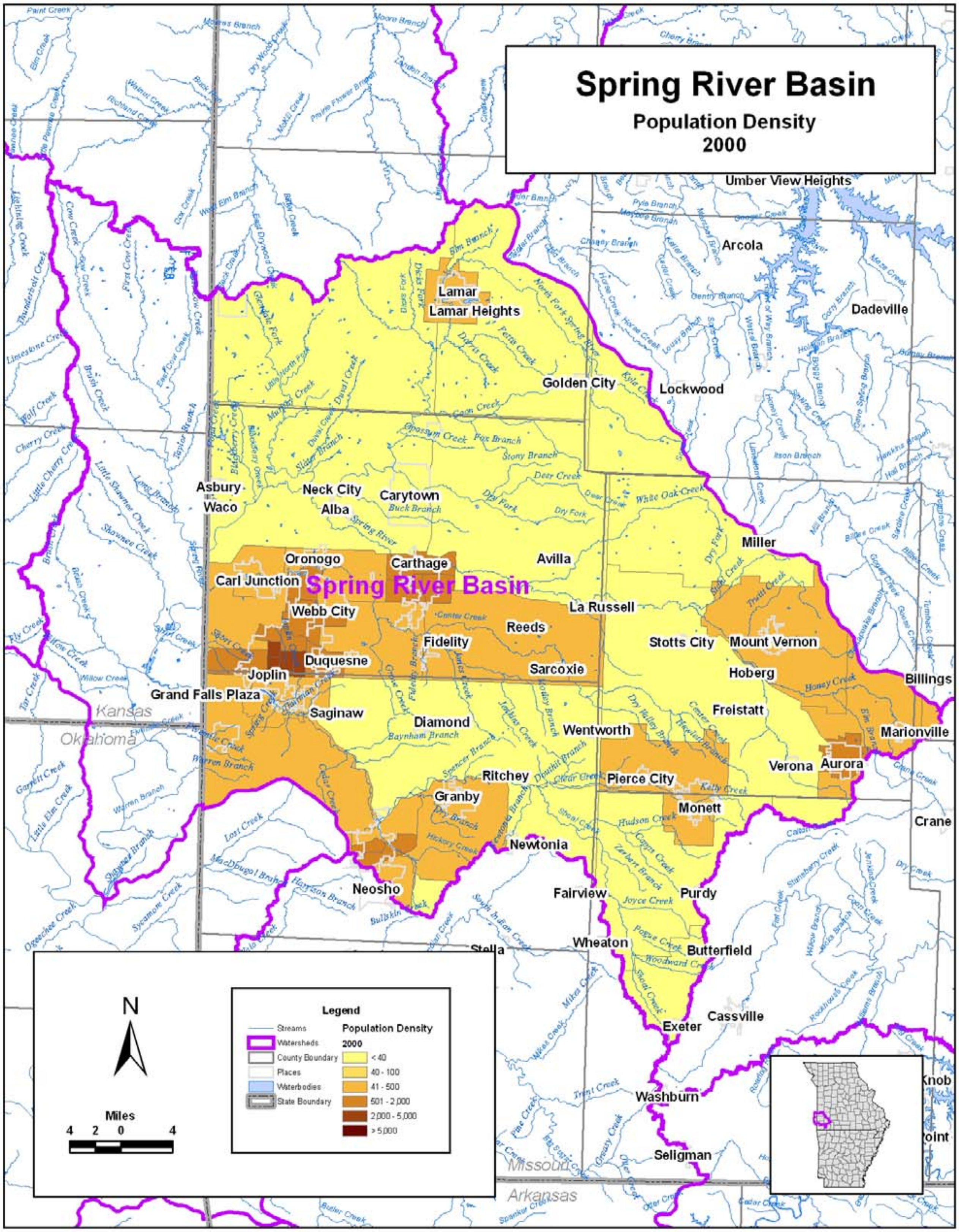

FIGURE 2. Spring River Basin – Population Density (2000)

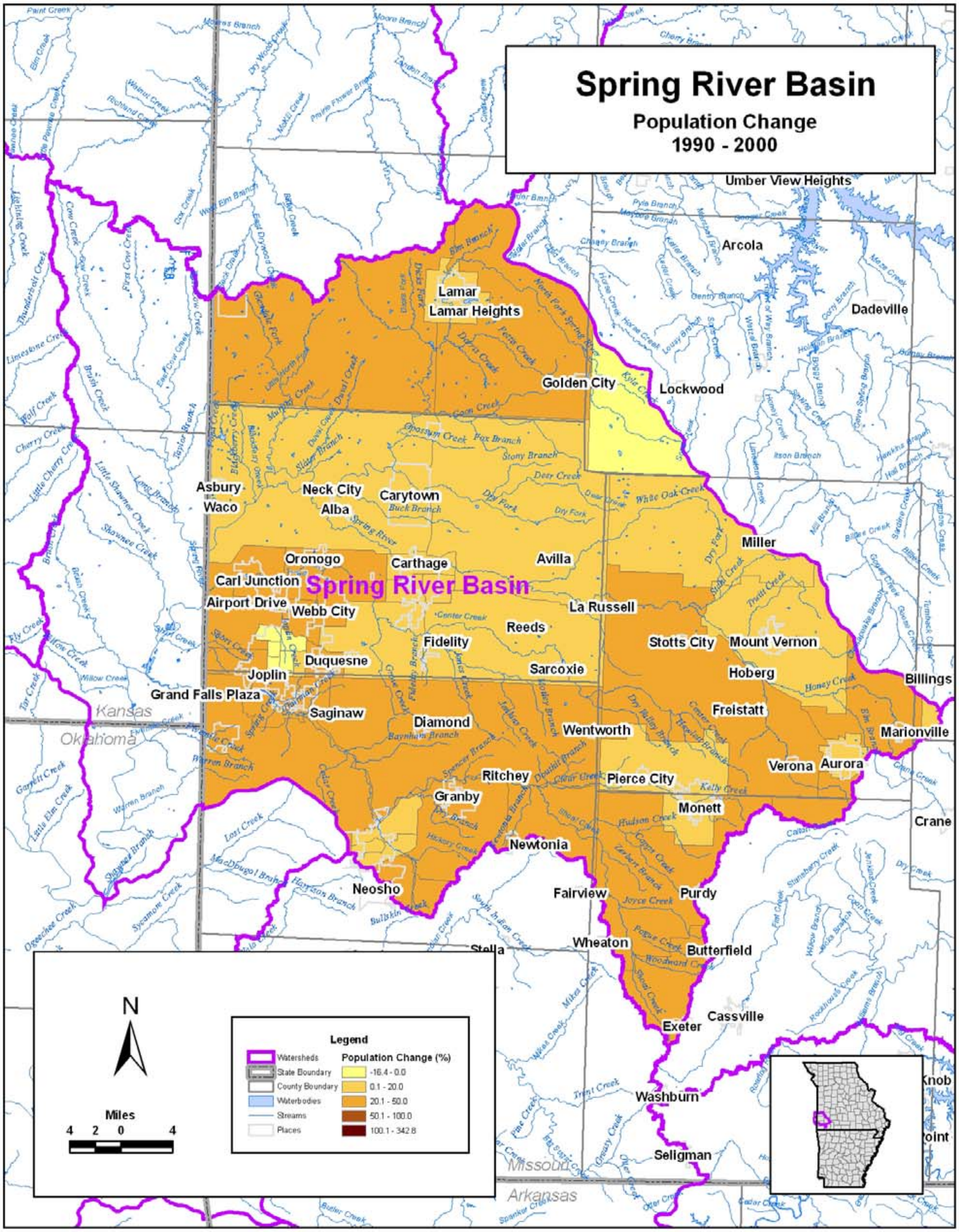

FIGURE 3. Spring River Basin – Population Change (1990 – 2000)

A large majority of the basin, including the headwaters areas, is dominated by grassland/pasture, cropland, and forest landuse (Figure 4). The areas in and around Joplin, Neosho, Monett and Aurora, Missouri are dominated by high and low density urban landuse. Table 1 summarizes land use for the basin.

TABLE 1. Spring River Basin Land Use (2000 – 2004)

Land Use Description	Area (sq. mi.)	% of Total
High Density Urban	80	3
Low Density Urban	55	2
Barren Cropland	11	1
Grassland	490	21
Forest	1277	55
Young Forest/Shrubland	69	3
Water	19	1
Total	2333	100

2.3. Permitted Point Source Discharges

Point source discharges may generally be categorized as domestic wastewater or industrial and commercial wastewater. Pollutants from domestic discharges typically include organic matter measured as biological oxygen demand (BOD), suspended solids and ammonia. Domestic discharges are also typically high in nitrogen and phosphorus. Industrial and commercial discharges can include a mix of domestic waste, heavy metals, and man-made organic chemicals. For purposes of discussion, point sources are described below as industrial, non-municipal domestic, municipal, and combined animal feeding operations (CAFOs). Municipal wastewater is typically a mixture of domestic and industrial/commercial wastewater. Since CAFOs are not continuous discharges, they will be discussed separately. This analysis is based on the National Pollutant Discharge Elimination System (NPDES) outfalls spatial dataset accessed from the Missouri Spatial Data Information Service (MSDIS) website.

The Spring River basin receives discharges from 78 permitted point source outfalls (Table 2 and Figure 5). Industrial outfalls have a combined design flow of 412 million gallons per day (MGD). However, industrial flows are largely from stormwater outfalls which do not discharge continuously. Municipal and non-municipal domestic outfalls have a combined design flow of 74 MGD. The most notable domestic discharges include the Joplin, Shoal Creek wastewater treatment facility (WWTF) (6.5 MGD), the Joplin, Turkey Creek WWTF (15 MGD), and the Monett WWTF (6 MGD).

CAFO outfalls only discharge waste under emergency conditions such as spills or breaks of water storage structures resulting from accidents or excessive rain. Animal waste from CAFOs is disposed of through land application, where it can enter water bodies through runoff. Most wastewater from treatment facilities and CAFOs is typically high in nitrogen and phosphorus.

The Spring River basin has the largest number of permitted CAFOs in the southwest Missouri region. The basin has 75 permitted CAFOs, including 5 dairy, 1 swine, 58 poultry and 11 turkey (Table 3 and Figure 5). A majority of the CAFOs are located within the southern half of the basin, with a relatively large concentration located along the Shoal Creek drainage located in Newton County. Combined, these facilities account for 284.8 dry tons of permitted waste, the largest total of CAFO waste within the gap analysis study basins.

TABLE 2. Permitted Point Sources in the Spring River Basin

Type	Number	Discharge (MGD)
Industrial	8	412
Non-Municipal Domestic	30	9
Municipal	40	65
Total	**78**	**486**

*MGD – Million gallons per day (based on design flow)

TABLE 3. CAFOs in the Spring River Basin

Type	Number	Annual Waste Production (dry tons)*
Dairy	5	12.3
Swine	1	2.3
Poultry	58	201.3
Turkey	11	68.9
Total	**75**	**284.8**

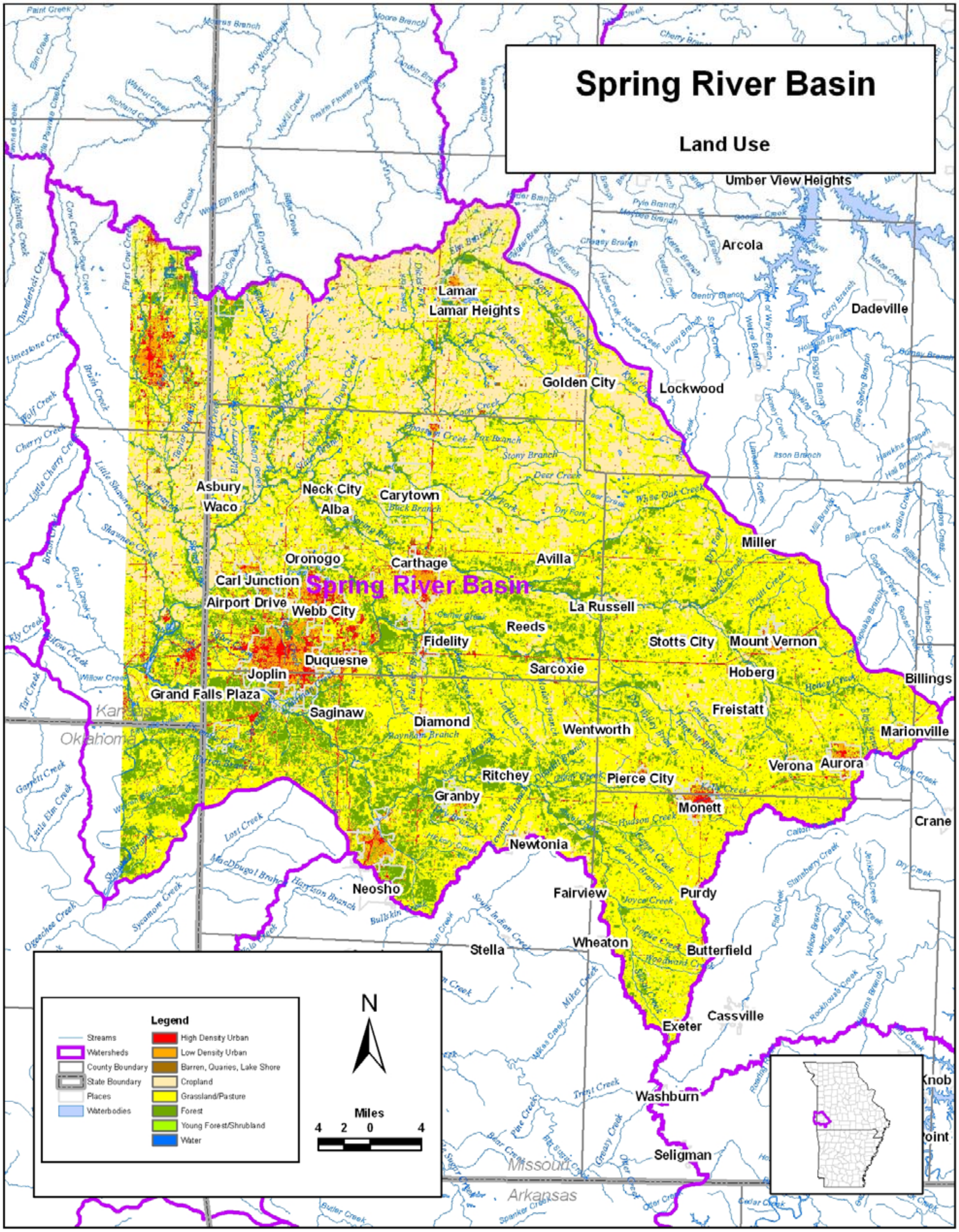

FIGURE 4. Spring River Basin – Land Use

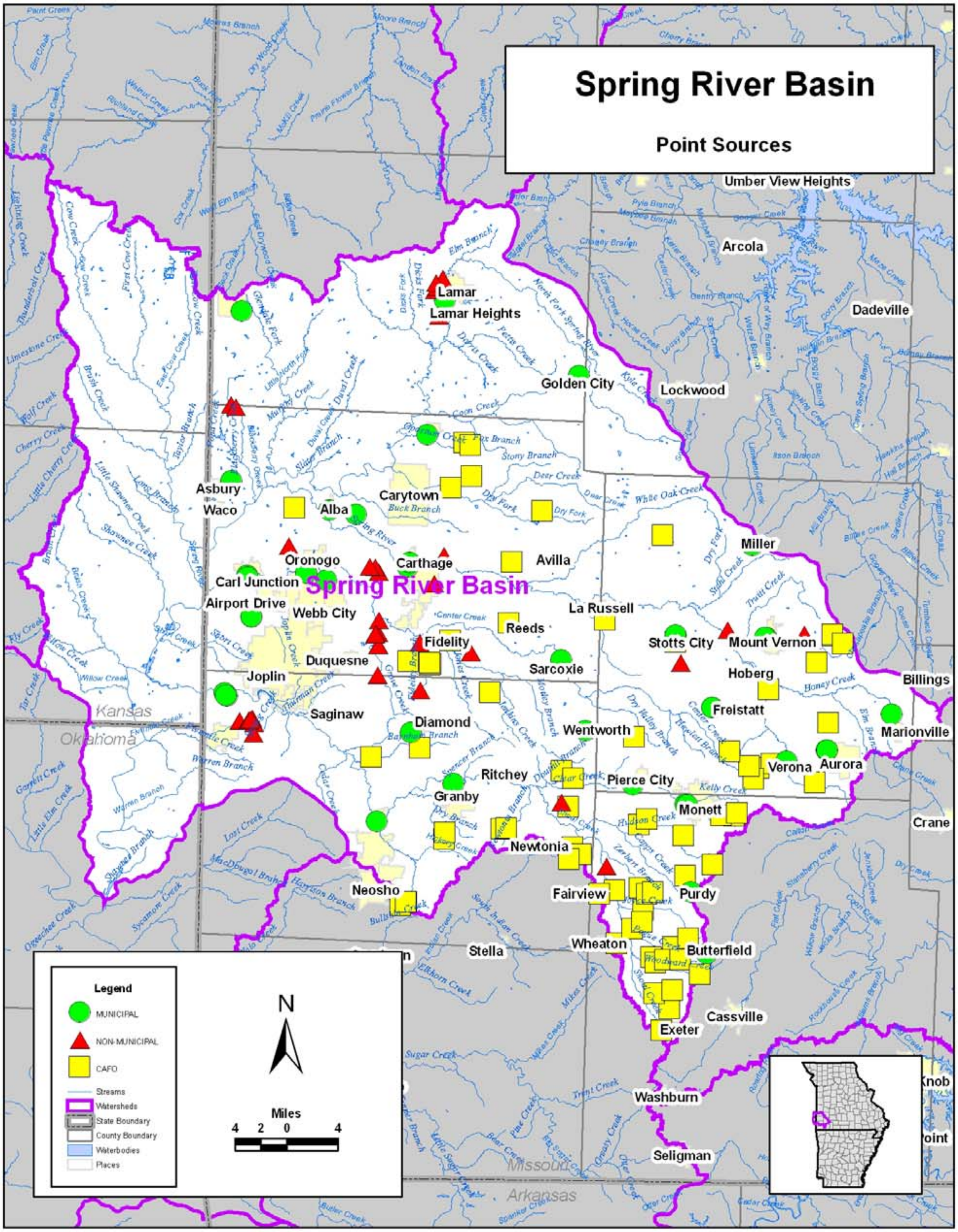

FIGURE 5.. Spring River Basin – Point Sources

2.4. Geology and Soils

The Spring River basin is contained within the Springfield Plain of the Ozark Highlands physiographic region. This region is underlain mostly by sedimentary bedrock including Ordovician-age dolostone and sandstone, Lower Mississippian-age limestone and dolostone, and Pennsylvanian-age sandstone and shale (USDA, 2006) (Figure 6). This region also has remnants of an ancient loess deposit that is thickest (up to several feet) in the northern and eastern parts of the region (2006).

The spatial distribution of soil series associations from the Springfield Plain within the Spring River basin reflects the geological control in this region (Figure 7). A brief description of each soil series landscape position and parent material is found below. This information was obtained from the Natural Resources Conservation Services' (NRCS) website at http://ortho.ftw.nrcs.usda.gov/cgi-bin/osd/osdnamequery.cgi. At this website, detailed taxonomic and morphological information for each soil series can be found.

Springfield Plain Soils

66 - Wilderness-Tonti

Wilderness series consists of very deep, moderately well drained soils that have a fragipan at depths of 15 to about 29 inches. These upland soils formed in colluvium and the underlying residuum from cherty limestone. Permeability is moderate above the fragipan and slow in the fragipan and moderate below the fragipan. Slope gradients range from 2 to 35 percent.

Tonti series consists of very deep, moderately well drained soils that formed in residuum from cherty limestone. These nearly level to moderately sloping soils are on uplands of the Ozark Highlands. Slopes range from 1 to 12 percent.

67 - Keeno-Hoberg-Creldon

Keeno series consists of very deep, moderately well drained soils on uplands with a fragipan at depths of 18 to 36 inches. These soils formed in residuum from cherty limestone. Permeability is moderate above the fragipan and slow in the fragipan. Slopes range from 2 to 14 percent.

Hoberg series consists of very deep, moderately well drained soils that have a fragipan. They formed in a thin mantle of loess and the underlying residuum from cherty limestone. Slopes range from 2 to 8 percent. Permeability is moderate above the fragipan, slow in the fragipan and moderate below the fragipan.

Creldon series consists of very deep, moderately well drained soils on uplands that have fragipans at a depth of 18 to 35 inches. These soils formed in a thin mantle of loess, colluvium, and the underlying loamy or clayey cherty residuum weathered from limestone. Permeability is moderately slow above the fragipan and very slow in the fragipan. Slope gradients range from 0 to 9 percent but dominantly are 1 to 3 percent.

69 – Verdigris-Hepler-Dapue-Cedargap-Bearthicket

Verdigris series consists of very deep, well drained soils that formed in silty alluvium on floodplains. Slope ranges from 0 to 3 percent.

Hepler series consists of very deep, somewhat poorly drained, moderately slowly permeable soils that formed in silty alluvial sediments. These nearly level to very gently sloping soils are on flood plains in the Cherokee Prairies and Ozark Highlands. Slope ranges from 0 to 3 percent.

Dapue series consists of very deep, well drained, moderately permeable soils formed in silty alluvium. They are on nearly level flood plains and low stream terraces. Slopes range from 0 to 3 percent.

Cedargap series consists of very deep, well drained soils formed in alluvium with a high content of chert fragments. These soils are on flood plains of small streams near active channels. Slopes range from 0 to 5 percent.

Bearthicket series consists of very deep, well drained soils formed in silty alluvium. These soils are on nearly level flood plains and low stream terraces in. Slopes range from 0 to 3 percent.

70 - Maplegrove-Eldorado-Creldon

Maplegrove series consists of very deep, moderately well drained, slowly permeable soils on uplands of the Cherokee Prairies. These soils formed in a thin mantle of silty loess over a thin mantle of loess over clayey residium. Slope gradient ranges from 1 to 3 percent.

Eldorado series consists of very deep, well drained, moderately permeable soils that formed in residuum weathered from Pennsylvanian age chert limestone. Slope ranges from 1 to 25 percent.

Creldon series consists of very deep, moderately well drained soils on uplands that have fragipans at a depth of 18 to 35 inches. These soils formed in a thin mantle of loess, colluvium, and the underlying loamy or clayey cherty residuum weathered from limestone. Permeability is moderately slow above the fragipan and very slow in the fragipan. Slope gradients range from 0 to 9 percent but dominantly are 1 to 3 percent.

74 – Parsons-Barden-Barco

Parsons series consists of very deep somewhat poorly drained soils that formed in material weathered from predominantly clayey alluvium or weathered fissile shales. These nearly level to very gently sloping soils are on broad smooth uplands in the Cherokee Prairies. Slopes range from 0 to 3 percent.

Barden series consists of very deep, moderately well drained, slowly permeable soils formed in a mantle of loess or other silty material and residuum from shale. These soils are on ridges and upland side slopes and have slopes of 0 to 5 percent.

Barco series consists of moderately deep, well drained soils that formed in residuum from acid sandstone and thin beds of silty and sandy shales of the Cherokee Prairies. These soils are on uplands and have slopes ranging from 1 to 35 percent.

75 – Kanima-Hartwell

Kanima series consists of very deep, well drained, moderately permeable soils that formed in excavated loamy material weathered from sandstone, shale, and limestone of Pennsylvanian age of the Cherokee Prairies, Arkansas Valley and Ridges and Ouachita Mountains. The gently sloping soils are in valleys and the very steep soils are on hills or ridges that were formed as the result of strip mining operations.

Hartwell series consists of very deep, somewhat poorly drained, slowly permeable soils formed in loess and residuum from shale. These soils are on uplands and have slopes of 0 to 5 percent.

76 – Hector-Cliquot-Bolivar

Hector series consists of shallow, well drained, moderately rapidly permeable soils that formed in residuum from sandstone bedrock. These soils are on nearly level to moderately steep ridgetops and steep and very steep mountain sides. Slopes range from 2 to 60 percent.

Cliquot series consists of deep, moderately well drained, slowly permeable soils formed in colluvium and the underlying residuum from shale or interbedded shale and sandstone on ridgetops and side slopes. Slope ranges from 3 to 20 percent.

Bolivar series consists of moderately deep, moderately permeable soils that formed in residuum from acid sandstone with thin beds of clayey and sandy shales. These soils are on undulating to gently rolling uplands and have slopes ranging from 1 to 50 percent.

93 – Verdigris-Osage-Lanton

Verdigris series consists of very deep, well drained soils that formed in silty alluvium on floodplains in the Cherokee Prairies. Slope ranges from 0 to 3 percent.

Osage series consist of very deep, poorly drained, very slowly permeable soils that formed in thick clayey alluvium. These soils are on flood plains along major streams and have slopes ranging from 0 to 2 percent.

Lanton series consists of very deep, poorly and somewhat poorly drained soils that are dark in the surface layer and to a depth of 24 inches or more. These soils formed in alluvium on flood plains and in depressions. They have moderately slow permeability in the solum and slow permeability in the clayey substratum. Slopes range from 0 to 3 percent.

102 – Pits quarries-Parsons-Opolis-Barden

Parsons series consists of very deep somewhat poorly drained soils that formed in material weathered from predominantly clayey alluvium or weathered fissile shales. These nearly level to very gently sloping soils are on broad smooth uplands in the Cherokee Prairies. Slopes range from 0 to 3 percent.

Opolis series consists of very deep, moderately well drained soils that formed in a thin mantle of silty loess over residuum on plains in the Cherokee Prairies. Slope ranges from 0 to 3 percent.

Barden series consists of very deep, moderately well drained, slowly permeable soils formed in a mantle of loess or other silty material and residuum from shale. These soils are on ridges and upland side slopes and have slopes of 0 to 5 percent.

139 – Secesh-Rueter-Nixa-Clarksville

Secesh series consists of very deep, well drained soils on floodplains, stream terraces, and footslopes. They formed in about 2 feet of loamy alluvium and the underlying cherty residuum or alluvium from limestone and sandstone. Slopes range from 0 to 8 percent.

Rueter series consists of very deep, somewhat excessively drained soils that formed in colluvium and residuum from cherty limestone on steep side slopes and narrow ridgetops. Slopes range from 3 to 70 percent.

Nixa series consists of very deep, moderately well drained, very slowly permeable soils on upland ridgetops and sideslopes of the Ozark Highlands. These nearly level to steep soils formed in colluvium and loamy residuum weathered from cherty limestone. Slopes range from 1 to 35 percent.

Clarksville series consists of very deep, somewhat excessively drained soils formed in hillslope sediments and the underlying clayey residuum from cherty dolomite or cherty limestone on steep side slopes and narrow ridgetops. Slopes range from 1 to 70 percent.

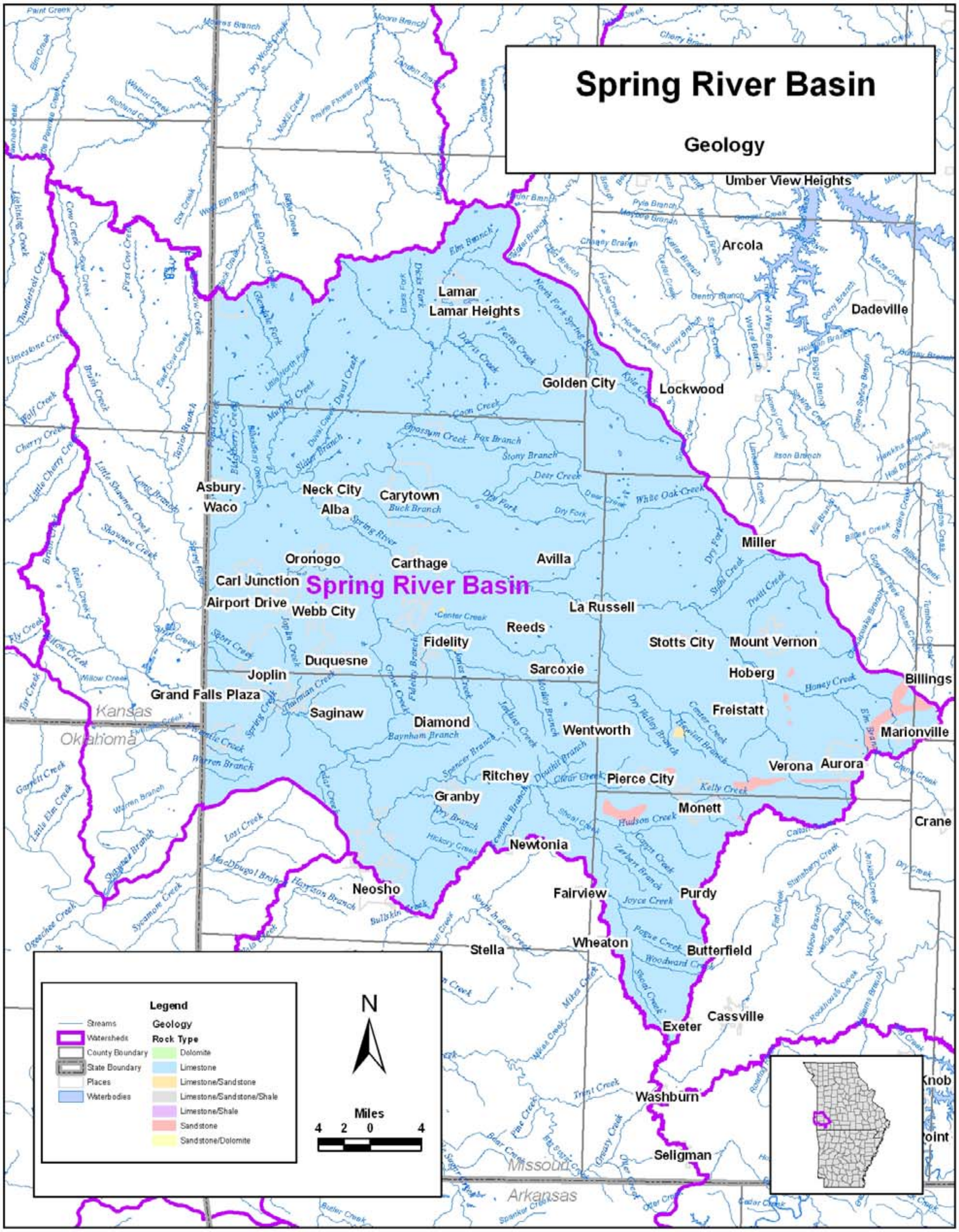

FIGURE 6. Spring River Basin - Geology

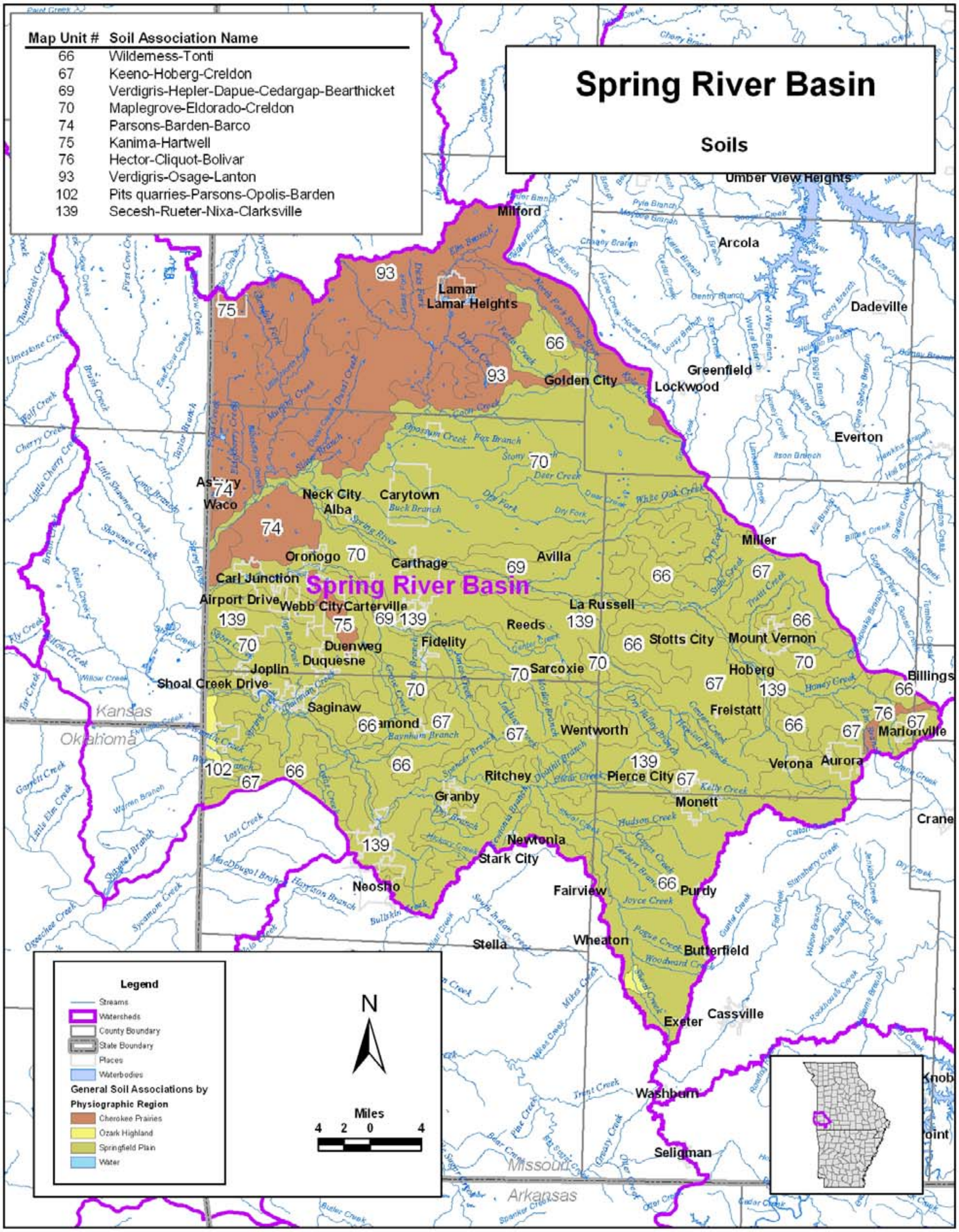

FIGURE 7. Spring River Basin – General Soil Associations

2.5. Climate and Hydrology

Climate for the region is considered temperate, with an average annual temperature of 59°F with average annual precipitation around 40 inches (Adamski *et al.*, 1995). Thirty year monthly average temperatures at the Joplin Regional Airport range from around 33°F in January to 90°F in July (Figure 8). Monthly average precipitation starts to rise in late winter and peaks in late spring with 5 to 5.4 inches of rainfall in May and June. Relatively high average rainfall totals also occur in the months of September and November with between 5.2 and 4 inches of rainfall. January and February receive the lowest average totals for the year with around 2 inches of rainfall per month (NOAA, 2007).

There are four United States Geological Survey (USGS) gaging stations in the basin (Figure 9, Table 4). Three of the gages are located on the Spring River at Carthage (07185765), near Waco (07186000), and near Quapaw, Oklahoma (07187000). The other gage is located on Shoal Creek above Joplin (07188000). Three of the gages (07186000, 07187000, and 07188000) have over 50 years of record while the Spring River gage at Carthage has 18 years of record.

Monthly mean discharge data from the four gaging stations show the highest mean flows occurring during the months of March, April, and May, corresponding to the spring wet season (Table 5). The lowest average runoff occurs during the month of August at all four gaging stations, corresponding with the hot, dry summer months. The highest flow on record occurred on the same date, 9/26/1993, at the Waco and Quapaw gages with flows of 151,000 cubic feet per second (cfs) and 230,000 cfs respectively. The highest flow at the Carthage gage occurred on 11/01/2001 (24,800 cfs) and at the Shoal Creek gage on 5/18/1943 (62,100 cfs). The lowest flows on record occurred during mid to late summer of 1954 for the gages at Waco, Shoal Creek, and Quapaw with flows of 4.2 cfs, 12 cfs, and 5.8 cfs respectively. The gage at Carthage measured its lowest flow of 28 cfs in September of 2005 (Table 6).

