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

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ACRONYMS AND ABREVIATIONS

ACWI	Advisory Committee on Water Information
ADEQ	Arkansas Department of Environmental Quality
BOD	Biochemical Oxygen Demand
CAFO	Concentrated Animal Feeding Operation
CC	Crowder College
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 Resource Coalition
ft.	feet
GIS	Geographic Information System
HUC	Hydrologic Unit Code
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
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

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 this 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 mult-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 Elk River basin is the subject of this report.

The Elk River basin is approximately 1,031 square miles located primarily in southwest Missouri, but also includes portions of northeast Oklahoma and northwest Arkansas. Major tributaries of the Elk River include Buffalo, Indian, and Big Sugar Creeks. Water quality regulatory concerns in the basin include a nutrient total maximum daily load on the Elk River and its tributaries and the impairment of Indian Creek and the Elk River for bacteria.

Water quality data from the Elk River basin were compiled from multiple collection entities including the Missouri Department of Natural Resources, the Newton County Health Department, Crowder College, the Arkansas Department of Environmental Quality, and the U.S. Geological Survey. The data were analyzed for total phosphorus, total nitrogen, nitrate plus nitrite as nitrogen, and *Escherichia coli* (*E. coli*). Nutrient levels varied throughout the basin, but were frequently observed above recommended eutrophic threshold values recommended by Dodds *et al.* (1998). Phosphorus and nitrogen levels were most notably elevated in a tributary to McKisic Creek near Bentonville, Arkansas. *Escherichia coli* (*E. coli*) geometric means frequently exceeded state criteria; particularly in the Indian Creek watershed where the greatest concentration of combined animal feeding operations (CAFOs) exists in the Elk River basin.

Based on a data gap analysis of the existing water quality data in the Elk 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. Further data analysis and potential special storm water studies are also recommended to better understand non-point source loading issues. 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 (UMC) to perform the WQIP Data Gap Analysis. This report presents the data gap analysis for the Elk River basin (hydrologic unit 11070208). The data gap analysis for the Elk 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 Elk 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 whom 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 have been collected in the Elk 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. Summary – 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 Elk River basin provided below describes the basin characteristics, population and land use, point sources and permitted discharges, geology and soils, and climate and hydrology.

2.1. Basin Characteristics

The Elk River basin (1,031 mi^2) is located mostly in southwest Missouri. The western portion of the basin extends into northeast Oklahoma draining portions of Ottawa and Delaware Counties. The Elk River reaches its confluence with the Neosho River in Delaware County, Oklahoma. The basin also drains McDonald, Newton, and Barry Counties in Missouri, as well as Benton County in Arkansas. The headwaters begin in northern Benton and Western Berry Counties (≈ 1,300 feet asl) flowing nearly 60 miles before reaching its confluence with the Neosho River, or Grand Lake of the Cherokees, in northeast Oklahoma. Major tributary drainage areas include Little Sugar Creek, Indian Creek and Buffalo Creek (Figure 1).

Neosho, Missouri is the largest metropolitan area within the basin. Located in south central Newton County, the City of Neosho has a population of near 10,000, although only about half of the metro area, the southern half, drains to the Elk River basin. Buffalo Creek is the primary drainage for the City of Neosho. It drains the south-western side of the city, from east to west, flowing about 21 miles before its confluence with the Elk River's main stem. The few remaining communities within the Elk River basin are relatively small (<2,000). Communities of note are Goodman (Pop. 1,183), Anderson (Pop. 1,856), Lanagan (Pop. 411), Pineville (Pop. 768) Noel (Pop. 1,480), and Stella (Pop. 178). It should be noted that all thematic data in this report are confined to the Elk 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 (41 -100 persons per mi^2) in the basin occurs in northeast part of the basin which includes the town of Stark City (Figure 2). The remainder of the basin has a population density less then 35 persons per mi^2.

An analysis of population change in the basin between 1990 and 2000 shows the highest percentage of change (20% to 50% increase) to occur on the fringes of the basin (Figure 3), most notably in Newton and Barry Counties. Much of Newton County is drained by Buffalo Creek and Indian Creek, and the majority of the Newton County area is drained by tributaries to Big Sugar Creek. The majority of the basin showed less than 20% change between 1990 and 2000.