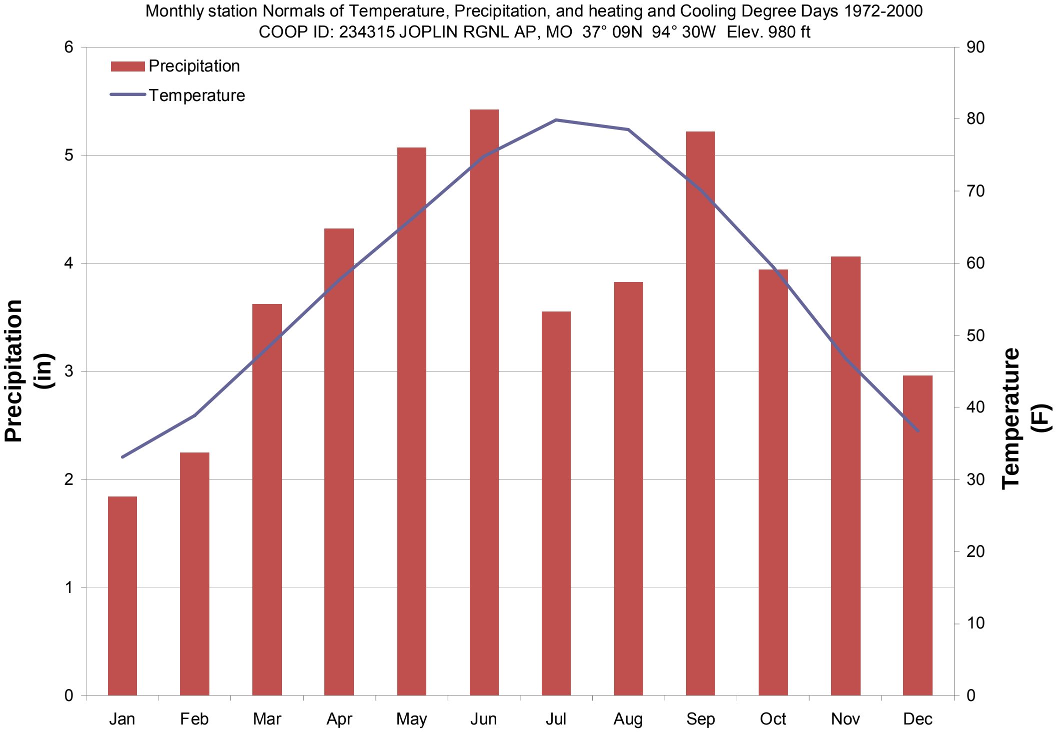

FIGURE 8. Monthly Average Precipitation and Temperature at the Joplin, Missouri Climate Station

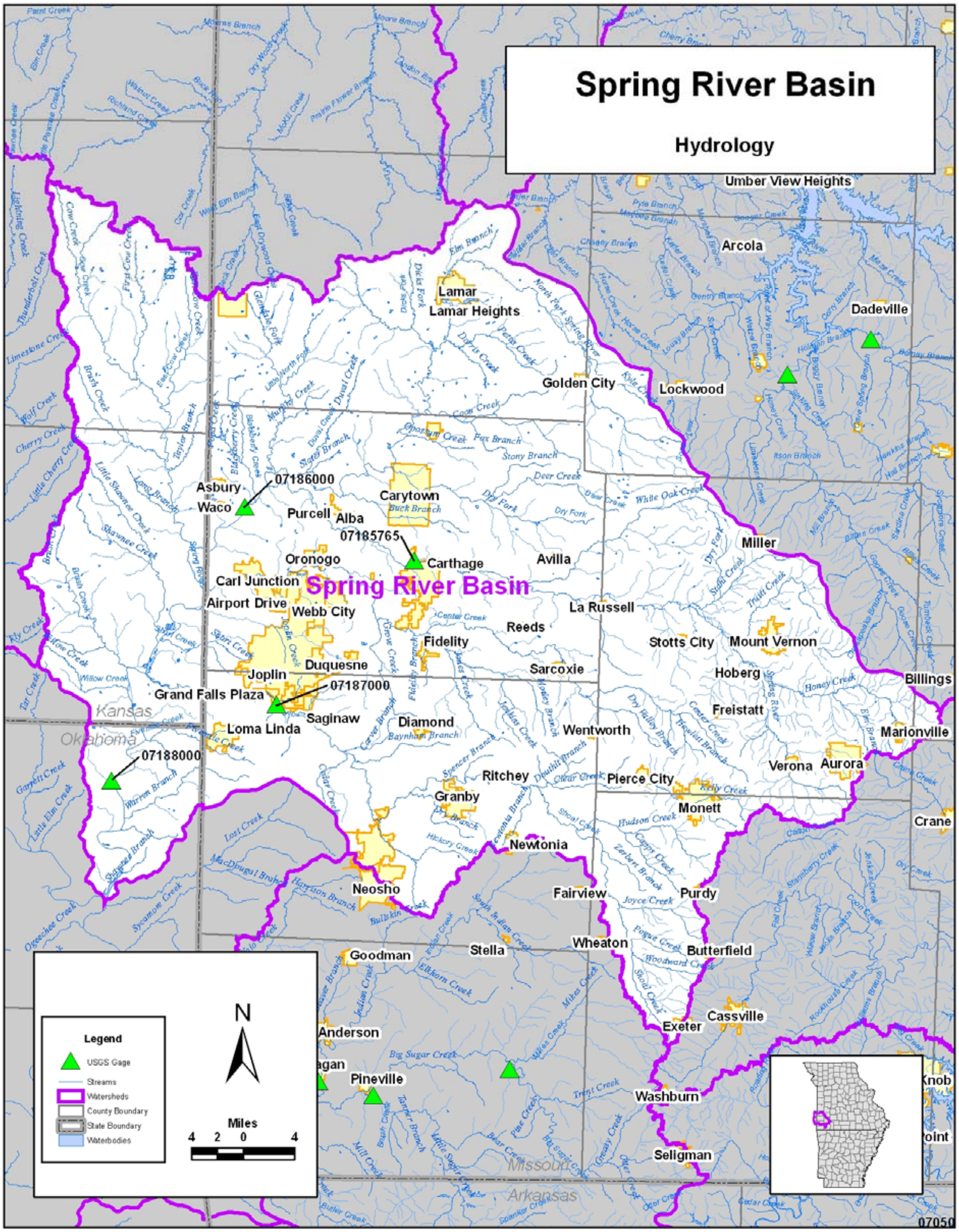

FIGURE 9. Spring River Basin – Hydrologic Gaging Station Locations

TABLE 4. Description of USGS Gaging Stations in the Spring River Basin

Station ID	Station Name	Drainage Area (mi^2)	Elevation (ft)	Start Year	Years of Record
7185765	Spring River at Carthage, MO	425	924	1967	15
7186000	Spring River near Waco, MO	1,164	833	1923	84
7187000	Shoal Creek above Joplin, MO	427	887	1942	50
7188000	Spring River near Quapaw, OK	2,510	746	1940	67

Note: Information on all USGS gages in Missouri can be found at http://waterdata.usgs.gov/mo/nwis/rt. (Source: USGS, 2005)

TABLE 5. Mean Monthly Discharge for USGS Gaging Stations in the Spring River Basin

Station ID	Station Name	Jan (cfs)	Feb (cfs)	Mar (cfs)	Apr (cfs)	May (cfs)	Jun (cfs)	Jul (cfs)	Aug (cfs)	Sept (cfs)	Oct (cfs)	Nov (cfs)	Dec (cfs)
7185765	Spring River at Carthage, MO	414	422	660	531	571	411	276	130	191	206	449	386
7186000	Spring River near Waco, MO	754	937	1,218	1,454	1,587	1,367	704	418	540	645	947	722
7187000	Shoal Creek above Joplin, MO	347	391	561	646	709	567	349	212	244	283	396	358
7188000	Spring River near Quapaw, OK	1,669	2,140	2,933	3,338	3,681	2,942	1,756	760	1,343	1,602	2,255	1,740

Source: USGS, 2005

TABLE 6. Discharge Frequency at USGS Gaging Stations in the Spring River Basin

Station ID	Station Name	Low Q (cfs)	Low Date	90% Q (cfs)	50% Q (cfs)	Mean Q (cfs)	10% Q (cfs)	Max Q (cfs)	Max Date
7185765	Spring River at Carthage, MO	28	9/12/2005	67	212	390	754	24,800	11/12/2001
7186000	Spring River near Waco, MO	4.2	7/28/1954	65	300	935	1,800	151,000	9/26/1993
7187000	Shoal Creek above Joplin, MO	12	9/7/1954	89	237	421	860	62.100	5/18/1943
7188000	Spring River near Quapaw, OK	5.8	7/8/1954	216	849	2,177	4,320	230,000	9/26/1993

Notes: Q = discharge; Low Q = lowest flow on record; 90% Q = 90% of recorded flows exceed this discharge; 50% Q = 50% of recorded flows exceed this discharge; Mean Q = average of all recorded flows; 10% Q = 10% of recorded flows exceed this discharge; Max Q = maximum flow peak on record (Source: USGS, 2005)

2.6. Regulatory Issues

Section 303(d) of the federal Clean Water Act (CWA) requires each state to identify those waterbodies not meeting water quality standards. Water quality standards are established by the states and consist of beneficial uses, water quality criteria to protect the beneficial uses, and an antidegradation policy. States must compile and submit their 303(d) list of impaired waterbodies to the U.S. Environmental Protection Agency (EPA) for final approval on a biannual basis. The EPA has the authority to approve, reject or modify the list. States are required to establish a total maximum daily load (TMDL) for those waterbodies on an EPA-approved 303(d) list. A TMDL is a regulatory tool designed to restore the full beneficial uses of a waterbody. By definition a TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources (EPA, 2006).

Several waterbodies within the Spring River basin have been identified as impaired by Missouri, Kansas and Oklahoma for multiple causes (Table 7). The most prevalent impairments include metals from mining activities, sedimentation, nutrient enrichment, bacteria, and low dissolved oxygen.

TABLE 7. Impaired Waters and Total Maximum Daily Loads in the Spring River Basin

State	Waterbody	Pollutant	Source(s)	Status
Missouri	Capps Creek (4.0 miles)	bacteria	Rural Nonpoint Source	2004/2006 303(d) List
Missouri	Center Creek (11.0 miles)	zinc	Tri-State AML	TMDL approved 10/25/2006
Missouri	Center Creek (12.8 miles)	zinc	Tri-State AML	2004/2006 303(d) List
Missouri	Center Creek (12.8 miles)	cadmium	Tri-State AML	2004/2006 303(d) List
Missouri	Center Creek (12.8 miles)	lead	Tri-State AML	2004/2006 303(d) List
Missouri	Douger Branch (2.0 miles)	zinc	Aurora AML	TMDL approved 8/29/2006
Missouri	Douger Branch (2.5 miles)	cadmium	Aurora AML	2004/2006 303(d) List
Missouri	Douger Branch (2.5 miles)	lead	Aurora AML	2004/2006 303(d) List
Missouri	Clear Creek (2.0 miles)	ammonia	Monett WWTP	TMDL approved 12/1/1999
Missouri	Clear Creek (2.0 miles)	BOD	Monett WWTP	TMDL approved 12/1/1999
Missouri	Clear Creek (2.0 miles)	suspended solids	Monett WWTP	TMDL approved 12/1/1999
Missouri	Clear Creek (3.0 miles)	low dissolved oxygen	Monett WWTP	2004/2006 303(d) List
Missouri	Hickory Creek (1.0 miles)	bacteria	Unknown	2004/2006 303(d) List
Missouri	Lamar Lake	nutrients/algae	Agricultural Nonpoint Source	TMDL approved 9/20/2006
Missouri	North Fork Spring River (51.5 miles)	sediment	Agricultural Nonpoint Source	TMDL approved 11/22/2006
Missouri	North Fork Spring River (29.9 miles)	unknown pollutant	Unknown	2004/2006 303(d) List
Missouri	North Fork Spring River (11.5 miles)	unknown pollutant	Unknown	2004/2006 303(d) List
Missouri	North Fork Spring River (1.0 miles)	low dissolved oxygen	Lamar WWTP	2004/2006 303(d) List
Missouri	North Fork Spring River (3.1 miles)	low dissolved oxygen	Lamar WWTP	2004/2006 303(d) List
Missouri	North Fork Spring River (1.0 miles)	ammonia	Lamar WWTP	2004/2006 303(d) List
Missouri	Shoal Creek (17.5 miles)	fecal coliform	Rural Nonpoint Source	TMDL approved 11/18/2003
Missouri	Joyce Creek (5.0 miles)	fecal coliform	Rural Nonpoint Source	Incorporated into Shoal Creek TMDL in 2007
Missouri	Pogue Creek (2.5 miles)	fecal coliform	Rural Nonpoint Source	Incorporated into Shoal Creek TMDL in 2007
Missouri	Turkey Creek (5.0 miles)	zinc	Multiple AMLs	TMDL approved 10/25/2006
Missouri	Turkey Creek (7.0 miles)	cadmium	Multiple AMLs	2004/2006 303(d) List
Missouri	Turkey Creek (3.5 miles)	zinc	Duenweg AML	TMDL approved 10/25/2006
Missouri	Spring River (3.0 miles)	*E. coli*	Urban/Rural Point/Nonpoint	2004/2006 303(d) List
Kansas	Cow Creek*	chlordane	Urban Runoff	TMDL approved 12/31/2005
Kansas	Cow Creek	sulfate	Strip Mining Activity	TMDL approved 2/25/2005
Kansas	Cow Creek*	low dissolved oxygen	Not Identified	2006 303(d) List
Kansas	Mined Land Lake #01	nutrients/eutrophication	Not Identified	2006 303(d) List
Kansas	Mined Land Lake #06	nutrients/eutrophication	Not Identified	2006 303(d) List
Kansas	Mined Land Lake #06	sulfate	Previous Mining Activity	TMDL approved 1/06/2005
Kansas	Mined Land Lake #07	sulfate	Previous Mining Activity	TMDL approved 1/06/2005
Kansas	Mined Land Lake #22	perchlorate	Not Identified	2006 303(d) List
Kansas	Playter's Lake	nutrients/eutrophication	Nonpoint Source	TMDL approved 1/06/2005
Kansas	Pittsburg College Lake	pH	High Trophic State	TMDL approved 9/30/2002
Kansas	Pittsburg College Lake	nutrients/eutrophication	Fertilizer/Stormwater Runoff	TMDL approved 9/30/2002
Kansas	Shawnee Creek	low dissolved oxygen	Low Flow	TMDL approved 9/30/2005
Kansas	Spring River*	cadmium	Previous Mining Activity	TMDL approved 6/24/2005
Kansas	Spring River*	copper	Previous Mining Activity	TMDL approved 6/24/2005
Kansas	Spring River*	lead	Previous Mining Activity	TMDL approved 6/24/2005
Kansas	Spring River*	zinc	Previous Mining Activity	TMDL approved 6/24/2005
Kansas	Turkey Creek	low dissolved oxygen	Not Identified	2006 303(d) List
Oklahoma	Spring River	enterococcus bacteria	Unknown	2004 303(d) List
Oklahoma	Spring River	lead	Unknown	2004 303(d) List
Oklahoma	Spring River	turbidity	Unknown	2004 303(d) List
Oklahoma	Spring River	zinc	Unknown	2004 303(d) List

*includes multiple tributaries

2.6.1. Metals Contamination from Mining Activities

Zinc and lead mining in Spring River basin began in the 1850s and was a prevalent industry until the 1960s (Kiner et al., 1997). Over 3,000 combined zinc and lead mines have been recorded in the basin within the state of Missouri (MSDIS, 2007). The largest concentration of mines occurs in Jasper and Newton Counties in an area around Joplin known as the Tri-State Mining District. Between 1849 and 1950, 50 percent of the zinc and 10 percent of the lead mined worldwide came from the Tri-State Mining District (MDNR, 2006a). There are 2,031 mines within a ten-mile radius of Joplin, 399 mines within a ten-mile radius of Grandby, and 102 mines within a ten-mile radius of Sarcoxie. The Aurora Mining District, located in Lawrence County near the town of Aurora, represents another large concentration of mines. The Aurora Mining District ranks second only to the Joplin area in terms of lead and zinc output. Within a ten-mile radius of the town of Aurora there are 397 mines (Figure 10).

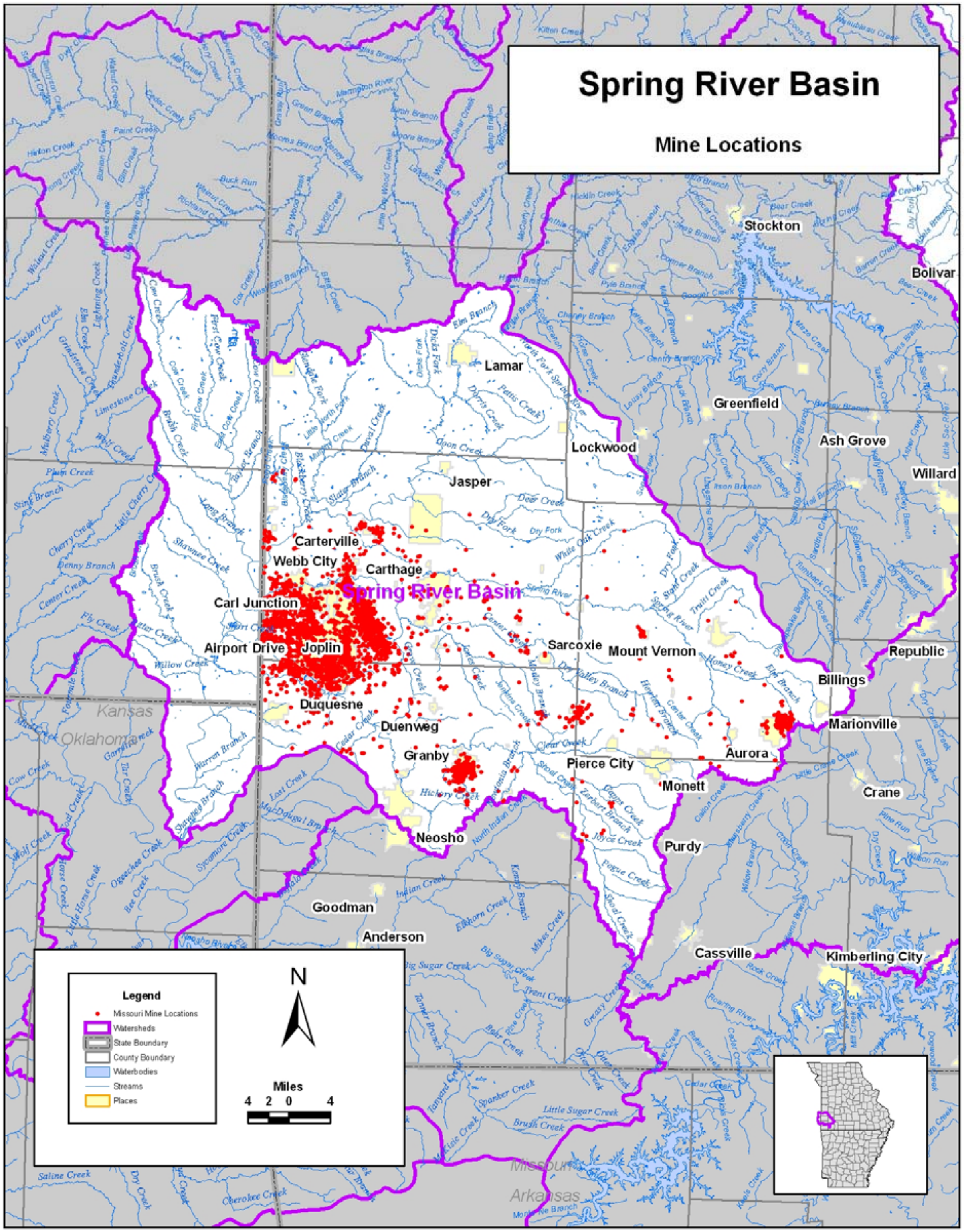

FIGURE 10. Spring River Basin - Mines

Mining related impacts to water quality in the Spring River basin are well documented. Angelo *et al.* (2007) showed elevated concentrations of cadmium, lead, and zinc in the Spring River basin corresponded with diminished mussel assemblages. Carlson (1999) and Trimble (2001) reported high concentrations of zinc and lead in floodplain and active channel sediments near Aurora in Honey and Chat Creeks (Chat Creek is also known as Douger Branch). Contaminated floodplains can contribute polluted sediment to streams for many years (Leece and Pavlowsky, 1995; Marcus and Nimmo, 2001).

The abandoned mine lands (AMLs) of the Tri-State and Aurora Mining Districts are responsible for the 303(d) listings of several waterbodies in Missouri, Kansas and Oklahoma. The contaminants primarily responsible include zinc, lead, and cadmium. Notable 303(d) impairments attributed to the Tri-State Mining Distrct include the Spring River in Kansas and Oklahoma and Center and Turkey Creeks in Missouri. The Aurora Mining District is responsible for the 303(d) listing of Douger Branch. Mining related activities have also been attributed to the 303(d) listing of Cow Creek and Mined Land Lakes #01, #06 and #07 in Kansas for sulfate.

The Missouri Department of Natural Resources (MDNR) and the Kansas Department of Health and Environment have completed multiple TMDLs for streams throughout the Spring River basin due to mining-related contaminants. MDNR has completed zinc TMDLs for Center Creek, two segments of Turkey Creek, and Douger Branch. MDNR attributes the contamination to the dissolution of zinc minerals found on the land and in the walls of flooded mines. MDNR anticipates the long-term levels of zinc should decline as these surfaces continue to weather or are immobilized through remediation efforts (MDNR, 2006a; MDNR, 2006b). KDHE has completed a TMDL on the Spring River for cadmium, copper, lead, and zinc.

Cleanup of metals has been ongoing in the Tri-State and Aurora mining areas under the oversight of the EPA. The old-lead mining area in Jasper County was placed on the National Priorities List as a Superfund site in 1991. Cleanup of the Superfund site has included the evacuation and replacement of lead and cadmium contaminated soil, returning mined materials to the subsurface, and erosion prevention (MDNR, 2006a). In the Aurora mining area a site screening investigation of heavy metals prompted a recommendation that the area be entered into the Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS also called Superfund) in 2001. A Preliminary Assessment/Site Inspection report completed in 2002 confirmed the presence of mine waste contamination and the site was referred to EPA for Removal Action. EPA completed Removal Action of the contaminated soils in November 2002 and Brownfield[1] funds are currently being utilized to redevelop part of the area (MDNR, 2006b).

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[1] With certain legal exclusions and additions, the term 'brownfield site' [Brownfield] means real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant or contaminant. This Brownfields Site definition is found in Public Law 107-118 (H.R. 2869) - "Small Business Liability Relief and Brownfields Revitalization Act" signed into law January 11, 2002.

2.6.2. Biological Impairments Due to Sediment

In 2006 a TMDL was approved by the EPA for North Fork Spring River for sediment. North Fork Spring River was initially placed on Missouri's 303(d) list in 1998 based on best professional judgment and general fisheries data. Biological assessments conducted in 2003-2004 confirmed that North Fork Spring River is biologically impaired; however little sediment data actually exists to directly document its impacts to the river. Nevertheless MDNR has identified agricultural nonpoint sources as the primary cause of sediment impairment to the North Fork Spring River (MDNR, 2006c). MDNR had previously proposed changing the listing of "sediment" to "habitat loss" to better describe the issue of biological impairment. The degradation of aquatic habitat in streams may not only be attributed to sediment, but may also be caused by other problems such as channelization, alteration of streambanks and riparian zones, and alteration of normal flow regimes. EPA denied this change since TMDLs may only address pollutants (e.g., sediment) and not pollution (e.g., habitat loss) (MDNR, 2006d). MDNR has subsequently added "unknown pollutant" to the 2004/2006 303(d) List as a cause of impairment for the majority of North Fork Spring River.

2.6.3. Nutrient Impairments

Excessive nutrients are responsible for the 303(d) listing of multiple small lakes in the Spring River basin in Missouri and Kansas. In 2006 a TMDL was completed by MDNR for Lamar Lake for nutrients. MDNR attributed agricultural activities as the primary source of nitrogen and phosphorus loading to the Lamar Lake watershed. Algae growth from excessive nutrients in Lamar Lake, which serves as the town's drinking water supply, has led to chronic taste and odor problems. Although Missouri has no nutrient criteria, the TMDL assigned a target endpoint for total phosphorus of 40 μg/L based on the reference lake approach (MDNR, 2006e). TMDLs have also been completed by the KDHE for Playter's and Pittsburg College Lakes. The KDHE attributes nonpoint sources and lawn fertilizer transported through stormwater runoff as the primary causes of excessive nutrients (KDHE, 2004; KDHE, 2005). Excessive algae growth in Pittsburg College Lake has also resulted in pH levels in excess of criteria (KDHE, 2005). Mined Land Lakes #01 and #06 have also been 303(d) listed by the KDHE for excessive nutrients, but do not have completed TMDLs.

2.6.4. Bacteria Impairments

MDNR and the Oklahoma Department of Environmental Quality (ODEQ) have both identified streams in the Spring River basin as impaired for bacteria. In 2003 MDNR completed a TMDL for Shoal Creek for fecal coliform. During the 1990s Crowder College collected fecal coliform data averaging more than 5,000 colonies per 100 mL (cfu), which exceeds Missouri's fecal coliform criterion of 200 cfu/100mL for streams designated for whole body contact recreation (MDNR, 2003). A study by the Food and Agriculture Policy Research Institute (FAPRI) at the University of Missouri suggested that humans and cattle were the major contributors of bacteria. During periods of high surface runoff, poultry litter was also found to be a significant bacteria source. More recently MDNR proposed the inclusion of Pogue Creek, Joyce Creek, Capps Creek, and Hickory Creek (tributaries to Shoal Creek), and another portion of Shoal Creek to the draft 2004/2006 303(d) List for bacteria. However, MDNR ultimately chose to revise the Shoal Creek TMDL to include these segments rather than create separate TMDLs

(MDNR, 2007). More recently MDNR included three miles of the Spring River on its 2004/2006 303(d) List for *E. coli*. *E. coli* data collected in 2005 and 2006 in Spring River at multiple sites near the City of Carthage exceeded the river's criteria of 126 cfu/100mL. MDNR attributes the source of the bacteria to both point and nonpoint sources. The ODEQ has not completed any TMDLs for bacteria in the Spring River basin, but has included the Spring River on its 2004 303(d) List as impaired for enterococcus bacteria. The ODEQ 2004 303(d) List identifies the source of bacteria impairment as unknown (ODEQ, 2004).

2.6.5. Low Dissolved Oxygen Impairments

Dissolved oxygen (DO) is often used as a measure of aquatic health. Low concentrations of DO can stress aquatic life communities and create hypoxic conditions. Instream DO concentrations naturally fluctuate on a diurnal basis and can vary significantly between different physiographic regions. Factors that can influence DO concentrations include channel slope, riparian cover, width to depth ratios, sediment oxygen demand, bed roughness, and the presence of aquifer inputs. Both the KDHE and MDNR have a minimum DO criterion of 5 mg/L.

Multiple streams in the Spring River basin have been identified as impaired for low DO in both Kansas and Missouri. The source of these impairments is complex and is not always clear. The KDHE completed a TMDL for Shawnee Creek in 2005 and determined that point sources and biochemical oxygen demand (BOD) in particular were not factors in the impairment of DO. BOD is a measure of the amount of oxygen required to stabilize organic matter in a stream and as such is often used as a surrogate for assessing DO impairment. The KDHE found that DO impairments were most prevalent in low flow conditions when there is little aeration. The Shawnee Creek TMDL called for assessing sedimentation issues, which potentially could be responsible for reducing stream slope and aeration capability and exerting an oxygen demand. The TMDL also recommended installing grass buffers near the stream to reduce sediment loading. Turkey and Cow Creeks have also been identified by the KDHE as impaired for low DO, but their 303(d) list provides no indication as to why.

MDNR currently has Clear Creek and the North Fork Spring River identified as impaired for low DO on their 2004/2006 303(d) List. Low DO was first identified as an issue in Clear Creek in 1978 when it was measured at 2-3 mg/L two miles downstream of the Monett Wastewater Treatment Plant. MDNR attributed BOD, ammonia and suspended solids loadings from the Monett WWTP as the cause of the low DO and subsequently issued a TMDL for these parameters in 1999 (MDNR, 1999). However, low DO continues to be an issue in Clear Creek and was added to the 303(d) list during the most recent listing cycle. The North Fork Spring River was also recently added to the 2004/2006 303(d) List for low DO, which MDNR attributes to the Lamar WWTP.

III. METHODS

Understanding the methods of data collection, management, and analyses is important for interpreting water quality results. MEC compiled and interpreted water quality data from multiple collection entities that used a variety of methods. Data sources used in this report are documented below along with a review of their methodologies and data quality. Methods used by MEC for collecting, storing, and analyzing water quality data are also discussed below. This section is limited to water chemistry and bacteria data. Methods for handling other biological data are discussed in the biological monitoring section.

3.1. Data Collection

MEC compiled water quality data collected in the Spring River basin from MDNR and USGS databases. Additional data were also provided directly from Pittsburg State University (PSU) in June 2006, Newton County Health Department (NCHD) in June 2007, and the EPA in January 2008. MDNR databases include data collected from its own water quality monitoring programs and numerous other state, federal, and municipal sources. Organizations that contributed to the MDNR water quality dataset included Crowder College, the USGS, FAPRI, KDHE, the Oklahoma Conservation Commission (OCC), and EPA. Although MDNR included USGS data in its databases, MEC obtained USGS data directly from the USGS National Water Information System (NWIS).

It should be noted that the final analysis of water quality data was limited to a select set of monitoring sites and sample dates. Data management and data assessment issues (discussed in sections 3.2 and 3.3) limited the total number of monitoring sites in the Spring River to 46 (Figure 11).

Brief descriptions of the programs responsible for collecting the data summarized in this report are presented in the following sections.

Missouri Department of Natural Resources

MDNR designed their water quality monitoring programs for the following major purposes:

- Characterize background or reference water quality conditions;
- Better understand daily, flow event, and seasonal water quality variations and their underlying processes;
- Characterize aquatic biological communities;
- Assess time trends in water quality;
- Characterize local and regional impacts of point and nonpoint source discharges on water quality;
- Assess compliance with water quality standards or wastewater permit limits, and;
- Support development of strategies to return impaired waters to compliance with water quality standards (MDNR, 2004).

MDNR uses a combination of a fixed station network, special water quality studies, a toxics monitoring program, a biological monitoring program, fish tissue monitoring, and two volunteer monitoring programs to achieve these goals.

MEC identified 103 MDNR water quality monitoring sites within the Spring River basin. Eleven of these sites were chosen for use in this report based on their spatial and temporal availability. Water quality parameters collected at these monitoring sites included: temperature, flow, specific conductivity, hardness, alkalinity, turbidity, dissolved oxygen (DO), pH, chlorophyll *a*, total nitrogen as nitrogen (TN), total Kjeldahl nitrogen (TKN), total phosphorus (TP), ammonia as nitrogen (NH_3-N), nitrate plus nitrite as nitrogen (NO_3+NO_2), total suspended solids (TSS), volatile suspended solids (VSS), biochemical oxygen demand (BOD), carbonaceous biochemical oxygen demand (CBOD), fecal coliform, *Escherichia coli* (*E. coli*), calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, iron (total and dissolved), dissolved manganese, cadmium (total and dissolved), chromium (total and dissolved), copper (total and dissolved), nickel (total and dissolved), lead (total and dissolved), and zinc (total and dissolved). MDNR sample dates ranged from September 1978 to March 2006.

Food and Agricultural Policy Research Institute at the University of Missouri

FAPRI is an organization charged with providing objective, quantitative analysis to promote effective agricultural policy. In the mid 1990s FAPRI established a team of analysts to lead the Missouri Water Quality Initiative project. The mission was to quantitatively assess environmental policy in a manner similar to FAPRI's assessment of agricultural policy. Grants funding this project have supported extensive water quality monitoring efforts in Missouri.

Water quality data collected by FAPRI were available from the MDNR database for one monitoring site within the Spring River basin. Sample dates ranged from April 2001 to October 2003. Water quality sample parameters measured included *E. coli*, fecal coliform, TSS, specific conductivity, TP, TN, and NO_3+NO_2.

Kansas Department of Health and Environment

Water quality data collected by KDHE were available from the MDNR database for five monitoring sites within the Spring River basin. Sample dates ranged from July 1967 to November 2003. Water quality sample parameters measured included: temperature, flow, specific conductivity, hardness, alkalinity, turbidity, TSS, total dissolved solids, DO, pH, TN, TKN, TP, NH_3-N, NO_3+NO_2, BOD, fecal coliform, calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, total iron, total manganese, total aluminum, total arsenic, total cadmium, total cobalt, total chromium, total copper, total nickel, total lead, total thalium, and zinc (total and dissolved).

Oklahoma Conservation Commission

The OCC collect's water quality data as part of its Rotating Basin Monitoring Program in which waters impaired by nonpoint source pollution are identified. Water quality data collected by OCC were available from the MDNR database for one monitoring site within the Spring River basin. Water quality sample parameters measured included: flow, specific conductivity, hardness, alkalinity, total dissolved solids, DO, pH, TN, TKN, TP, NH_3-N, NO_3+NO_2, and CBOD.

United States Environmental Protection Agency

Water quality data collected by EPA were available from the MDNR database for 38 monitoring sites within the Spring River basin. Sample dates ranged from August 1988 to September 1993. Water quality parameters measured included: flow, alkalinity, hardness, specific conductivity, total dissolved solids, DO, pH, CBOD, NH_3-N, NO_3+NO_2, calcium, dissolved cadmium, dissolved lead, dissolved zinc, and sulfate.

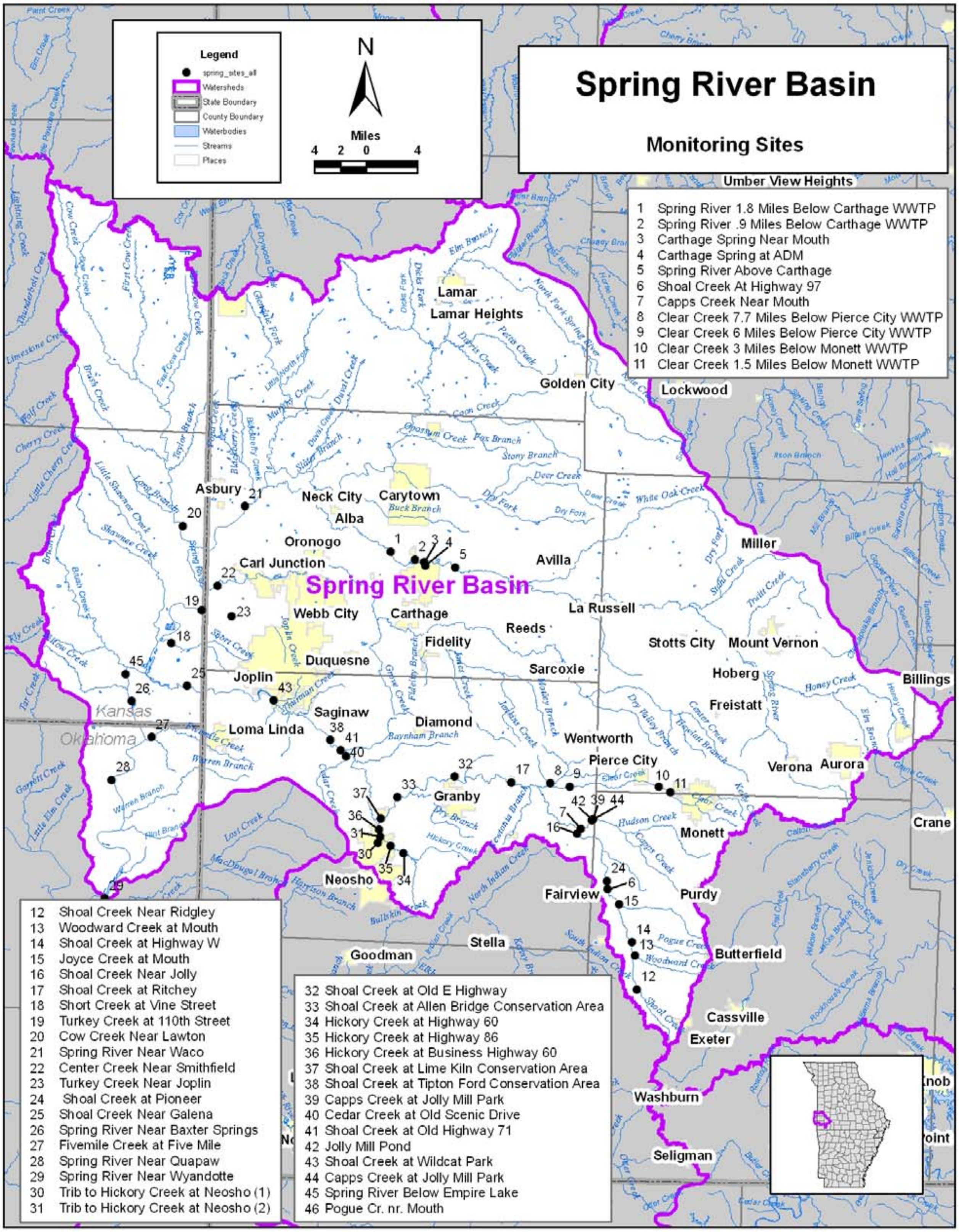
Additional water quality data from a short term intensive study conducted in May 2006 were also made available directly from EPA. The EPA water quality study included over 160 monitoring sites. Water quality parameters measured included: hardness, organic carbon, aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, selenium, silver, sodium, thallium, vanadium, and zinc. All metals were measured for both total and dissolved forms.

Newton County Health Department

Water quality data collected by the NCHD were available for 57 monitoring sites in the Spring River basin. These sites were selected based on ease of public access and geographic location. Sample dates ranged from June 2005 to June 2007. Water quality parameters measured included *E. coli*, TP, NH_3-N, nitrate and nitrite.

Crowder College

Data were collected by Crowder College researchers at three sites within the Spring River basin between January 1990 and August 2004. Parameters sampled for included: flow, DO, pH, specific conductivity, turbidity, BOD, TSS, chloride, fecal coliform, TKN, TP, NH_3-N, and NO_3+NO_2. This collection effort was funded through a 319 grant from MDNR in cooperation with the Missouri Department of Conservation (MDC). Among other project objectives, this data will be used to develop nutrient TMDLs for streams in the Shoal Creek basin.



1 Spring River 1.8 Miles Below Carthage WWTP
2 Spring River .9 Miles Below Carthage WWTP
3 Carthage Spring Near Mouth
4 Carthage Spring at ADM
5 Spring River Above Carthage
6 Shoal Creek At Highway 97
7 Capps Creek Near Mouth
8 Clear Creek 7.7 Miles Below Pierce City WWTP
9 Clear Creek 6 Miles Below Pierce City WWTP
10 Clear Creek 3 Miles Below Monett WWTP
11 Clear Creek 1.5 Miles Below Monett WWTP

12 Shoal Creek Near Ridgley
13 Woodward Creek at Mouth
14 Shoal Creek at Highway W
15 Joyce Creek at Mouth
16 Shoal Creek Near Jolly
17 Shoal Creek at Ritchey
18 Short Creek at Vine Street
19 Turkey Creek at 110th Street
20 Cow Creek Near Lawton
21 Spring River Near Waco
22 Center Creek Near Smithfield
23 Turkey Creek Near Joplin
24 Shoal Creek at Pioneer
25 Shoal Creek Near Galena
26 Spring River Near Baxter Springs
27 Fivemile Creek at Five Mile
28 Spring River Near Quapaw
29 Spring River Near Wyandotte
30 Trib to Hickory Creek at Neosho (1)
31 Trib to Hickory Creek at Neosho (2)

32 Shoal Creek at Old E Highway
33 Shoal Creek at Allen Bridge Conservation Area
34 Hickory Creek at Highway 60
35 Hickory Creek at Highway 86
36 Hickory Creek at Business Highway 60
37 Shoal Creek at Lime Kiln Conservation Area
38 Shoal Creek at Tipton Ford Conservation Area
39 Capps Creek at Jolly Mill Park
40 Cedar Creek at Old Scenic Drive
41 Shoal Creek at Old Highway 71
42 Jolly Mill Pond
43 Shoal Creek at Wildcat Park
44 Capps Creek at Jolly Mill Park
45 Spring River Below Empire Lake
46 Pogue Cr. nr. Mouth

FIGURE 11. Water Quality Monitoring Sites in the Spring River Basin

Pittsburg State University

Water quality data collected by PSU in Kansas were available from the MDNR database for seven monitoring sites in the Spring River basin. The PSU data were collected during a water quality survey performed by Chambers *et al.* (2005) in 2001. Water quality parameters measured included flow, DO, pH, specific conductivity, turbidity, NH_3-N, NO_3+NO_2, TP, and total reactive phosphorus.

U.S. Geological Survey (Water Resource Division)

USGS conducts studies of surface water in cooperation with local and state governments and with other federal agencies in every state. Two significant USGS water quality monitoring efforts include the National Water-Quality Assessment Program (NAWQA) and the National Stream Quality Accounting Network (NASQAN). USGS disseminates water quality data to the public with the goal of supporting national, regional, state, and local information needs and decisions related to water quality management and policy. Water quality data from USGS were identified for 99 monitoring stations in the Spring River basin. USGS water quality data in the Spring River basin ranged from June 1944 to September 2004 and included over 300 parameter codes[2], which can be grouped into the following categories: biological, major inorganics, minor and trace inorganics, nutrients, organics, physical properties, radiochemicals, and sediment.

3.2. Data Management

Water quality data collected from different agencies were stored in a Microsoft (MS) Access™ database. The format selected for the WQIP database is similar to the format used by USGS in the National Water Information System. The water quality data are stored in a single table, such that each record consists of a single monitoring site, sample date, sample time, parameter code, and result value. Other fields stored in this table include the collection entity, alternate site codes, and remark codes. Non-water quality data (e.g., site locations and parameter descriptions) are stored in separate tables.

USGS parameter codes were used where possible to identify water quality parameters in the database. USGS parameter codes clearly indicate the constituent measured and often the method used to measure that constituent. Parameter codes generally were not available from non-USGS data sources. USGS parameter codes were assigned when possible to non-USGS data; however, this was not possible in some instances where sufficient metadata was not readily available. For example, some data did not indicate whether the samples were filtered or unfiltered or the time period for biochemical oxygen demand (5-day or ultimate). MEC assigned an arbitrary generic parameter code if the correct USGS parameter code could not be identified.

Multiple observational data were identified in the WQIP database where possible. Multiple observations occur when more than one observation is stored for the same site and time. This situation typically occurs when QA/QC data are stored along with the observation for that time period. Where multiple observations were known, these

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[2] Parameter codes are 5-digit codes used by the USGS to identify the constituent measured and the units of measure.

data were identified with a remark code. However, all multiple observation data were likely not identified through the screening process.

Analyte concentrations either too low or high are typically censored by laboratories to avoid a false-quantification of a constituent. Typically, analyte concentrations considered too low for laboratory detection limits are reported as not detected (ND). Bacteria samples above the maximum detection limit are typically reported as "too numerous to count" (TNTC). Censored data were identified in the WQIP database in the remark code field.

The WQIP database maintained a primary and secondary value field for the purpose of handling censored data. In general, both the primary and secondary value fields were populated with the laboratory result value unless the value was censored. If the data point was censored, the primary value field was populated with either the minimum detection limit for ND samples or the maximum detection limits for TNTC samples. Where laboratory detection limits were not available for ND samples, a value of zero was entered in the primary value field. The secondary value field was populated with one-half the detection limit for ND samples, and double the maximum detection limit for TNTC samples. The secondary value field was used for purposes of generating water quality statistics.

Within the MDNR databases ND samples are reported as values slightly less than one half the detection limit (e.g., a detection limit of 0.3 would be reported as 0.1499). MDNR reported TNTC samples as twice the maximum detection limit. In both cases, MDNR did not assign descriptors to ND or TNTC samples. MEC made no attempt to identify non-detect and TNTC samples originating from the MDNR databases.

The WQIP database includes a spatial table to identify the location of the water quality sampling sites. The spatial table includes the site code, site description, latitude, longitude, and 8-digit USGS Hydrologic Unit Code (HUC). The USGS and MDNR databases provided the site codes, descriptions, and geographic coordinates associated with the water quality data. In some instances, data with geographic coordinates were not available. These records were maintained in the database, but were not used for data analysis.

The spatial information provided by MDNR and USGS databases appeared questionable for some sites. For example, the geographic coordinates did not always plot in the HUC indicated by the MDNR and USGS databases. In these instances, the HUC codes were reassigned to their plotted position. In other instances the plotted position of a site did not agree with the site description. If the geographic coordinates could not be trusted, data from that site were not used for data analysis.

MEC attempted to identify co-located monitoring sites so the water quality data could be pooled for purposes of data analysis[3]. The criteria for identifying co-located monitoring sites were primarily based on best professional judgment. Sites were

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[3] Only co-located sites with "data of interest" were identified. The methods for selecting the "data of interest" are described in the data assessment section.

combined if two or more sites plotted in relatively close proximity. Monitoring sites were not considered to be co-located if the sites straddled a tributary or a point source. Co-located sites are identified in the database by use of a consistent alternate site number. The site number is the key identifier used in the database to relate a site to its water quality data and metadata.

3.3. Data Assessment

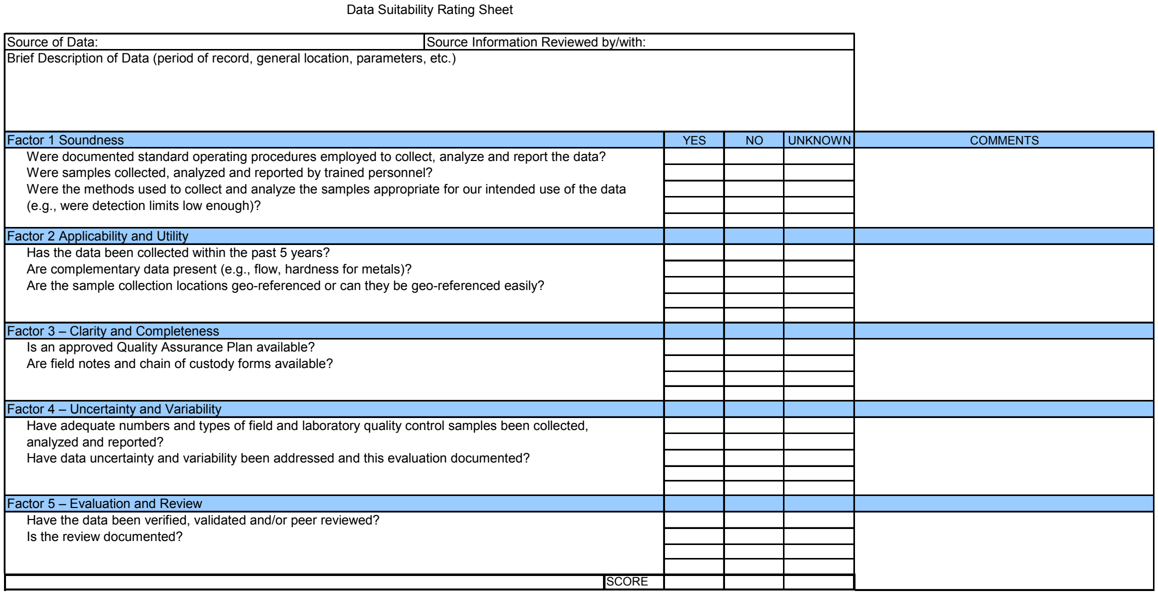
Methods of data assessment in terms of data source quality, selection of parameters and periods of interest, methods of analysis, and data limitations are discussed below.

3.3.1 Data Quality Assessment

When evaluating the quality and relevance of existing water quality and other data as part of the Data Gap Analysis project, MEC used five general assessment factors. This approach was based on U.S. Environmental Protection Agency Science Policy Council's "A Summary of General Assessment Factors for Evaluating Quality of Scientific and Technical Information", June 2003 (EPA 100/B-03/001) (EPA, 2003). The five factors are:

1. Soundness – the extent to which scientific and technical procedures, measure, methods or models employed to generate the data are reasonable, and consistent with, the intended application of the data.
2. Applicability and Utility – the extent to which the data is relevant to our intended use, which is to substitute for acquiring all new data to assess water quality in southwest Missouri.
3. Clarity and Completeness – the degree of clarity and completeness with which the data, assumptions, methods, quality assurance, sponsoring organizations and analyses employed to generate the information are documented.
4. Uncertainty and Variability – the extent to which the qualitative and quantitative uncertainty and variability in the data are evaluated and characterized.
5. Evaluation and Review – the extent of independent verification, validation, and peer review of the data, procedures, measures, methods or models.

A checklist was developed to rate the suitability of existing data (Figure 12). While most, if not all, data collected during the project will be available through the WQIP database, the data were attributed with the collection entity. In this manner, the data user can determine which data are suitable for inclusion in their particular study or data presentation.



Data Suitability Rating Sheet

Source of Data:

Source Information Reviewed by/with:

Brief Description of Data (period of record, general location, parameters, etc.)

Factor 1 Soundness	YES	NO	UNKNOWN	COMMENTS
Were documented standard operating procedures employed to collect, analyze and report the data?				
Were samples collected, analyzed and reported by trained personnel?				
Were the methods used to collect and analyze the samples appropriate for our intended use of the data (e.g., were detection limits low enough)?				
Factor 2 Applicability and Utility				
Has the data been collected within the past 5 years?				
Are complementary data present (e.g., flow, hardness for metals)?				
Are the sample collection locations geo-referenced or can they be geo-referenced easily?				
Factor 3 – Clarity and Completeness				
Is an approved Quality Assurance Plan available?				
Are field notes and chain of custody forms available?				
Factor 4 – Uncertainty and Variability				
Have adequate numbers and types of field and laboratory quality control samples been collected, analyzed and reported?				
Have data uncertainty and variability been addressed and this evaluation documented?				
Factor 5 – Evaluation and Review				
Have the data been verified, validated and/or peer reviewed?				
Is the review documented?				
SCORE				

FIGURE 12. Data Suitability Rating Sheet

The checklist was based on the five factors described above. Within each factor, several objective questions (listed below) were asked and if all of the responses were affirmative, the data received a one point credit for that factor. Therefore, the data sources received scores of 0 to 5, with 5 as the highest score. Data sources also received partial credit (0.5 points) if they met most of the requirements for a factor.

Factor 1 – Soundness
- Were documented standard operating procedures employed to collect, analyze and report the data?
- Were samples collected, analyzed and reported by trained personnel?
- Were the methods used to collect and analyze the samples appropriate for our intended use of the data (e.g., were detection limits low enough)?

Factor 2 – Applicability and Utility
- Have the data been collected within the past 5 years?
- Are complementary data present (e.g., flow, hardness for metals)?
- Are the sample collection locations geo-referenced or can they be geo-referenced easily?

Factor 3 – Clarity and Completeness
- Is an approved Quality Assurance Plan available?
- Are field notes and chain of custody forms available?

Factor 4 – Uncertainty and Variability
- Have adequate numbers and types of field and laboratory quality control samples been collected, analyzed and reported?
- Have data uncertainty and variability been addressed and this evaluation documented?

Factor 5 – Evaluation and Review

- Have the data been verified, validated and/or peer reviewed?
- Is the review documented?

Most of the data included in the database are from the USGS and MDNR, which both received a score of 5. For other organizations' data included in the MDNR database it was not possible to assess the data in this manner. Data received directly from other entities were evaluated and the received the following average ratings:

Newton County Health Department	2.0
Pittsburg State University	2.5
Food and Agricultural Policy Research Institute	3.5
Kansas Department of Health and Environment	4.5
Oklahoma Conservation Commission	4.5
United States Environmental Protection Agency	5.0

These ratings do not infer that the data received from these entities are not accurate. It simply limits the data's usefulness in certain applications that require rigorous quality assurance/quality control documentation.

3.3.2. Parameters of Interest

Although all readily available water quality data from the Spring River basin were compiled into the WQIP database, the assessment was limited to the following parameters:

- Total Phosphorus as Phosphorus (TP),
- Total Nitrogen as Nitrogen (TN),
- Nitrate plus Nitrite as Nitrogen ($NO_3 + NO_2$),
- *Escherichia coli* (*E. coli*).
- Total Zinc (Zn)
- Dissolved Zinc (dissolved Zn)
- Total Lead (Pb)
- Dissolved Lead (dissolved Pb)

The WQIP project workgroup selected nutrients (TP, TN, and $NO_3 + NO_2$) and *E. coli* as parameters of concern since they represent direct or indirect indications of threats to the water quality resources in southwest Missouri. *E. coli* was selected for analysis over fecal coliform based on EPA recommendations. EPA epidemiological studies indicated *E. coli* was the better predictor of acute gastrointestinal illness than fecal coliform for freshwater recreation. Zinc and lead were added to the initial four parameters because metals are a known water quality concern in the Spring River basin.

3.3.3. Periods of Interest

MEC limited data analysis to those water quality sample stations with a minimum of 10 samples during selected periods of record. In the "first cut" of water quality data, MEC identified only those stations with at least 10 samples over the entire period of record.

MEC's "final cut" of sample stations was based on those sites with a minimum of 10 samples for any of the five selected parameters after the period of interest was selected.

The periods of interest were selected on a parameter-by-parameter basis and were based on a variety of factors. Ideally, data analyses would be performed with data collected from all monitoring sites at the same dates, times, and frequency. However, this is not possible for a multitude of reasons. Therefore, reasonable attempts were made to select a period of interest most representative of all monitoring sites' sampling histories.

Analysis of TP was limited to sampling dates on or after October 1, 1998. Although TP data date back several decades, sampling did not commence at most sites until around 1999 (Figure 13). Therefore, the period of record was set to the beginning of the 1999 water year (i.e., October 1, 1998).

Analysis of TN and NO_3+NO_2 was also limited to sampling dates on or after October 1, 1998. The most common period of record for most sampling sites begins around 1999 (Figures 14 and 15). Therefore, the period of record was set to the beginning of the 1999 water year (i.e., October 1, 1998).

Analysis of total and dissolved zinc was limited to sampling dates on or after October 1, 1998. A relatively high frequency of sampling took place between 1975 and 1981; however, sampling at these locations has discontinued (Figures 16 and 17). The most common period of record representing relatively recent data began around 1999. Therefore, the period of record was set to the beginning of the 1999 water year (i.e., October 1, 1998).

Analysis of total and dissolved lead (Figures 18 and 19) was limited to sampling dates on or after October 1, 1998. A relatively high sampling frequency occurred between 1973 and 1989 for both of these parameters. However, this high frequency of data collection was halted in 1989 creating a data gap that lasted until 1999 for total lead and 1993 for dissolved lead. In order to maintain the same period of record for both total and dissolved zinc the period of record was set to the beginning of the 1999 water year (i.e., October 1, 1998).

Analysis of *E. coli* was limited to sampling dates on or after October 1, 1998. With the exception of one station dating back to 1994, all available *E. coli* samples occur on or after March 1, 1999 (Figure 20). Therefore, the period of record was set to the beginning of the 1999 water year (i.e., October 1, 1998).

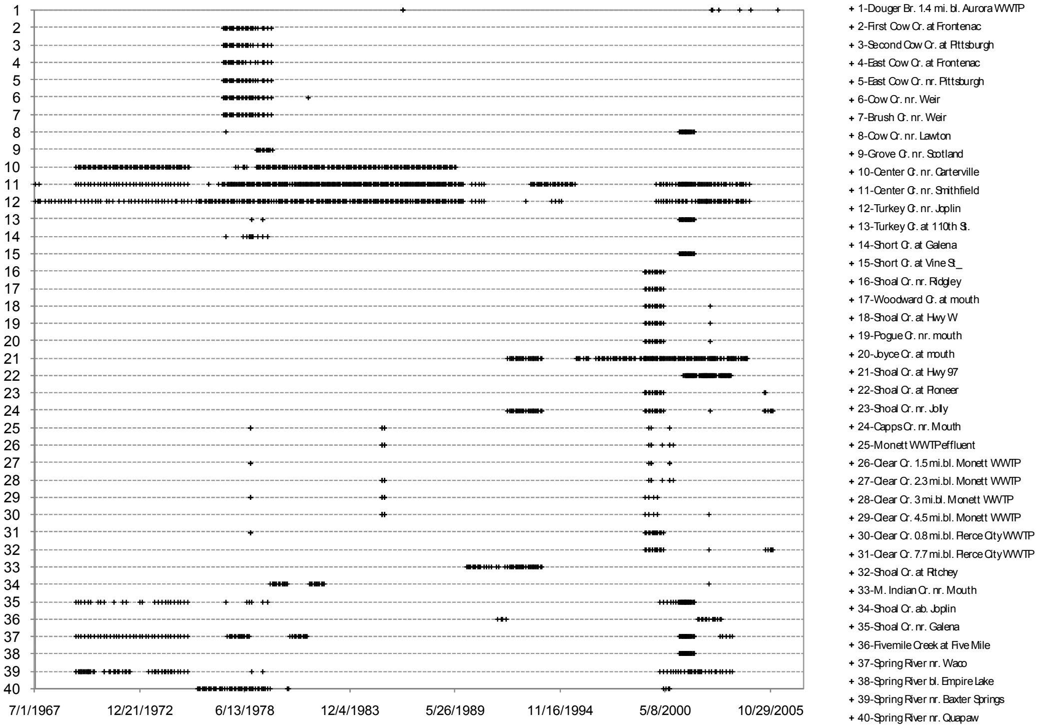


FIGURE 13. Total Phosphorus Sampling Frequency and Period of Record in the Spring River Basin

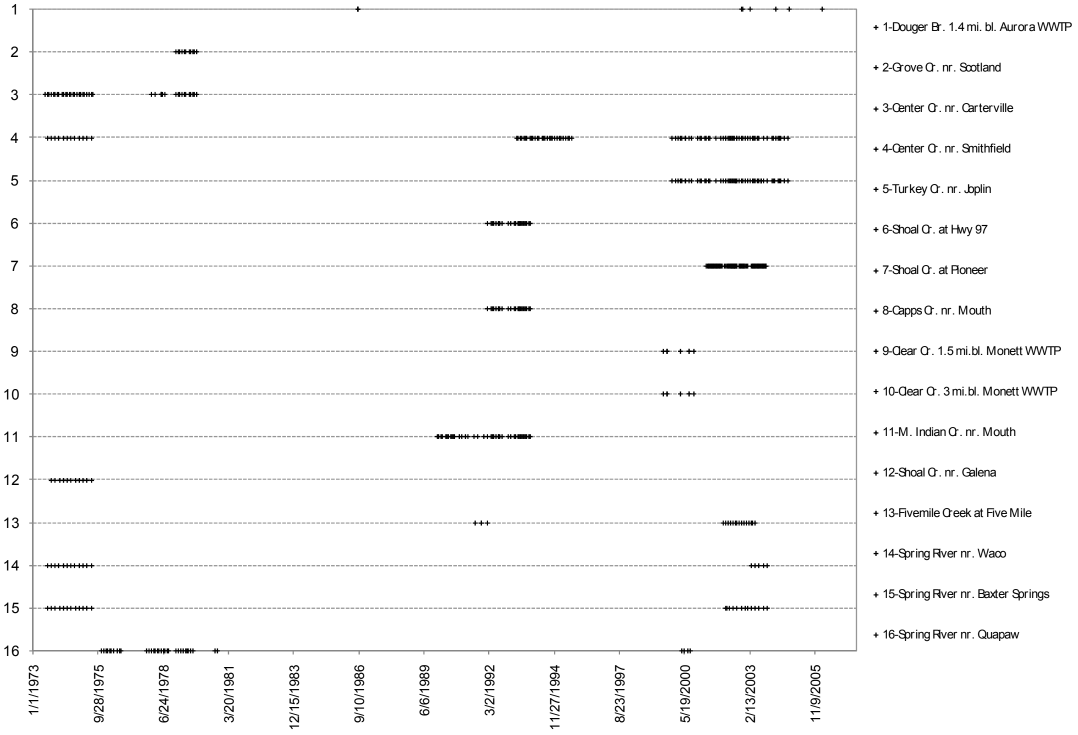


FIGURE 14. Total Nitrogen Sampling Frequency and Period of Record in the Spring River Basin

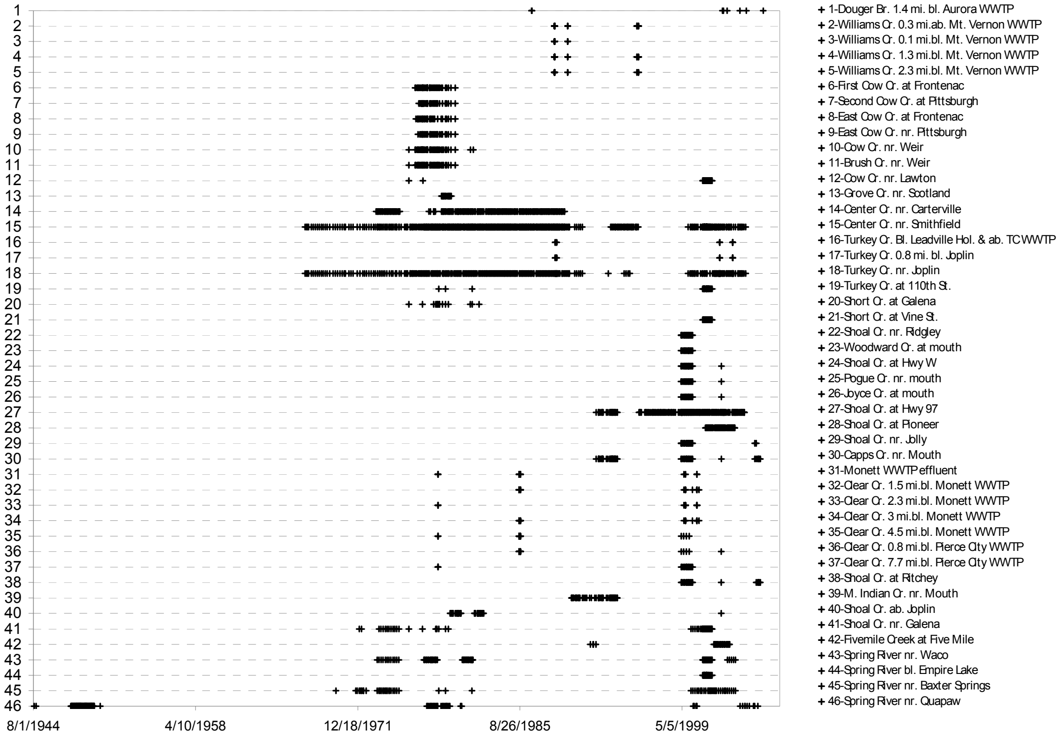


FIGURE 15. Nitrate plus Nitrite Sampling Frequency and Period of Record in the Spring River Basin

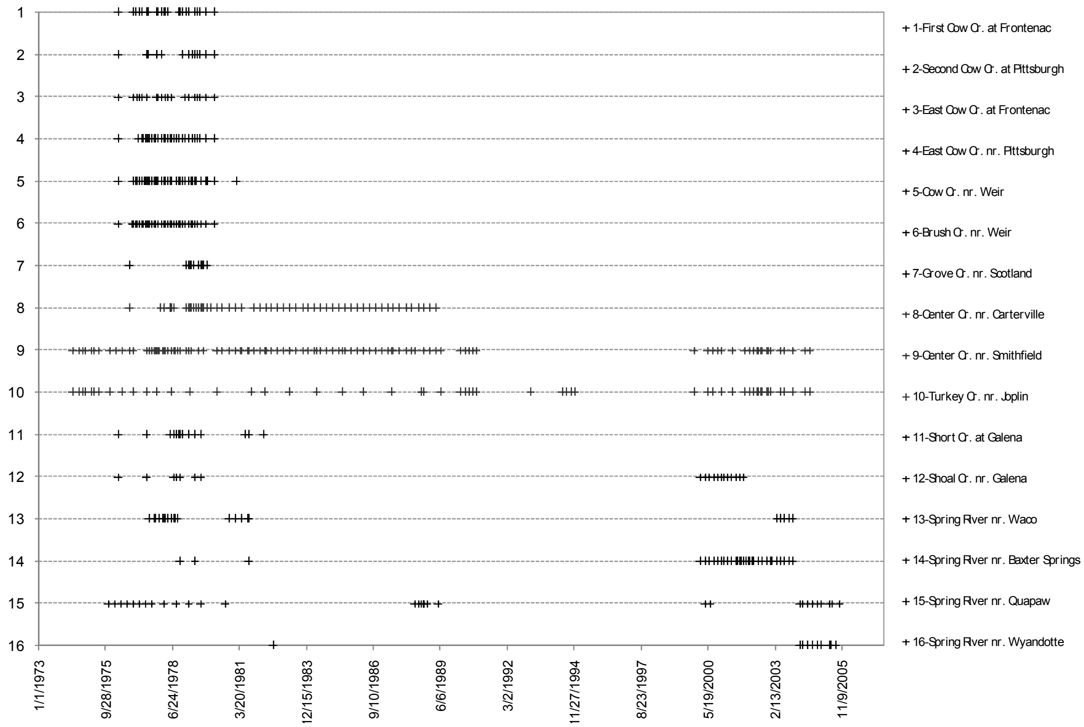


FIGURE 16. Total Zinc Sampling Frequency and Period of Record in the Spring River Basin

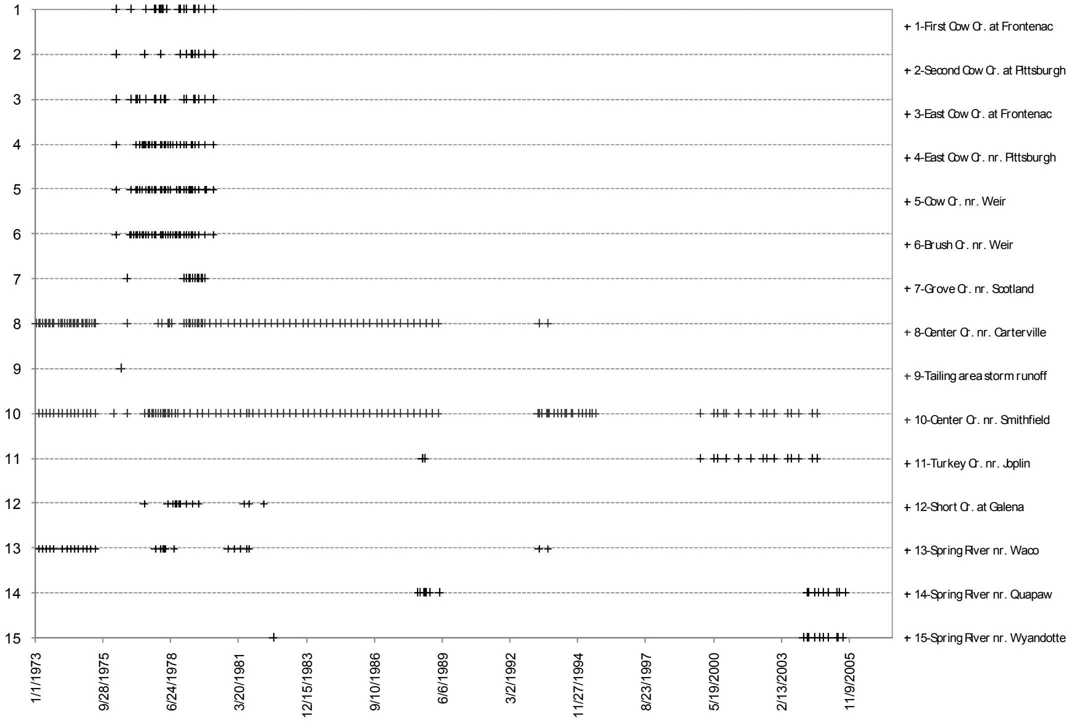


FIGURE 17. Dissolved Zinc Sampling Frequency and Period of Record in the Spring River Basin

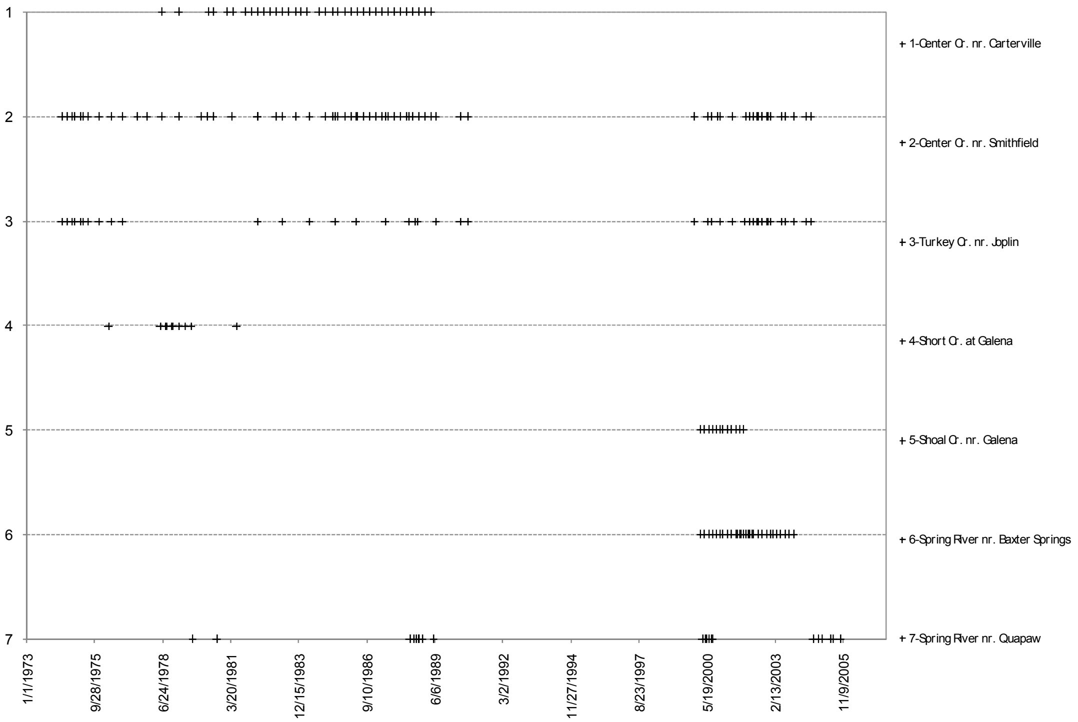


FIGURE 18. Total Lead Sampling Frequency and Period of Record in the Spring River Basin

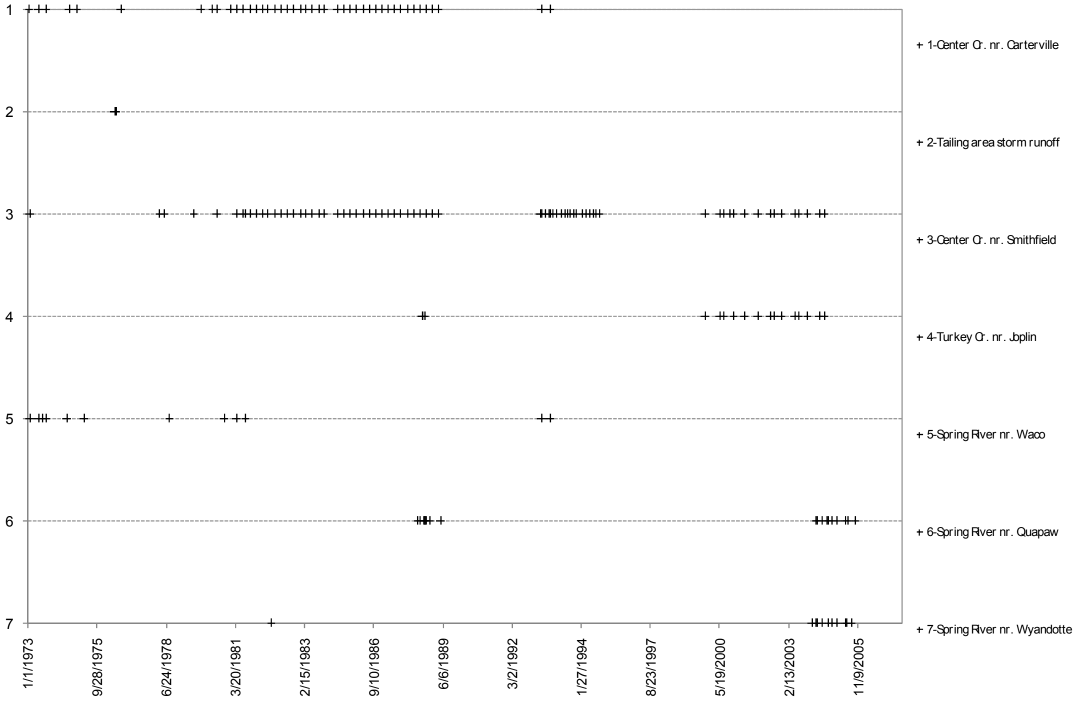


FIGURE 19. Dissolved Lead Sampling Frequency and Period of Record in the Spring River Basin

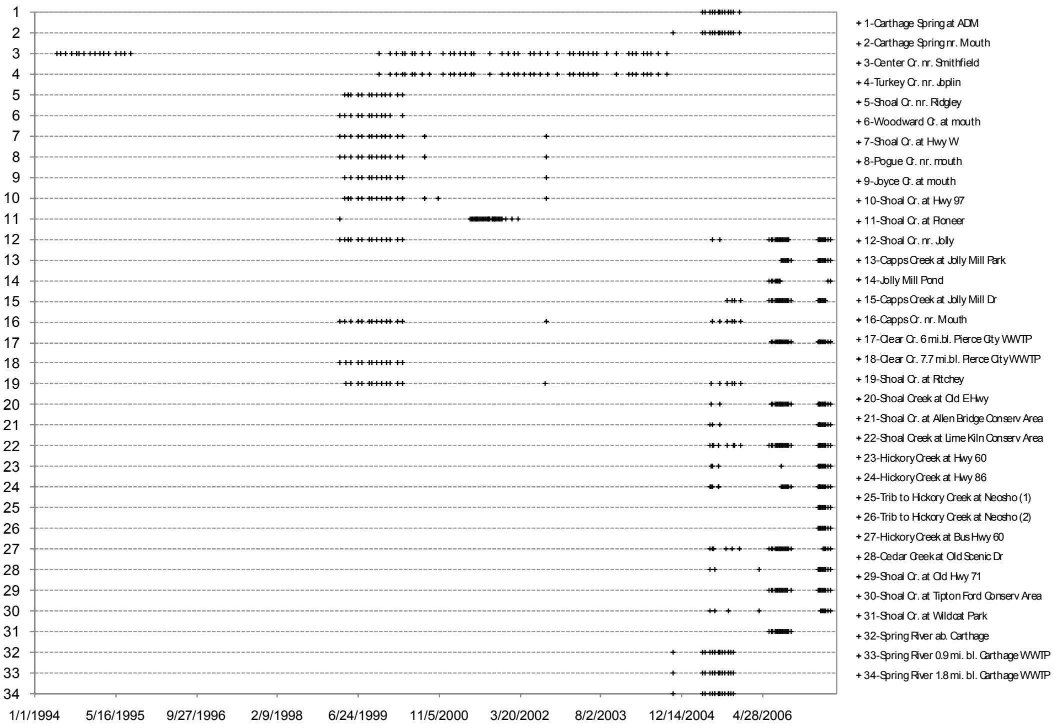


FIGURE 20. *E. coli* Sampling Frequency and Period of Record in the Spring River Basin

3.3.4. Data Analysis

Water quality data in the Spring River basin were to characterize stream water quality and direct future monitoring efforts through the identification of data gaps. Data analysis methods presented in this document include statistical summary tables, time series graphs, boxplots, bar charts, and maps. Software used as part of the data analysis included MS Access^{TM}, MS Excel^{TM}, Grapher^{TM}, and ArcGIS^{TM}. Data results are displayed in the tables and figures in order of upstream to downstream with the caveat that all Spring River sites are listed subsequent to other monitoring sites.

TN values were based on direct analytical determination or the combined sum of individual forms such as organic nitrogen, ammonia, nitrite, and nitrate. Therefore, some TN values were calculated prior to data analysis by summing TKN (organic nitrogen plus ammonia) and NO_3+NO_2 values for each site after grouping by the smallest temporal scale available (i.e., either by date or time). Not all samples were attributed with a collection time, but all samples were attributed with a collection date. Where multiple TKN and NO_3+NO_2 component values existed for a given day and were not attributed with a collection time, the component values were averaged prior to summing.

Multiple closely related analytical measurements of NO_3+NO_2 were available with their own parameter codes. Rather than select a single parameter code to represent NO_3+NO_2, we chose to aggregate the various related parameter codes. NO_3+NO_2 data analyzed in this report includes filtered NO_3+NO_2, unfiltered NO_3+NO_2, nitrate added to nitrite where they were analyzed separately, and nitrate where nitrite was unavailable. In most surface waters, nitrite is only available in trace amounts. We assumed that nitrate samples are reasonably representative of NO_3+NO_2 levels. A review of the database supported this assumption that nitrite levels were very low or below detection limits.

3.3.5. Data Limitations

The data analyses presented in this report are based on data with certain limitations which potentially hinder its interpretation and use. Some data limitations are inherent to most water quality data and are described below as statistical limitations. Other data limitations originate from data gaps and lack of data comparability.

Statistical limitations of water quality data potentially include non-normality, seasonality, and serial correlation. Water quality data tend to be more right skewed than normally distributed; however, the statistical distribution of the WQIP water quality data was not analyzed. Seasonality is a characteristic of water quality data that reflects known cycles in the data and may impact any statistical procedure which assumes a stationary time series. Serial correlation is the redundancy of information that may result from samples being taken too close together temporally relative to the time period of interest. Serial correlation implies samples are not independent and potentially could mask the true population variance. Although not necessary for the purposes of this report, more rigorous statistical analyses of the data could be utilized to address these statistical limitations.

The National Water Quality Monitoring Council (NWQMC)[4] cites the lack of commonly accepted data elements as a significant limitation in the secondary use of water quality data. A lack of common water quality data elements (WQDE)[5] limits the comparability, sharing, and value of water quality data. The Methods and Data Comparability Board (MDCB), a Workgroup under the NWQMC, formed a WQDE Workgroup in 1999 specifically to address this issue. The Workgroup developed a minimal set of WQDE needed to serve most, if not all, secondary uses of the respective types of data and to make an informed assessment regarding data comparability (NWQMC, 2006). The recommended WQDE, including information on detection limits and sample times, are largely lacking from the WQIP database. The lack of WQDE potentially limits the value of the data analyses presented in this report.

In addition to a lack of WQDE (i.e., “core metadata”), other data gaps limit the interpretation of the water quality data. For example, flow data, which is largely lacking, is typically necessary for a proper analysis of water quality data, since water quality varies during different flow regimes. The issue of lack of WQDE and other data gaps are discussed in further detail in Section 6.

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[4] The NWQMC was formed in 1997 as the permanent successor to the Intergovernmental Task Force on Monitoring Water Quality (ITFM). The NWQMC reports to the Advisory Committee on Water Information (ACWI), convened by the Department of the Interior under the Federal Committee of Water Information (FACA).

[5] The NWQMC considers WQDE to be the “core metadata” necessary to allow data comparability assessments.

IV. WATER QUALITY SUMMARY AND STATISTICS

A discussion and characterization of nutrients, metals and *E. coli* in the Spring River basin are presented below. Basic summary statistics including sample count, geometric means (herein after referred to as geomean), minimum, maximum, standard deviation and percentiles are provided for each parameter in a table format. A graduated symbol map, boxplot comparisons, and a bar graph ordered by geometric means are also presented for each parameter. For most parameters a single station was chosen to depict long-term trend analysis using a bar graph of annual geomeans.

4.1. Nutrients and Algal Biomass

Cultural eutrophication (the adverse effects of excess nutrient inputs) of surface water is an issue confronting the State of Missouri as well as the rest of the nation. Approximately 10 percent of all waters listed on Missouri's 2002 303(d) list[6] are considered impaired due to nutrients. The effects of cultural eutrophication can include the following (MDNR, 2005a):

- Proliferation of nuisance algae and the resulting unsightly and harmful bottom deposits;
- Turbidity due to suspended algae and the resulting unsightly green color;
- Dissolved oxygen depletion resulting from decomposition of overabundant algae and other plants that can have a negative impact on aquatic life; and
- Organic enrichment when algal blooms die off, which perpetuates the cycle of excessive plant growth.

Nutrient impairment may be gauged by two general categories – causal and response variables. TP and TN are typically the causal variables of interest, since limnologists consider them to be the most essential parameters for nutrient enrichment. Two early indicator response variables of system enrichment include chlorophyll *a* and some measure of turbidity (MDNR, 2005c; EPA, 2000). A discussion of causal (TP, TN, NO_2+NO_3) variables observed in the Spring River basin is summarized below; however, no chlorophyll *a* data were available for analysis.

4..1.1. Phosphorus

Phosphorus is a naturally occurring nutrient found in streams and rivers and is essential to all forms of life. Minimal levels of phosphorus are important for maintaining the ecological health and regulating the autotrophic[7] state in lotic[8] ecosystems. Excessive levels of phosphorus have been linked to eutrophication and increased production of autotrophs (e.g., algae). Phosphorus is generally regarded as the most common cause of autotrophic eutrophication in reservoirs, lakes and streams (Correll, 1999; Dodds, 2006).

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[6] Section 303(d) of the Clean Water Act and its accompanying regulations (CFR Part 130 Section 7) requires each state to identify waterbodies (i.e., lakes, reservoirs, rivers, streams, and wetlands) with impaired beneficial uses which require load allocations, waste load allocations, and total maximum daily loads.

[7] The autotrophic state is the gross primary production during lighted periods. An autotroph is an organism that produces organic matter from carbon dioxide using either light or reactions of inorganic compounds as a source of energy.

[8] Lotic refers to flowing water.

Phosphorus occurs in a variety of molecular forms in the environment, but is rarely found in volatile states. Phosphates bind strongly to most soils and sediment; therefore, surface waters receive most of their phosphorus from surface flows. The dominant form of phosphorus found in aquatic ecosystems is the pentavalent form. Among the pentavalent forms of phosphorus, only orthophosphate may be assimilated by autotrophs. Other forms of phosphorus may be chemically or enzymatically hydrolyzed to orthophosphate under appropriate conditions (Correll, 1999).

Phosphorus may be discharged to aquatic systems from both point and nonpoint sources. Historically, point sources such as wastewater treatment outfalls have been considered the most significant sources of phosphorus. However, the influence of non-point sources has taken on greater significance as treatment technologies have improved. Agricultural runoff of field fertilizers and animal manure, as well as runoff from residential and commercial fertilized lawns are commonly recognized nonpoint sources of phosphorus (Correll, 1999; Dodds *et al.*, 1998). Nonpoint sources may be responsible for greater than 90% of phosphorus loading in about one-third of US streams and rivers (Newman, 1996).

Baseline nutrient levels vary based on regional differences in geology, topography, and land uses (Dodds, 2006). The U.S. Environmental Protection Agency (EPA) has suggested an appropriate TP reference condition for the Ozark Highlands Ecoregion is 6.6 µg/L[9] (EPA, 2000). However, the Regional Technical Assistance Group (RTAG) for EPA Region 7 has recommended in draft a TP benchmark of 75 µg/L for all Region 7 states (email correspondence with Gary Welker – EPA Region 7 Nutrient Regional Coordinator – 2/20/2007). The RTAG and MDNR recommendations are supported by Dodds *et al.* (1998), which suggests the threshold between mesotrophic and eutrophic rivers is characterized by a TP level of 75 µg/L.

A trend analysis was conducted using data from the Center Creek near Smithfield station. The Smithfield station had the most complete long-term TP recordset of any station in the Spring River basin. Annual geomean TP levels generally appear to decrease throughout the 1970s and 1980s (Figure 21). There was no apparent trend in TP levels after about 1990. However, the TP annual geomean did spike to approximately 320 µg/L in 2001. The 2001 spike in TP reached a level not observed since the early 1970s.

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[9] This value is based on the 25th percentile of EPA's entire nutrient database for level III ecoregion 39.