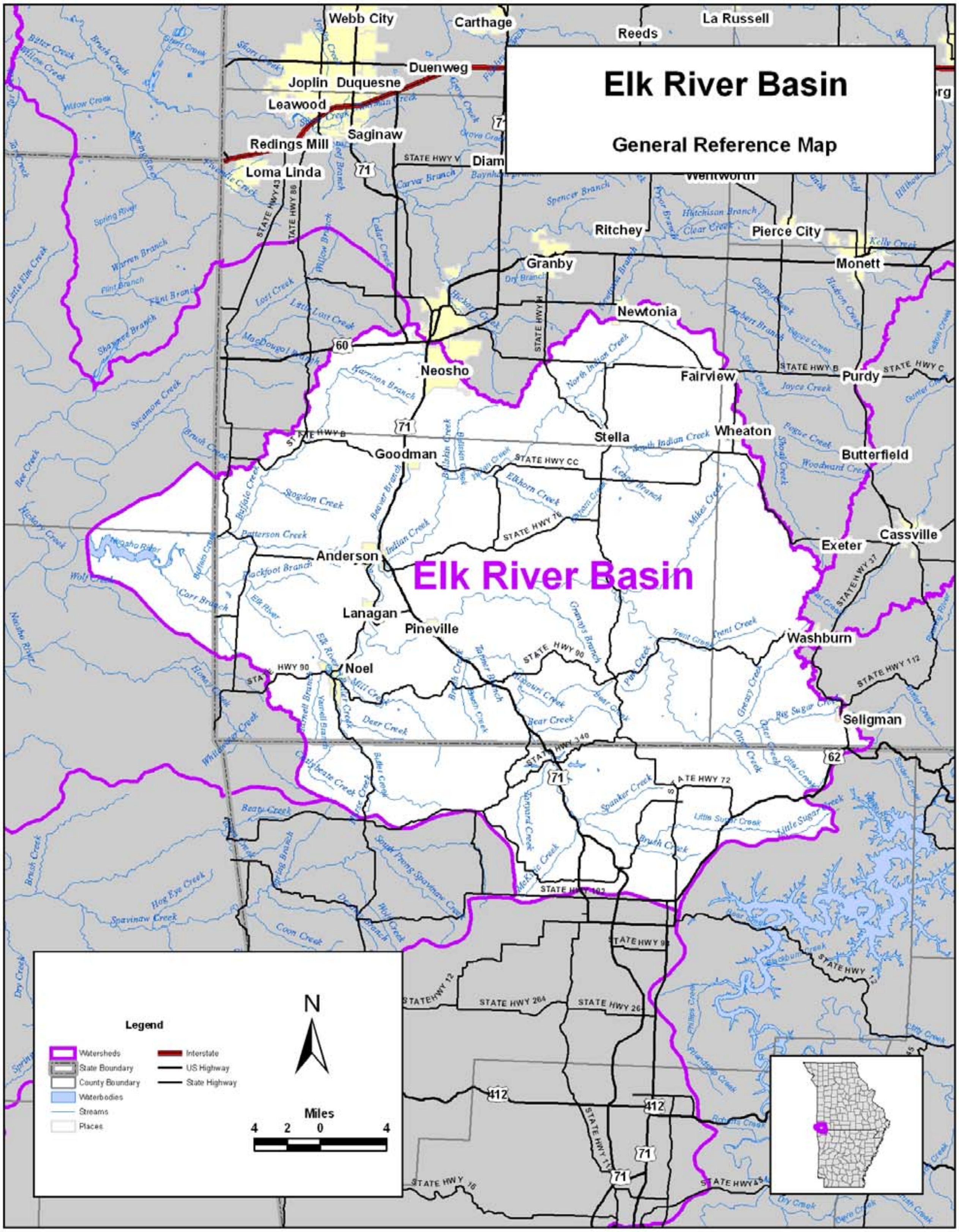

FIGURE 1. Elk River Basin – General Reference Map

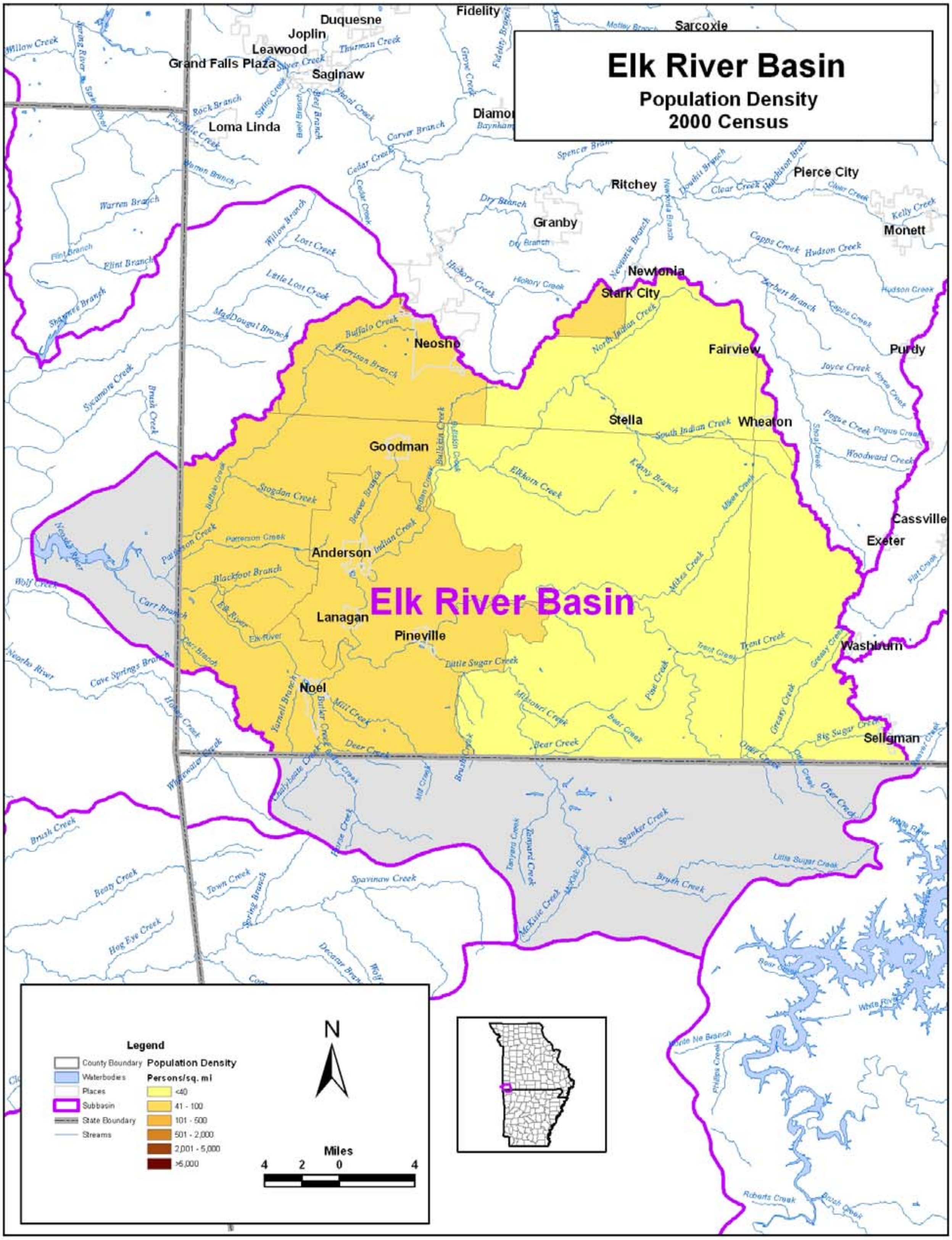

FIGURE 2. Elk River Basin – Population Density (2000)

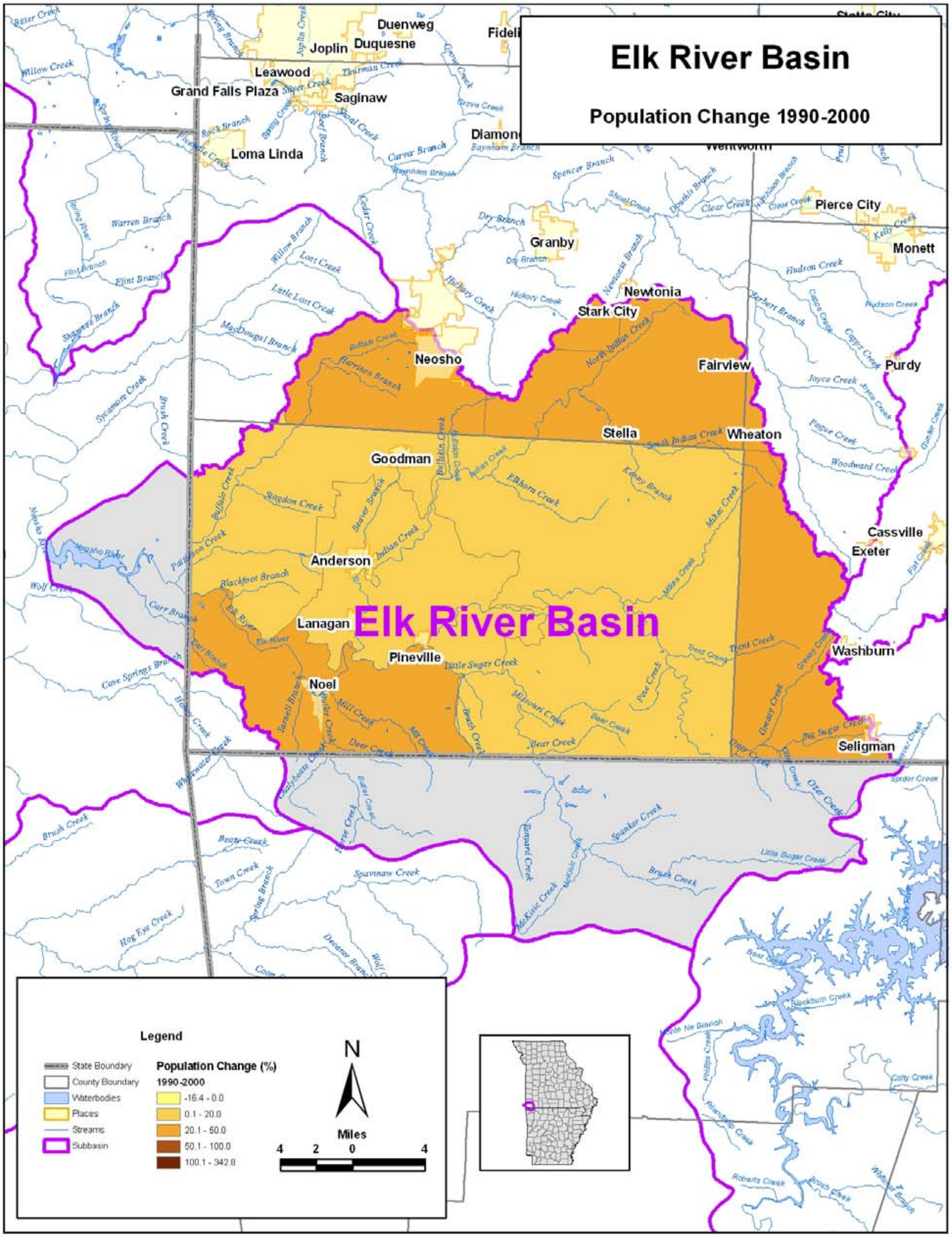

FIGURE 3. Elk River Basin – Population Change (1990-2000)

A large majority of the basin, including the headwaters areas, is dominated by grassland/pasture, and forest landuse (Figure 4). There is very little urban landuse in the basin. The only areas classified as either high or low density urban are in and around the communities of Neosho, Goodman, Anderson and Pineville. Overall, the Elk River basin is predominantly rural, with very little urban area influence. Table 1 summarizes land use for the basin.

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

Land Use Description	Area (sq. mi.)	% of Total
High Density Urban	17	2
Low Density Urban	6	1
Barren, Quarries, Lake Shore	8	1
Cropland	24	3
Grassland	441	42
Forest	433	41
Young Forest/Shrubland	95	10
Water	4	1

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 concentrated 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 (Figure 5).

The Elk River basin receives discharges from 30 permitted point source outfalls (Table 2) with combined design flow of 14 million gallons per day (MGD). Sixty-four percent of that combined flow comes from non-municipal domestic point sources within the basin while 21% comes from municipal sources.

CAFO outfalls are only used to 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 Elk River basin has a relatively large number of permitted CAFOs. The basin has 50 permitted CAFOs, including 47 swine, 2 poultry and 1 turkey (Table 3). A majority of the CAFOs are located within the northeastern part of the basin along the Indian Creek drainage in Newton County. Combined, these facilities account for 146.5 dry tons of permitted waste.

TABLE 2. Permitted Point Sources in the Elk River Basin

Type	Number	Discharge (MGD)*
Industrial	2	2
Non-Municipal Domestic	13	9
Municipal	15	3
Total	**30**	**14**

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

TABLE 3. CAFOs in the Elk River Basin

Type	Number	(dry tons)
Swine	2	122.8
Poultry	47	14.4
Turkey	1	9.3
Total	**50**	**146.5**