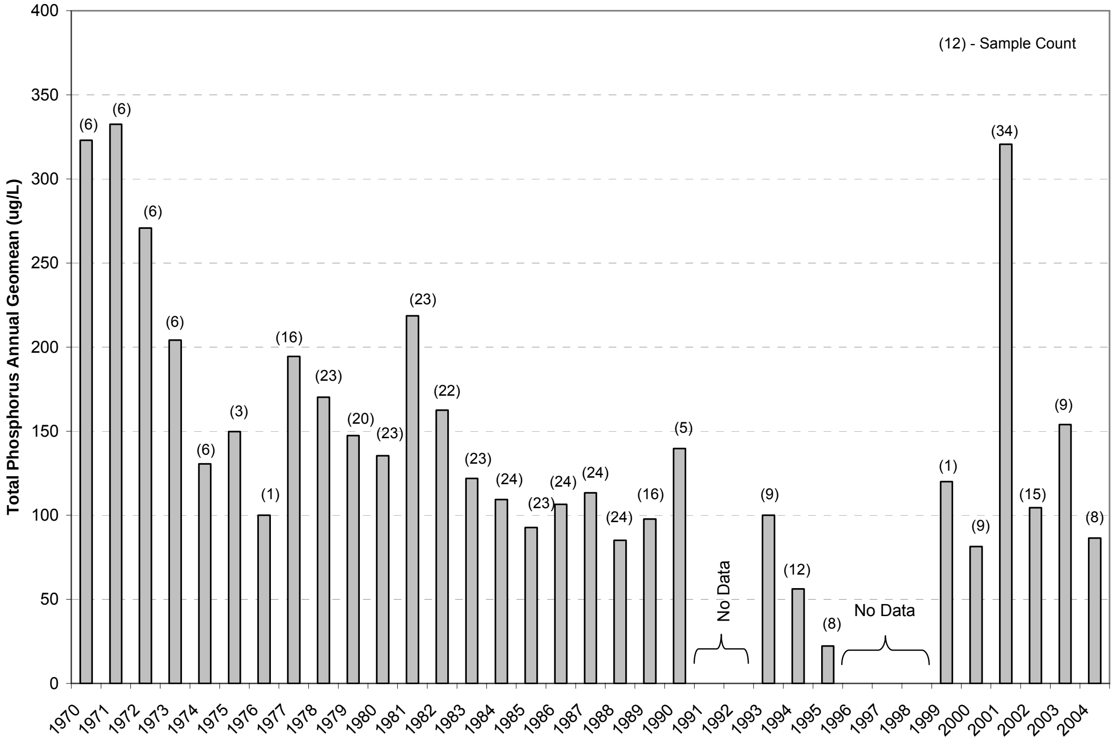

FIGURE 21. Total Phosphorus Annual Geometric Means Measured at the Center Creek near Smithfield Station

The observed TP levels suggest there are several significant phosphorus loading sources throughout the Spring River basin. Clear Creek had the highest observed TP geomeans in the Spring River basin, with values ranging from 1,864 to 16,926 µg/L (Table 8 and Figure 22). CAFOs and the Monett WWTP may be responsible for the phosphorus loadings in Clear Creek and Shoal Creek. Within Shoal Creek TP geomeans increase from a range of 26 to 70 µg/L to a range of 545 to 725 µg/L from upstream to downstream of the Clear Creek confluence. Other tributaries to the Spring River with elevated levels of TP include Turkey Creek (760 to 1,448 µg/L), Cow Creek (881 µg/L), Short Creek (1,120 µg/L), and Center Creek (172 µg/L). The three sampling stations on the Spring River have TP geomeans ranging from 202 to 753 µg/L. TP geomeans were generally the lowest along Fivemile, Woodward, Pogue, and Shoal Creeks (upstream of the Clear Creek confluence) where geomeans ranged from16 µg/L to 70 µg/L.

A boxplot and barchart comparison of TP values illustrates that approximately half of the sampling sites are significantly above the Dodds *et al.* (1998) eutrophic threshold value of 75 µg/L (Figures 23 and 24). Only 6 of the 23 water quality monitoring stations in the Spring River basin, which were largely outside the influence of urban areas, had interquartile TP ranges below the Dodds *et al.* (1998) eutrophic threshold value of 75 µg/L. Figure 24 illustrates that the Spring River near Baxter water quality station (the most downstream Spring River station with TP values) is ranked near the middle of all Spring River basin stations with regard to TP geomeans.

TABLE 8. Total Phosphorus Statistics for the Spring River Basin

											Percentiles			
Site Number	Station Name	Begin Date	End Date	Count (#)	Median (µg/L)	Mean (µg/L)	Geomean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Std.Dev. (µg/L)	10th (µg/L)	25th (µg/L)	75th (µg/L)	90th (µg/L)
371320094391100	Cow Cr. nr. Lawton	1/27/2001	11/17/2001	26	730	1,070	881	370	3,360	764	460	563	1,455	1,915
7186480	Center Cr. nr. Smithfield	11/2/1999	9/14/2004	76	140	276	172	30	1,760	312	70	90	348	730
7186600	Turkey Cr. nr. Joplin	11/2/1999	9/14/2004	57	800	889	760	80	2,430	478	400	570	1,190	1,480
370740094373000	Turkey Cr. at 110th St_	1/27/2001	11/17/2001	25	1,570	1,604	1,448	520	3,440	727	788	1,060	2,000	2,514
370524094395900	Short Cr. at Vine St.	1/27/2001	11/17/2001	25	860	1,596	1,120	450	8,500	1,849	546	670	1,540	3,044
364224094002301	Shoal Cr. nr. Ridgley	4/5/1999	3/22/2000	16	40	182	49	10	1,300	343	10	10	173	505
364442094003401	Woodward Cr. at mouth	4/6/1999	3/22/2000	12	15	20	17	10	40	13	10	10	25	40
364535094004901	Shoal Cr. at Hwy W	4/5/1999	8/27/2002	13	30	29	26	10	40	12	12	20	40	40
364550094003301	Pogue Cr. nr. mouth	4/5/1999	8/28/2002	13	30	28	25	10	50	14	10	20	40	40
364810094015501	Joyce Cr. at mouth	4/6/1999	8/27/2002	13	30	56	33	10	370	95	12	30	40	48
3230/7.3	Shoal Cr. at Hwy 97	10/12/1998	8/13/2004	112	75	105	70	10	1,100	152	30	50	100	158
7186690	Shoal Cr. at Pioneer	4/20/2001	10/7/2003	111	38	66	43	12	860	118	23	29	49	74
365253094053301	Shoal Cr. nr. Jolly	4/6/1999	8/4/2005	18	40	205	64	10	960	304	10	22	247	710
3234/0.6	Capps Cr. nr. Mouth	4/6/1999	12/13/2005	19	30	154	54	10	800	240	10	25	110	542
3239/2.0	Clear Cr. 1.5 mi.bl. Monett WWTP	6/30/1999	10/4/2000	10	16,950	17,235	16,926	10,100	23,000	3,212	15,365	16,700	18,550	19,400
3239/1.4	Clear Cr. 3 mi.bl. Monett WWTP	6/30/1999	10/4/2000	10	14,900	15,550	15,428	12,800	20,900	2,172	14,330	14,700	15,575	17,570
3238/1.6	Clear Cr. 7.7 mi.bl. Pierce City WWTP	4/7/1999	3/21/2000	12	1,850	1,964	1,864	970	2,900	647	1,310	1,550	2,350	2,890
365619094110801	Shoal Cr. at Ritchey	4/7/1999	12/13/2005	18	390	806	545	200	2,140	764	227	280	1,495	2,029
7187560	Shoal Cr. nr. Galena	2/1/2000	11/17/2001	38	845	853	725	200	2,520	477	310	451	1,195	1,380
7187980	Fivemile Creek at Five Mile	1/8/2002	4/7/2003	13	20	20	16	5	40	12	5	10	30	38
7186000	Spring River nr. Waco	1/27/2001	11/4/2003	31	430	633	425	62	1,910	570	128	222	800	1,750
Pitt-S7	Spring River bl. Empire Lake	1/27/2001	11/17/2001	26	700	845	753	270	1,700	426	490	580	1,005	1,585
7187600	Spring River nr. Baxter Springs	2/1/2000	11/4/2003	29	204	207	202	140	320	49	150	170	229	271

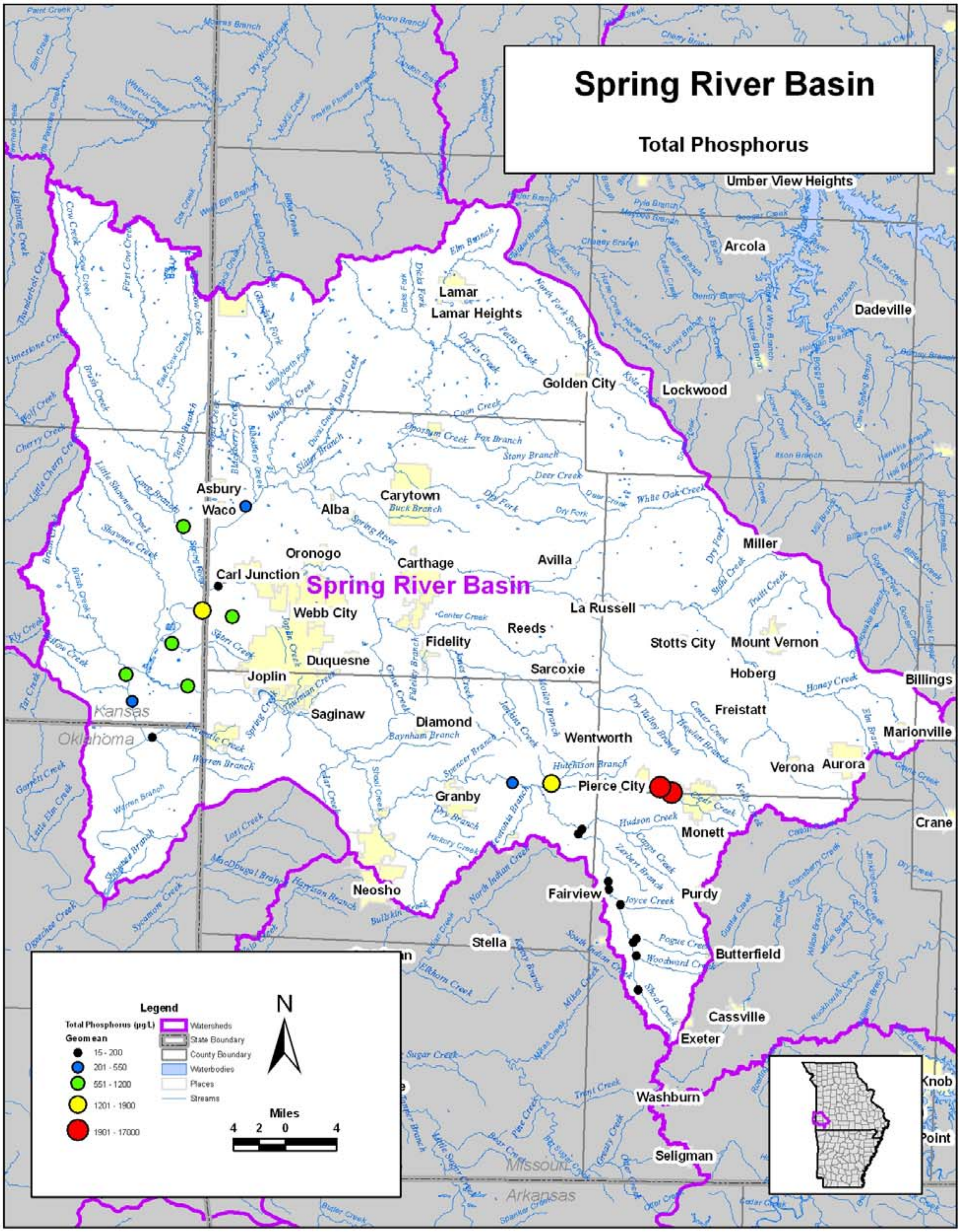

FIGURE 22. Graduated Symbol Map of Total Phosphorus Geometric Means in the Spring River Basin

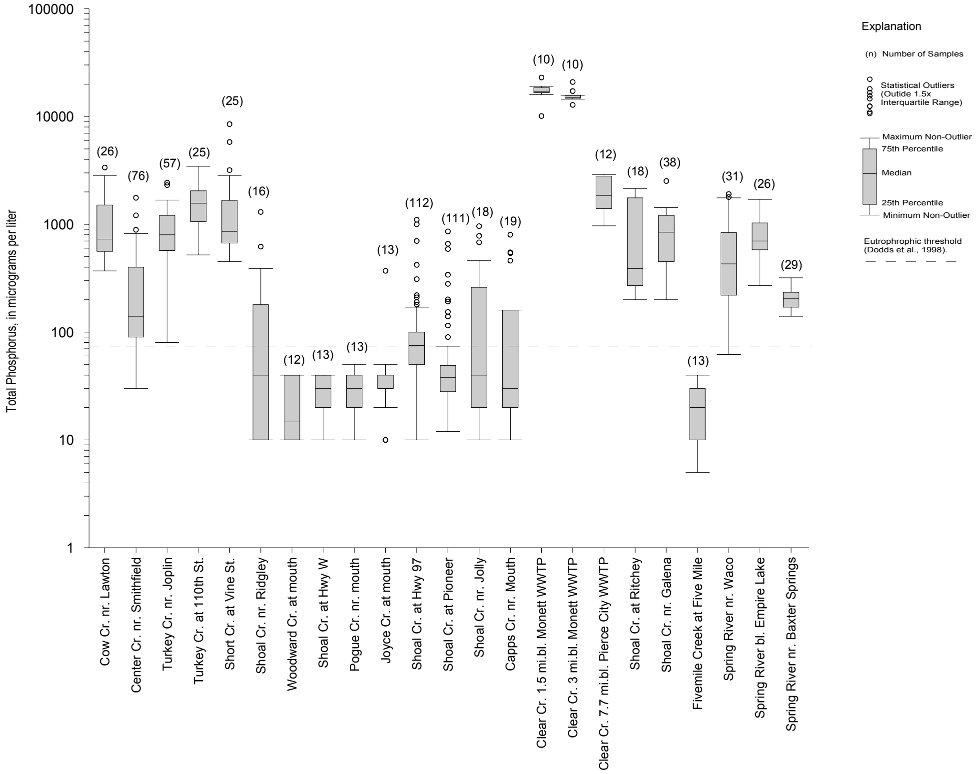

FIGURE 23. Box Plot of Total Phosphorus Levels in the Spring River Basin

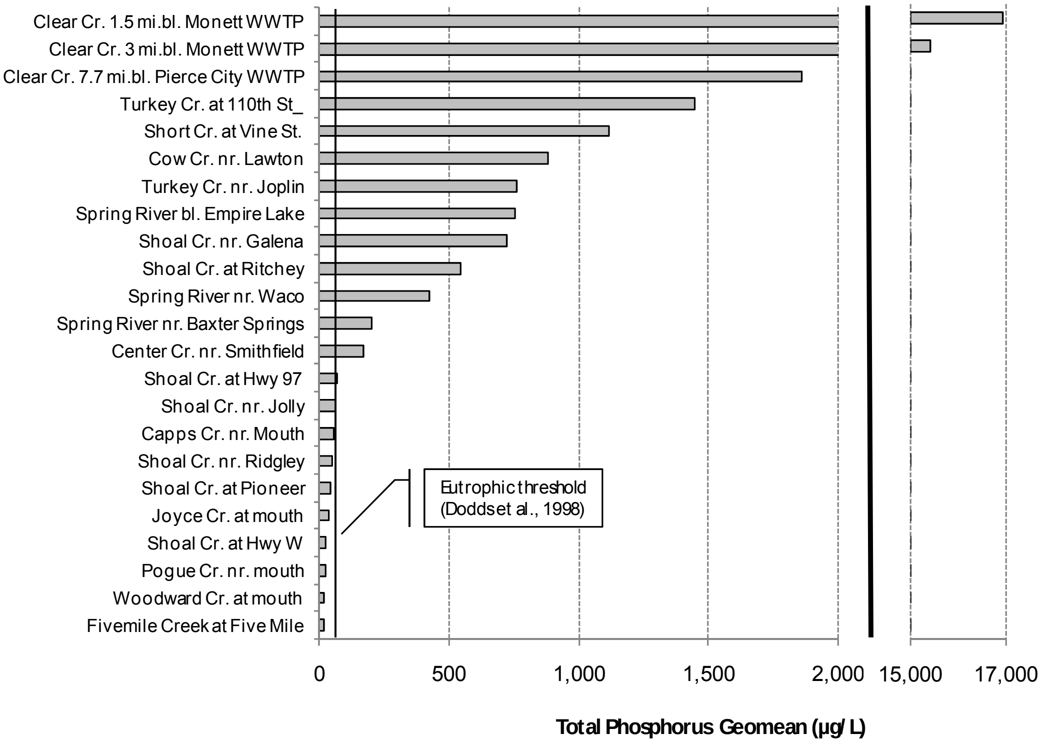

FIGURE 24. Bar Chart of Total Phosphorus Geometric Means in the Spring River Basin

4..1.2. Nitrogen

Like phosphorus, nitrogen is a found in variety of chemical forms and is an essential nutrient for living organisms. Nitrogen may be present in the air, water, soil, rocks, plants, and animals. The chemical forms of nitrogen include organic nitrogen compounds, nitrogen gas (N_2), ammonia (NH_3), ammonium (NH_4), nitrite (NO_2), nitrate (NO_3), nitrous oxide (N_2O), and nitric oxide (NO). Reactive nitrogen[10] is biologically the most important form of nitrogen. Although most nitrogen is not in a reactive form, nitrogen migrates throughout the environment and changes chemical forms in what is commonly termed the nitrogen cycle (Driscoll *et al.*, 2003; Seelig and Nowatzki, 2001).

Microorganisms may utilize nitrogen in its organic form as an energy source in a process referred to as mineralization. The process of mineralization transforms organic nitrogen to inorganic nitrogen in two steps. The first step is ammonification, whereby microorganisms extract energy from organic nitrogen and release NH_4 as a byproduct. Nitrification is the second step, in which *Nitrosomas* bacteria convert the NH_4 into NO_2 and *Nitrobacter* bacteria convert the NO_2 into NO_3. Conversion of NO_2 to NO3 typically occurs more readily than conversion of NH_4 to NO_3; therefore, NO_3 concentrations typically far exceed those of NO_2. The opposite of mineralization is immobilization, whereby microorganisms convert inorganic nitrogen into its organic form (Seelig and Nowatzki, 2001).

In a symbiotic relationship with nitrogen fixing bacteria, some plants are capable of extracting elemental nitrogen gas (N_2) from the atmosphere and converting it into a NH_3, where it may be readily assimilated into organic nitrogen. A microbial process called denitrification releases nitrogen from decomposing plant matter back into the atmosphere. Denitrification converts NO_3 to the gaseous forms of N_2O and elemental N_2. Nitrogen may also be volatilized to the atmosphere as NH_3 during ammonification. The loss of nitrogen to the atmosphere is a natural mechanism that helps protect water resources from excessive levels of nitrogen (Seelig and Nowatzki, 2001).

Anthropogenic activities have effectively increased the delivery of nitrogen to water bodies. Although a variety of pathways exist for reactive nitrogen to enter aquatic systems, surface runoff from agricultural and urban areas is one of the most cited. Stormwater runoff from lawns, agricultural fields, golf courses, parks and gardens often contains relatively high concentrations of nitrogen and may reach streams in its highly soluble form (i.e., NO_3) or absorbed to soil particles as the positively charged NH_4. Industrial discharges and municipal wastewater effluents also contribute significant levels of nitrogen to stream systems as point sources (Driscoll *et al.,* 2003; Seelig and Nowatzki, 2001).

4.1.2.1 Total Nitrogen

A trend analysis was conducted using data from the Center Creek near Smithfield station. The Smithfield station had the most complete long-term TN recordset of any station in the Spring River basin. However, TN data was lacking from 1976 to 1992 and

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[10] Reactive nitrogen refers to all forms of nitrogen that are readily available to biota (largely ammonia, ammonium and nitrate).

again from 1997 to 1999. Based on available annual geomean TN data, there were no apparent trends. From 1973 to 2004 total annual TN geomeans at the Center Creek near Smithfield station ranged from approximately 2,350 µg/L in 2000 to 5,320 µg/L in 1973 (Figure 25).

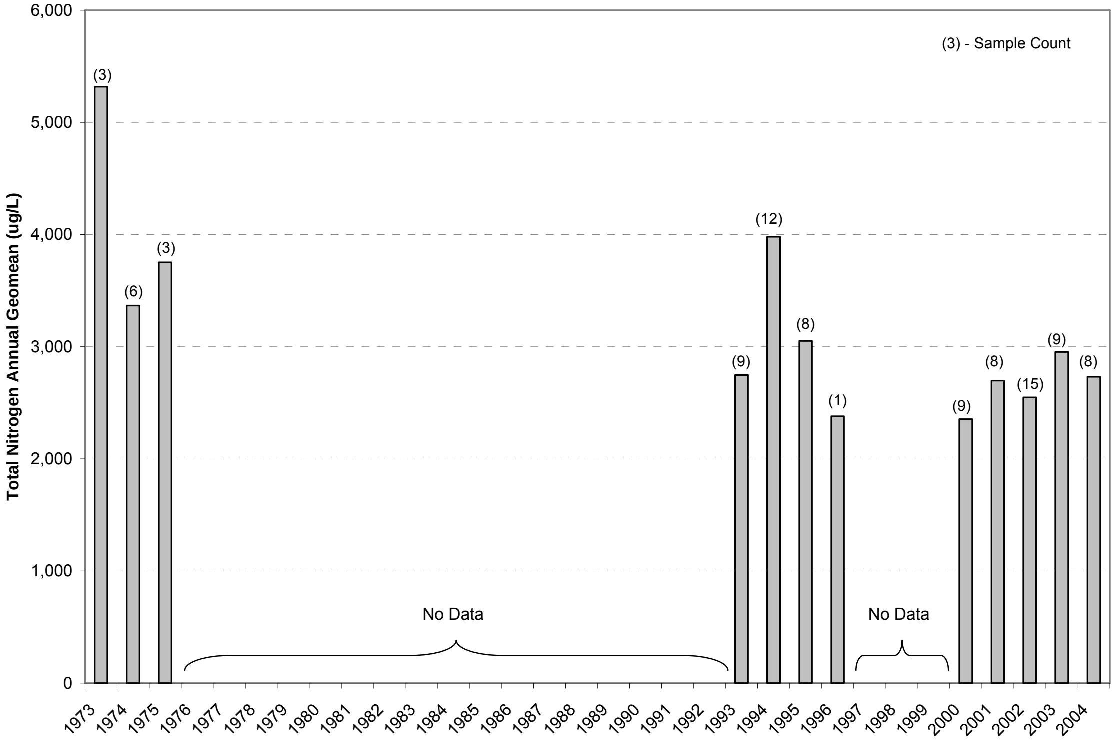

FIGURE 25. Total Nitrogen Annual Geometric Means Measured at the Center Creek near Smithfield Station

The highest levels of TN geomeans in the Spring River basin were observed in Clear Creek. TN geomeans in Clear Creek ranged from 13,925 µg/L three miles below the Monett WWTP to 15,904 µg/L one mile below the Monett WWTP (Table 9 and Figure 26). The proximity of these stations to the Monett WWTP suggests wastewater may be contributing to the elevated TN levels. Outside of Clear Creek TN geomeans ranged from 619 µg/L at Fivemile Creek at Five Mile to 5,544 µg/L at Turkey Creek near Joplin. All monitoring stations, with the exception of Fivemile Creek at Five Mile, had TN result values and geomeans greater than the Dodds *et al.* (1998) eutrophic threshold value of 1,500 µg/L (Figures 27 and 28).

TABLE 9. Total Nitrogen Statistics for the Spring River Basin

											Percentiles			
Site Number	Station Name	Begin Date	End Date	Count (#)	Median (µg/L)	Mean (µg/L)	Geomean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Std.Dev. (µg/L)	10th (µg/L)	25th (µg/L)	75th (µg/L)	90th (µg/L)
7186480	Center Cr. nr. Smithfield	11/2/1999	9/14/2004	50	2,530	2,688	2,629	1,890	5,960	645	2,088	2,335	3,007	3,282
7186600	Turkey Cr. nr. Joplin	11/2/1999	9/14/2004	57	5,400	6,266	5,544	1,540	14,200	3,236	3,154	3,870	7,940	11,774
7186690	Shoal Cr. at Pioneer	4/20/2001	10/28/2003	112	3,135	3,228	3,175	2,040	5,780	609	2,466	2,935	3,463	3,996
3239/2.0	Clear Cr. 1.5 mi.bl. Monett WWTP	6/30/1999	10/4/2000	10	16,675	16,095	15,904	12,349	20,600	2,599	13,115	13,925	17,738	18,170
3239/1.4	Clear Cr. 3 mi.bl. Monett WWTP	6/30/1999	10/4/2000	10	14,850	14,070	13,925	11,500	16,900	2,103	11,589	11,825	15,750	16,180
7187980	Fivemile Creek at Five Mile	1/8/2002	5/12/2003	15	730	661	619	260	1,020	223	364	485	820	858
7187600	Spring River nr. Baxter Springs	2/5/2002	11/4/2003	13	2,130	2,152	2,089	1,420	3,230	544	1,492	1,790	2,550	2,800

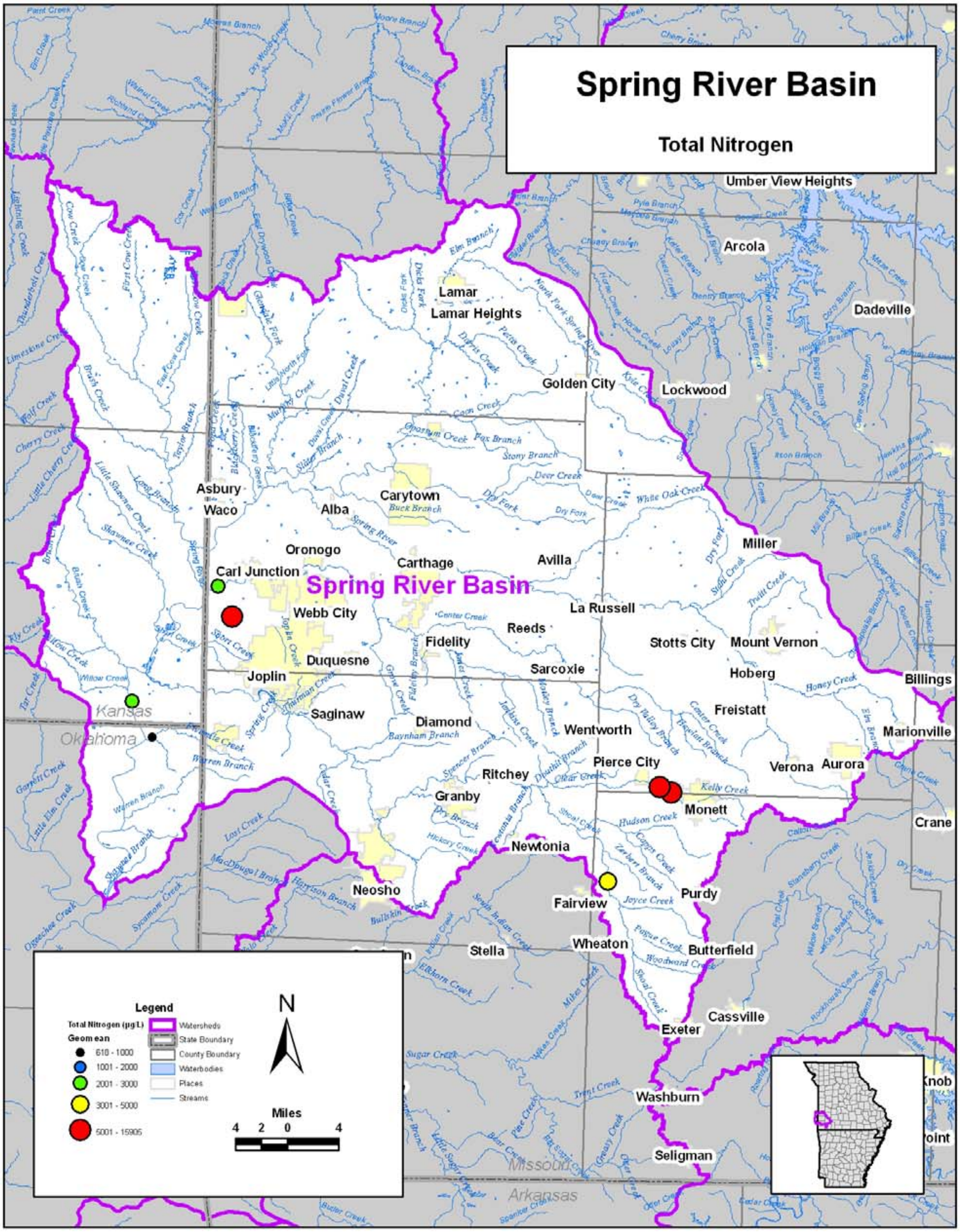

FIGURE 26. Graduated Symbol Map of Total Nitrogen Geometric Means in the Spring River Basin

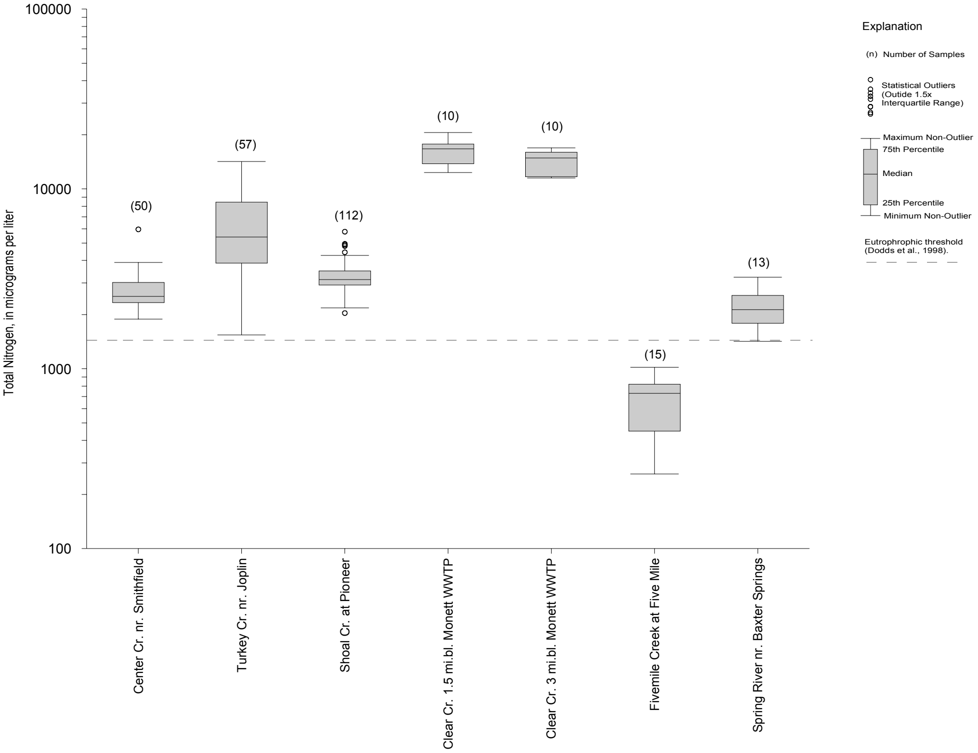

FIGURE 27. Box Plot of Total Nitrogen Levels in the Spring River Basin

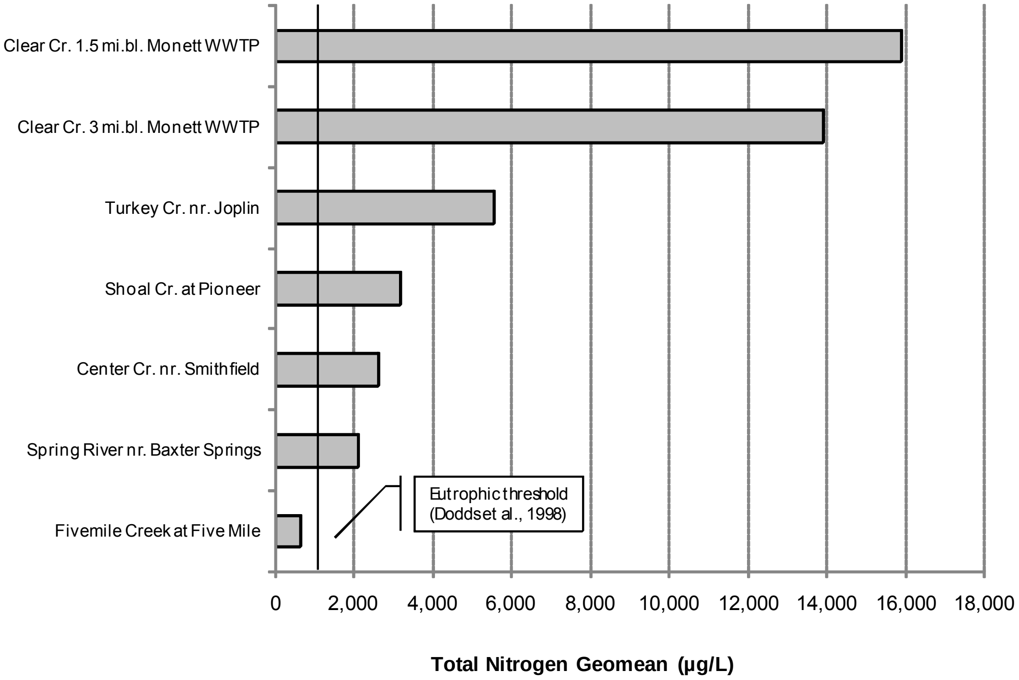

FIGURE 28. Bar Chart of Total Nitrogen Geometric Means in the Spring River Basin

4.1.2.2 Nitrate plus Nitrite Nitrogen

A trend analysis was conducted using data from the Center Creek near Smithfield station. The Smithfield station had the most complete long-term NO_3+NO_2 recordset of any station in the Spring River basin. Annual geomean NO_3+NO_2 levels appeared to decrease in the mid-1970s prior to rebounding to over 7,000 µg/L in 1980. After 1980 NO_3+NO_2 annual geomeans appeared to decrease reaching a low of approximately 2,200 µg/L in 1999. NO_3+NO_2 annual geomeans remained relatively level after 1999 ranging from approximately 2,200 µg/L to 2,560 µg/L (Figure 29).

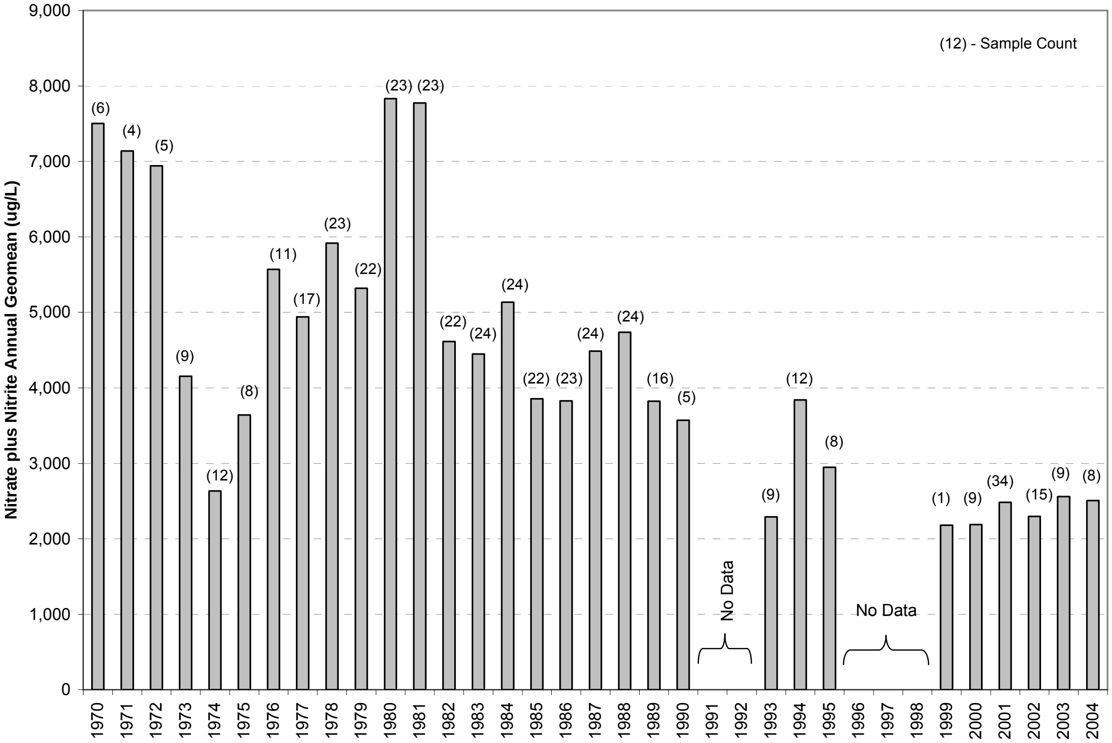

FIGURE 29. Total Nitrate plus Nitrite Annual Geometric Means Measured at the Center Creek near Smithfield Station

The spatial patterns observed with the NO_3+NO_2 data closely mimicked the TN data. The highest levels of NO_3+NO_2 were observed in Clear Creek where geomeans ranged from 4,102 µg/L 7.7 miles below the Pierce City WWTP to 14,692 µg/L 1.5 miles below the Monett WWTP (Table 10 and Figures 30, 31 and 32). NO_3+NO_2 geomeans along the Spring River ranged from 1,184 µg/L at its most downstream station (near Quapaw) to 1,669 µg/L below Empire lake. Along the Shoal Creek branch, NO_3+NO_2 geomeans ranged from 2,126 µg/L near Galena to 4,514 at Ritchey. Much like TN and TP, NO_3+NO_2 concentrations in Shoal Creek downstream of the Clear Creek confluence may to be influenced by the CAFOs and WWTPs. NO_3+NO_2 geomeans were generally the lowest along Short Creek, Cow Creek, Fivemile Creek and the lower reaches of the Spring River.

TABLE 10. Nitrate plus Nitrite Nitrogen Statistics for the Spring River Basin

Site Number	Station Name	Begin Date	End Date	Count (#)	Median (µg/L)	Mean (µg/L)	Geomean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Std.Dev. (µg/L)	Percentiles 10th (µg/L)	Percentiles 25th (µg/L)	Percentiles 75th (µg/L)	Percentiles 90th (µg/L)
371320094391100	Cow Cr. nr. Lawton	1/27/2001	11/17/2001	26	1,350	1,400	1,198	200	4,200	766	500	1,125	1,700	2,000
7186480	Center Cr. nr. Smithfield	11/2/1999	9/14/2004	76	2,355	2,461	2,416	1,370	4,560	498	1,930	2,148	2,730	3,105
7186600	Turkey Cr. nr. Joplin	11/2/1999	9/14/2004	57	4,300	4,924	4,350	1,170	11,300	2,528	2,442	3,180	6,120	8,996
370740094373000	Turkey Cr. at 110th St.	1/27/2001	11/17/2001	25	2,800	2,876	2,711	1,000	4,900	964	1,940	2,200	3,600	4,220
370524094395900	Short Cr. at Vine St.	1/27/2001	11/17/2001	25	1,700	1,800	1,202	10	4,700	1,116	320	1,300	2,100	3,180
364224094002301	Shoal Cr. nr. Ridgley	4/5/1999	3/22/2000	16	2,600	2,515	2,426	840	3,500	569	2,100	2,375	2,725	3,000
364442094003401	Woodward Cr. at mouth	4/6/1999	3/22/2000	12	2,700	2,792	2,775	2,400	3,400	323	2,510	2,600	2,825	3,290
364535094004901	Shoal Cr. at Hwy W	4/5/1999	8/27/2002	13	2,500	2,677	2,643	2,100	3,400	459	2,240	2,400	3,100	3,380
364550094003301	Pogue Cr. nr. mouth	4/5/1999	8/28/2002	13	3,700	3,969	3,942	3,400	5,000	497	3,520	3,600	4,300	4,580
364810094015501	Joyce Cr. at mouth	4/6/1999	8/27/2002	13	3,100	3,208	3,143	1,800	4,400	638	2,800	2,900	3,600	3,880
3230/7.3	Shoal Cr. at Hwy 97	10/12/1998	8/13/2004	112	2,700	2,668	2,543	1,100	5,500	804	1,600	2,175	3,100	3,600
7186690	Shoal Cr. at Pioneer	4/20/2001	10/15/2003	105	2,920	2,906	2,851	1,560	4,970	557	2,120	2,640	3,210	3,564
365253094053301	Shoal Cr. nr. Jolly	4/6/1999	8/4/2005	18	2,900	3,773	3,180	1,500	14,200	3,053	2,200	2,700	3,200	5,533
3234/0.6	Capps Cr. nr. Mouth	4/6/1999	12/13/2005	19	3,500	6,612	5,244	2,900	16,100	4,910	3,180	3,300	12,810	13,220
3239/2.0	Clear Cr. 1.5 mi.bl. Monett WWTP	6/30/1999	10/4/2000	10	14,750	14,845	14,692	11,850	18,600	2,256	12,615	12,925	16,425	17,340
3239/1.4	Clear Cr. 3 mi.bl. Monett WWTP	6/30/1999	10/4/2000	10	14,100	13,520	13,373	11,000	16,400	2,084	11,090	11,325	15,250	15,680
3238/1.6	Clear Cr. 7.7 mi.bl. Pierce City WWTP	4/7/1999	3/21/2000	12	3,900	4,150	4,102	3,400	5,800	691	3,510	3,750	4,400	4,940
365619094110801	Shoal Cr. at Ritchey	4/7/1999	12/13/2005	18	3,250	5,439	4,514	2,700	13,700	3,794	2,800	3,200	8,225	10,950
7187560	Shoal Cr. nr. Galena	2/1/2000	11/17/2001	38	2,000	2,212	2,126	1,020	3,850	637	1,600	1,700	2,675	2,993
7187980	Fivemile Creek at Five Mile	1/8/2002	5/12/2003	15	660	599	556	210	880	211	314	435	770	808
7186000	Spring River nr. Waco	1/27/2001	11/4/2003	31	1,700	1,781	1,668	770	3,200	646	1,190	1,300	2,150	2,800
Pitt-S7	Spring River bl. Empire Lake	1/27/2001	11/17/2001	26	1,750	1,815	1,669	600	3,400	729	950	1,225	2,250	2,850
7187600	Spring River nr. Baxter Springs	2/1/2000	11/4/2003	29	1,590	1,553	1,365	340	3,430	744	682	1,090	1,970	2,416
7188000	Spring River nr. Quapaw	4/11/2000	9/27/2005	13	1,200	1,252	1,184	690	2,210	442	794	970	1,490	1,750

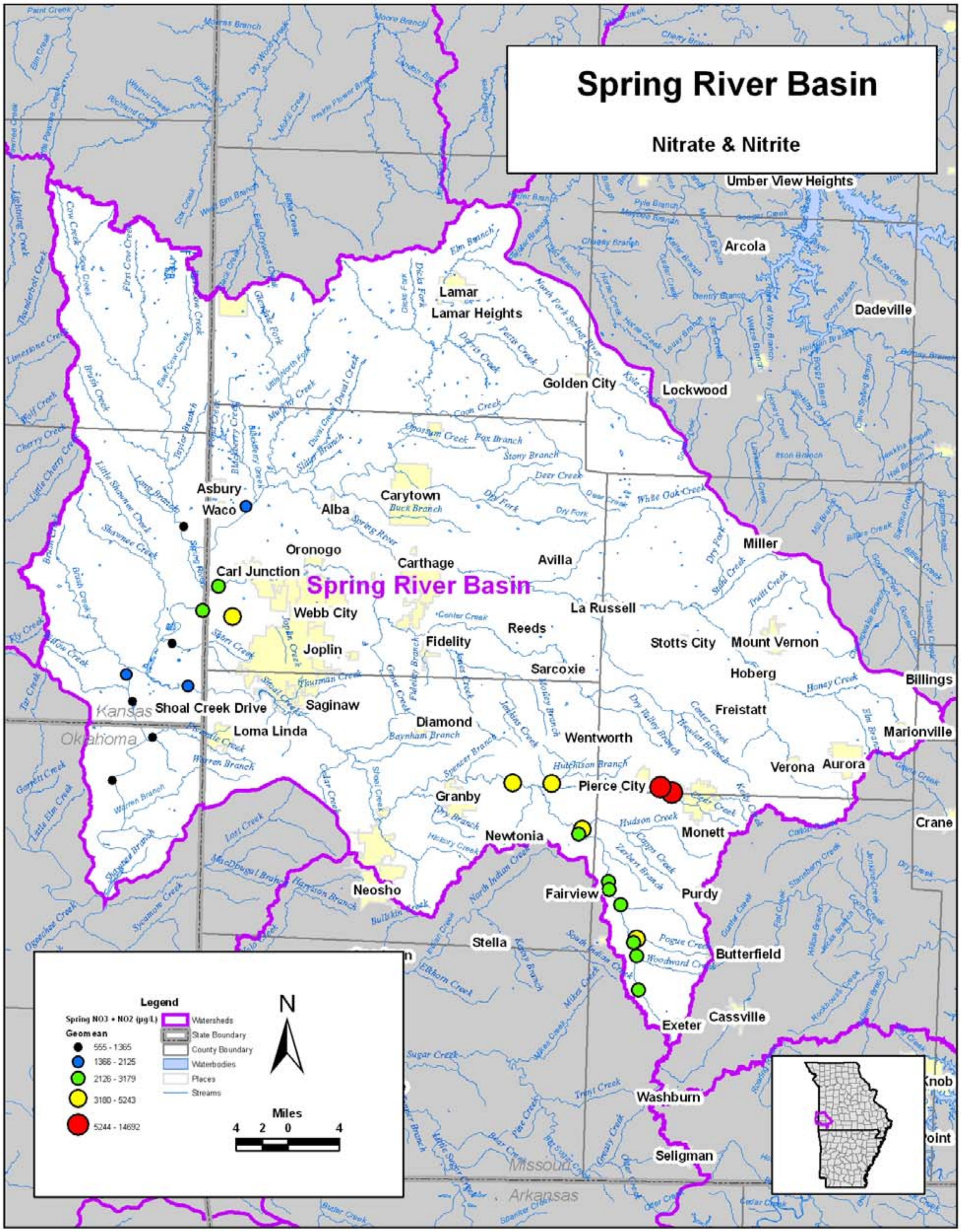

FIGURE 30. Graduated Symbol Map of Nitrite plus Nitrate Geometric Means in the Spring River Basin

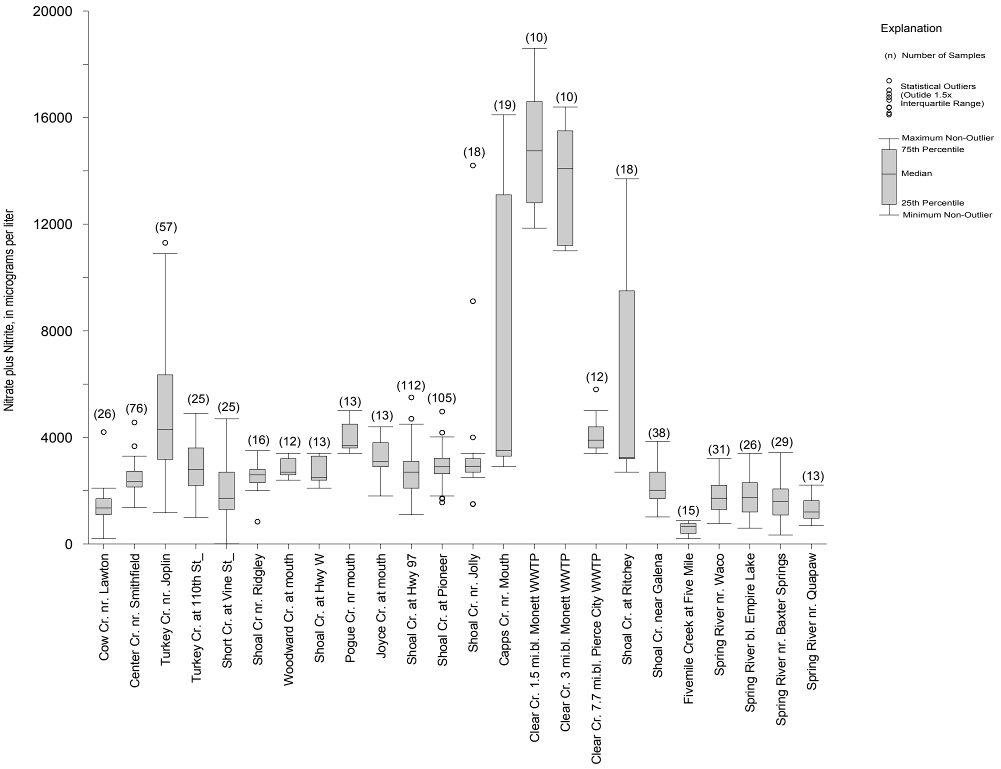

FIGURE 31. Box Plot of Nitrite plus Nitrate Levels in the Spring River Basin

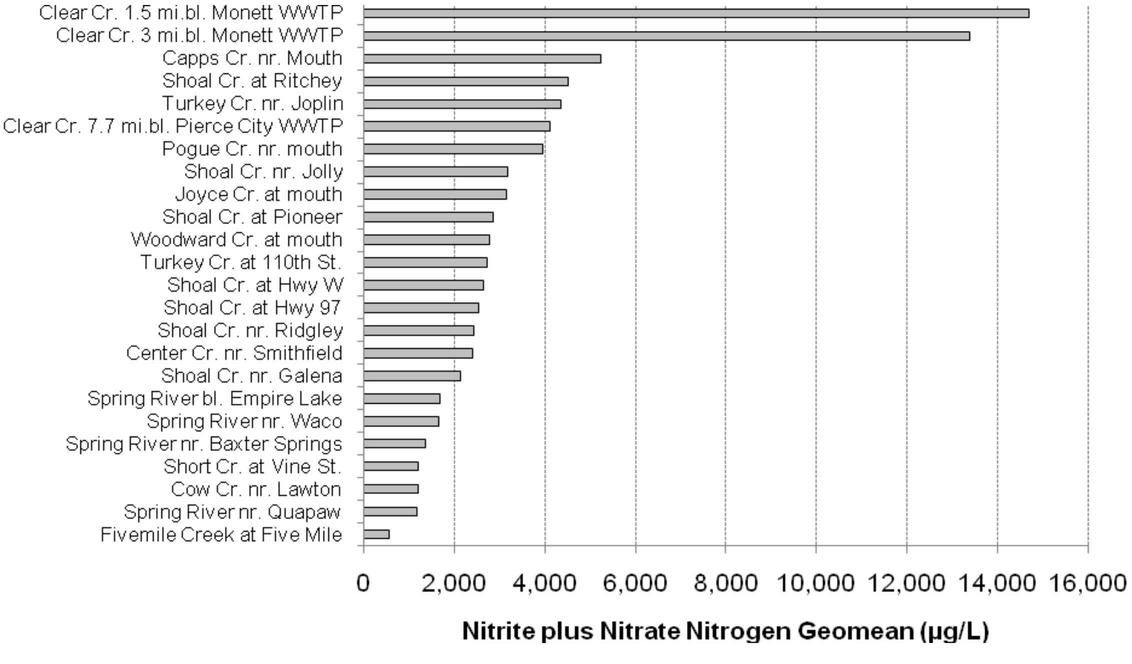

FIGURE 32. Bar Chart of Nitrite plus Nitrate Geometric Means in the Spring River Basin

4.1.3 Nutrient Limitations

The concept of nutrient limitation is considered key to understanding eutrophic systems. According to Leibig's Law of Minimum the least available element or nutrient relative to a primary producer's requirements limits its growth. Under reasonable growth conditions, algae have relatively well defined elemental and nutrient requirements. As algae grow, these organisms take up nutrients from the water in proportion to these requirements. A comparison of nutrient levels in water to algal cell stoichiometry is one method to determine the limiting nutrient. Typically, mass TN:TP ratios less than 10 are considered nitrogen-limiting and TN:TP ratios greater than 20 are considered phosphorus-limiting (Smith *et al.*, 1999).

Although TN:TP ratios offer a "first cut" at identifying the growth limitation factor, Michaelis-Menton kinetics suggest nutrients do not always limit algal growth. The Michaelis-Menton model suggests that at high nutrient concentrations, the algal growth rate is independent of the available nutrient supply. At nutrient levels approximately 5 times the half-saturation constant (k_s) (i.e., the nutrient concentration at which the algal growth rate is one-half its maximum value) algal growth is no longer limited by nutrients and becomes constant. At such high nutrient concentrations other factors such as light limit algal growth (Chapra, 1997). Literature values of k_s constants for phosphorus and nitrogen vary widely. However, EPA suggests typical k_s constants for phosphorus range from 0.5-30 μg/L and that the k_s constant for nitrogen is 25 μg/L (EPA, 1985).

TN:TP ratio calculations were limited to those stations with TN and TP data available from the same dates, since TN:TP ratios were calculated by site and date. TN:TP ratios were arithmetically averaged over all dates by site.

The analysis of TN:TP ratios suggests the limiting nutrient varies throughout the Spring River basin, if nutrients are in fact limiting (Table 11). Data from 1999 and 2000 clearly suggest that Clear Creek downstream of the Monett WWTP has excessive phosphorus levels and may be nitrogen limited. Data from Center, Shoal, and Turkey Creeks suggests the opposite (i.e., there are excessive levels of nitrogen and phosphorus may be limiting). TN:TP ratios also suggest that Turkey Creek may be slightly nitrogen limited whereas the Spring River does not appear to have any nutrient limitations.

Michaelis-Menton kinetics suggest only a few of the sites with TN:TP ratio data are nutrient limited. With the exception of Shoal Creek at Pioneer and Fivemile Creek at Five Mile, both the TN and TP geomeans at all sites far exceeded five times their half-saturation constant. Therefore, these sites are likely not nutrient limited. However, TP and TN geomeans at Shoal Creek at Pioneer and Fivemile Creek at Five Mile suggest these two waterbodies may be nutrient limited. Based on their TN:TP ratios, these two waterbodies are likely phosphorus limited if they are nutrient limited.

TABLE 11. TN:TP Ratios for Monitoring Sites in the Spring River Basin

Site Number	Station Name	TN:TP (Average)	Count	Period of Record
7186480	Center Cr. nr. Smithfield	54.49	50	11/2/1999-9/14/2004
7186600	Turkey Cr. nr. Joplin	7.88	57	11/2/1999-9/14/2004
7186690	Shoal Cr. at Pioneer	89.54	111	4/20/2001-10/7/2003
3239/2.0	Clear Cr. 1.5 mi. bl. Monett WWTP	0.97	10	6/30/1999-10/4/2000
3239/1.4	Clear Cr. 3 mi. bl. Monett WWTP	0.91	10	6/30/1999-10/4/2000
7187980	Fivemile Creek at Five Mile	50.25	15	1/8/2002-4/7/2003
7187600	Spring River nr. Baxter Springs	10.64	13	2/1/2000-11/4/2003

4.2. Escherichia coli

E. coli is an indicator organism used to test for the presence of pathenogenic bacteria. Although *E. coli* are generally not harmful, their presence in high levels indicates that fecal contamination and the potential presence for pathogens exists. Sources of *E. coli* can include wild and domestic animal waste, domestic wastewater, and sewer overflows. The EPA conducted a series of epidemiological studies that examined the relationship between swimming-associated illnesses and the microbiological quality of the waters used by recreational bathers, prior to releasing its recommended criteria in 1986 (EPA, 2003b). Based on these EPA studies, MDNR developed *E. coli* criteria for Missouri's recreational waters. MDNR designated *E. coli* whole body contact recreation (WBCR) criteria of 126 cfu/100 mL and 548 cfu/100 mL for Category A and B waters[11], respectively. The water quality criteria are expressed as a recreational season (April 1 – October 31) geometric mean. Although, bacteria criteria apply only to the recreational season, the analysis presented below is based on data collected year round.

A trend analysis was conducted using data from the Center Creek near Smithfield station. The Smithfield station had the most complete long-term *E. coli* recordset of any station in the Spring River basin. Annual geomean *E. coli* levels ranged from approximately 20 cfu/100 mL to approximately 70 cfu/100 mL from 1994 to 2004 (note that no data were available in 1997 and 1998). However, there was no apparent temporal trend based on the available dataset (Figure 33).

The *E. coli* data suggests many streams within the Shoal Creek watershed are impaired for bacteria. However, it is important to reiterate that comparison to bacteria criteria is for reference purposes only and does not constitute an analysis of standards attainment. Within the Shoal Creek watershed there are nine sampling stations in streams designated as WBCR Category A with *E. coli* geomeans in excess of their criterion of 126 cfu/100mL. These nine sites are located on Shoal Creek (5 sites), Capps Creek (2 sites), and Hickory Creek (2 sites) where *E. coli* geomeans range from 136 to 907 cfu/100mL (Table 12). One site on Pogue Creek (WBCR Category B) has an *E. coli* geomean of 589 cfu/100 mL, which is in excess of its criterion of 548 cfu/100mL. All four of these creeks with *E. coli* data in excess of criteria are either currently listed on Missouri's 303(d) List for bacteria or have a completed bacteria TMDL.

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[11] Category A applies to those water segments that have been established by the property owner as public swimming areas allowing full and free access by the public for swimming purposes and waters with existing whole body contact recreational use(s). Category B applies to waters designated for whole body contact recreation not contained in Category A.

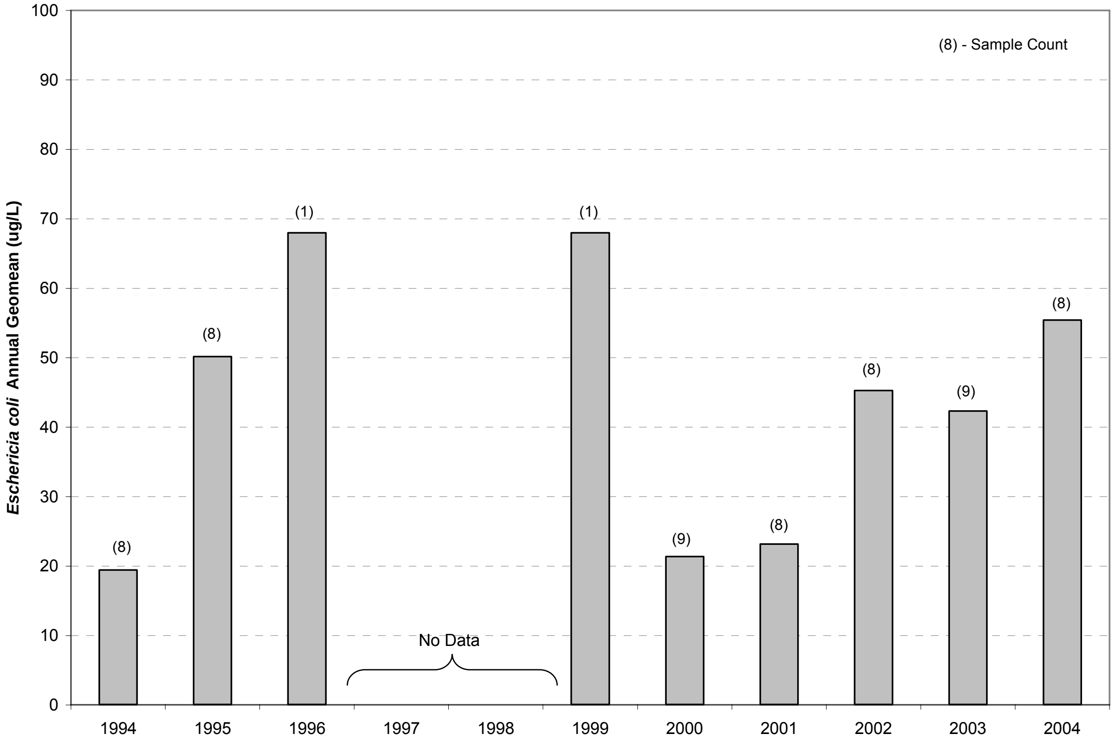


FIGURE 33. *E. coli* Annual Geometric Means Measured at the Center Creek near Smithfield Station

There do not appear to be any clear spatial trends with regards to *E. coli* concentrations in the Shoal Creek watershed. The relatively even distribution of *E. coli* levels depicted in Figure 34 suggests there may be many nonpoint sources of bacteria in the Shoal Creek watershed. Boxplot and barchart comparisons of *E. coli* concentrations also suggest that *E. coli* levels vary throughout the basin (Figures 35 and 36). These findings are consistent with this report's findings of several CAFOs in this area.

E. coli data also suggest that Carthage Spring is a significant bacteria loading source to the Spring River. Carthage Spring (a tributary to Spring River) near its mouth has an *E. coli* geomean of 4,692 cfu/100mL. The *E. coli* geomean in Spring River increases from 109 cfu/100 mL above the Carthage Spring confluence to 187 cfu/100 mL below Carthage Spring confluence. The Spring River is designated as a WBCR Category A water; therefore, appears to be impaired based on its criterion of 126 cfu/100 mL. MDNR recently included this segment of the Spring River on its 2004/2006 303(d) List.

TABLE 12. *E. coli* Statistics for the Spring River Basin

Site Number	Station Name	Begin Date	End Date	Count (#)	Median (cfu/100mL)	Geomean (cfu/100mL)	Minimum (cfu/100mL)	Maximum (cfu/100mL)	Std.Dev. (cfu/100mL)	Percentiles 10th (cfu/100mL)	 25th (cfu/100mL)	 75th (cfu/100mL)	 90th (cfu/100mL)
3160/26.9/0.1/0.4	Carthage Spring at ADM	4/19/2005	12/8/2005	17	133	89	2	870	256	9	16	467	542
3160/26.9/0.1/0.1	Carthage Spring nr. Mouth	10/21/2004	12/8/2005	18	4,820	4,692	576	55,000	13,549	1,176	2,330	11,210	19,198
7186480	Center Cr. nr. Smithfield	11/2/1999	9/14/2004	43	56	35	1	630	131	3	17	99	120
7186600	Turkey Cr. nr. Joplin	11/2/1999	9/14/2004	43	140	110	1	12,000	2,001	10	24	400	1,248
364224094002301	Shoal Cr. nr. Ridgley	4/5/1999	3/22/2000	16	71	287	7	58,000	18,359	20	32	7,825	36,000
364442094003401	Woodward Cr. at mouth	3/3/1999	3/22/2000	12	106	122	20	1,100	366	39	45	270	816
364535094004901	Shoal Cr. at Hwy W	3/3/1999	8/27/2002	16	225	193	10	11,000	2,696	26	107	383	555
364550094003301	Pogue Cr. nr. mouth	3/3/1999	8/28/2002	16	600	589	64	9,800	2,357	190	285	1,055	2,000
364810094015501	Joyce Cr. at mouth	4/6/1999	8/27/2002	13	330	348	8	46,000	12,638	50	160	860	1,612
3230/7.3	Shoal Cr. at Hwy 97	4/6/1999	8/27/2002	21	660	907	40	44,000	15,472	140	250	960	39,000
7186690	Shoal Cr. at Pioneer	3/2/1999	3/12/2002	34	326	179	1	27,000	4,615	16	106	469	1,258
365253094053301	Shoal Cr. nr. Jolly	3/2/1999	6/20/2007	45	420	488	12	55,000	11,511	100	220	687	1,661
NEWTON_95	Capps Creek at Jolly Mill Park	8/23/2006	6/20/2007	18	267	298	124	1,986	419	139	231	360	552
NEWTON_93	Jolly Mill Pond	6/6/2006	6/20/2007	11	185	192	46	4,839	1,409	48	58	334	649
NEWTON_83	Capps Creek at Jolly Mill Dr	9/20/2005	5/22/2007	28	160	237	50	4,839	985	95	120	411	905
3234/0.6	Capps Cr. nr. Mouth	3/2/1999	12/13/2005	20	120	112	14	1,300	301	22	48	230	473
3238/3.4	Clear Cr. 6 mi.bl. Pierce City WWTP	6/20/2006	6/20/2007	26	411	426	141	1,120	293	210	260	731	931
3238/1.6	Clear Cr. 7.7 mi.bl. Pierce City WWTP	3/1/1999	3/21/2000	13	230	267	24	1,700	474	74	180	700	946
365619094110801	Shoal Cr. at Ritchey	4/7/1999	12/13/2005	19	44	65	9	4,839	1,093	13	22	195	248
NEWTON_20	Shoal Creek at Old E Hwy	6/13/2005	6/20/2007	28	124	136	16	1,300	298	40	66	256	387
NEWTON_22	Shoal Creek at Allen Bridge Conserv Area	6/7/2005	6/20/2007	13	69	87	33	281	72	49	61	144	191
NEWTON_52	Shoal Creek at Lime Kiln Conserv Area	6/7/2005	6/20/2007	35	88	99	7	1,553	431	19	43	167	568
NEWTON_49	Hickory Creek at Hwy 60	6/15/2005	6/20/2007	14	117	145	64	1,073	266	67	89	179	369
NEWTON_50	Hickory Creek at Hwy 86	6/6/2005	6/20/2007	23	88	84	36	272	55	39	55	124	150
NEWTON_100	Trib to Hickory Creek at Neosho (1)	4/3/2007	6/20/2007	10	51	45	12	276	82	15	18	95	154
NEWTON_101	Trib to Hickory Creek at Neosho (2)	4/3/2007	6/20/2007	10	258	274	147	749	194	148	163	405	514
NEWTON_51	Hickory Creek at Bus Hwy 60	6/7/2005	6/20/2007	28	155	194	63	4,839	927	89	131	198	554
NEWTON_9	Cedar Creek at Old Scenic Dr	6/7/2005	6/20/2007	13	105	100	29	268	75	52	68	154	225
NEWTON_92	Shoal Cr. at Old Hwy 71	6/6/2006	6/20/2007	26	147	170	42	1,986	410	69	113	205	457
NEWTON_6	Shoal Cr. at Tipton Ford Conserv Area	6/7/2005	6/20/2007	11	147	114	26	308	86	40	68	192	210
NEWTON_94	Shoal Cr. at Wildcat Park	6/6/2006	10/18/2006	17	79	88	3	1,046	257	38	66	140	404
3160/30.0	Spring River ab. Carthage	10/21/2004	10/27/2005	18	95	109	31	371	88	65	78	171	218
3160/26.1	Spring River 0.9 mi. bl. Carthage WWTP	10/21/2004	10/27/2005	16	199	187	59	490	145	80	107	291	461
3160/23.4	Spring River 1.8 mi. bl. Carthage WWTP	10/21/2004	10/27/2005	16	114	164	68	2,420	784	73	96	171	1,315

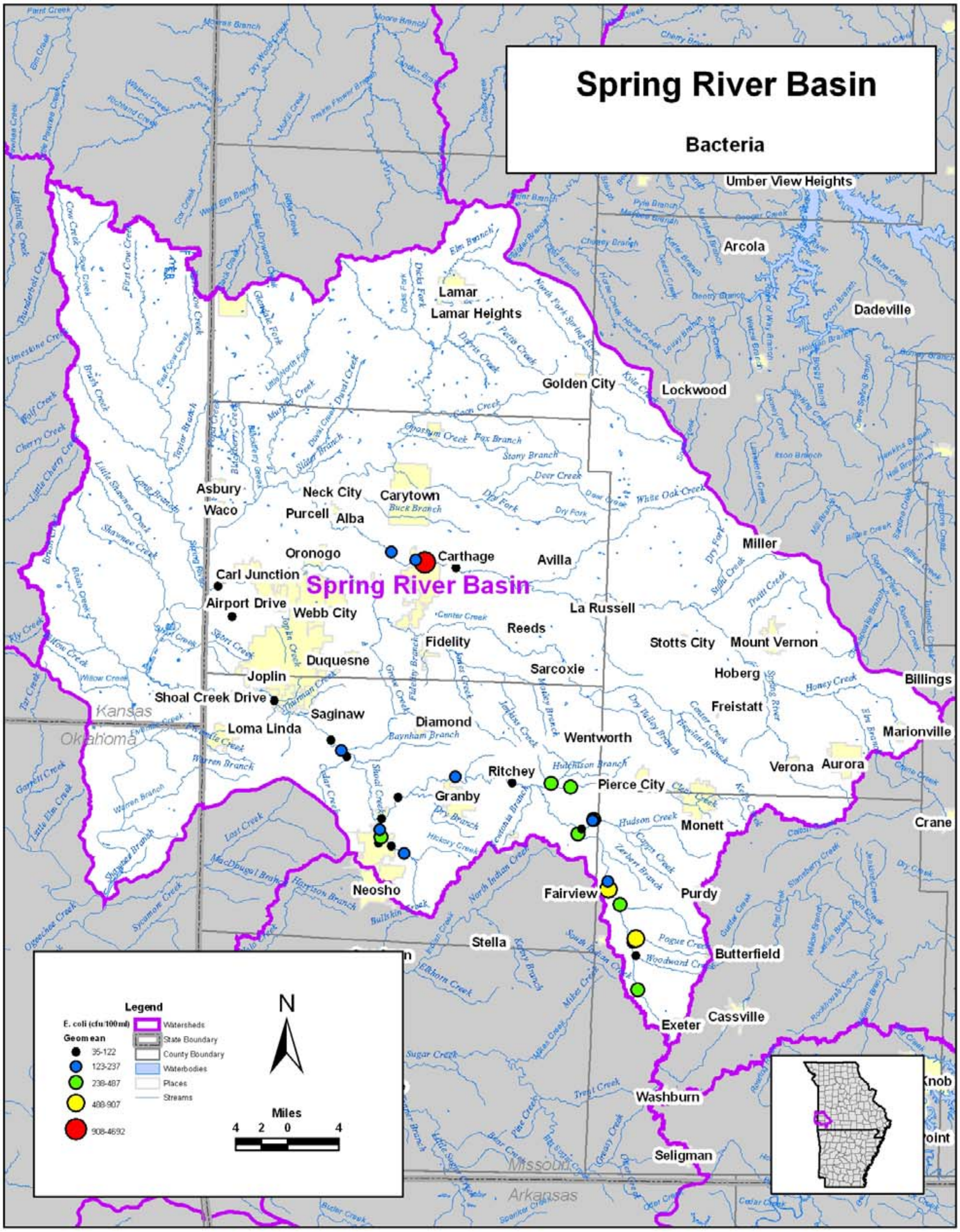


FIGURE 34. Graduated Symbol Map of *E. coli* Geometric Means in the Spring River Basin

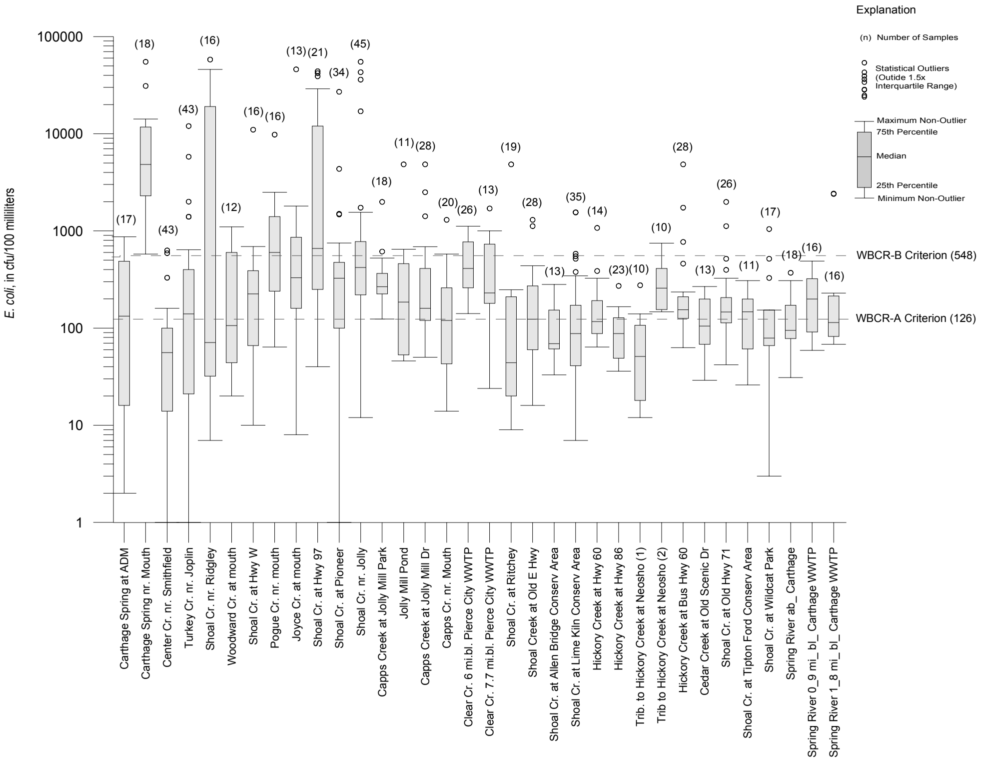


FIGURE 35. Box Plot of *E. coli* Levels in the Spring River

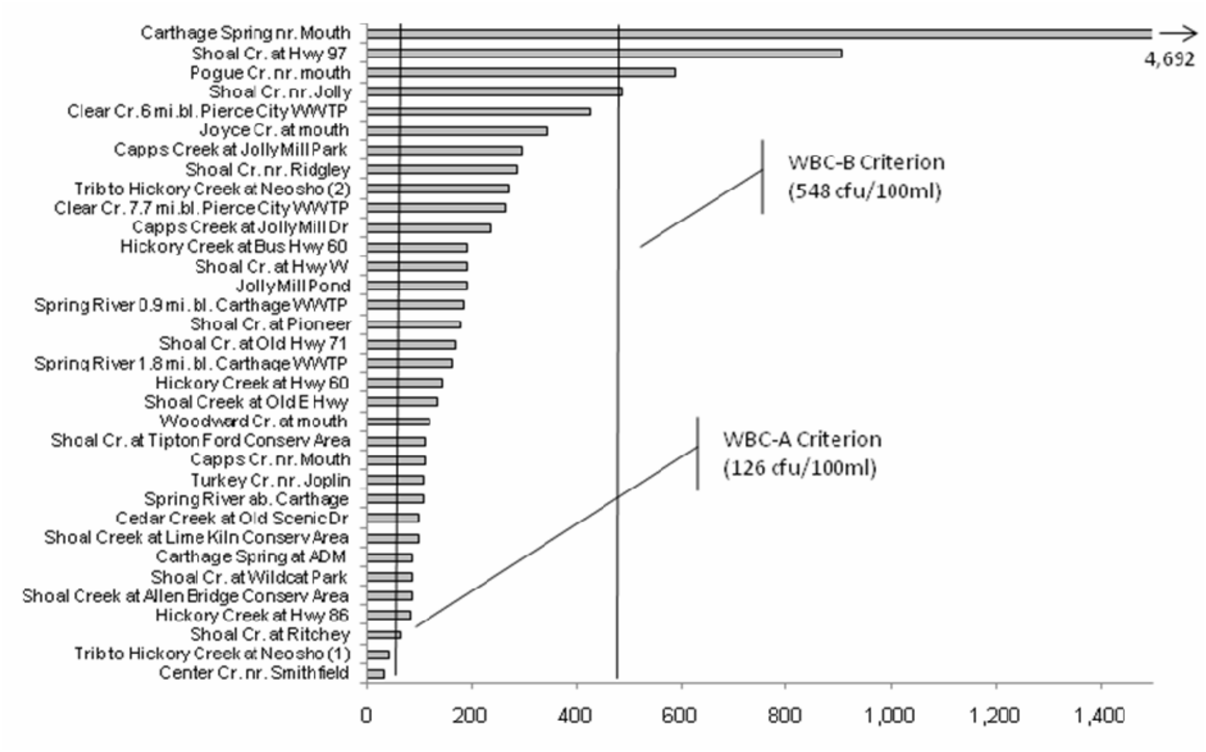


FIGURE 36. Bar Chart of *E. coli* in the Spring River Basin

4.3. Lead and Zinc

Missouri was a world leader in lead and zinc production from the mid-1800's to the 1960's. The Tri-State District in the Spring River basin mines was one of three major lead and zinc producing areas in the state (Castillon, 1996). Lead and zinc commonly form together geologically and are, therefore, mined from the same areas. Lead is used for a variety of things including storage batteries, as an earthquake shock absorbent in building foundations and until recent decades, as an additive in gasoline. Zinc is primarily an industrial metal as it is used mainly as an alloy for die-cast metal products and as an anticorrosion additive for steel (Castillon, 1996).

Mining and the resultant metal contamination is one of the primary water quality concerns in the Spring River basin. With lead and zinc as the primary mining commodities, there has been serious concern for their effect on water quality. Davis and Schumacher (1992) observed that the mining activities exerted a substantial influence on water quality, most notably on Center, Turkey and Short Creeks which drain approximately 93% of the lead-zinc mined areas of the watershed (Figure 10). These creeks drain 70%, 18%, and 5% of this area, respectively (Kiner *et al.*, 1997).

Both lead and zinc are known to be toxic to most animals. Elevated levels of lead can cause reproductive damage and may alter the neurology in some aquatic life and waterfowl. However, lead is also of particular concern from a human health perspective, with correlations between lead levels in drinking water supplies and in the blood (EPA, 1980). Lead can accumulate in humans causing chronic neurological problems such as reduced cognitive abilities, and excess lethargy. Acute poisoning can cause a variety of gastrointestinal problems including diarrhea, vomiting, poor appetite, and weight loss. Zinc's mechanism of toxicity remains largely unknown but is suspected of inhibiting the respiratory function in fish by causing direct damage to the gills (Jackson *et al.*, 2005).

The State of Missouri has defined criteria for both lead and zinc for the designated uses of protection of aquatic life (AQL) and drinking water supply (DWS). Dissolved metals apply to the AQL designation since they more closely approximate the bioavailable fraction of metal in the water column than do total recoverable metals. The dissolved fraction of metals in the water column are considered more toxic to aquatic life than the undissolved fraction, since they are readily sorbed or bound by biological tissue. Total recoverable metals apply to the DWS designation.

The toxicity of dissolved metals in the water column can depend on a number of factors including hardness. Therefore, the chronic AQL criteria for dissolved zinc and dissolved lead are expressed by the following hardness dependant equations:

Zinc (µg/L): $e^{(0.8473*\ln(\text{Hardness}) + 0.785271)}*0.986$
Lead (µg/L): $e^{(1.273*(\ln(\text{Hardness}) -4.704797)}*(1.46203 - (\ln(\text{Hardness})*0.145712)$

where, hardness is expressed in milligrams per liter as calcium carbonate.

These criteria were calculated for the Spring River basin using the 25th percentile of hardness values for all sites. The AQL lead criterion was calculated as 3.9 µg/L and the AQL zinc criterion was calculated as 159 µg/L. The lead and zinc DWS criteria are 15 µg/L and 5,000 µg/L, respectively. It should be noted that discussion of criteria presented below are for reference purposes only and should not be construed as an analysis of compliance with standards. For instance, DWS is not a designated use for any of the sampled streams; therefore, comparison to its criterion is irrelevant from a regulatory perspective. Additionally, the chronic AQL criteria are based on a 4-day average; therefore, comparison to geomeans is also irrelevant from a regulatory perspective.

Evaluations of two separate lead and zinc datasets are presented below. The first dataset is based on historical data covering approximately 6 years from 1999 to 2005 from a total of 6 monitoring stations. The second dataset is based on a short-term intensive metals survey of the Spring River basin conducted by the EPA in May of 2006 from over 160 monitoring stations. The first and second datasets are described below as the historical and EPA datasets, respectively.

4.3.1. Historical Lead Data Analysis

A trend analysis was conducted using data from the Center Creek near Smithfield station. The Smithfield station had the most complete total lead recordset of any station in the Spring River basin. While annual geomean total lead levels appear to increase significantly from 1974 to 1979, annual geomeans were calculated with relatively small sample sizes during this period (Figure 37). Since 1983 annual geomean total lead levels are near10 µg/L; however, no data were available from 1991 to 1998.