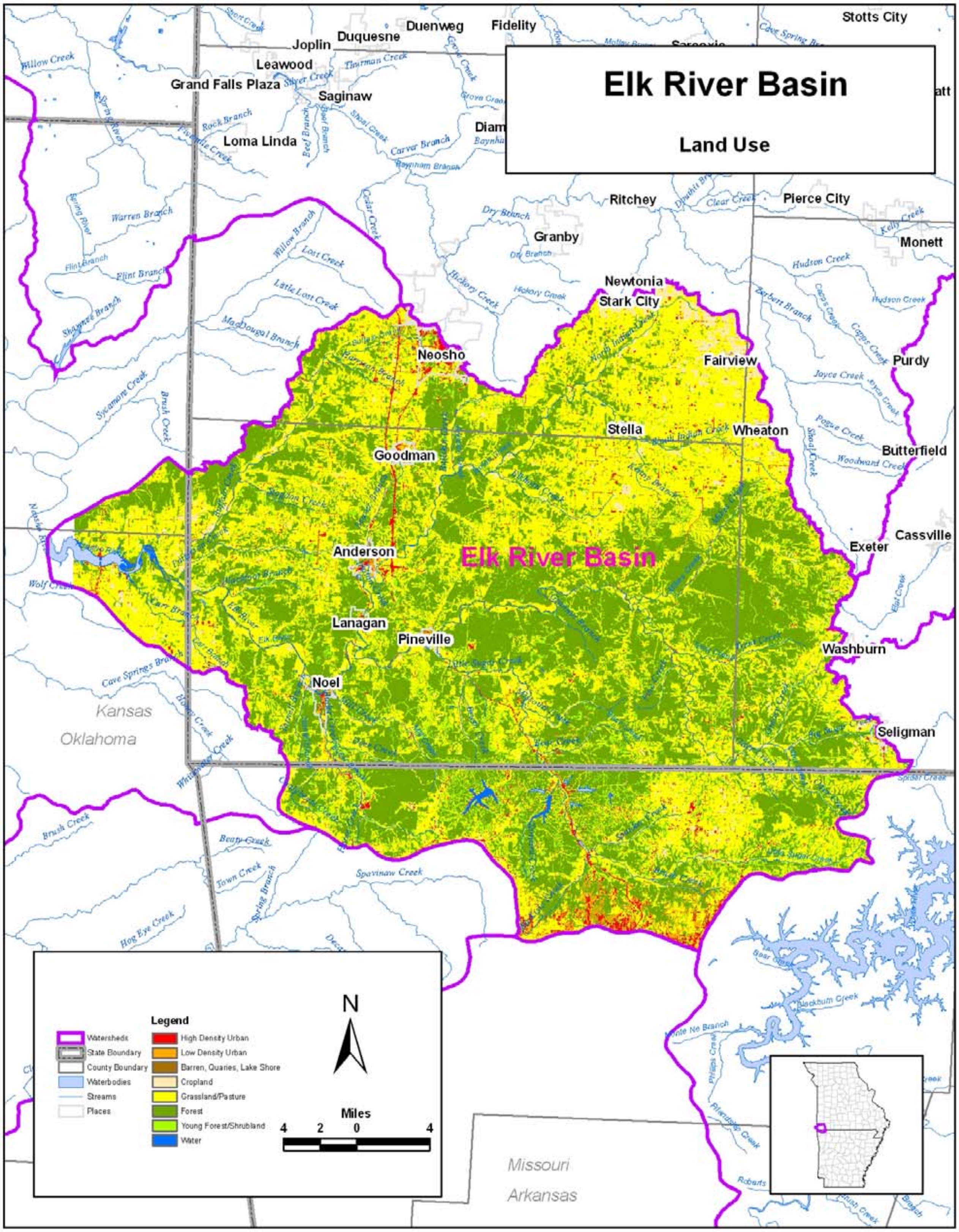

FIGURE 4. Elk River Basin – Land Use

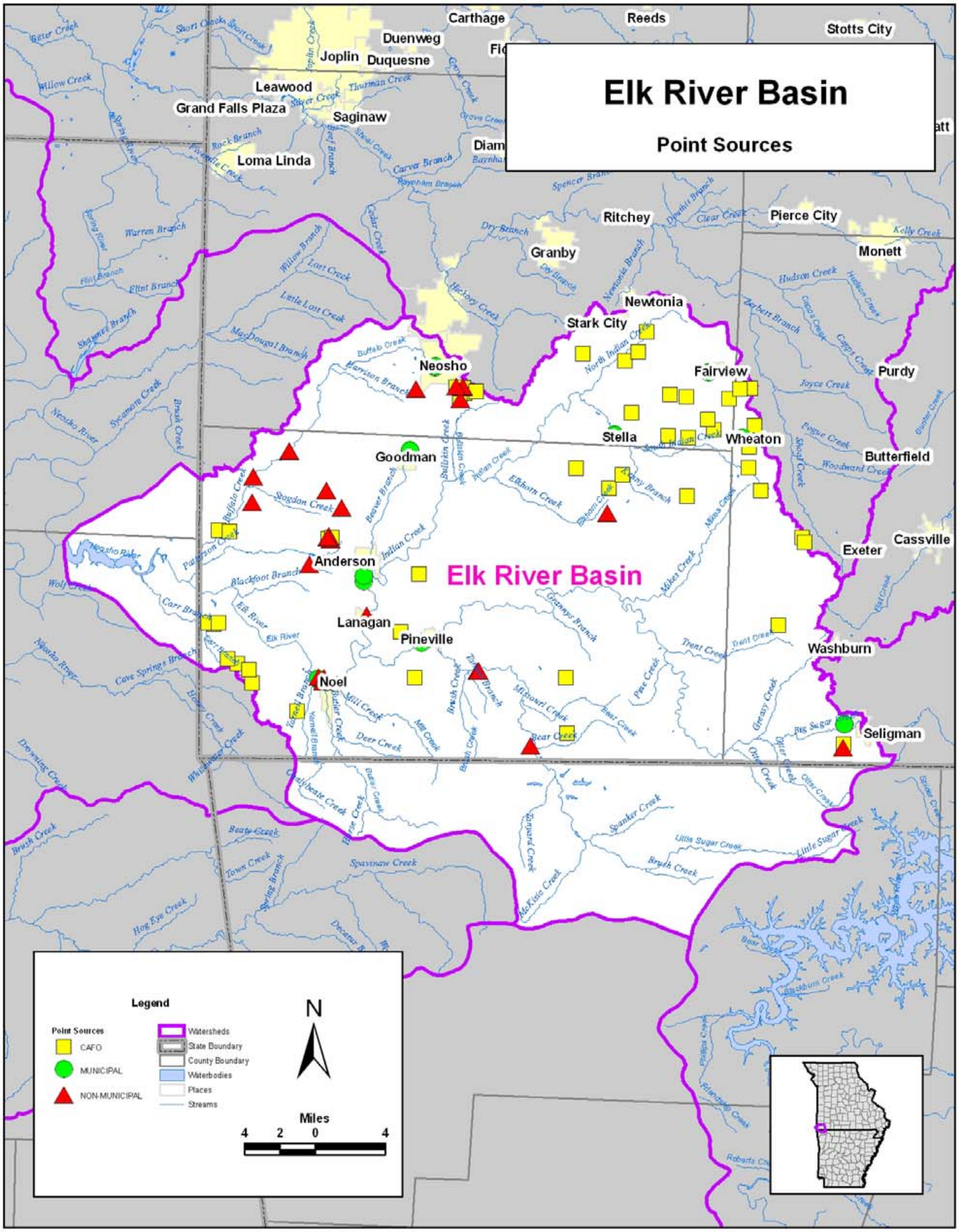

FIGURE 5. Elk River Basin – Point Sources

2.4. Geology and Soils

The Elk River basin spans the Springfield Plain, the Elk river Hills, and the Springfield Rolling Plain, all of which are part 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 Elk River Hills within the Elk River basin reflect the geological control in this region (Figure 7). A brief description of each soil series landscape position and parent material are described in 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.

Ozark Highlands Soils

53 – Tonti-Goss-Alsup

Alsup series consists of deep, moderately well drained, moderately slowly permeable soils formed in a mantle of colluvium or loess and the underlying residuum from shale or interbedded shale, siltstone, and limestone. They are on summits, side slopes, and foot slopes of uplands. Slopes range from 2 to 35 percent.

Goss series consists of very deep, well drained soils formed in colluvium and residuum weathered from cherty limestone or cherty dolomite and some interbedded shale. These soils are on uplands. Slopes range from 1 to 70 percent.

Tonti series consists of very deep, moderately well drained 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.

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 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.

68 - Rueter-Moko-Clarksville

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.

Moko series consists of shallow and very shallow, well drained and somewhat excessively drained soils that formed in loamy colluvium or residuum from limestone or dolostone. They are on dissected uplands in the Ozarks of northern Arkansas and southern Missouri. Slopes range from 3 to 100 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.

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.

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.

77 – Verdigris-Osage-Lanton

Verdigris (see 69 – Verdigris-Hepler-Dapue-Cedargap-Bearthicket above)

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.

86 - Ocie-Mano-Gatewood-Alred

Ocie series consists of deep, moderately well drained, slowly permeable soils formed in hillslope sediments and the underlying residuum from cherty dolomite or limestone with thin interbedded sandstone. These soils are on upland saddles, benches, and sideslopes. Slopes range from 1 to 35 percent.

Mano series consists of very deep, moderately well drained soils on hills. These soils formed in colluvial sediments from cherty limestone and the underlying residuum from cherty dolomite. Slopes range from 1 to 50 percent.

Gatewood series consists of moderately deep, moderately well drained soils of the uplands. They formed in gravelly hillslope sediments and the underlying residuum from cherty limestone or dolomite and shale. Slope gradients range from 1 to 60 percent.

Alred series consists of very deep, well drained soils formed in cherty hillslope sediments and the underlying clayey residuum. These soils are on moderately sloping to very steep uplands. Slopes range from 1 to 60 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.

107 – Eldorado-Dennis-Craig

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

Dennis series consists of very deep, somewhat poorly drained soils that formed in material weathered from shale of Pennsylvanian age. These soils are on nearly level to sloping uplands of the Cherokee Prairies. Slopes are 0 to 8 percent.

Craig series is a member of the clayey-skeletal, mixed, thermic family of Mollic Paleudalfs. These soils have very dark brown and very dark grayish brown silt loam A horizons, dark grayish brown silt loam A2 horizons, brown silt loam B1 horizons, dark yellowish brown and yellowish red very cherty clay loam B2t horizons and B3 horizons.