The historical dataset suggests lead levels are relatively low with respect to criteria in the Spring River basin. Total lead geomeans ranged from 3.6 µg/L at Spring River near Baxter Springs to 7.4 µg/L at Spring River near Quapaw (Table 13). The only stations with total lead maximum levels above the DWS criterion of 15 µg/L included Center Creek near Smithfield and Spring River near Quapaw. Dissolved lead geomeans ranged from 1.6 µg/L at Center Creek near Smithfield to 5.0 µg/L at the Quapaw and Wyandotte Spring River stations (Table 14). Although the dissolved lead geomeans slightly exceeded the 3.4 µg/L AQL criterion at the Spring River stations, it is important to note the uncertainty associated with these levels. All samples collected at both Spring River stations were reported as below a detection limit of 10 µg/L (identified in Table 14 as half the detection limit [i.e., 5 µg/L] for statistical purposes). Therefore, the detection limits were insufficient for determining whether dissolved lead levels were in fact above the AQL criterion of 3.4 µg/L.

The historical lead dataset is generally insufficient for making conclusions regarding spatial trends and patterns in the Spring River basin. Figures 38 and 39 appear to suggest lead levels are greatest near the mouth of the basin. However the relative lack of stations, differing sample sizes and periods of record, and frequent non-detects make these observations inconclusive. Boxplot and barchart comparisons (Figures 40 and 41) of the lead data also indicate lead levels differ throughout the basin and are highly variable at certain locations (i.e., Center Creek near Smithfield). This may indicate multiple lead sources and infrequent transient loading events. However, more sample data is needed collected under various flow conditions to verify such conclusions.

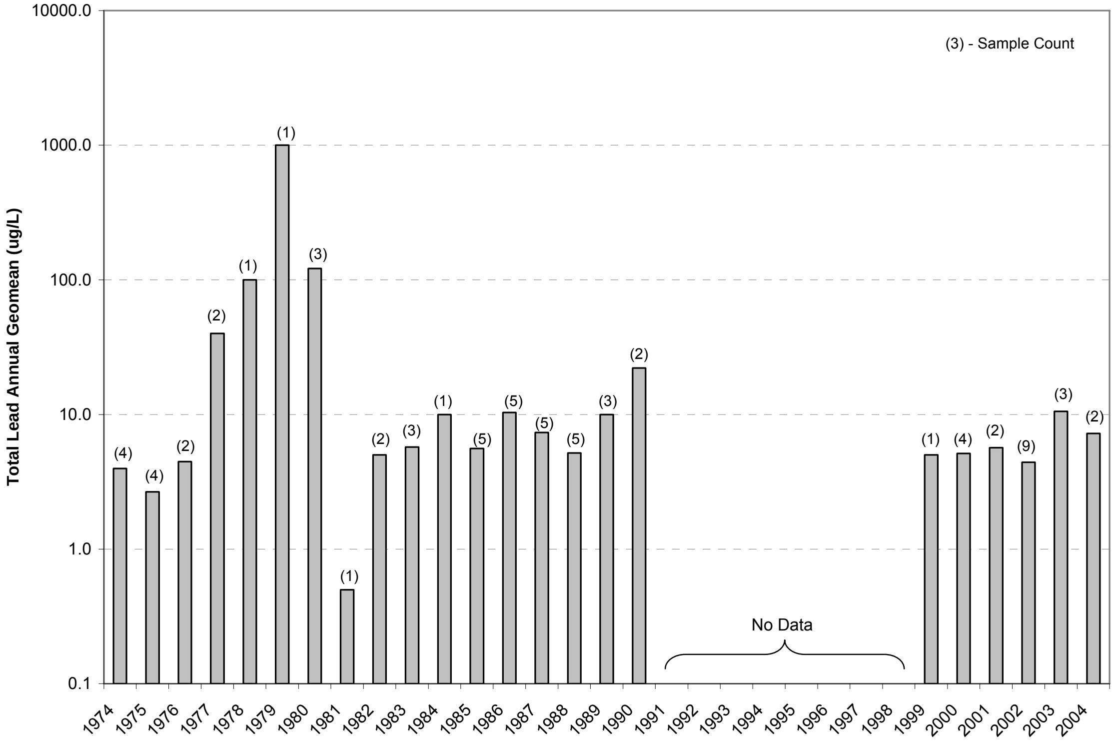


FIGURE 37. Total Lead Annual Geometric Means Measured at the Center Creek near Smithfield Station

TABLE 13. Total Lead Statistics for the Spring River Basin

Site Number	Station Name	Begin Date	End Date	Count (#)	Median (µg/L)	Mean (µg/L)	Geomean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Std.Dev. (µg/L)	Percentiles			
											10th (µg/L)	25th (µg/L)	75th (µg/L)	90th (µg/L)
7186480	Center Cr. nr. Smithfield	11/2/1999	7/21/2004	21	5.0	9.7	5.6	1.3	66.0	14.2	1.6	2.4	9.4	17.9
7186600	Turkey Cr. nr. Joplin	11/2/1999	7/20/2004	20	3.8	4.5	4.1	1.9	9.2	2.0	2.7	3.2	5.8	7.0
7187560	Shoal Cr. near Galena	2/1/2000	10/30/2001	12	3.3	4.6	4.0	2.0	12.0	2.9	2.5	2.7	5.4	8.1
7187600	Spring River nr. Baxter Springs	2/1/2000	11/4/2003	29	3.8	4.1	3.6	0.5	13.5	2.3	2.0	2.8	4.6	5.7
7188000	Spring River nr. Quapaw	3/16/2000	9/27/2005	13	5.0	12.9	7.4	2.9	69.4	19.0	3.3	5.0	10.6	30.2

TABLE 14. Dissolved Lead Statistics for the Spring River Basin

Site Number	Station Name	Begin Date	End Date	Count (#)	Median (µg/L)	Mean (µg/L)	Geomean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Std.Dev. (µg/L)	Percentiles			
											10th (µg/L)	25th (µg/L)	75th (µg/L)	90th (µg/L)
7186480	Center Cr. nr. Smithfield	11/2/1999	7/21/2004	15	0.7	10.9	1.6	0.3	50.0	20.3	0.3	0.4	3.8	50.0
7186600	Turkey Cr. nr. Joplin	11/2/1999	7/20/2004	14	1.2	11.6	2.5	0.7	50.0	20.8	1.0	1.1	1.5	50.0
7188000	Spring River nr. Quapaw	3/4/2004	9/27/2005	10	5.0	5.0	5.0	5.0	5.0	0.0	5.0	5.0	5.0	5.0
7188180	Spring River nr. Wyandotte	1/18/2004	8/17/2005	10	5.0	5.0	5.0	5.0	5.0	0.0	5.0	5.0	5.0	5.0

Note: Statistics from the Center and Turkey Creek stations may be skewed by erroneous data. The USGS reported three dissolved lead values for each of these two stations as below a reporting limit of 100 ug/L (for statistical purposes values reported as less than reporting limits are set to half this value). Total lead values for the same dates at the same stations were reported as significantly less than 100 ug/L. Therefore, it appears that the reporting limit identified by the USGS of 100 ug/L may be erroneous. Additionally, it is important to note that all samples from the Spring River stations were below a reporting limit of 10 ug/L, which is reported here as 5 ug/L for statistical purposes. Therefore, the actual dissolved lead concentration from the Spring River stations cannot be known with any certainty.

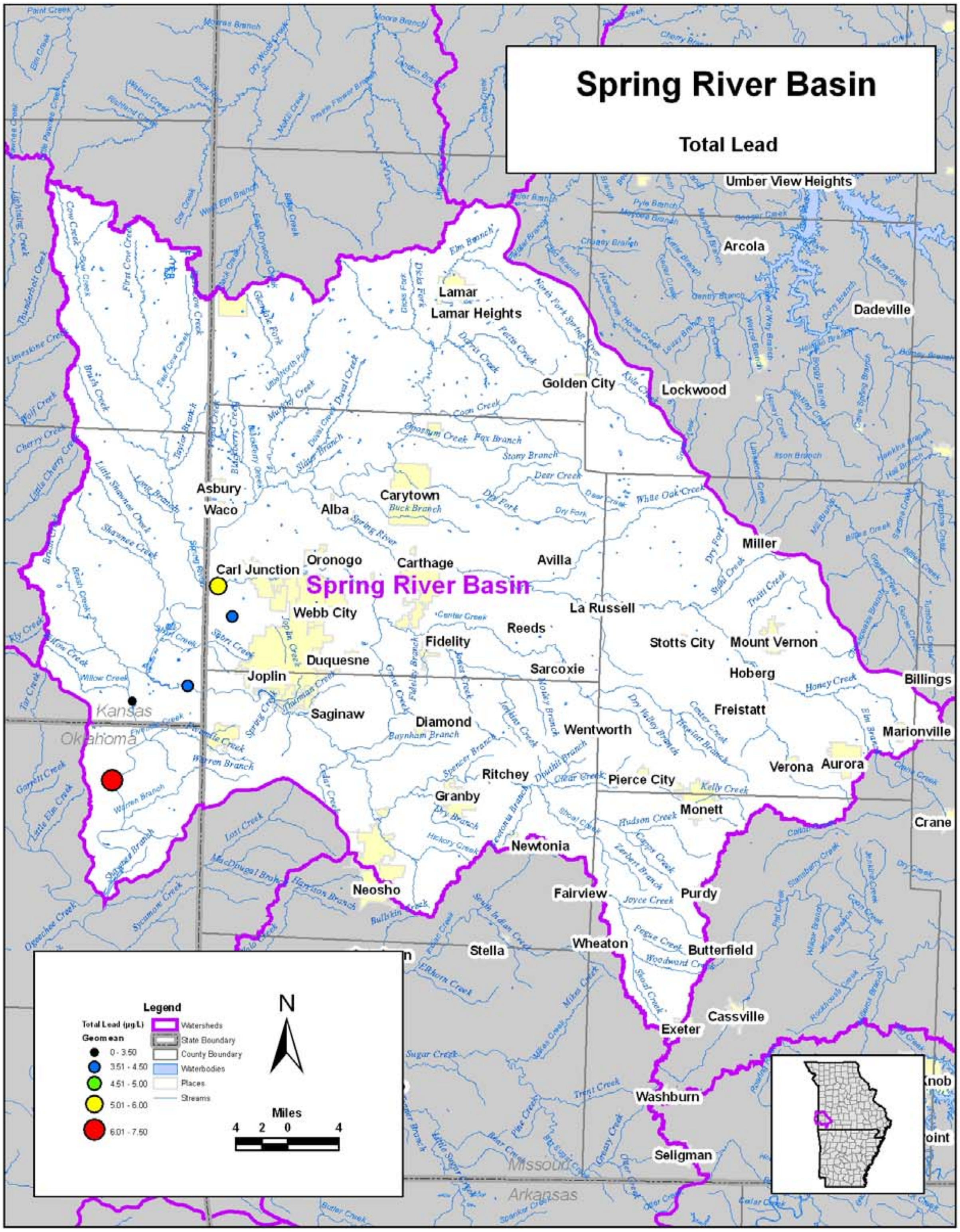


FIGURE 38. Graduated Symbol Map of Total Lead Geometric Means in the Spring River Basin

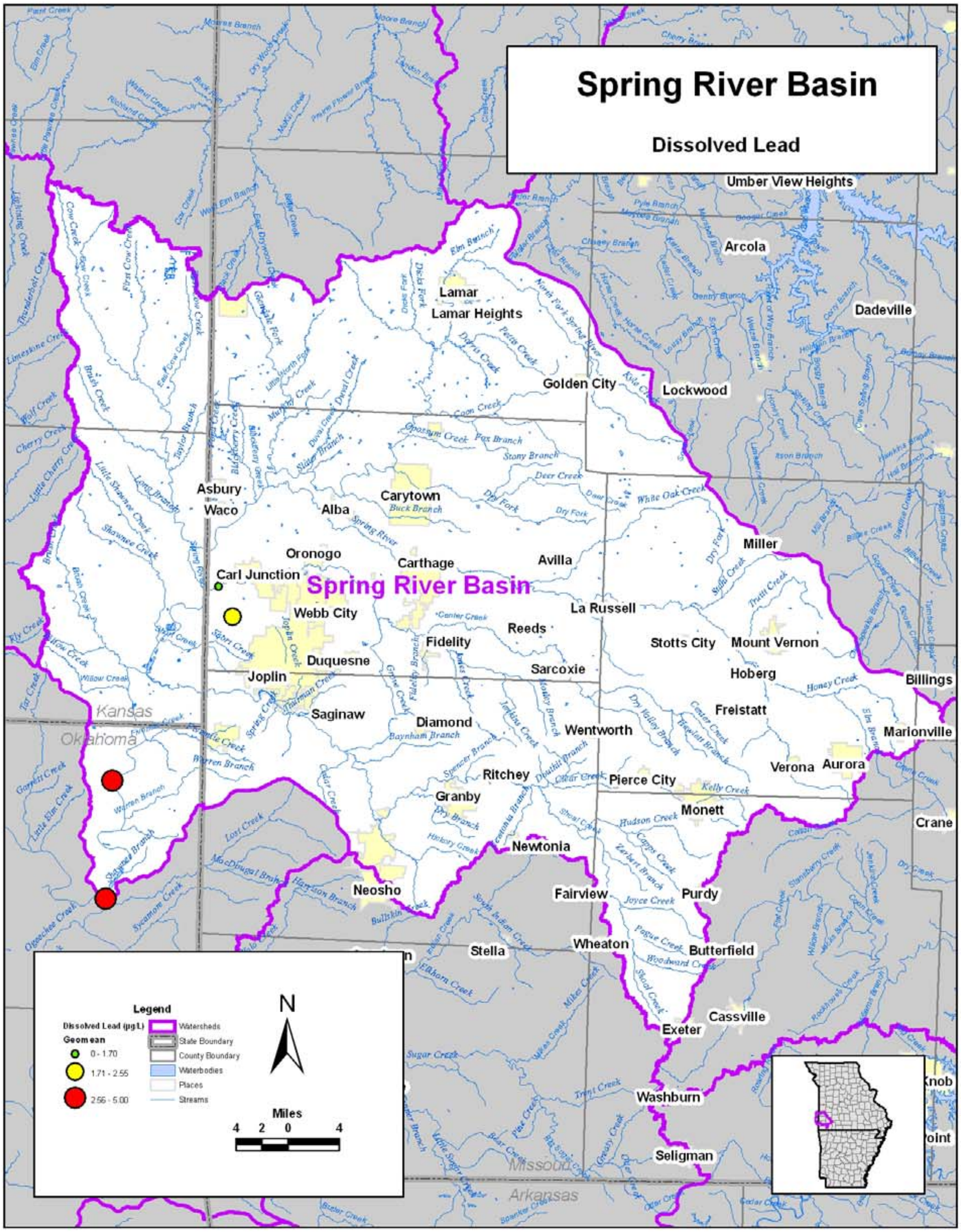


FIGURE 39. Graduated Symbol Map of Dissolved Lead Geometric Means in the Spring River Basin

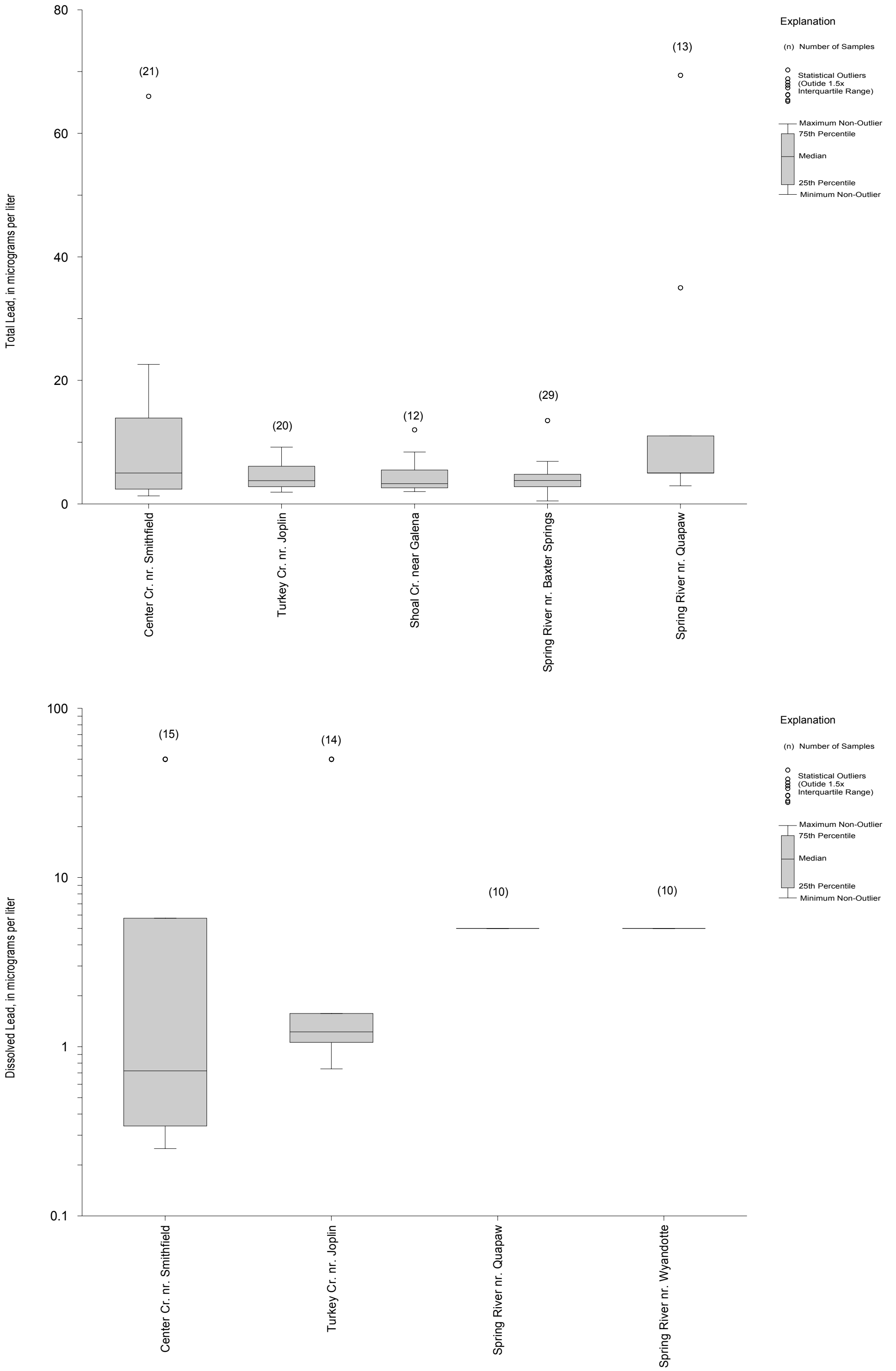
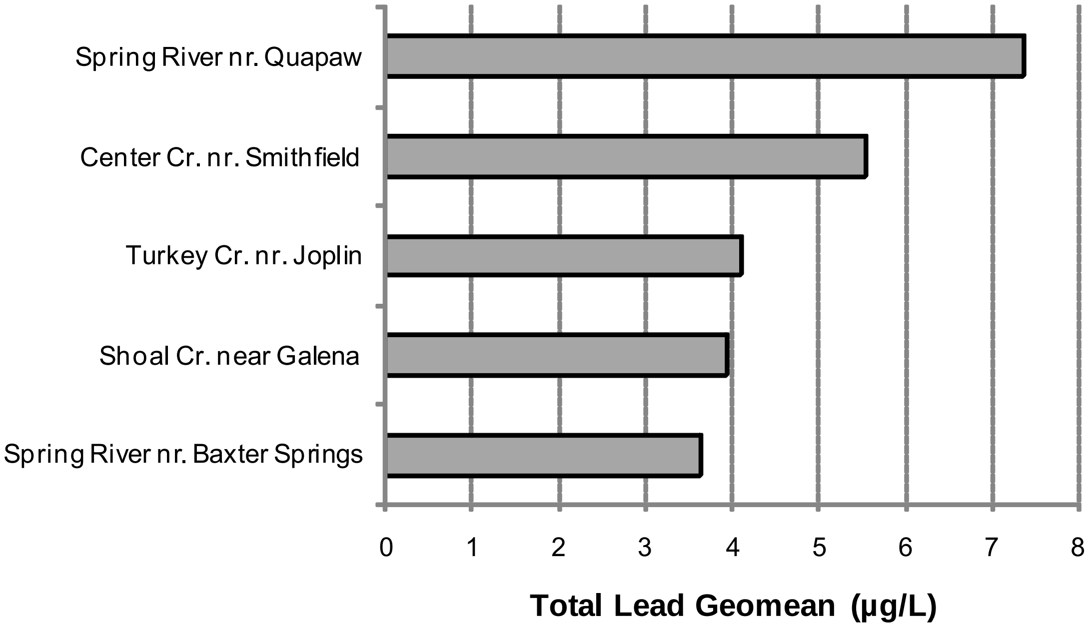


FIGURE 40. Boxplots of Total and Dissolved Lead Levels in the Spring River Basin



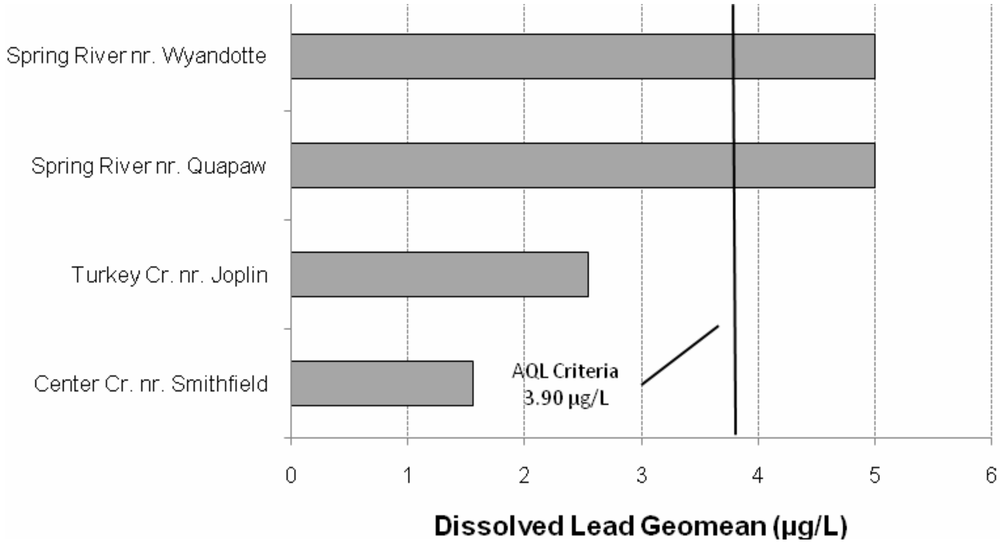


FIGURE 41. Barcharts of Total and Dissolved Lead Geomeans in the Spring River Basin

4.3.1. Historical Zinc Data Analysis

A trend analysis was conducted using data from the Center Creek near Smithfield station. The Smithfield station had the most complete total zinc recordset of any station in the Spring River basin. Annual geomean total zinc levels appear to decrease in the 1970s from a high of approximately 995 µg/L in 1975 to a low of 305 µg/L in 1978 (Figure 42). Throughout the 1980s, annual geomean total zinc levels range from approximately 370 µg/L to 520 µg/L with no apparent trend. Data are not available throughout most of the 1990s. Annual geomean total zinc levels after 1999 appear to decrease from levels in the 1980s. From 1999 to 2004 total annual zinc geomeans ranged from approximately 240 µg/L to 370 µg/L.

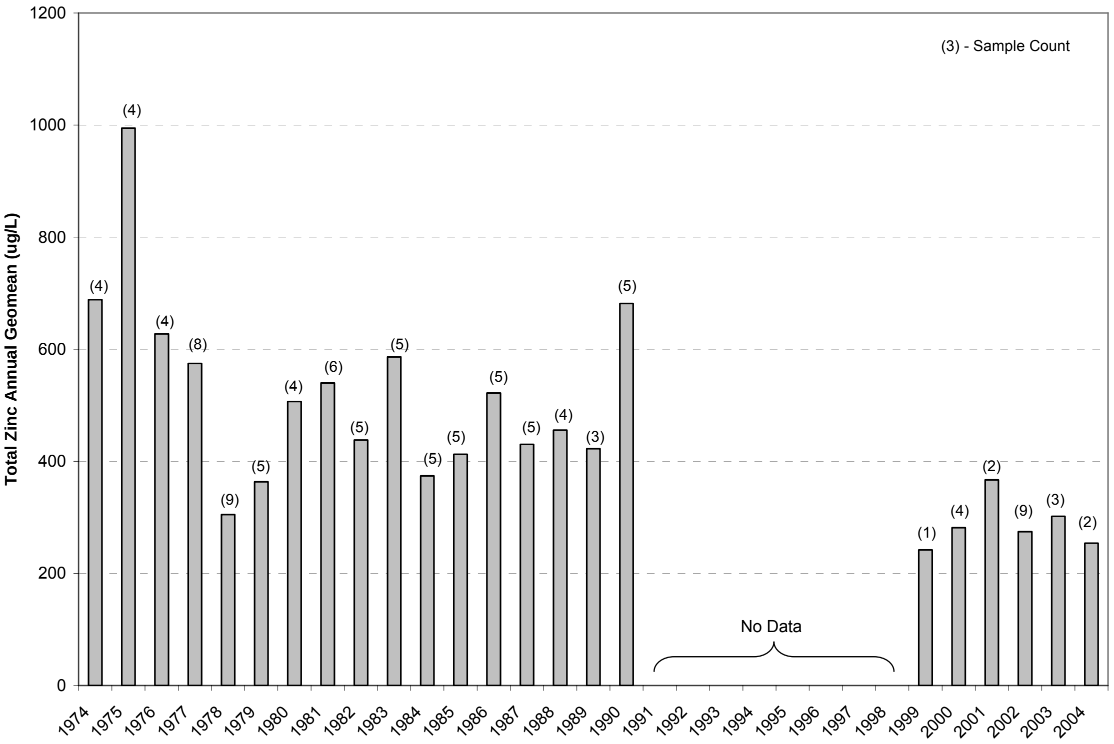


FIGURE 42. Total Zinc Annual Geometric Means Measured at the Center Creek near Smithfield Station

The historical dataset suggests zinc levels are relatively elevated with respect to criteria at few locations within the Spring River basin. Total zinc geomeans ranged from 39.2 µg/L at Shoal Creek near Galena to 383 µg/L at Turkey Creek near Joplin (Table 15). The maximum observed total zinc level (i.e., 960 µg/L at Spring River near Quapaw) was significantly less than the DWS criterion of 5,000 µg/L. However, dissolved zinc geomeans exceeded the AQL criterion of 159 µg/L at two stations. Center Creek near Smithfield and Turkey Creek near Joplin had dissolved zinc geomeans of 180 µg/L and 334 µg/L, respectively (Table 16).

Similar to the historical lead data, the lack of historical zinc data throughout the Spring River basin prohibits making many definitive conclusions regarding spatial trends and patterns. Figures 43 and 44 indicate the greatest zinc levels are in the vicinity of Carl Junction northwest of Joplin. However, there are too few monitoring stations to make any conclusive spatial inferences. Although little may be concluded regarding spatial patterns, boxplot and barchart comparisons (Figures 45 and 46) suggest zinc impact levels vary significantly in the Spring River basin. Relative to other monitoring stations, zinc levels appear low at Shoal Creek near Galena and Spring River near Wyandotte. The low zinc levels potentially make the Galena and Wyandotte stations good candidates for potential future reference sites.

TABLE 15. Total Zinc Statistics for the Spring River Basin

Site Number	Station Name	Begin Date	End Date	Count (#)	Median (µg/L)	Mean (µg/L)	Geomean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Std.Dev. (µg/L)	Percentiles			
											10th (µg/L)	25th (µg/L)	75th (µg/L)	90th (µg/L)
7186480	Center Cr. nr. Smithfield	11/2/1999	7/21/2004	21	271.0	300.4	283.6	149.0	700.0	114.9	188.0	242.0	361.0	371.0
7186600	Turkey Cr. nr. Joplin	11/2/1999	7/20/2004	20	356.0	392.9	383.1	258.0	633.0	96.5	315.9	333.0	416.8	494.6
7187560	Shoal Cr. nr. Galena	2/1/2000	10/30/2001	12	75.5	69.1	39.2	0.1	103.0	32.0	16.3	64.8	89.0	95.6
7187600	Spring River nr. Baxter Springs	2/1/2000	11/4/2003	29	154.0	158.9	143.1	60.0	329.0	72.4	78.4	94.0	204.0	273.0
7188000	Spring River nr. Quapaw	4/11/2000	9/27/2005	12	155.0	270.8	182.8	60.0	960.0	282.5	72.0	100.5	265.0	653.5

TABLE 16. Dissolved Zinc Statistics for the Spring River Basin

Site Number	Station Name	Begin Date	End Date	Count (#)	Median (µg/L)	Mean (µg/L)	Geomean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Std.Dev. (µg/L)	Percentiles			
											10th (µg/L)	25th (µg/L)	75th (µg/L)	90th (µg/L)
7186480	Center Cr. nr. Smithfield	11/2/1999	7/21/2004	15	186.0	188.9	180.3	93.0	327.0	59.6	121.2	160.0	207.0	259.6
7186600	Turkey Cr. nr. Joplin	11/2/1999	7/20/2004	14	356.5	345.2	334.9	199.0	488.0	85.0	241.7	282.3	401.8	443.8
7188180	Spring River nr. Wyandotte	1/18/2004	8/17/2005	10	20.0	22.1	15.0	2.5	40.0	15.1	2.5	9.5	37.5	40.0

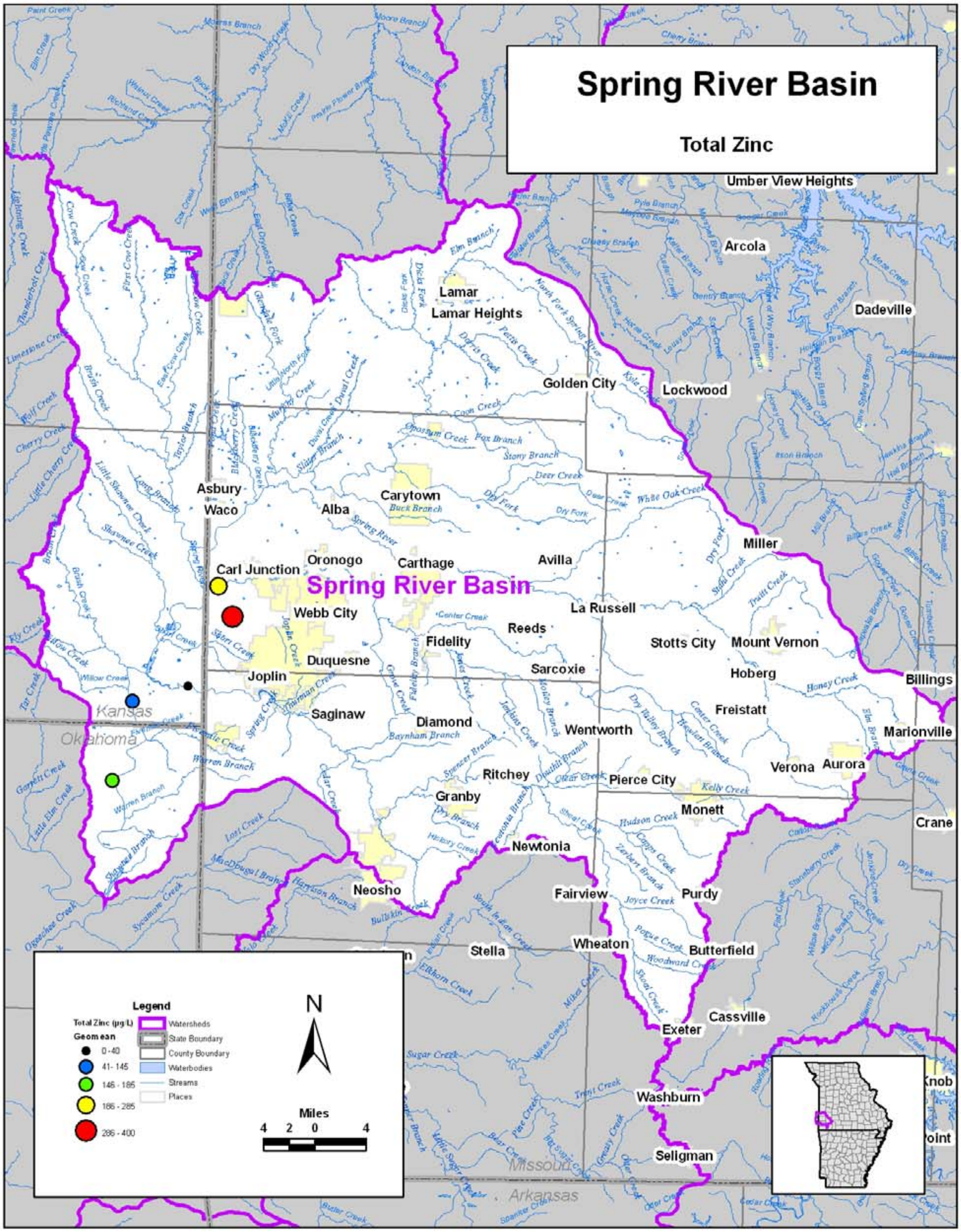


FIGURE 43. Graduated Symbol Map of Total Zinc Geometric Means in the Spring River Basin

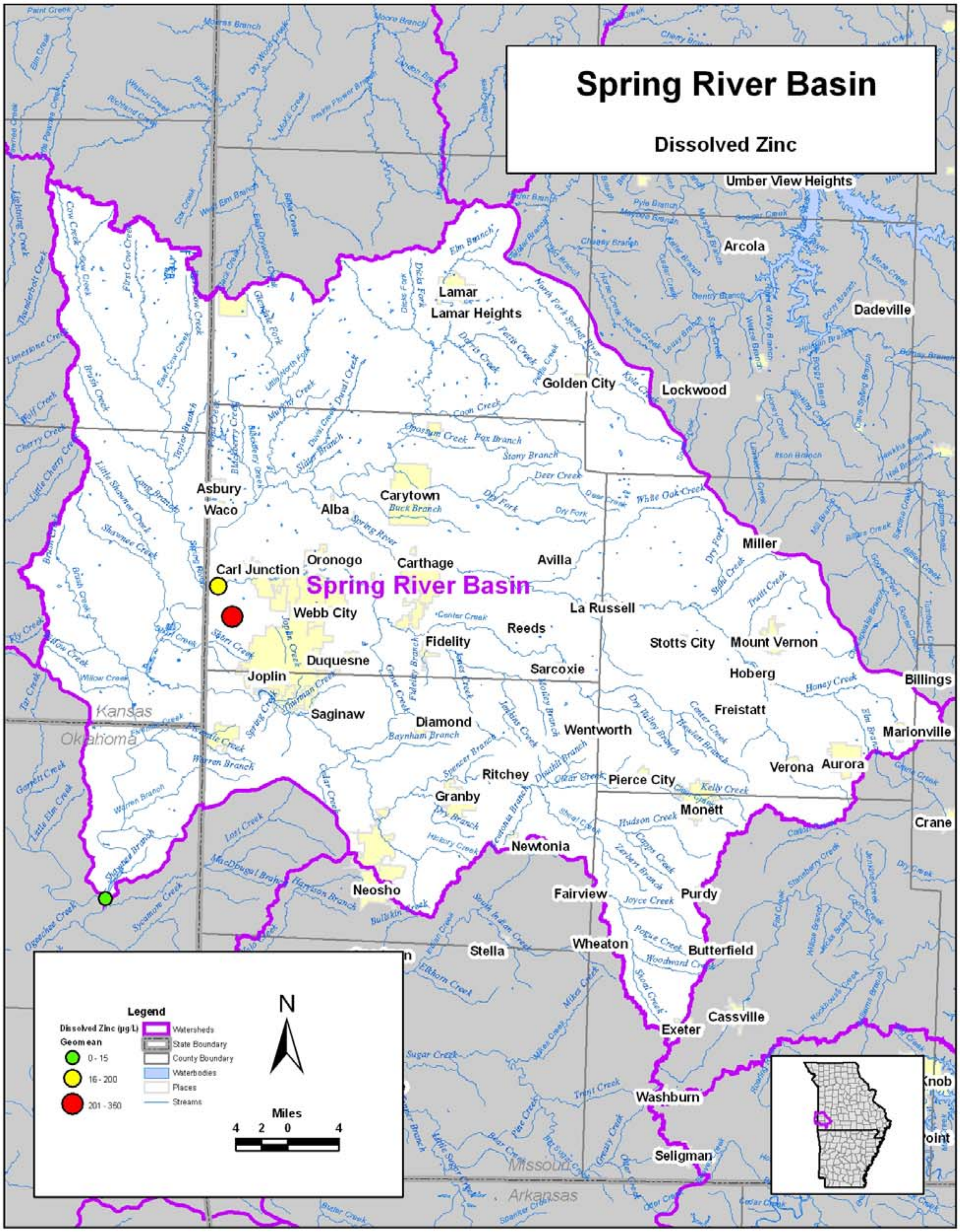


FIGURE 44. Graduated Symbol Map of Dissolved Zinc Geometric Means in the Spring River Basin

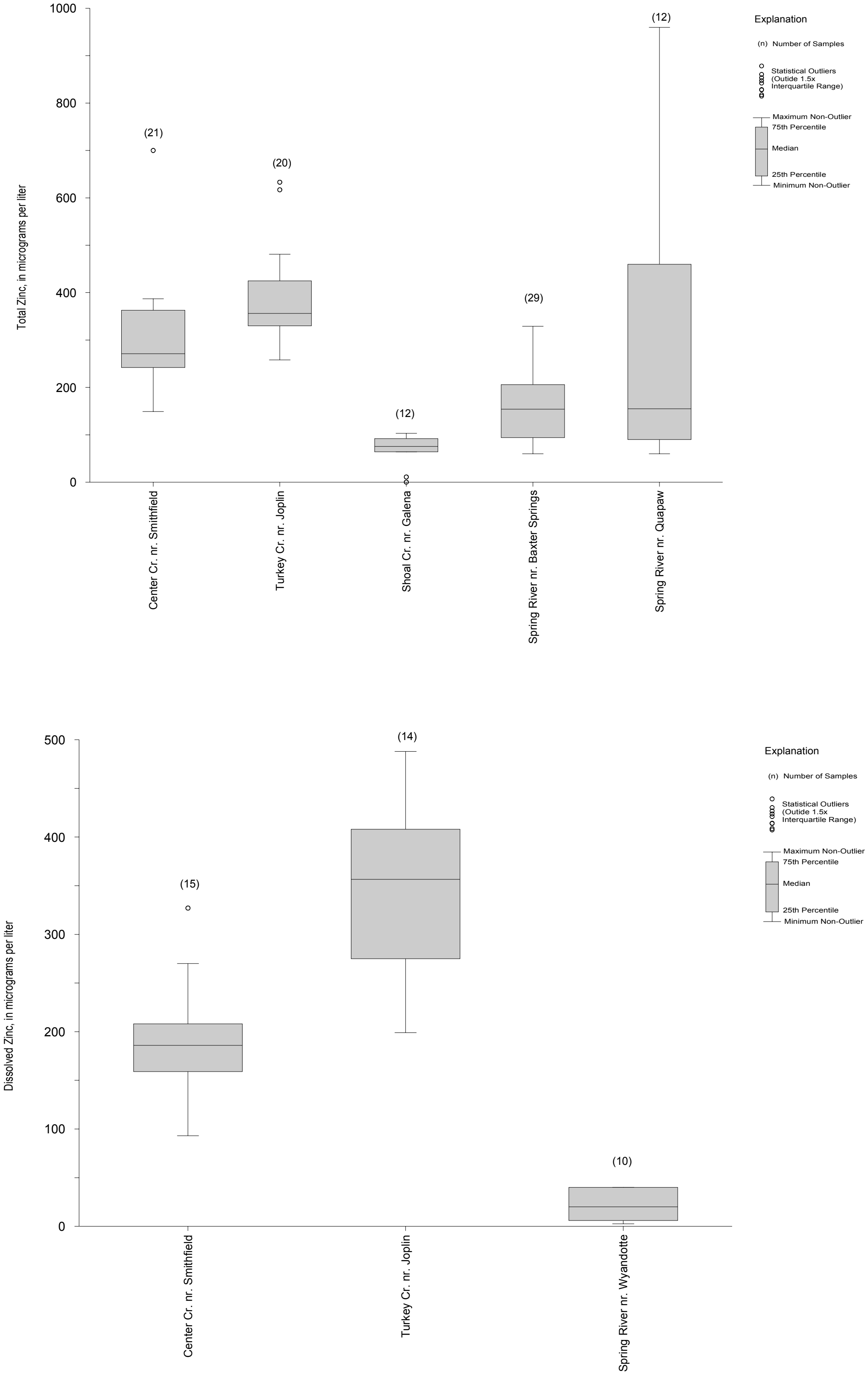
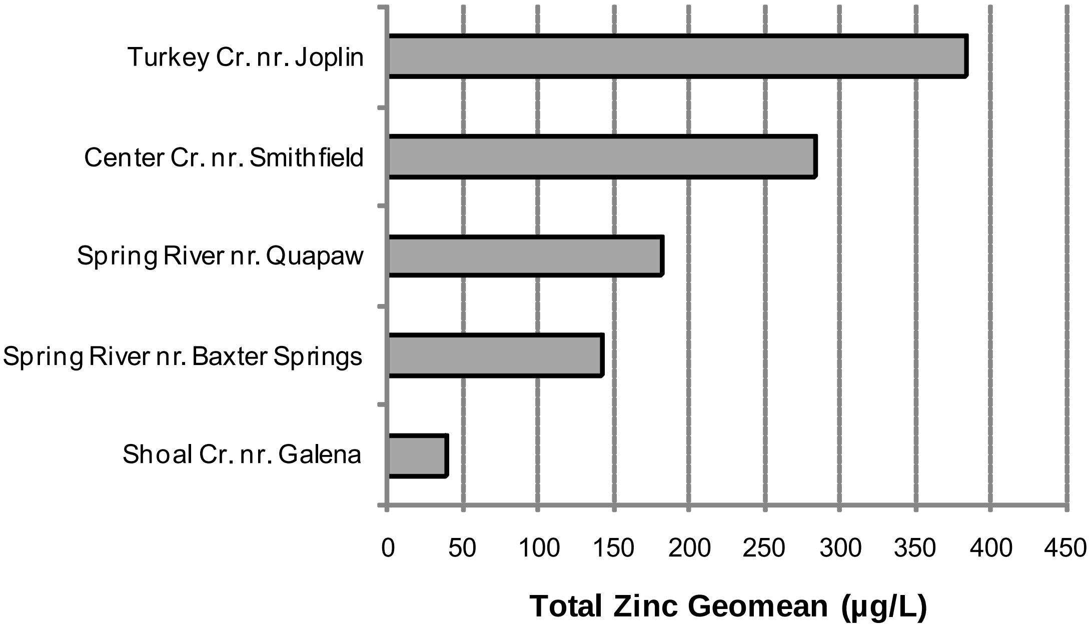


FIGURE 45. Boxplot of Total and Dissolved Zinc Levels in the Spring River Basin



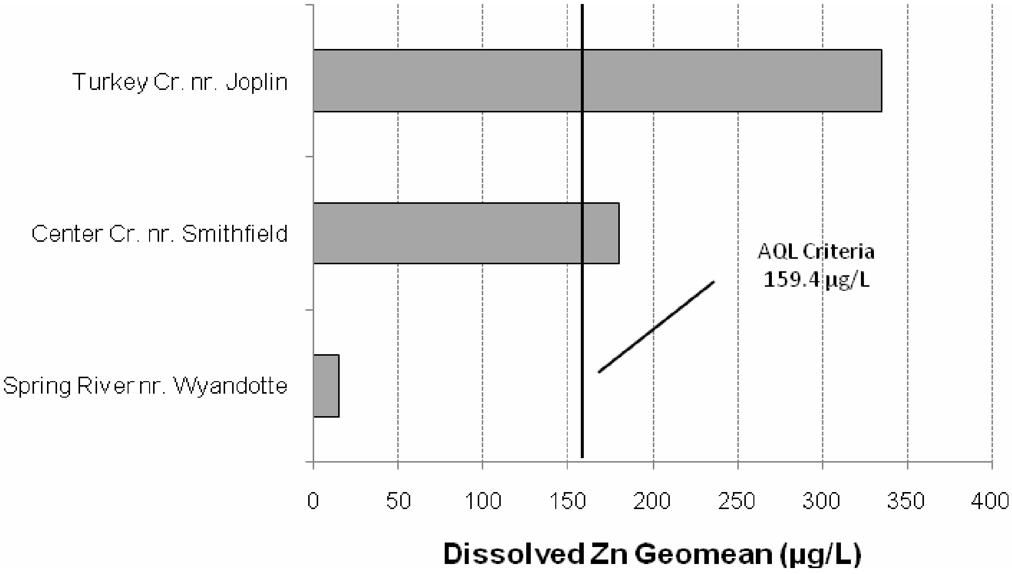


FIGURE 46. Barcharts of Total and Dissolved Zinc Geomeans in the Spring River Basin

4.3.2. May 2006 EPA Metals Study Data

In May 2006 EPA conducted a short-term intensive study of metal concentrations in the Spring River basin. Data from this study were analyzed separately from the historical data summarized above for a couple reasons. The historical data were collected from a relatively few stations over several years. In contrast, the EPA data were collected from a relatively large number of stations over a very short period. With few exceptions, only one sample was collected from each of the over 160 stations in the Spring River basin during the May 2006 study. Due to these differences, it was considered more appropriate to analyze the EPA data as its own dataset. Furthermore, the minimum sample size of at least 10 samples, applied to the historical data, would have precluded any analysis of the EPA data.

Over 20 different metals were analyzed as part of the May 2006 EPA study. However, for purposes of this report, only the lead and zinc data were assessed. It should also be noted that not all lead and zinc data from the EPA study were included in this analysis. Data from unidentifiable stations were ignored since their locations were unknown. Furthermore, data from stations outside of the Spring River basin were not considered.

4.3.2.1. EPA Lead Data

Analysis of EPA data suggests significant lead loading sources may be limited to a few streams. Geomeans of total lead data grouped by stream never exceeded the DWS criterion of 15.0 µg/L (Table 17). However, multiple stations in Center Creek and Spring River did exceed the DWS total lead criterion (Figure 47). The greatest concentration of total lead was observed in Center Creek at 41.0 µg/L. The only station with a dissolved lead concentration greater than the detection limit of 10 µg/L was in Willow Creek (Table 18 and Figure 48). It should be noted that the dissolved lead detection limit exceeds the AQL criterion of 3.9 µg/L.

TABLE 17. Total Lead Statistics from EPA's May 2006 Spring River Basin Study

Stream	Site Count	Sample Count	Samples Below Detection Limit (#)	Median (µg/L)	Mean (µg/L)	Geomean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Std. Dev. (µg/L)	Percentiles			
										10th (µg/L)	25th (µg/L)	75th (µg/L)	90th (µg/L)
North Fork Spring River	5	8	8	5.0	5.0	5.0	5.0	5.0	0.0	5.0	5.0	5.0	5.0
Cow Creek	5	5	5	5.0	5.0	5.0	5.0	5.0	0.0	5.0	5.0	5.0	5.0
Center Creek	31	36	25	5.0	10.1	7.6	5.0	41.0	9.1	5.0	5.0	14.4	24.3
Turkey Creek	16	19	18	5.0	5.4	5.3	5.0	11.4	1.6	5.0	5.0	5.0	5.0
Short Creek	5	6	5	5.0	6.6	6.1	5.0	13.0	3.6	5.0	5.0	5.0	9.8
Shawnee Creek	5	7	7	5.0	5.0	5.0	5.0	5.0	0.0	5.0	5.0	5.0	5.0
Shoal Creek	41	44	44	5.0	5.0	5.0	5.0	5.0	0.0	5.0	5.0	5.0	5.0
Willow Creek	4	5	5	5.0	5.0	5.0	5.0	5.0	0.0	5.0	5.0	5.0	5.0
Unnamed tributary to Spring River 1	3	3	3	5.0	5.0	5.0	5.0	5.0	0.0	5.0	5.0	5.0	5.0
Unnamed tributary to Spring River 2	2	3	2	9.8	9.8	8.5	5.0	14.6	6.8	6.0	7.4	12.2	13.6
Warren Branch	5	6	6	5.0	5.0	5.0	5.0	5.0	0.0	5.0	5.0	5.0	5.0
Spring River	38	40	36	5.0	6.2	5.7	5.0	17.7	3.6	5.0	5.0	5.0	7.5

Notes: Stream listed in upstream to downstream order. Site count is the number of monitoring stations on the respective stream inclusive of its tributaries. Sample count is the total number of samples collected from all the sites on a stream. Samples below detection limit is a count of samples with results reported as below detection limits. The detection limit for total lead was 10 µg/L; however, is reported here as half that value for statistical purposes.

TABLE 18. Dissolved Lead Statistics from EPA's May 2006 Spring River Basin Study

Stream	Site Count	Sample Count	Samples Below Detection Limit (#)	Median (µg/L)	Mean (µg/L)	Geomean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Std. Dev. (µg/L)	Percentiles			
										10th (µg/L)	25th (µg/L)	75th (µg/L)	90th (µg/L)
North Fork Spring River	5	7	7	5.0	5.0	5.0	5.0	5.0	0.0	5.0	5.0	5.0	5.0
Cow Creek	5	5	5	5.0	5.0	5.0	5.0	5.0	0.0	5.0	5.0	5.0	5.0
Center Creek	31	35	35	5.0	5.0	5.0	5.0	5.0	0.0	5.0	5.0	5.0	5.0
Turkey Creek	16	18	18	5.0	5.0	5.0	5.0	5.0	0.0	5.0	5.0	5.0	5.0
Short Creek	5	6	6	5.0	5.0	5.0	5.0	5.0	0.0	5.0	5.0	5.0	5.0
Shawnee Creek	5	7	7	5.0	5.0	5.0	5.0	5.0	0.0	5.0	5.0	5.0	5.0
Shoal Creek	41	42	42	5.0	5.0	5.0	5.0	5.0	0.0	5.0	5.0	5.0	5.0
Willow Creek	4	5	4	5.0	21.5	9.7	5.0	70.9	33.0	5.0	5.0	21.5	51.1
Unnamed tributary to Spring River 1	3	3	3	5.0	5.0	5.0	5.0	5.0	0.0	5.0	5.0	5.0	5.0
Unnamed tributary to Spring River 2	2	3	3	5.0	5.0	5.0	5.0	5.0	0.0	5.0	5.0	5.0	5.0
Warren Branch	5	6	6	5.0	5.0	5.0	5.0	5.0	0.0	5.0	5.0	5.0	5.0
Spring River	38	40	40	5.0	5.0	5.0	5.0	5.0	0.0	5.0	5.0	5.0	5.0

Notes: Stream listed in upstream to downstream order. Site count is the number of monitoring stations on the respective stream inclusive of its tributaries. Sample count is the total number of samples collected from all the sites on a stream. Samples below detection limit is a count of samples with results reported as below detection limits. The detection limit for dissolved lead was 10 µg/L; however, is reported here as half that value for statistical purposes.

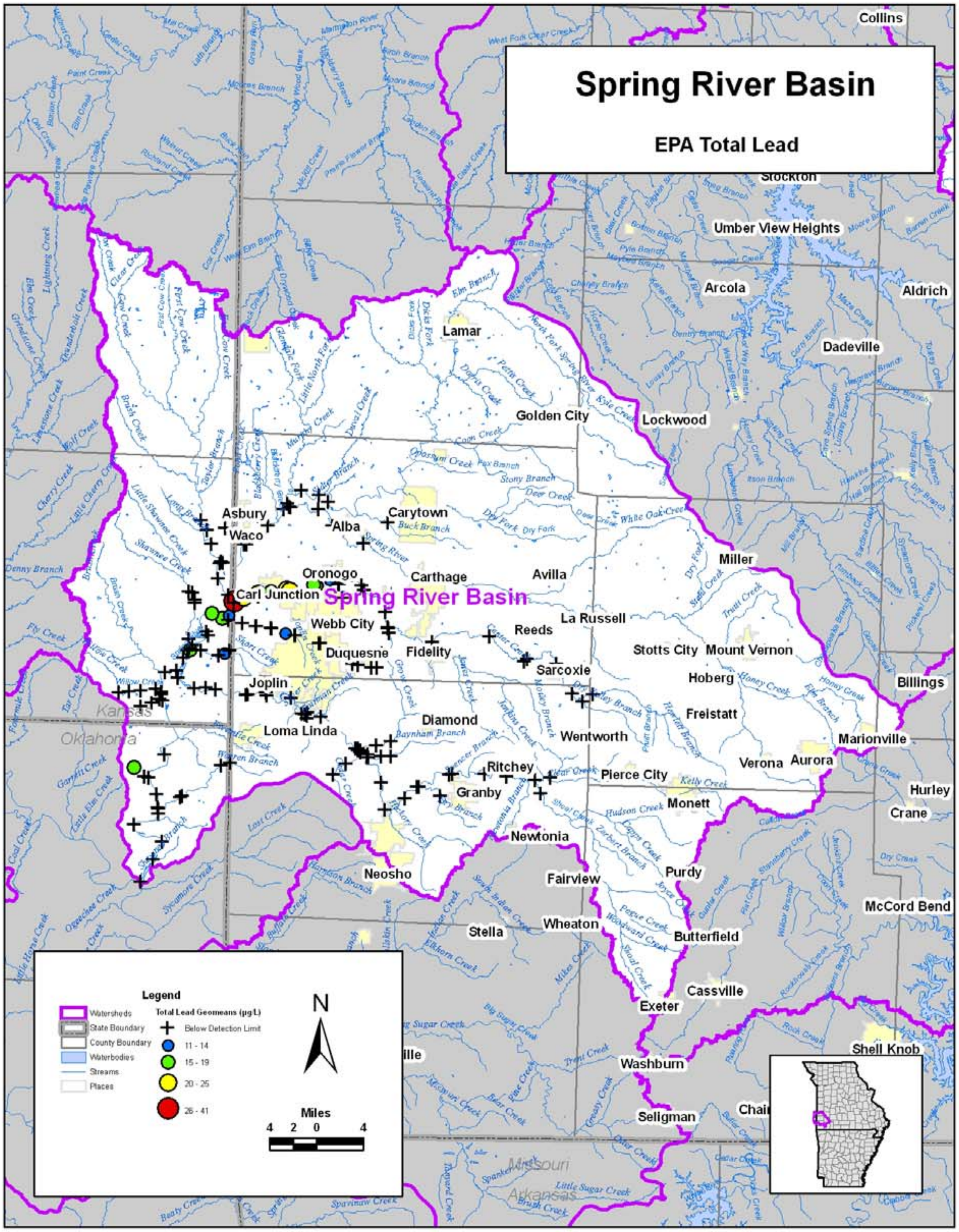


FIGURE 47. Graduated Symbol Map of May 2006 EPA Study Total Lead Geometric Means from the Spring River Basin

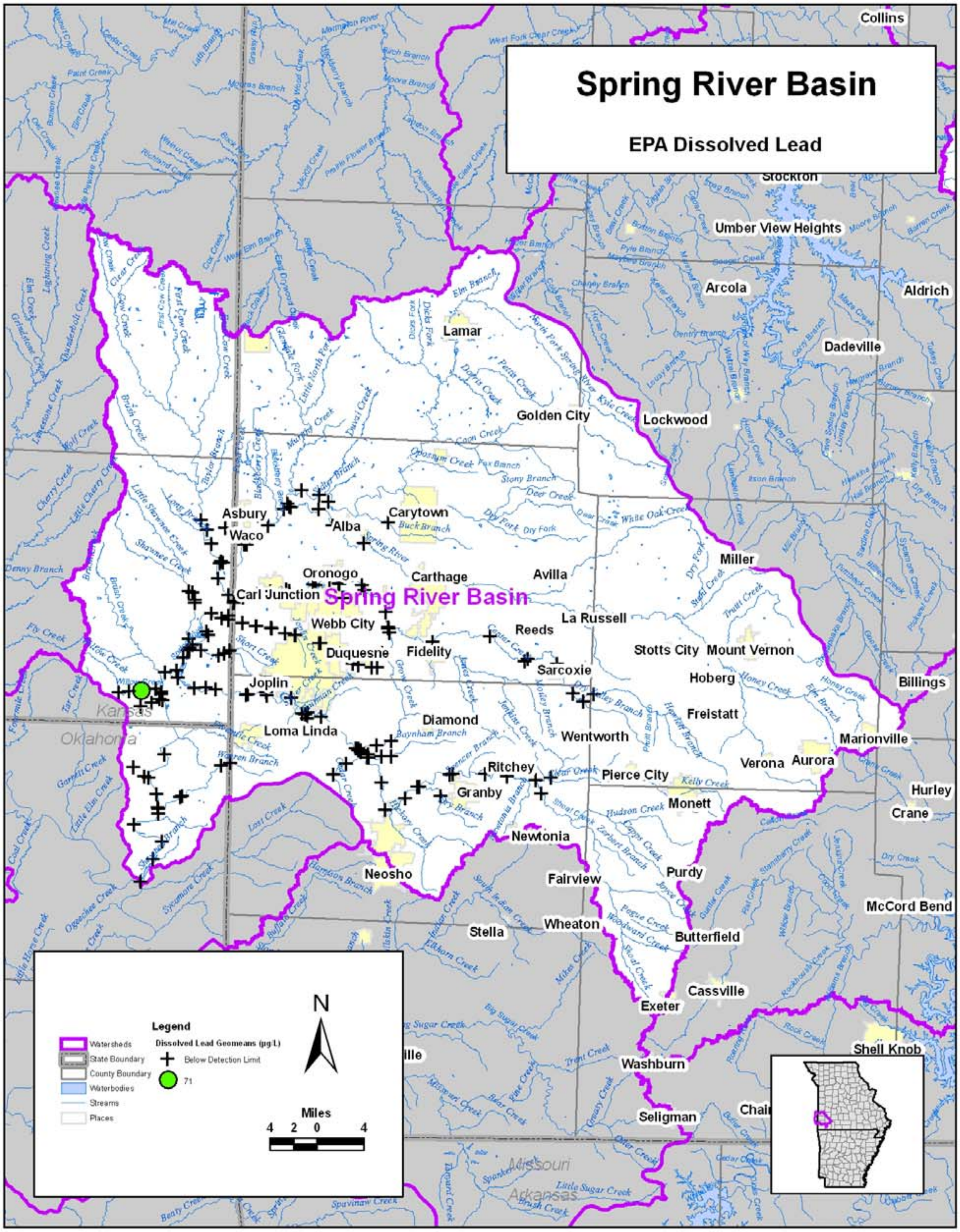


FIGURE 48. Graduated Symbol Map of May 2006 EPA Study Dissolved Lead Geometric Means from the Spring River Basin

4.3.2.2. EPA Zinc Data

A longitudinal profile of total zinc levels in the Spring River suggests there are multiple zinc loading sources throughout the Spring River basin (Figure 49). Total zinc levels in the Spring River increase most significantly near the Center Creek confluence. Zinc levels were greatest in Bens Branch (a tributary to Center Creek) with total and dissolved concentrations reaching 9,470 µg/L and 9,230 µg/L, respectively (Tables 19 and 20). However, total zinc levels in Center Creek just upstream of the Spring River confluence were 1,180 µg/L. Downstream of Turkey Creek there was a significant decline in total zinc levels followed by a sharp increase prior to the Short Creek confluence. This may reflect a zinc loading source that was not characterized by the EPA May 2006 study. Total zinc levels also appeared to spike upwards just downstream of the Short Creek confluence. This spike may be attributed to the relatively high levels of total zinc in Short Creek, which ranged from 1,110 µg/L to 4,345 µg/L (Table 20). Figures 50 and 51 further illustrate that there are multiple zinc loading sources in the Spring River basin.

The May 2006 EPA zinc data also suggests there may be multiple exceedances of zinc criteria throughout the Spring River basin. Geomeans of dissolved zinc data grouped by stream exceeded the AQL criterion of 159 µg/L in five streams (i.e., Turkey Creek, Short Creek, Willow Creek, and two unnamed tributaries to Spring River). Maximum observed dissolved zinc concentrations also exceeded the AQL criterion in Cow Creek, Center Creek, Shawnee Creek, Shoal Creek, and in the Spring River. Center Creek, Douger Branch, Turkey Creek, and the Spring River are currently 303(d) listed as impaired for zinc (Table 7).

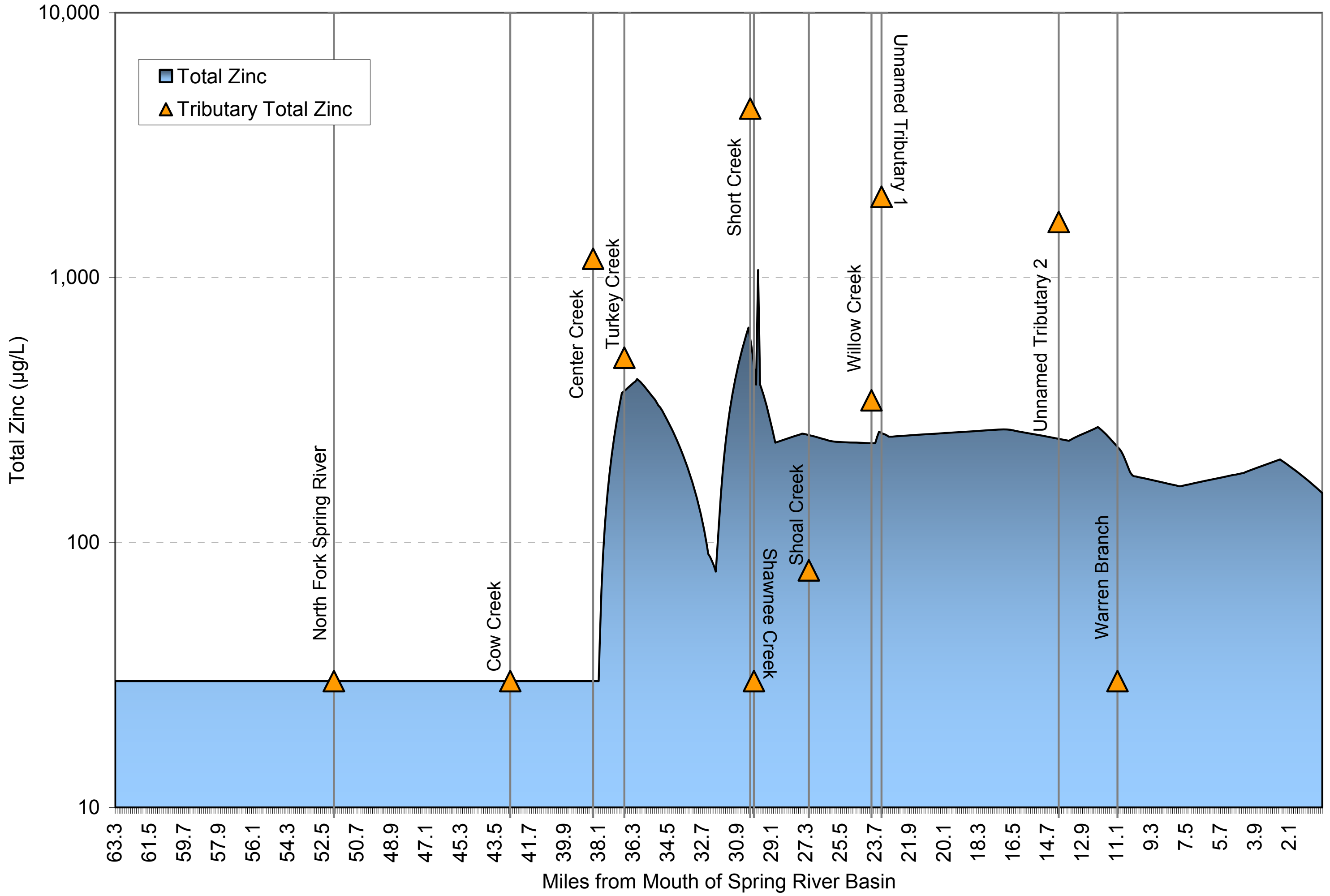


FIGURE 49. Longitudinal Profile of Total Zinc Concentrations in the Spring River Depicted with Tributary Locations and Concentrations from the May 2006 EPA Spring River Basin Study (Note: Tributary concentrations based on data from station closest to confluence).

TABLE 19. Total Zinc Statistics from EPA's May 2006 Spring River Basin Study

										Percentiles			
Stream	Site Count	Sample Count	Samples Below Detection Limit (#)	Median (µg/L)	Mean (µg/L)	Geomean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Std. Dev. (µg/L)	10th (µg/L)	25th (µg/L)	75th (µg/L)	90th (µg/L)
North Fork Spring River	5	8	8	30.0	30.0	30.0	30.0	30.0	0.0	30.0	30.0	30.0	30.0
Cow Creek	5	5	4	30.0	336.0	66.1	30.0	1560.0	684.2	30.0	30.0	30.0	948.0
Center Creek	31	36	19	30.0	853.5	131.2	30.0	9470.0	2269.5	30.0	30.0	660.0	760.0
Turkey Creek	16	19	1	370.0	409.8	280.5	30.0	1789.0	405.9	93.2	157.5	470.5	543.5
Short Creek	5	6	0	1860.0	2411.0	2088.4	1110.0	4345.0	1424.4	1178.0	1280.0	3460.0	3991.0
Shawnee Creek	5	7	6	30.0	35.4	34.1	30.0	56.9	12.0	30.0	30.0	30.0	46.1
Shoal Creek	41	44	38	30.0	50.0	40.3	30.0	218.0	45.0	30.0	30.0	35.2	122.3
Willow Creek	4	5	1	340.0	457.7	250.9	30.6	1120.0	465.0	122.2	259.7	538.0	887.2
Unnamed tributary to Spring River 1	3	3	0	2780.0	2873.3	2778.6	2020.0	3820.0	903.6	2172.0	2400.0	3300.0	3612.0
Unnamed tributary to Spring River 2	2	3	0	961.5	961.5	699.7	302.0	1621.0	932.7	433.9	631.8	1291.3	1489.1
Warren Branch	5	6	4	30.0	40.1	36.6	30.0	80.7	22.7	30.0	30.0	30.0	60.4
Spring River	38	40	14	181.0	199.6	116.0	30.0	1070.0	207.1	30.0	30.0	261.0	395.0

Notes: Stream listed in upstream to downstream order. Site count is the number of monitoring stations on the respective stream inclusive of its tributaries. Sample count is the total number of samples collected from all the sites on a stream. Samples below detection limit is a count of samples with results reported as below detection limits. The detection limit for total zinc was 60 µg/L; however, is reported here as half that value for statistical purposes.

TABLE 20. Dissolved Zinc Statistics from EPA's May 2006 Spring River Basin Study

										Percentiles			
Stream	Site Count	Sample Count	Samples Below Detection Limit (#)	Median (µg/L)	Mean (µg/L)	Geomean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Std. Dev. (µg/L)	10th (µg/L)	25th (µg/L)	75th (µg/L)	90th (µg/L)
North Fork Spring River	5	7	7	30.0	30.0	30.0	30.0	30.0	0.0	30.0	30.0	30.0	30.0
Cow Creek	5	5	4	30.0	356.0	66.9	30.0	1660.0	729.0	30.0	30.0	30.0	1008.0
Center Creek	31	35	19	30.0	747.8	107.3	30.0	9230.0	2229.7	30.0	30.0	439.8	472.0
Turkey Creek	16	18	1	356.0	316.3	252.5	30.0	514.0	168.3	105.5	132.9	449.3	502.3
Short Creek	5	6	0	1790.0	2358.2	1991.0	941.0	4390.0	1491.9	1056.6	1230.0	3440.0	4010.0
Shawnee Creek	5	7	5	30.0	83.0	53.4	30.0	264.0	102.1	30.0	30.0	61.0	182.8
Shoal Creek	41	42	35	30.0	43.0	36.5	30.0	163.0	34.1	30.0	30.0	30.0	85.8
Willow Creek	4	5	0	297.0	540.6	334.7	98.5	1470.0	627.4	146.4	218.1	619.5	1129.8
Unnamed tributary to Spring River 1	3	3	0	2640.0	2586.7	2354.0	1290.0	3830.0	1270.8	1560.0	1965.0	3235.0	3592.0
Unnamed tributary to Spring River 2	2	3	0	868.5	868.5	524.2	176.0	1561.0	979.3	314.5	522.3	1214.8	1422.5
Warren Branch	5	6	6	30.0	30.0	30.0	30.0	30.0	0.0	30.0	30.0	30.0	30.0
Spring River	38	40	17	91.1	119.9	76.4	30.0	657.0	135.9	30.0	30.0	146.5	234.2

Notes: Stream listed in upstream to downstream order. Site count is the number of monitoring stations on the respective stream inclusive of its tributaries. Sample count is the total number of samples collected from all the sites on a stream. Samples below detection limit is a count of samples with results reported as below detection limits. The detection limit for dissolved zinc was 60 µg/L; however, is reported here as half that value for statistical purposes.

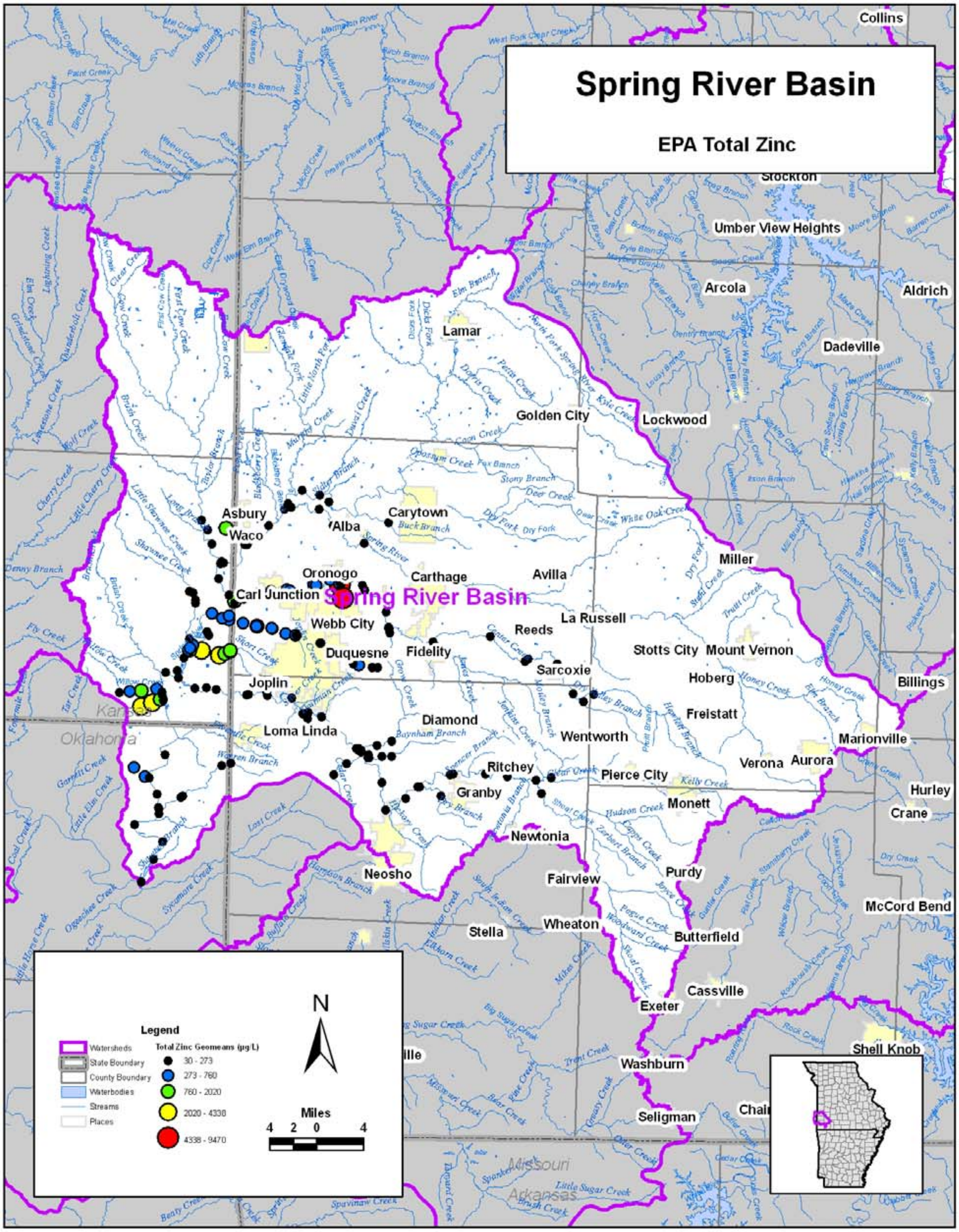


FIGURE 50. Graduated Symbol Map of May 2006 EPA Study Total Zinc Geometric Means from the Spring River Basin

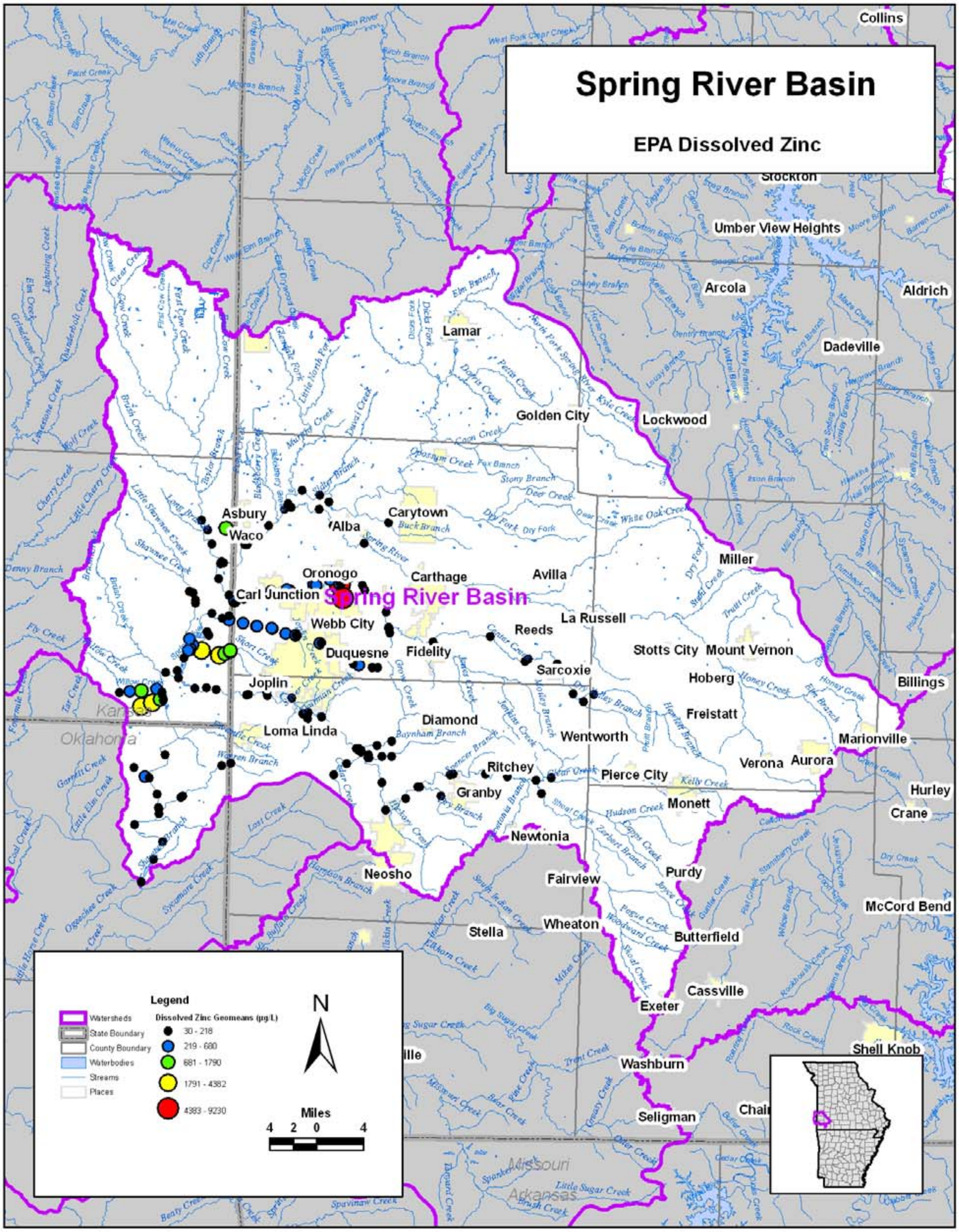


FIGURE 51. Graduated Symbol Map of May 2006 EPA Study Dissolved Zinc Geometric Means from the Spring River Basin

V. BIOLOGICAL MONITORING

MDNR, the Missouri Department of Conservation (MDC), and the USGS have conducted multiple biological data collection efforts throughout the Spring River basin since the 1990s (Table 21). Based on readily available GIS data, sampling locations for sites from the MDNR, MDC, and USGS were compiled for this report and are presented below:

1) The MDNR database includes 28 macroinvertebrate sampling locations in the Spring River basin on 11 waterbodies (Figure 52). All samples were collected between March of 1997 and October of 2004. Information included with these data are waterbody, latitude and longitude, the date collected and the sample number.

2) The MDC database includes only 2 fish sampling locations within the Spring River basin. These samples were collected in July of 2001 and July of 2002. Information included with this dataset are latitude and longitude, date collected, waterbody, and a variety of other data fields, some of which lack explanation.

3) The National Water-Quality Assessment Program (NAWQA) data from the USGS is a comprehensive and very well organized dataset. At any particular site, both macroinvertebrate and fish data were collected between 1993 and 2004. These data while informative are limited within the study area, with only two sites located within the Spring River basin.

TABLE 21. Summary of Digital Biological Databases for the Spring River Basin

Data Types	Collection Agency	Number of Sites	Collection Dates
Macro-Invertebrates	MDNR	28	1997-2004
Fish	MDC	2	2001-2002
Fish and Macro-Invertebrates	USGS (NAWQA)	2	1993-2004

MDNR has made available its macro-invertebrate data from a searchable database found at www.dnr.mo.gov/env/esp/biologicalassessments.htm. The MDNR database includes species counts, biological metric scores, and water quality data, where available. Also available from this website are biological assessment reports for select bioassessment studies.

MDNR has completed three biological assessment reports for waterbodies within the Spring River basin. Reports have been completed for the Upper North Fork of the Spring River, the Lower North Fork of the Spring River, and Clear Creek; all of which suggested impairment issues. Both the Upper and Lower North Fork of the Spring River assessments found evidence of elevated ammonia and nutrient levels, a high abundance of tolerant taxa, potential sedimentation issues, and impaired biological communities. MDNR noted the high percentage of row crop coverage in the Upper and Lower Fork of the Spring River basin as potentially contributing to biological impairment and sedimentation issues (MDNR, 2004a and MDNR, 2004b). MDNR conducted the Clear Creek assessment downstream of the Monett WWTF. The macroinvertebrate communities were assigned biological ratings from partially to non-sustaining. MDNR attributed impairment issues in Clear Creek to the WWTF, urban runoff, and livestock impacts (MDNR, 2000).

The Spring River basin has a particularly diverse fish community structure due to its location. The basin straddles two major aquatic community divisions: the Ozark-Neosho and the Prairie-Neosho. Eighty-six species of fish have been collected in the Spring River basin since the 1930s. Some fish species have been absent from more recent collection efforts; however, this may be a result of inadequate sampling methods (MDC, 2000).

There are several rare, threatened, and endangered species of flora and fauna within the Spring River basin. Federally endangered species include the gray bat (*Myotis grisescens*), running buffalo clover (*Trifolium stoloniferum*), and the American burying beetle (*Nicrophorus americanus*). Federally threatened species include the Ozark cavefish (*Amblyopsis rosae*), the Neosho madtom (*Notorus placidus*), geocarpon (*Geocarpon minimum*), western prairie fringed orchid (*Platenthera praeclara*), the Mead's milkweed (*Asclepias meadii*). Additionally, within the Spring River basin, the State of Missouri has identified 27 endangered species, 23 rare or threatened species, and 18 species for its watch list (MDC, 2000).