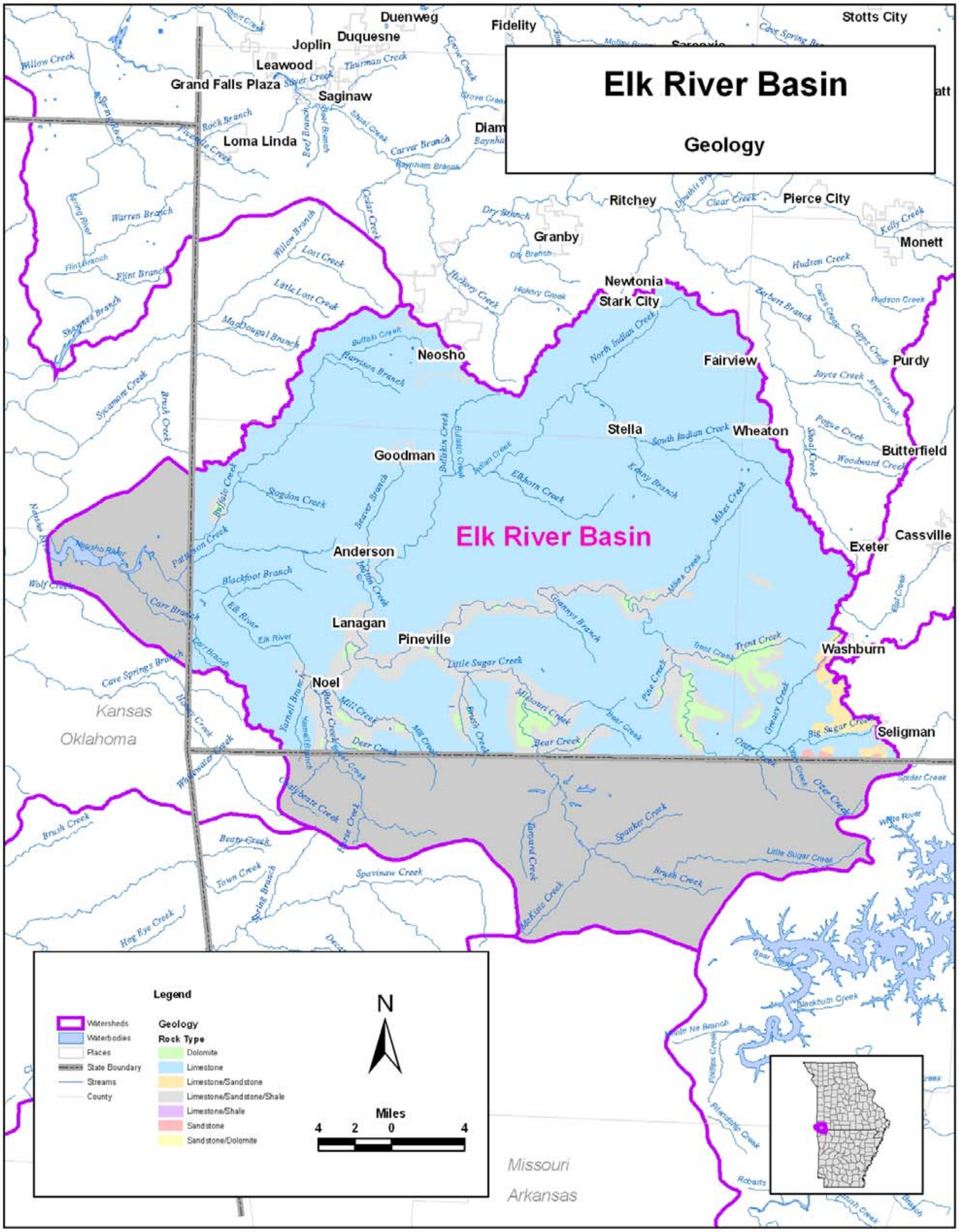

FIGURE 6. Elk River Basin - Geology

FIGURE 7. Elk 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 Bentonville 4 S climate station range from around 33°F in January to 78°F in July (Figure 8). Monthly average precipitation starts to rise in late winter and peaks in late spring with 5.3 to 5.2 inches of rainfall in May and June. Relatively high average rainfall totals also occur in the months of September and November with between 4.6 and 4.8 inches of rainfall. January and February receive the lowest average totals for the year with around 2.2 to 2.5 inches of rainfall per month (NOAA, 2005).

There are five United States Geological Survey (USGS) gaging stations in the basin (Figure 9, Table 4). One of the gages is located on the Elk River near Tiff City (07189000). The other four gages are located on Big Sugar Creek near Powel (07188653), Little Sugar Creek near Pineville (07188838), Indian Creek near Lanagan (07188885), and Buffalo Creek at Tiff City (07189100). The gage on the Elk River has 66 years of record while the rest of the gages have five or fewer years of record.

Monthly mean discharge data from the five gaging stations show the highest mean flows occurring during the months of April and May, corresponding to the spring wet season (Table 5). The lowest average runoff occurs during the month of September at all gaging stations but the Elk River at Tiff City gage, which occurs in August, corresponding with the hot, dry summer months. The highest flow on record occurred on the same date at Little Sugar Creek and Buffalo Creek, 01/05/2005, with flows of 8,290 cubic feet per second (cfs) and 6,530 cfs respectively, while the max flow at Big Sugar Creek occurred on 06/17/2000 (15,500 cfs), at Indian Creek on 02/24/2001 (13,200 cfs), and on the Elk River on 04/19/1941 (137,000 cfs). The lowest flows on record occurred during the month of September in 2005 for the gages at Big Sugar Creek and Indian Creek with flows of 3.6 cfs, and 24.0 cfs respectively. The lowest flow on Buffalo Creek also took place in September in 2002 with a flow of 0.09 cfs. Little Sugar Creek saw its all time low in October of 2004 with 21 cfs and the Elk River experienced its low in September of 1954. With the exception of the Tiff City gage, all of the maximum and minimum flows have taken place in the 21st century. Flow statistics for the five discharge gaging stations are summarized in Table 6.

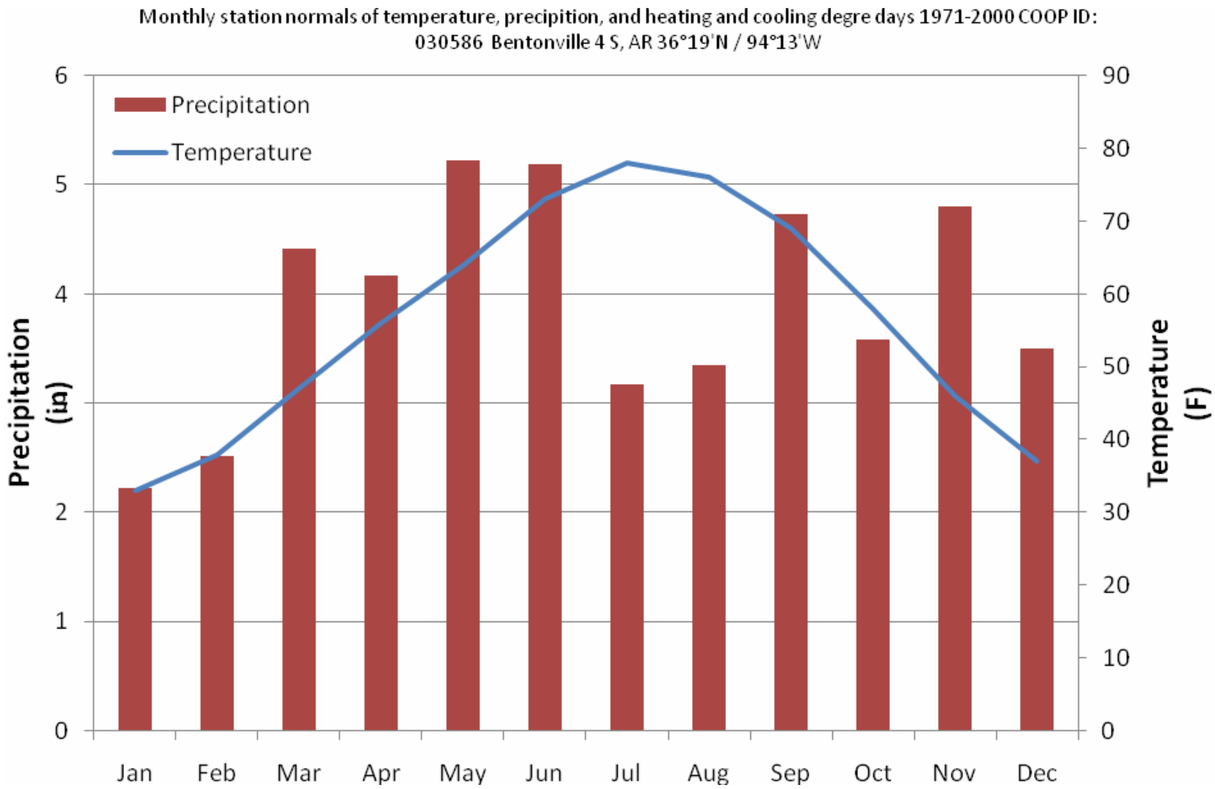

FIGURE 8. Monthly Average Precipitation and Temperature at the Bentonville, Arkansas Climate Station

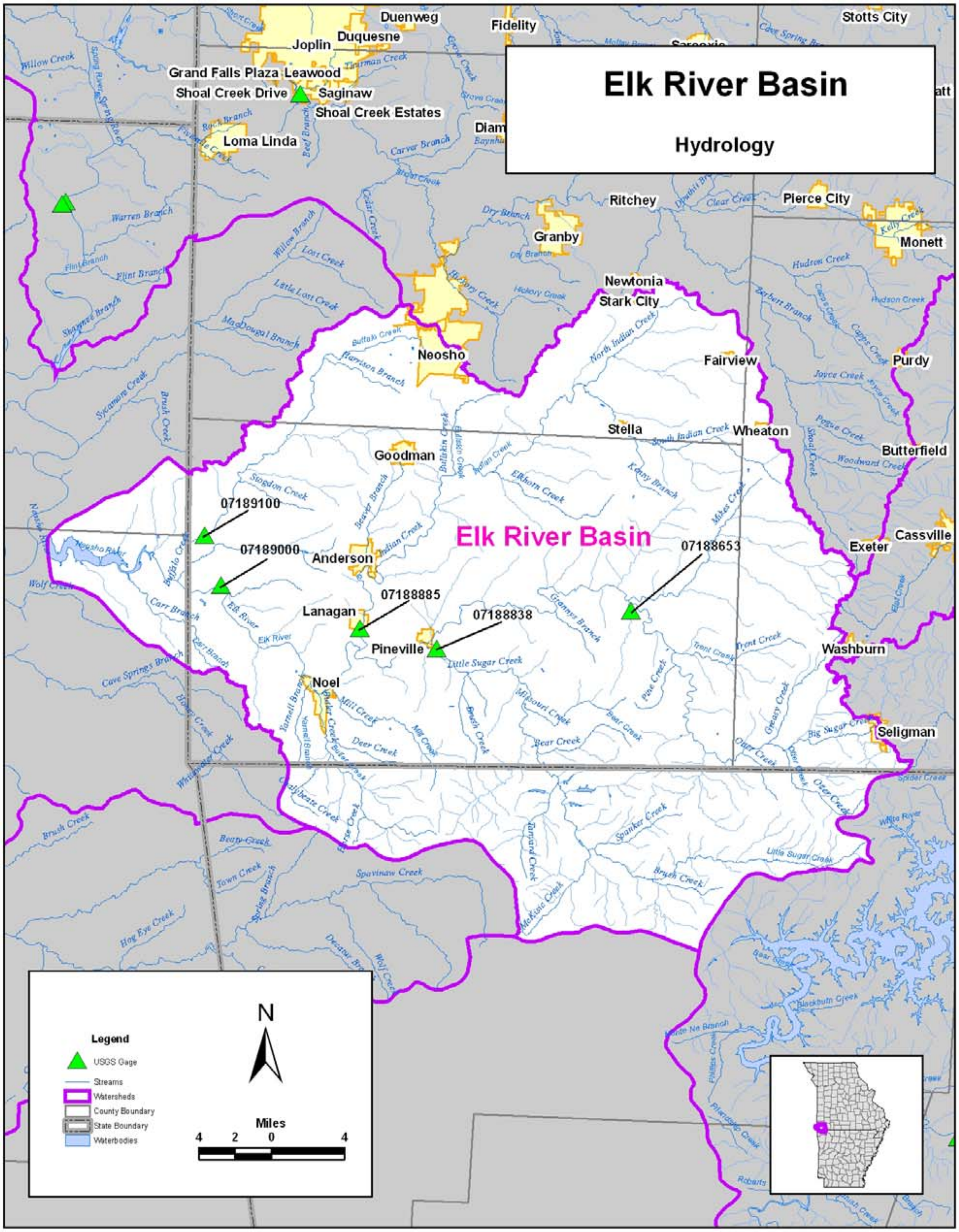

FIGURE 9. Elk River Basin – Hydrologic Gaging Station Locations

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

Station ID	Station Name	Drainage Area (mi^2)	Elevation (ft)	Start Year	Years of Record
7188653	Big Sugar Creek near Powell, MO	141	971	2000	5
7188838	Little Sugar Creek near Pineville, MO	195	859	2004	1
7188885	Indian Creek near Lanagan, MO	239	830	2000	5
7189000	Elk River near Tiff City, MO	872	751	1939	66
7189100	Buffalo Creek at Tiff City, MO	61	786	2000	5

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 Elk 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)
7188653	Big Sugar Creek near Powell, MO	194	166	155	163	206	164	64.7	22.8	10.2	19.3	72.1	111
7188838	Little Sugar Creek near Pineville, MO	989	192	153	261	122	100	40.6	38.6	35.1	38.7	358	297
7188885	Indian Creek near Lanagan, MO	315	265	239	261	412	239	138	49.4	39.4	43.7	110	135
7189000	Elk River near Tiff City, MO	730	881	1,326	1,574	1,503	959	486	256	283	403	712	763
7189100	Buffalo Creek at Tiff City, MO	138	106	95.5	100	150	107	50.8	6.18	4.16	7.32	22.4	45.5

Source: USGS, 2005

TABLE 6. Discharge Frequency at USGS Gaging Stations in the Elk 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
7188653	Big Sugar Creek near Powell, MO	3.6	9/11/2005	9.8	50	104	202	15,500	6/17/2000
7188838	Little Sugar Creek near Pineville, MO	21	10/6/2004	30	110	219	399	8,290	1/5/2005
7188885	Indian Creek near Lanagan, MO	24	9/10/2005	33	82	181	340	13,200	2/24/2001
7189000	Elk River near Tiff City, MO	5.1	9/5/1954	88	344	822	1,720	137,000	4/19/1941
7189100	Buffalo Creek at Tiff City, MO	0.09	9/17/2002	2.3	22	66.8	118	6,530	1/5/2005

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 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).

Within the Elk River basin the following streams are listed on a 303(d) List or have a completed TMDL:

- Cave Spring Branch;
- Big Sugar Creek;
- Buffalo Creek;
- Elk River;
- Little Sugar Creek;
- Indian Creek;
- Middle Indian Creek;
- North Indian Creek;
- South Indian Creek; and
- Patterson Creek.

The pollutants identified as responsible for these impairments include bacteria and nutrients.

Bacteria

Indian Creek in Missouri and Elk Creek in Oklahoma have both been 303(d) listed for bacteria. A 5-mile segment of Indian Creek is on Missouri's 2004/2006 303(d) list due to rural nonpoint source pollution based on *Escherichia coli* (*E. coli*) found in excess of criteria. Oklahoma has a 13.1 mile segment of the Elk River listed as impaired on its 2006 303(d) list based on Enterococcus from unknown sources (ODEQ, 2006). However, the draft 2008 Oklahoma 303(d) list proposes delisting this segment based on new data (ODEQ, 2008).

Nutrients

In 1998 the Elk River and its tributaries were listed on the Missouri's 303(d) list of impaired waterways for nutrients. The listing was based on the proliferation of nuisance algae, turbidity due to suspended algae, and low dissolved oxygen as a result of overabundant plant life. Preliminary findings in a 2004 USGS report (USGS, 2005) created in support of the Missouri TMDL stated "A substantial nutrient load is carried in the Elk River and its tributaries". It also showed that Little Sugar Creek appeared to be the dominant source of phosphorous to the Elk River. In 2004 a TMDL was completed by the Missouri Department of Natural Resources (MDNR) for the Elk River basin. In addition to the Elk River, the TMDL addressed the following waterbodies: Big Sugar Creek, Little Sugar Creek, Buffalo Creek (two segments), Patterson Creek, Indian Creek, Middle Indian Creek (two segments), South Indian Creek, and North Indian Creek. The TMDL identified both point and nonpoint sources of nutrient impairment. Nonpoint sources have been attributed to livestock production and rapid population growth (MDNR, 2004).

Cave Spring Branch has been listed as impaired for nutrients by the MDNR since 1998, but was not included in the Elk River TMDL. Although Cave Spring Branch is still currently 303(d) listed, MDNR has determined that there is currently no evidence of exceedence of narrative water quality standards. There have been large reductions in nutrients discharged to Cave Spring Branch since 1999, at which time Simmons Food, Inc. upgraded their wastewater treatment plant. A study by the Oklahoma Department of Environmental Quality in 1998 found a good diversity of fish species in the creek and concluded the stream had recovered from the acute pollution events that occurred in July 1997. Furthermore, a 2004 MDNR benthic survey concluded the aquatic invertebrate community and levels of algae were similar to other streams in the area (MDNR, 2008).

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 Elk River basin from MDNR and USGS databases. Additional data were collected from Crowder College, the Arkansas Department of Environmental Quality, and the Newton County Health Department. The 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 and the USGS. Although the 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 Elk River to 26 (Figure 10).

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

The 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, 2005a).

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.

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 7 monitoring stations in the Elk River basin. These sites were monitored from October 2004 to December 2006 with the specific intent of providing information to the MDNR to assess TMDLs. USGS water quality data in the Elk River basin were collected from January 1961 to September 2004 and included over 500 parameter codes[1].

Crowder College

Data was collected by Crowder College researchers at 19 sites within the Elk River basin between 1991 and 2004. Parameters collected were TP, TN, NO3+NO2, *E. coli*, fecal coliform, and flow. This collection effort was funded through a 319 grant in cooperation with MDC. Among other project objectives, this data will be used to develop nutrient TMDL's for streams in the Shoal Creek basin and Elk River basin.