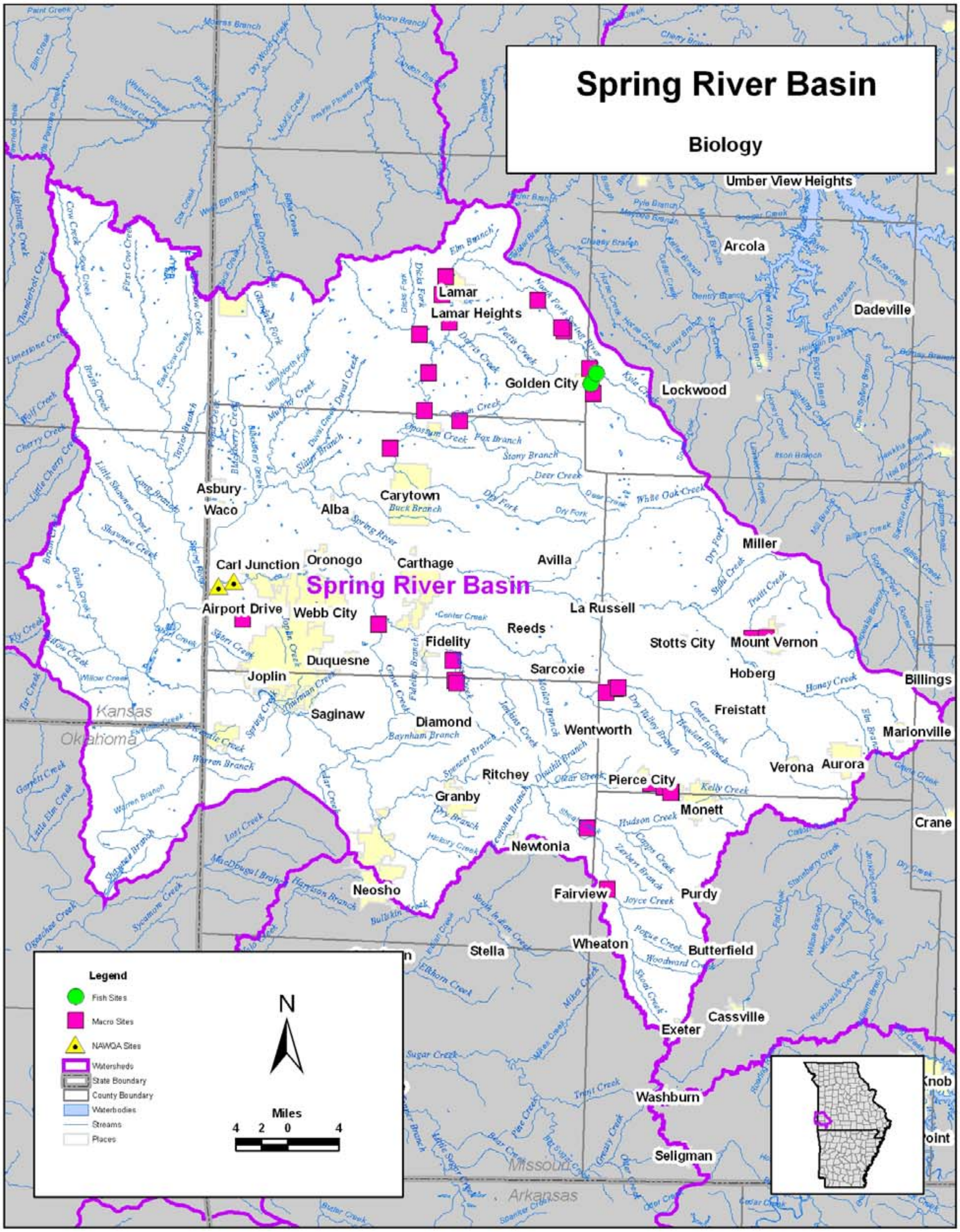


FIGURE 52. Biological Monitoring Sites in the Spring River Basin

VI. DATA GAPS

A data gap is defined here as a lack of information necessary to the goals of WQIP. Within the Spring River basin water quality data have been collected by various agencies for various purposes. However, the existing ambient data does not necessarily provide the information needed to address the broader goals of water quality researchers, managers and policy makers, or the WQIP. The information needs of the WQIP are defined by the following goals:

- Characterize regional background or reference water quality conditions;
- Characterize regional and seasonal water quality and flow variations and their underlying processes;
- Assess regional and temporal trends in water quality;
- Characterize the impacts of point and nonpoint source discharges on water quality; and
- Provide water quality information to:
    - Better understand the effects of land uses and use changes on water quality,
    - Measure effectiveness of watershed management programs,
    - Support development of management strategies to return impaired waters to compliance with water quality standards.

This section of the report identifies data deficiencies, or data gaps, for meeting the goals of the WQIP within the Spring River basin. Data gap issues discussed below include spatial gaps, temporal gaps, parameter gaps, detection limit gaps, metadata gaps, and unincorporated data. The data gap analyses presented below primarily address the issues of excessive nutrients, bacteria, and mining related contamination. It should be noted that although this gap analysis is limited to the 46 selected sampling stations, it is not limited to the periods of record or minimum sample sizes used in the data analysis section.

6.1. Spatial Gaps

Based on the information needs of the WQIP described above, the water quality monitoring network in the Spring River basin should be extensive consisting of both baseline and impact stations. Baseline stations account for natural or near-natural effects and trends and are located where there are likely minimal effects of point or nonpoint sources. These provide information regarding regional background or reference water quality conditions, provide a baseline for monitoring watershed management programs, and are located to monitor effects of land use changes. Impact stations are located downstream of present, and possible future, pollution sources.

The distribution of existing water quality sampling stations in the Spring River basin is insufficient to address the goals of the WQIP. The 46 sampling stations are primarily located in the Shoal Creek watershed (30 stations) and on the Spring River (8 stations). Coverage is most notably lacking from Cow and Center Creeks and the North Fork Spring River, where there is at most a single sampling station. In general sampling stations appear to be concentrated on the west and south sides of the watershed and lacking in the upper portions of the Spring River, east of Carthage, as well as on Center

Creek east of Joplin. The goals of WQIP could be much better served if the distribution of the existing sampling stations were much more spread out within the Spring River basin.

Determining the appropriate distribution for sample stations for the various goals of the WQIP is complex. Although not explicitly stated, an overall goal of the WQIP is to detect, isolate and identify sources of pollution. Stream ordering is an effective procedure for addressing this goal. This procedure effectively defines a water quality network with equal spatial coverage of the basin's water quality. Such an approach potentially necessitates a large number of sample stations. Addressing some of the more specific goals (e.g., assessing trends and management strategies) potentially requires fewer more targeted sample stations, but also requires greater knowledge of water quality conditions and pollutant sources. Designing a robust monitoring network may require a systematic approach to first better identify issues to help target long-term sampling locations.

Although the Spring River basin may not be fully characterized for water quality, several issues are known to exist and should be considered as part of an overall monitoring strategy. Areas with well documented water quality issues are listed below.

- Tri-State and Aurora Mining Districts
    - Zinc, lead and cadmium contamination
    - Sulfate-related contamination in Cow Creek
    - 303(d) listings for Center Creek, Douger Branch, Turkey Creek, and the Spring River

- Clear Creek
    - Ammonia, BOD, suspended solids, and low dissolved oxygen impairments from Monett WWTP
    - High levels of TP

- North Fork Spring River
    - Ammonia and low dissolved oxygen impairments from the Lamar WWTP
    - Sediment from agricultural nonpoint sources
    - Impairment of habitat from unknown pollutant(s)

- Shoal Creek Watershed
    - Bacteria impairments
    - High concentration of CAFOs

However, this list is not meant to imply that other areas do not require monitoring. As discussed above, further monitoring is needed throughout the basin to better target other potential loading sources.

6.2. Temporal Gaps

Temporal gaps refer to water quality data characterized by a period of record or sampling frequency insufficient for purposes of addressing information needs. The information needs of the WQIP goals potentially require both short term intensive studies and long-term monitoring. Temporal characteristics of sampling stations in the Spring River basin are discussed below.

Water quality data collection in the Spring River basin was relatively nominal until 1998, at which time the USGS began a fairly robust sampling regimen on some of the Spring River's larger tributaries. However, this series of data collection was fairly short-lived, like many of the other sampling routines of the various agencies. The Newton County Health Department began a more recent series of water quality sampling in 2004 and comprises a majority of the water quality data collected.

The observed sampling frequency in the Spring River basin can vary by site and collection entity (Figure 53), but generally appears to be lacking the ability to accommodate the goals of the WQIP prior to 1998. Although determining sampling frequency is typically based on the judgment of the monitoring system designer, some general rules do apply. Typically smaller streams with greater maximum to minimum flow ratios require sampling at a greater frequency than larger rivers. Tighter sampling frequencies (i.e., at least once a week) may also be called for during short term intensive surveys, or for monitoring bacteria levels at known recreational areas. Monthly sampling, however, is considered adequate for characterizing water quality over a long time period. Many of the sites sampled in the Spring River basin were sampled monthly, however, this sampling frequency continued for only a short time.

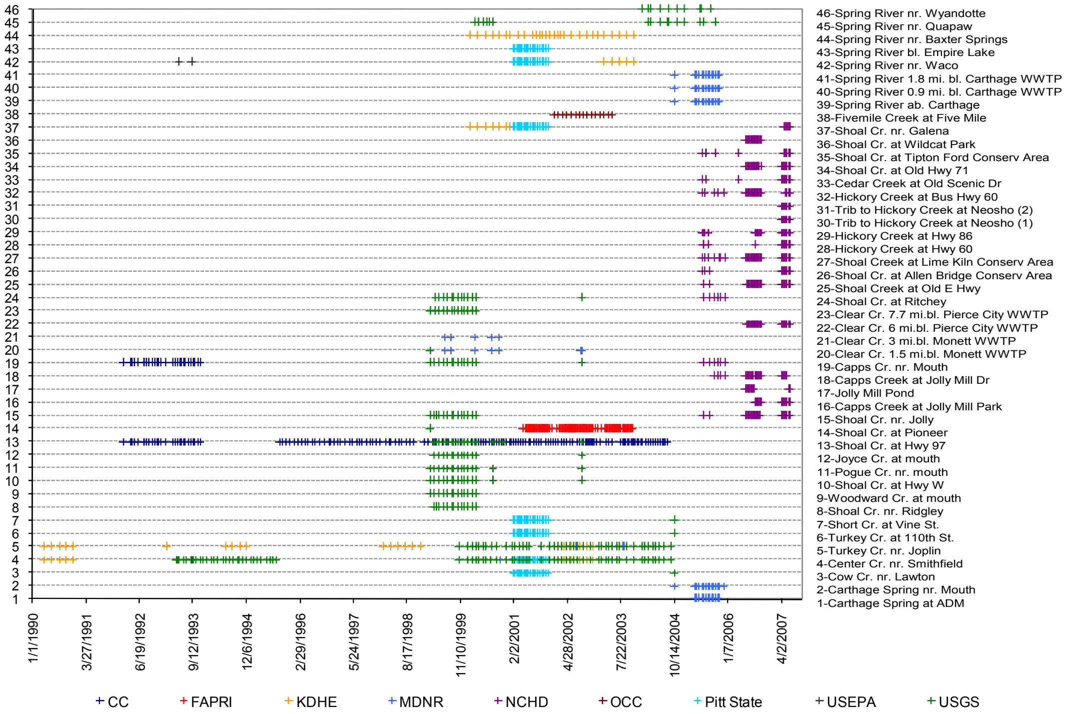


FIGURE 53. Monitoring Visits by Collection Entity from January 1990 to April 2007

6.3. Parameter Gaps

A parameter gap is a dataset characterized by missing or inappropriate water quality variables to address the issues of interest. Water quality data compiled for the WQIP were collected for a variety of interests, which do not necessarily address the issues of excessive nutrients and bacteria (i.e., the primary issues identified by the WQIP workgroup). Although numerous parameters could conceivably be measured to address these issues, this parameter gap analysis is limited to TP, TN, $NO_3 + NO_2$, chlorophyll *a*, total and dissolved zinc and lead, *E. coli*, and flow.

Nutrient data are largely lacking from sampling efforts in the Spring River basin. Collectively at all sites TP data were sampled 44% of the time and were never collected at 14 of the 46 stations (Table 22). Similarly NO3+NO2 data were collectively sampled for 45% of the time and were never sampled for at 12 of the 46 stations. TN data is particularly lacking since it is only available from a small number of sampling stations.

Although excessive algal growth is the primary concern with excessive nitrification, chlorophyll *a* data (i.e., a measure of algal growth) are nonexistent in the Spring River basin. Both benthic and sestonic chlorophyll *a* data are needed throughout the entire basin to better understand what eutrophication issues may exist. Such data could also be valuable in determining appropriate nutrient criteria for the region.

The majority of sampling efforts in the Spring River basin appear to focus on *E. coli*. Only 9 of the 46 sampling stations have no *E. coli*, and collectively *E. coli*. has been sampled for during 61% of all sample visits. Although *E. coli* represents one of the larger sampling efforts in the basin, it is primarily restricted to the Shoal Creek watershed.

Zinc and lead data are largely limited to ten sampling stations. Data for these parameters may be found in Cow, Center, Turkey, and Shoal Creeks, and in the Spring River. With Southwest Missouri having some of the highest concentrations of lead and zinc mines in the country it would be beneficial to collect this type of data concurrently with the other water quality parameters at sites located downstream of the known mine locations.

Flow data collected concurrently with water quality parameters are generally lacking in the Spring River basin. Flow data were collected only 39% of time when summed over all sample visits at all sampling stations. Flow data also appears to be limited to about half of the sampling sites. Ideally flow measurements should be taken concurrently with water quality samples. Flow values allow for a more robust analysis of water quality data. Periods of high flow are typically associated with stormwater runoff, which can cause increases in nutrient and bacteria levels. Flow data are also critical for understanding loadings (mass per time). Although few agencies apparently collect flow data, it should be noted, as discussed in Section 2.5, there are three USGS gaging stations in the Spring River basin. Discharge data from these USGS gaging stations could potentially be used in analyzing existing ambient water quality data in the Spring River basin.

Finally, the general lack of parameter characterization found throughout the Spring River basin may simply be addressed in the future by collecting additional parameters during site visits. Available water quality data to date indicates only a few parameters of interest are sampled for during site visits. An analysis of site visits suggests the most frequently sampled parameter is *E. coli*; however, on average this parameter is only sampled for 61% of the time. Although it varies by site on average nutrient data is sampled for about 45% of the time and there is no chlorophyll *a* data. Sampling agencies could better address the goals of the WQIP by collecting multiple parameters during site visits.

TABLE 22. Percent of Time Parameters were Collected During Site Visits

Station Name	Total Visits	TP	NO_3+NO_2	TN	*E. coli*	Chlorophyll *a*[1]	Total Zinc	Dissolved Zinc	Total Lead	Dissolved Lead	Flow
Carthage Spring at ADM	25	0%	0%	0%	68%	0%	0%	0%	0%	0%	0%
Carthage Spring nr. Mouth	26	0%	0%	0%	69%	0%	0%	0%	0%	0%	0%
Cow Cr. nr. Lawton	29	93%	97%	0%	0%	0%	7%	3%	0%	0%	97%
Center Cr. nr. Smithfield	557	78%	84%	16%	11%	0%	19%	24%	13%	14%	54%
Turkey Cr. nr. Joplin	325	83%	85%	18%	13%	0%	17%	5%	13%	5%	58%
Turkey Cr. at 110th St.	30	90%	93%	0%	0%	0%	10%	10%	3%	3%	97%
Short Cr. at Vine St.	26	96%	96%	0%	0%	0%	0%	0%	0%	0%	96%
Shoal Cr. nr. Ridgley	16	100%	100%	0%	100%	0%	0%	0%	0%	0%	100%
Woodward Cr. at mouth	13	92%	92%	0%	92%	0%	0%	0%	0%	0%	100%
Shoal Cr. at Hwy W	16	81%	81%	0%	100%	0%	0%	0%	0%	0%	94%
Pogue Cr. nr. mouth	16	81%	81%	0%	100%	0%	0%	0%	0%	0%	94%
Joyce Cr. at mouth	13	100%	100%	0%	100%	0%	0%	0%	0%	0%	100%
Shoal Cr. at Hwy 97	180	96%	95%	13%	12%	0%	0%	0%	0%	0%	23%
Shoal Cr. at Pioneer	119	93%	88%	94%	29%	0%	0%	0%	0%	0%	1%
Shoal Cr. nr. Jolly	45	40%	40%	0%	100%	0%	0%	0%	0%	0%	38%
Capps Creek at Jolly Mill Park	18	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
Jolly Mill Pond	11	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
Capps Creek at Jolly Mill Dr	28	14%	14%	0%	100%	0%	0%	0%	0%	0%	0%
Capps Cr. nr. Mouth	48	96%	90%	50%	42%	0%	0%	0%	0%	0%	75%
Clear Cr. 1.5 mi.bl. Monett WWTP	34	53%	53%	29%	3%	0%	0%	0%	0%	0%	15%
Clear Cr. 3 mi.bl. Monett WWTP	20	90%	90%	50%	0%	0%	0%	0%	0%	0%	20%
Clear Cr. 6 mi.bl. Pierce City WWTP	35	23%	23%	0%	74%	0%	0%	0%	0%	0%	0%
Clear Cr. 7.7 mi.bl. Pierce City WWTP	17	88%	88%	0%	76%	0%	0%	0%	0%	0%	82%
Shoal Cr. at Ritchey	19	95%	95%	0%	100%	0%	0%	0%	0%	0%	68%
Shoal Creek at Old E Hwy	28	0%	4%	0%	100%	0%	0%	0%	0%	0%	0%
Shoal Cr. at Allen Bridge Conserv Area	13	8%	15%	0%	100%	0%	0%	0%	0%	0%	0%
Shoal Creek at Lime Kiln Conserv Area	35	20%	20%	0%	100%	0%	0%	0%	0%	0%	0%
Hickory Creek at Hwy 60	14	14%	14%	0%	100%	0%	0%	0%	0%	0%	0%
Hickory Creek at Hwy 86	24	17%	17%	0%	96%	0%	0%	0%	0%	0%	0%
Trib to Hickory Creek at Neosho (1)	10	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
Trib to Hickory Creek at Neosho (2)	10	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
Hickory Creek at Bus Hwy 60	28	14%	14%	0%	100%	0%	0%	0%	0%	0%	0%
Cedar Creek at Old Scenic Dr	13	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
Shoal Cr. at Old Hwy 71	26	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
Shoal Cr. at Tipton Ford Conserv Area	12	8%	17%	0%	92%	0%	0%	0%	0%	0%	0%
Shoal Cr. at Wildcat Park	17	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
Shoal Cr. nr. Galena	92	75%	63%	12%	7%	0%	21%	7%	13%	0%	65%
Fivemile Creek at Five Mile	19	89%	100%	100%	0%	0%	0%	0%	0%	0%	79%
Spring River ab. Carthage	25	0%	0%	0%	72%	0%	0%	0%	0%	0%	0%
Spring River 0.9 mi. bl. Carthage WWTP	22	0%	0%	0%	73%	0%	0%	0%	0%	0%	0%
Spring River 1.8 mi. bl. Carthage WWTP	25	0%	0%	0%	64%	0%	0%	0%	0%	0%	0%
Spring River nr. Waco	139	68%	51%	12%	0%	0%	16%	54%	5%	19%	94%
Spring River bl. Empire Lake	26	100%	100%	0%	0%	0%	0%	0%	0%	0%	100%
Spring River nr. Baxter Springs	231	35%	26%	11%	0%	0%	14%	1%	13%	0%	54%
Spring River nr. Quapaw	430	11%	32%	9%	1%	0%	8%	4%	6%	5%	91%
Spring River nr. Wyandotte	73	0%	12%	0%	0%	0%	14%	15%	12%	15%	97%
Total of all stations	2978	44%	45%	9%	61%	0%	3%	3%	2%	1%	39%

Notes: [1]Includes both benthic and sestonic chlorophyll a

6.4. Detection Limit Gaps

A detection limit gap is defined here to mean a dataset characterized by insufficient detection levels. Where laboratory detection limits exceed ambient conditions, water quality data are difficult to interpret. Although laboratory methods have limits with regards to detection limits, laboratory methods in some instances may be altered to achieve lower detection limits. The purpose of this analysis is to identify where such laboratory methods may need to be adjusted.

It should be noted that to conduct this detection limit gap analysis, assumptions were made regarding detection limits that were not made for the water quality summary and statistics portion of the report. As previously discussed (see Section 3.2) the data sources did not always provide laboratory detection limits. In particular, the MDNR database utilizes a protocol for reporting laboratory non-detects to ease the end use of the data for statistical analysis. Reasonable attempts were made to determine MDNR non-detect values, but only for purposes of this detection limit gap analysis. It also should be noted that some detection limits are presented as “0” by some sources. This does mean to imply that 0.0 is the true laboratory detection limit; it only means a laboratory value was identified as a non-detectable, but no detection limit was provided.

There do not appear to be any significant detection limit issues with TP data in the Spring River basin. Most samples reported as ND had a relatively low detection limit of 20 μg/L (Table 23). Conceivably, however, if the purpose of monitoring is to determine reference conditions and a high percentage of samples are ND then laboratory methods may need to be adjusted in the future.

TABLE 23. Total Phosphorus Sample Results Reported Below Detection Limit

Agency	Station Name	Sample Count	Samples Below Detection Limit	Percent Below Detection Limit	Detection Limit[1]
KDHE	Center Cr. nr. Smithfield	159	2	1%	0(2)
USGS	Center Cr. nr. Smithfield	249	3	1%	10(2), 60(1)
USGS	Shoal Cr. nr. Ridgley	16	5	31%	20(5)
USGS	Woodward Cr. at mouth	12	6	50%	20(6)
USGS	Shoal Cr. at Hwy W	13	2	15%	20(2)
USGS	Pogue Cr. nr. mouth	13	3	23%	20(3)
USGS	Joyce Cr. at mouth	13	2	15%	20(2)
CC	Shoal Cr. at Hwy 97	154	7	5%	0(7)
USGS	Shoal Cr. at Hwy 97	18	3	17%	20(3)
USGS	Shoal Cr. nr. Jolly	16	4	25%	20(4)
CC	Capps Cr. nr. Mouth	27	5	19%	0(5)
NCHD	Capps Cr. nr. Mouth	6	1	17%	50(1)
USGS	Capps Cr. nr. Mouth	13	3	23%	20(3)
OCC	Fivemile Creek at Five Mile	13	3	23%	0(3)
OK-CCOKC	Fivemile Creek at Five Mile	4	1	25%	10(1)

Notes: [1]Detection limit reported in ug/L followed by the count in ( ) at that detection limit (e.g., 20(2)) means 2 samples with a laboratoy detection limit of 20 ug/L. NA = not applicable (i.e., 0% of the samples below the laboratory detection limit).

Detection limits do not appear to be an issue for assessing nitrogen values from the Spring River basin. Not a single TN sample in the WQIP database was reported to be below the detection limit. The highest reported detection limit for NO_3+NO_3 was a relatively low 10 μg/L (Table 24). As a measure of comparison 10 μg/L is significantly lower than the Dodds *et al.* (1998) recommended threshold value of 1,500 μg/L for TN (note that NO_3+NO_3 typically represents a high percentage of TN).

TABLE 24. Nitrate plus Nitrite Sample Results Reported Below Detection Limit

Agency	Station Name	Sample Count	Samples Below Detection Limit	Percent Below Detection Limit	Detection Limit[1]
USGS	Center Cr. nr. Smithfield	227	18	8%	8(2), 10(16)
KDHE	Turkey Cr. nr. Joplin	220	2	1%	0(2)
USGS	Turkey Cr. nr. Joplin	44	16	36%	6(2), 8(6), 10(8)
Pitt State	Short Cr. at Vine St.	25	1	4%	0(1)
NCHD	Hickory Creek at Bus Hwy 60	4	1	25%	0(1)
USGS	Spring River nr. Waco	41	1	2%	10(1)
USGS	Spring River nr. Baxter Springs	29	2	7%	0(2)
USGS-WRD	Spring River nr. Quapaw	36	3	8%	10(3)

Notes: [1]Detection limit reported in ug/L followed by the count in ( ) at that detection limit (e.g., 20(2)) means 2 samples with a laboratoy detection limit of 20 ug/L. NA = not applicable (i.e., 0% of the samples below the laboratory detection limit).

Detection limits for metals in the Spring River basin may need to be adjusted for lead, but likely not for zinc. Total lead detection limits are generally 20 μg/L or less (Table 25). Depending on how total lead data are being used some of these detection limits may be too high. Note that MDNR drinking water supply criteria for total lead is 15 μg/L. The issue with dissolved lead detection limits potentially appears more problematic. Several of the sites have 100%, or very nearly 100%, of its samples below the detection limit (Table 26). In many instances the dissolved lead detection limits are 10 μg/L or higher. Note that MDNR aquatic life criterion for dissolved lead is only 4 μg/L (assuming a hardness range of 150 to 174 mg/L as $CaCO_3$ [calcium carbonate]). In general total and dissolved zinc levels were infrequently reported below the detection limit (Tables 27 and 28). Zinc detection limits also appear to be relatively low. Dissolved zinc detection limits averaged around 5 µg/L, which is well below the aquatic life criterion of 151 µg/L (assuming a hardness range of 150 to 174 mg/L as $CaCO_3$).

TABLE 25 Total Lead Sample Results Reported Below Detection Limit

Agency	Station Name	Sample Count	Samples Below Detection Limit	Percent Below Detection Limit	Detection Limit[1]
KDHE	Center Cr. nr. Smithfield	32	8	25%	0(8)
USGS	Center Cr. nr. Smithfield	37	8	22%	1(1), 5(7)
KDHE	Turkey Cr. nr. Joplin	26	10	38%	0(10)
KDHE	Spring River nr. Waco	5	3	60%	1(3)
USGS	Spring River nr. Waco	2	2	100%	5(2)
KDHE	Spring River nr. Baxter Springs	29	1	3%	1(1)
USGS-WRD	Spring River nr. Quapaw	25	11	44%	5(4), 10(5), 20(2)
USGS-WRD	Spring River nr. Wyandotte	9	5	56%	10(5)

Notes: [1]Detection limit reported in ug/L followed by the count in ( ) at that detection limit (e.g., 20(2)) means 2 samples with a laboratoy detection limit of 20 ug/L. NA = not applicable (i.e., 0% of the samples below the laboratory detection limit).

TABLE 26. Dissolved Lead Sample Results Reported Below Detection Limit

Agency	Station Name	Sample Count	Samples Below Detection Limit	Percent Below Detection Limit	Detection Limit[1]
MDNR	Center Cr. nr. Smithfield	1	1	100%	2.5(1)
USEPA	Center Cr. nr. Smithfield	2	2	100%	0(2)
USGS	Center Cr. nr. Smithfield	73	58	79%	0(5), 1(10), 2(3), 4(1), 5(25), 10(11), 100(3)
MDNR	Turkey Cr. nr. Joplin	3	2	67%	5(2)
USGS	Turkey Cr. nr. Joplin	14	3	21%	100(3)
USGS	Turkey Cr. at 110th St.	1	1	100%	0(1)
USEPA	Spring River nr. Waco	2	2	100%	0(2)
USGS	Spring River nr. Waco	24	23	96%	0(14), 1(1), 2(7), 5(1)
USGS	Spring River nr. Baxter Springs	1	1	100%	0(1)
USGS-WRD	Spring River nr. Quapaw	20	17	85%	5(7), 10(10)
OK-HDL	Spring River nr. Wyandotte	1	1	100%	20(1)
USGS-WRD	Spring River nr. Wyandotte	10	10	100%	10(10)

Notes: [1]Detection limit reported in ug/L followed by the count in ( ) at that detection limit (e.g., 20(2)) means 2 samples with a laboratoy detection limit of 20 ug/L. NA = not applicable (i.e., 0% of the samples below the laboratory detection limit).

TABLE 27. Total Zinc Sample Results Reported Below Detection Limit

Agency	Station Name	Sample Count	Samples Below Detection Limit	Percent Below Detection Limit	Detection Limit[1]
KDHE	Turkey Cr. nr. Joplin	39	1	3%	0(1)
USGS	Spring River nr. Waco	17	2	12%	20(2)

Notes: [1]Detection limit reported in ug/L followed by the count in ( ) at that detection limit (e.g., 20(2)) means 2 samples with a laboratoy detection limit of 20 ug/L. NA = not applicable (i.e., 0% of the samples below the laboratory detection limit).

TABLE 28. Dissolved Zinc Sample Results Reported Below Detection Limit

Agency	Station Name	Sample Count	Samples Below Detection Limit	Percent Below Detection Limit	Detection Limit[1]
USGS	Spring River nr. Waco	73	8	11%	0(5), 2(1), 20(2)
USEPA	Spring River nr. Waco	2	2	100%	5(2)
USGS-WRD	Spring River nr. Quapaw	19	1	5%	5(1)
USGS-WRD	Spring River nr. Wyandotte	10	2	20%	5(2)

Notes: [1]Detection limit reported in ug/L followed by the count in ( ) at that detection limit (e.g., 20(2)) means 2 samples with a laboratoy detection limit of 20 ug/L. NA = not applicable (i.e., 0% of the samples below the laboratory detection limit).

6.5. Metadata Gaps

Metadata are data that provide information about sample collection and analysis. Properly documented metadata describe where, when, how, why, and by whom samples were collected and processed. Metadata also describe the conditions under which samples were collected (e.g., baseflow, weather, etc.). In order to increase the sharing and value of water quality data, the NWQMC recommends water quality collection entities, at a minimum, report metadata for the following seven categories of WQDE for chemical and microbiological analytes:

1. Contact,
2. Results,
3. Reason for Sampling,
4. Data/Time,
5. Location,
6. Sample Collection, and
7. Sample Analysis.

Water quality data compiled for WQIP contained significant metadata gaps. MDNR's databases (i.e., the primary source of WQIP's data) are compilations of data collected by multiple collection entities. Therefore, metadata gaps discussed here do not necessarily imply who is responsible for the missing metadata. Further investigation would be required to determine whether the metadata gaps discussed below originate from the original data sources.

Contact

The collection entity contact information was generally either provided for, or was readily attainable by MEC. However, the NWQMC also recommends laboratory contact information be provided. Laboratory contact information is potentially necessary for analysis clarification but generally was not available.

Results

The results data element is intended to characterize the analyte and the analytical result value. The NWQMC recommends collection entities use a common analyte identifier taken from an authoritative list (e.g., USGS or EPA STORET Parameter Code). Most collection entities appear to group their data into generic parameter categories. For example the category "TP" is not as specific as the USGS parameter codes for total phosphorus, which indicate the analytical method. Selection of an appropriate analyte identifier may require some verification with a laboratory, but allows for greater data comparability and analysis.

Reason for Sampling

The reason for sampling was generally not available. Some of the recommended reason categories provided by the NWQMC include reconnaissance, trend analysis, storm event, research, and regulatory benchmark. Documenting the reason for sampling may imply critical information to the end user of the water quality data. For example, storm event samples may imply very different, unique conditions compared to permit compliance samples.

Date/Time

Although sample collection dates were available, sample times were frequently not available. Sample times can be critical in data analysis, particularly where analyte concentrations fluctuate on a diurnal basis.

Location

The location data element recommended by the NWQMC characterizes more than the geographic coordinates of the sampling site. The location data element includes such information as station type, accuracy and method of determining the geographic coordinates, and stream stage. The station type denotes how to characterize a sampling site (e.g., ambient stream, storm sewer, outfall site). Metadata about the geographic coordinates (e.g., accuracy and datum) can be critical for determining the exact location of a site. Generally not much information was available regarding sample sites beyond the geographic coordinates. In some instances, however, even the geographic coordinates were not readily available. Unless a sample collection site can be identified, the water quality data are of little use. MEC identified 11 sampling sites in the Spring River basin with no geographic coordinates. These 11 sites were not included in this reports analysis of water quality. Spatial information for these sits potentially may be found with further investigation.

Sample Collection

The sample collection data element includes metadata on several aspects of sampling including sample type, sample identification, and collection method. Examples of sample type include routine, field blank and field replicate. Documenting the sample type can assure proper and consistent analysis of water quality data. A sample identification number can help facilitate potential questions between a researcher and the laboratory. The collection method (e.g., grab, integrated depth) allows for a more robust analysis of the water quality data. Generally, no sample collection metadata are available in the current WQIP database.

Sample Analysis

Sample analysis data elements are important to fully characterize the results of the water quality data. Accuracy, precision, and other QA/QC notes contribute to the confidence and interpretation of the data; however, they generally were not available. Two notable data elements missing from the water quality data were the detection level measure and type. The detection level measure describes the quantity of analyte below which the sample analysis equipment will not detect the analyte accurately. Examples of detection level types include method detection level, estimated detection level, practical quantification limit, and limit of detection.

6.6. Unincorporated Data

Not all available water quality data from the Spring River basin compiled by MEC were incorporated into the WQIP database at the time of the writing of this report. Although reasonable efforts were made to incorporate available data, some data sources were identified too late and/or were too difficult to incorporate with a reasonable amount of effort. Continuing efforts should be made to incorporate all water quality data into the WQIP database.

VII. RECOMMENDATIONS

The overall purpose of WQIP is to improve water quality while also protecting rural economic development and agricultural interests by providing factual information to facilitate sound regulatory and policy decision making. Based on an analysis of existing water quality data, the following categories of recommendations are suggested in support of this purpose:

- Monitoring coordinating board;
- Comprehensive monitoring network;
- Non-point source loading issues;
- Special studies in support of nutrient criteria development;
- Historical metals and mining impacts; and
- Continue to populate database with historical data.

Monitoring Coordinating Board

The creation of a monitoring coordinating board would help achieve the goals of WQIP in a more effective and efficient manner. The opportunity exists for the multiple water quality collection entities in southwest Missouri to collaborate more closely under the direction of a centralized monitoring coordinating board. The monitoring coordinating board should standardize sampling designs, quality assurance programs, metadata requirements, and develop a centralized database to facilitate the sharing of water quality data. With some synchronization of monitoring programs and better sharing of water quality data, redundant efforts could be eliminated and existing monitoring resources could be better leveraged.

The monitoring coordinating board should be responsible for developing a recommended minimum quality assurance program. Developing quality assurance programs can be a resource intensive effort for individual collection entities. However, by collaborating through a monitoring coordinating board, resources needed to develop a quality assurance program could be minimized. Additionally, a standardized quality assurance program would increase the value of the water quality data.

The Methods and Data Comparability Board (MDCB) of the National Water Quality Monitoring Council (NWQMC) recommends a minimum set of “core metadata”, or water quality data elements (WQDE), necessary for maximizing data comparability and usefulness. Based on the available water quality data, few of the necessary WQDE appear to be documented by most of the collection entities in the Spring River basin. The monitoring coordinating board should recommend which WQDE elements should be required for all water quality monitoring programs in southwest Missouri. It may not be necessary to adopt all the recommendations of the NWQMC, but the consistent use of at least some “core metadata” would greatly enhance the value of the water quality data. The NWQMC recommendations on WQDE can be found at the Advisory Committee on Water Information website (http://acwi.gov/methods/).

The monitoring coordinating board should maintain all water quality data from the various collection entities in a central database. To facilitate the development and updating of a central database and the sharing of water quality data, a common data storage format should be used by all collection entities. The actual storage software (i.e., spreadsheet or database program) is not as critical as the format of the data. By utilizing common protocols the transfer and utilization of shared data could be simplified. The format should accommodate the recommended WQDE of the NWQMC and the principles of good database design. For example, result values should be maintained in a numeric column separate from any remarks. The format should also accommodate the storage of censored data (e.g., less than laboratory detection limits). Methods of storing censored data values (e.g., use half the detection limit) by data collection entities are irrelevant as long as the detection limit and censored remark are clearly identified. Ultimately, developing an effective and robust common data storage format will increase the value of the data for all entities.

Comprehensive Monitoring Network

A comprehensive monitoring network should be designed for the Spring River basin to address the goals of WQIP. Water quality throughout much of the basin remains uncharacterized and more sample stations are needed to detect, isolate and identify known and potential sources of pollution. The information goals of WQIP should be carefully considered in developing the network design. Since the goals of WQIP are broad and extensive, monitoring locations should be spaced throughout all the major watersheds in the basin. Initial monitoring effort should continue for at least two years. Long-term monitoring stations should be established and more targeted monitoring should occur at the end of this two year period. The exact location of the sampling sites needs to be guided by information goals. For example, if the goal is to measure the effectiveness of watershed management programs then such programs need to be clearly defined in order to properly locate the sampling stations. Information goals are also important for determining the appropriate variables to measure and the frequency and duration at which to measure them. In summary, the historical and current sample stations found throughout the Spring River basin do not fully address the WQIP goals. A well designed monitoring network that clearly addresses the goals of the WQIP is needed.

Non-Point Source Loading Issues

One of the primary goals of WQIP is to characterize the impacts of point and nonpoint source discharges on water quality. Characterizing point and nonpoint source influences requires water quality data collected during multiple flows during both baseflow and runoff conditions. USGS data are well attributed with flows and flow conditions, but much of the remaining WQIP data lacks any flow characterization. Where lacking, flow attributes may be derived from USGS gaging stations in close proximity or historical precipitation data. Efforts should be made to characterize as much of the WQIP data as possible with flow attributes. Load duration curves and relationships between runoff conditions and parameter levels should then be analyzed based on flow attributes. Where available data are insufficient to characterize nonpoint loadings, special storm event studies may be necessary.

Special Studies in Support of Nutrient Criteria Development

In 2005, MDNR mutually agreed with the EPA to develop region specific nutrient criteria for water bodies in the State of Missouri. MDNR has placed first priority on developing lake and reservoir nutrient criteria, which likely will be proposed in 2008. Stakeholder group involvement in the development of stream nutrient criteria will commence in 2008 and it is anticipated that criteria will be effective by 2010.

WQIP can serve an integral role in assuring appropriate stream nutrient criteria are developed for the southwest Missouri area. Appropriate nutrient criteria development will require stakeholder participation and significant data analysis. WQIP already consists of multiple stakeholders and has consolidated a significant amount of nutrient data. WQIP stakeholders are encouraged to participate in the stream nutrient criteria stakeholder meetings beginning next year. Significant data analysis, however, is still necessary for the development of nutrient criteria. As part of this data analysis, MDNR recommends the following (MDNR, 2005b):

- Develop load duration curves to evaluate loading across multiple flow regimes;
- Develop regression lines for response variables, such as sestonic and benthic chlorophyll, and turbidity based on the causal variables of total nitrogen and total phosphorus; and
- Evaluate potential correlations between stream order and nutrient data (causal and response).

Much of the Spring River basin remains uncharacterized for nutrient levels, as illustrated in this report. Where nutrient data are available, they are likely insufficient for all the data analysis methods recommended by MDNR. Additional causal (nutrient) and response (algae) data from various flow regimes are necessary. Paired causal and response variable data are not currently available from the Spring River basin and flow conditions are generally lacking. WQIP should, therefore, design and implement special nutrient water quality studies with the goal of supporting the development of technically sound nutrient criteria.

Historical Metals and Mining Impacts

Mining related metals contamination is well documented in the Spring River basin and has resulted in the 303(d) listing of multiple streams. However, there are relatively little historical metals data addressing this issue. In May 2006 EPA conducted an extensive metals study in the Spring River basin to better characterize the issue. EPA's efforts were successful in spatially identifying where contamination exists. EPA study data provide an excellent opportunity to develop further studies. A long-term monitoring program should now be developed to track trends in metal levels at targeted locations.

Continue to Populate Database with Historical Data

Much water quality data in the Spring River basin have not been incorporated into the WQIP database due to a lack of common metadata and suitable data storage format. Also, additional water quality data were received after the cutoff date for this analysis. Efforts should be made to add any currently unincorporated water quality data to the database. If collection entities choose to collaborate on monitoring efforts, utilize common core metadata, and a suitable data storage format, future updates to the database should require less effort.

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