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

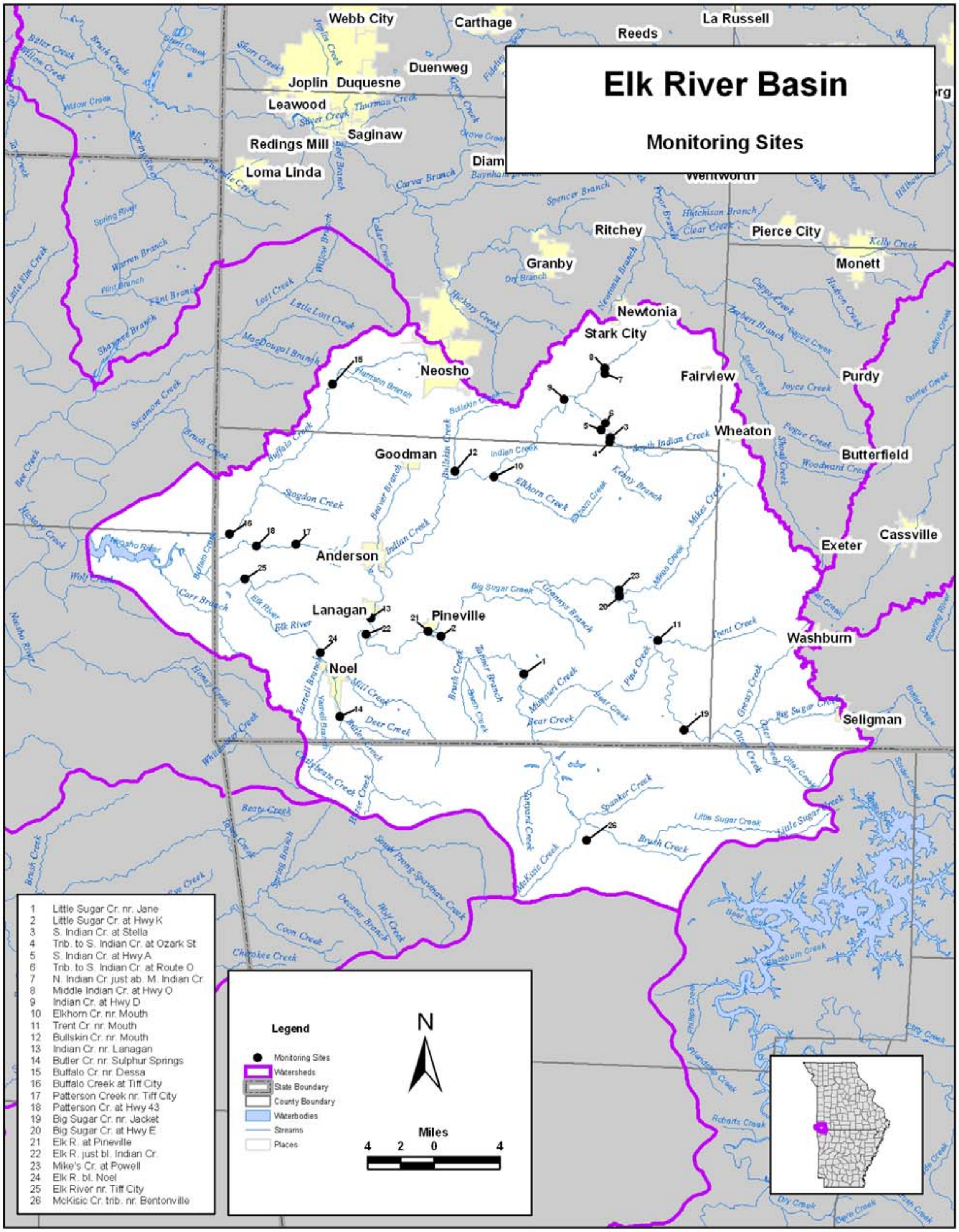

FIGURE 10. Water Quality Monitoring Sites in the Elk River Basin

Newton County Health Department

Water quality data collected by the NCHD were available from the MDNR database for 9 monitoring sites in the Elk River basin. The data were collected between June 2005 and June 2007. *E. coli* measurements were taken at all of the sites while TP and NO3NO2 were also collected at some sites.

Arkansas Department of Environmental Quality

The ADEQ collected water quality data at two sites within the Elk River basin between December 1989 and July 2006. ADEQ maintains surface water quality monitoring stations throughout the state as part of their Ambient Water Quality Monitoring Program. The Environmental Preservation and Technical Services Division oversees maintenance of these stations.

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 sample was 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 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, the 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[2]. The criteria for identifying co-located monitoring sites were primarily based on best professional judgment. Sites were 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.

[2] 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.

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, 2003a). 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 11). 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 11. 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 georeferenced 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
Crowder College	2.0
Arkansas Department of Environmental Quality	2.4
United States Geological Survey	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 Elk River basin were compiled into the WQIP database, the assessment was limited to the following five parameters:

- Total Phosphorus as Phosphorus (TP),
- Total Nitrogen as Nitrogen (TN),
- Nitrate plus Nitrite as Nitrogen ($NO_3 + NO_2$),
- *Escherichia coli* (*E. coli*).

The WQIP project workgroup selected these four water quality parameters since they represent direct or indirect indications of threats to the water quality resources of the Elk River basin. *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.

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 December 5, 1989. Although TP data dates back several decades, sampling did not commence at most sites until around 1989 (Figure 12). Therefore, the period of record was set to include 1989 to the present.

Analysis of TN and NO_3+NO_2 was limited to sampling dates on or after October 11, 1989. The most common period of record for most sampling sites for both of these parameters begins around 1989 (Figures 13 and 14). Therefore, the period of record was set near the beginning of the 1989 water year (i.e., October 1, 1989).

Analysis of *E. coli* was limited to sampling dates on or after May 18, 1994. With only 9 sites producing *E. coli* data, all dates were included in the analysis (Figure 15). Choosing a sampling period other than this would result in too little data. Therefore, the period of record was set to May 18, 1994 and after.

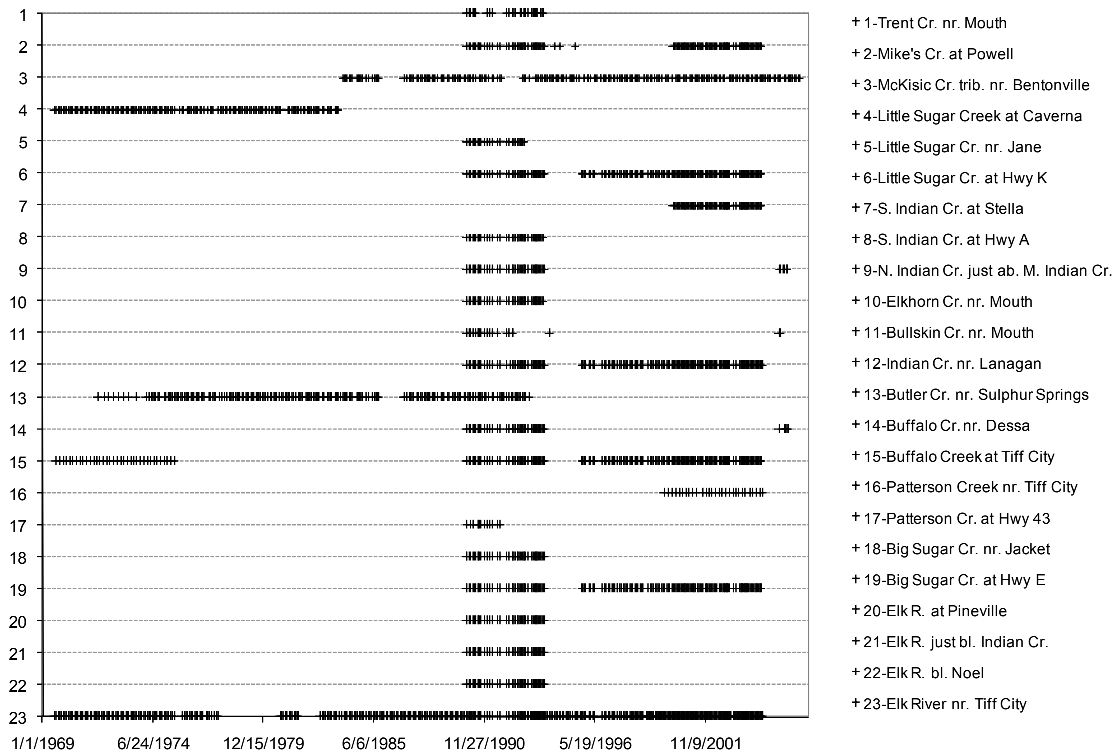

FIGURE 12. Total Phosphorus Sampling Frequency and Period of Record in the Elk River Basin

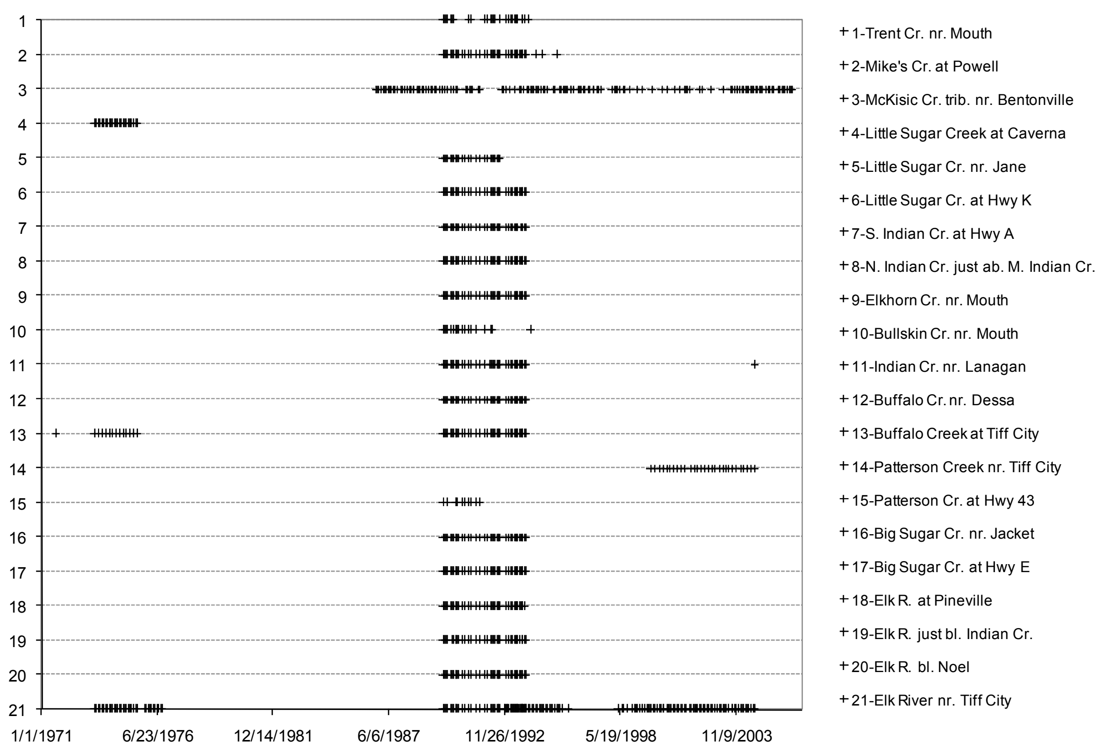

FIGURE 13. Total Nitrogen Sampling Frequency and Period of Record in the Elk River Basin

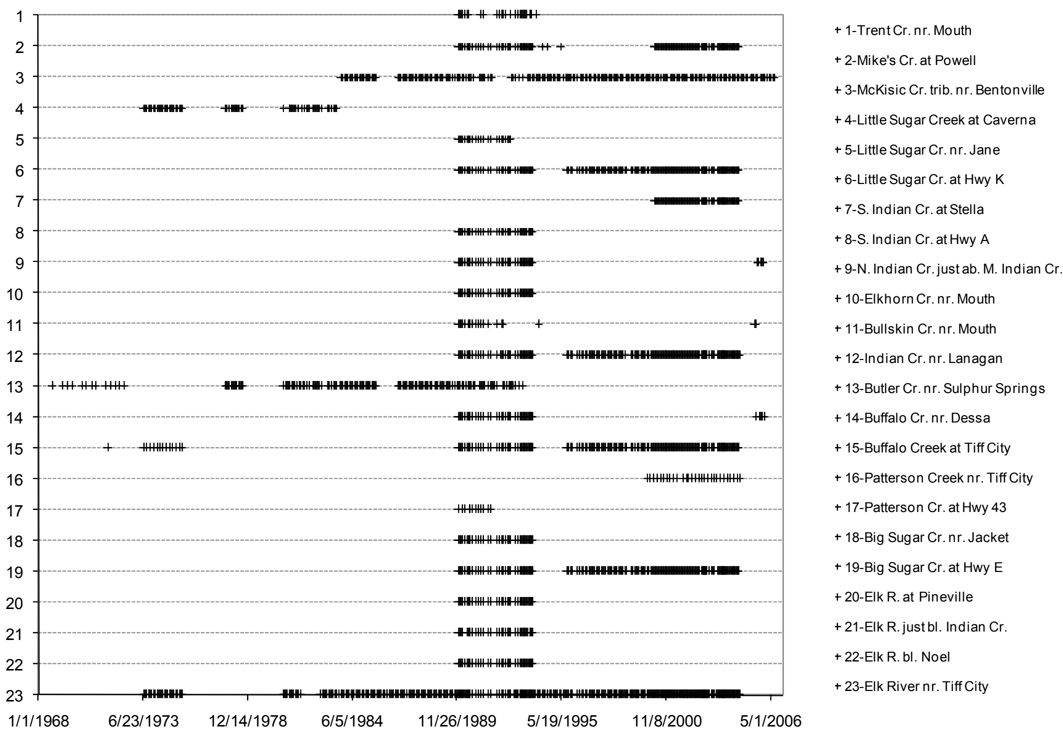

FIGURE 14. Nitrate plus Nitrite Sampling Frequency and Period of Record in the Elk River Basin

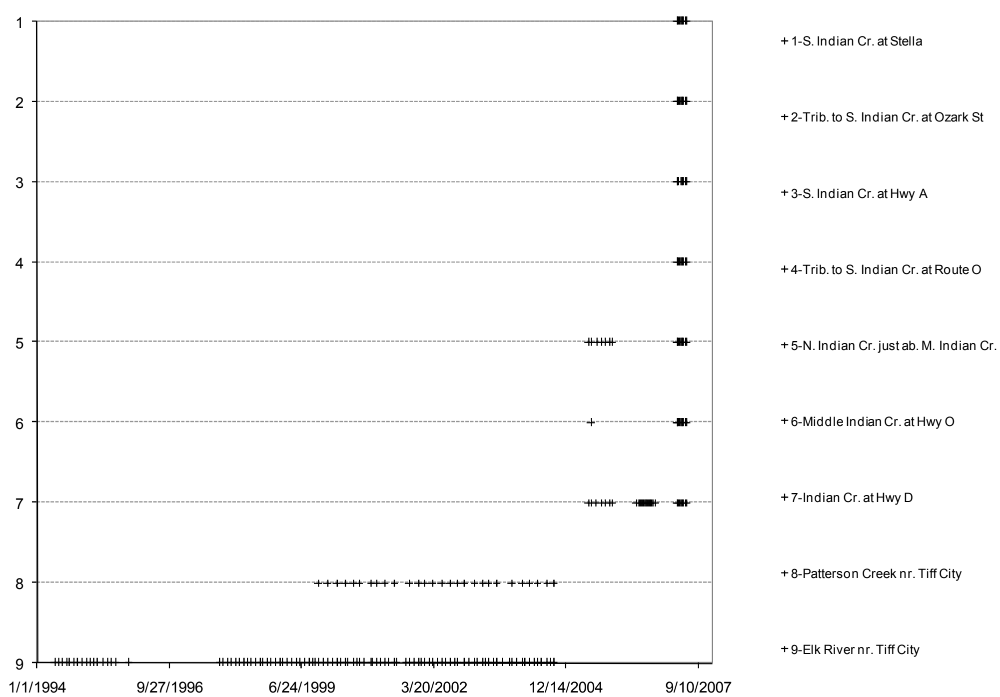

FIGURE 15. *E. coli* Sampling Frequency and Period of Record in the Elk River Basin

3.3.4. Data Analysis

Water quality data in the Elk River basin were analyzed 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™, MS Excel™, Grapher™, and ArcGIS™. Data results are displayed in the tables and figures in order of upstream to downstream with the caveat that all Elk 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 tends 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)[3] 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)[4] 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.

[3] 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).

[4] 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 and *E. coli* in the Elk 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 for each parameter 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[5] are considered impaired due to nutrients, including all listed sections within the Elk River basin. The effects of cultural eutrophication can include the following (MDNR, 2005b):

- 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, 2005b; EPA, 2000b). A discussion of causal (TP, TN, NO_2+NO_3) variables observed in the Elk 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[6] state in lotic[7] 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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[5] 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.

[6] 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.

[7] 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[8] (EPA, 2000a). 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 Elk River near Tiff City station. The Tiff City station had the most complete long-term TP recordset of any station in the Elk River basin. Annual geomean TP levels indicated no apparent trend in the 1970s but appeared to increase throughout the 1980s and 1990s (Figure 16). The greatest annual geomeans were observed from 2000 to 2003. In 2004 the TP annual geomean dropped to approximately 60 µg/L from a high of approximately 160 µg/L just two years prior. More data is needed to determine whether this represents a downward trend or just data variability.

The observed TP levels suggest significant phosphorus loading sources from Arkansas and from the northern reaches of the Elk River basin. The McKisic Creek tributary near Bentonville had the highest observed TP geomeans in the Elk River basin, with values ranging from 116 to 9,100 µg/L (Table 7 and Figure 17). The phosphorus loading sources for McKisic Creek are unclear because the McKisic Creek site is located in Arkansas. Point source data for the gap analysis has only been compiled for the state of Missouri. However, the Little Sugar Creek site near Jane, downstream of McKisic Creek, displays the next highest TP geomean within the basin with values ranging from 130 to 1,570

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

μg/L. It can be assumed that the elevated TP levels at this site are influenced by the McKisic Creek tributary. Other tributaries to the Elk River with elevated levels of TP include North Indian Creek (5 to 1,180 μg/L), and Buffalo Creek (5 to 1,100 μg/L), The four sampling stations on the Elk River have TP geomeans ranging from 71 to 128 μg/L.. TP geomeans were generally the lowest along Patterson, Butler, and and Mike's Creek where geomeans ranged from 31 μg/L to 44 μg/L.

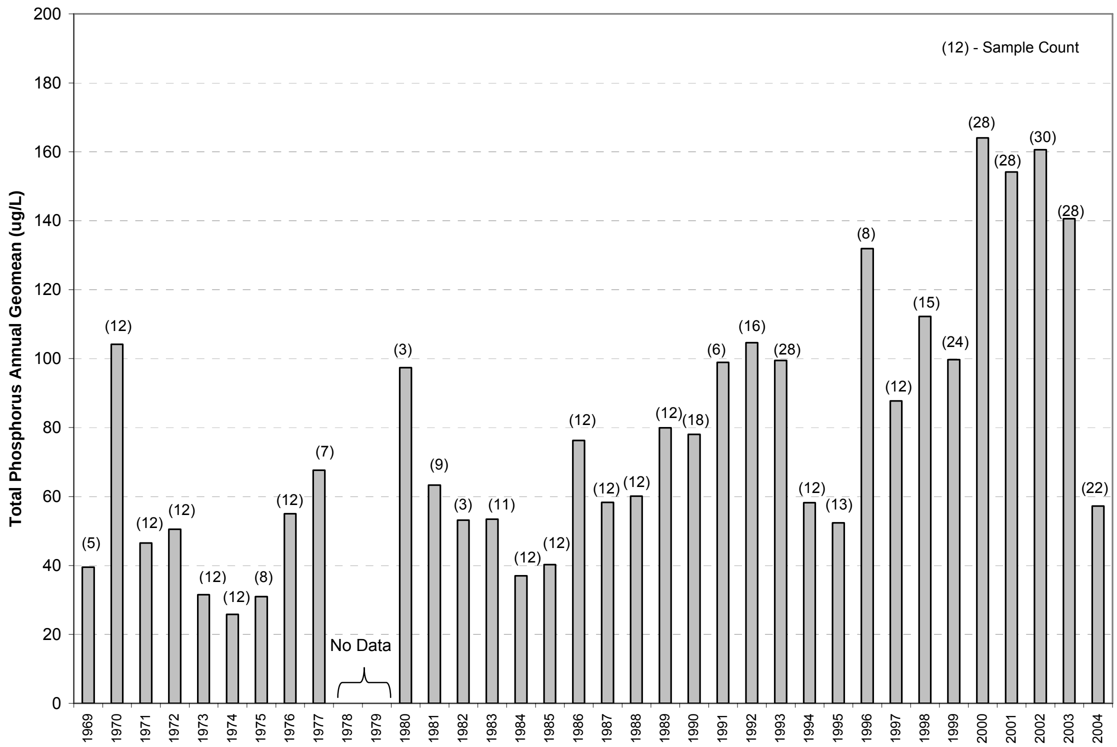

FIGURE 16. Total Phosphorus Annual Geometric Means Measured at the Elk River near Tiff City Station

A boxplot and barchart comparison of TP values illustrates that almost half of the sampling exceed the Dodds *et al.* (1998) eutrophic threshold value of 75 μg/L (Figures 18 and 19). Only 2 of the 22 water quality monitoring stations in the Elk 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 19 illustrates that the Elk River near Tiff City water quality station (the most downstream Elk River station with TP values) is ranked in the upper half of all Elk River basin stations with regard to TP geomeans.

TABLE 7. Total Phosphorus Statistics for the Elk 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)
3250/24.9/0.1	Trent Cr. nr. Mouth	1/3/1990	10/28/1993	32	220	213	104	5	970	213	6	50	292	329
7188660	Mike's Cr. at Powell	1/3/1990	8/13/2004	127	40	92	42	5	920	156	5	20	90	160
7188800	McKisic Cr. trib. nr. Bentonville	12/5/1989	7/11/2006	165	3,840	3,743	3,214	116	9,100	1,738	1,460	2,420	5,045	6,000
3249/7.7	Little Sugar Cr. nr. Jane	1/3/1990	11/11/1992	30	315	396	350	130	1,570	263	256	282	385	610
3249/0.7	Little Sugar Cr. at Hwy K	1/3/1990	8/13/2004	173	200	235	184	10	2,000	217	90	140	250	378
3259/3.8	S. Indian Cr. at Stella	4/10/2000	8/13/2004	78	75	92	67	5	1,000	115	30	42	107	143
3259/3.3	S. Indian Cr. at Hwy A	1/19/1990	10/28/1993	44	110	231	73	5	1,160	288	5	17	355	640
3260/3.0	N. Indian Cr. just ab. M. Indian Cr.	1/3/1990	11/29/2005	52	390	392	172	5	1,180	319	5	72	625	793
3257/0.2	Elkhorn Cr. nr. Mouth	1/3/1990	10/28/1993	45	90	218	70	5	870	258	5	20	370	602
3264/0.5	Bullskin Cr. nr. Mouth	1/3/1990	7/26/2005	22	35	191	48	5	790	268	5	6	315	667
7188885	Indian Cr. nr. Lanagan	1/3/1990	9/15/2004	174	70	108	61	5	1,300	156	10	40	110	200
7188910	Butler Cr. nr. Sulphur Springs	12/5/1989	2/23/1993	35	50	53	44	15	130	31	15	33	60	100
3273/5.2	Buffalo Cr. nr. Dessa	1/3/1990	12/20/2005	51	200	244	177	5	1,100	197	60	130	295	490
7189100	Buffalo Creek at Tiff City	1/3/1990	8/13/2004	173	70	128	74	5	1,250	180	20	50	140	270
7188950	Patterson Creek nr. Tiff City	11/2/1999	9/14/2004	29	30	33	31	20	100	15	20	25	30	42
3268/2.7/0.5	Patterson Cr. at Hwy 43	1/3/1990	9/12/1991	13	100	216	82	5	620	230	5	30	330	586
3250/33.8	Big Sugar Cr. nr. Jacket	1/3/1990	11/18/1993	46	105	213	72	5	990	270	5	20	265	620
3250/19	Big Sugar Cr. at Hwy E	1/3/1990	8/13/2004	173	60	97	57	5	790	121	10	30	110	178
3246/20.8	Elk R. at Pineville	1/3/1990	11/18/1993	46	135	182	108	5	820	182	35	60	210	480
3246/14.7	Elk R. just bl. Indian Cr.	1/3/1990	11/18/1993	46	100	149	71	5	950	171	5	32	215	320
3246/X	Elk R. bl. Noel	1/3/1990	11/18/1993	46	150	187	128	10	750	152	40	93	228	335
7189000	Elk River nr. Tiff City	10/11/1989	9/14/2004	291	110	148	107	5	1,000	128	40	60	190	300

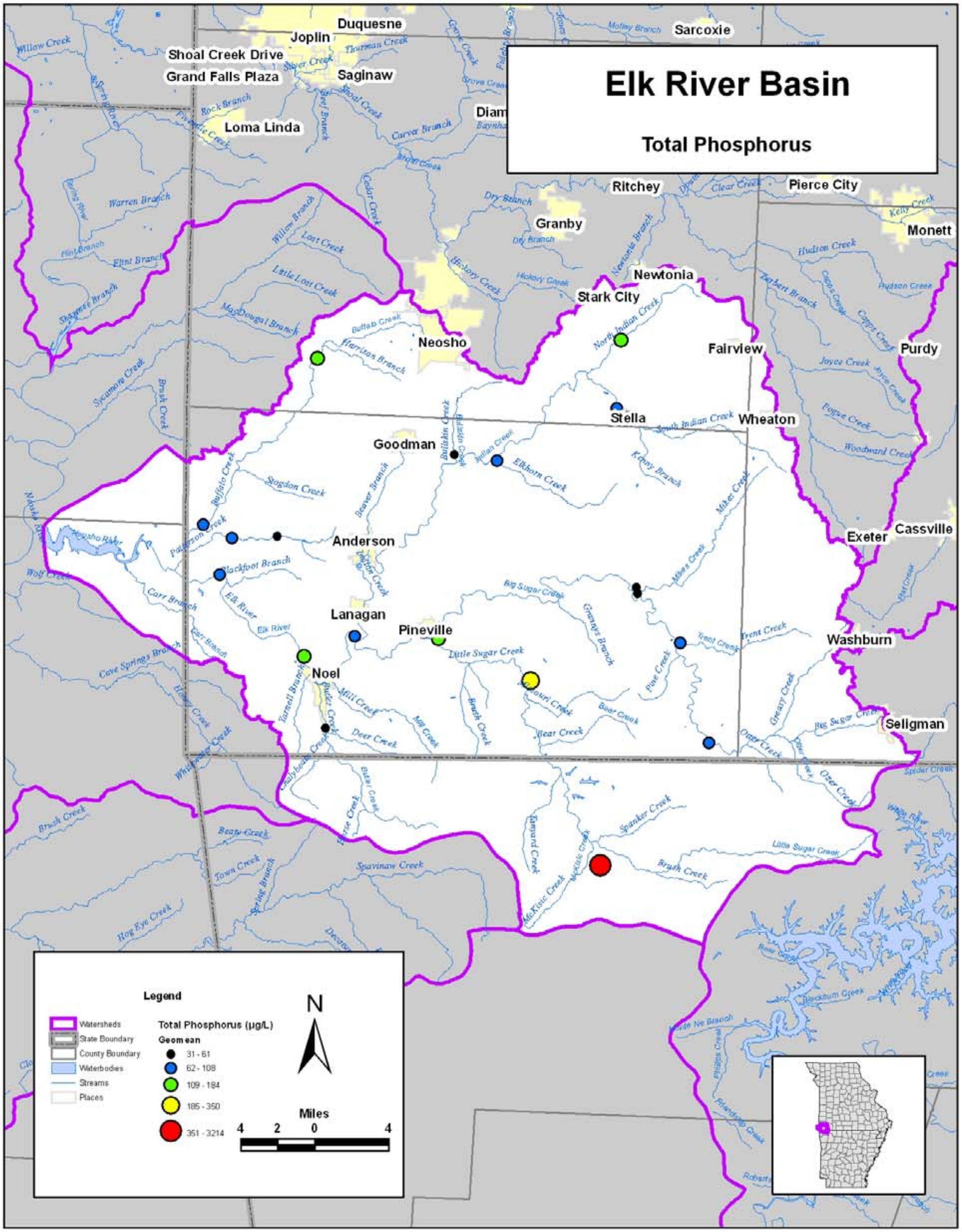

FIGURE 17. Graduated Symbol Map of Total Phosphorus Geometric Means in the Elk River Basin

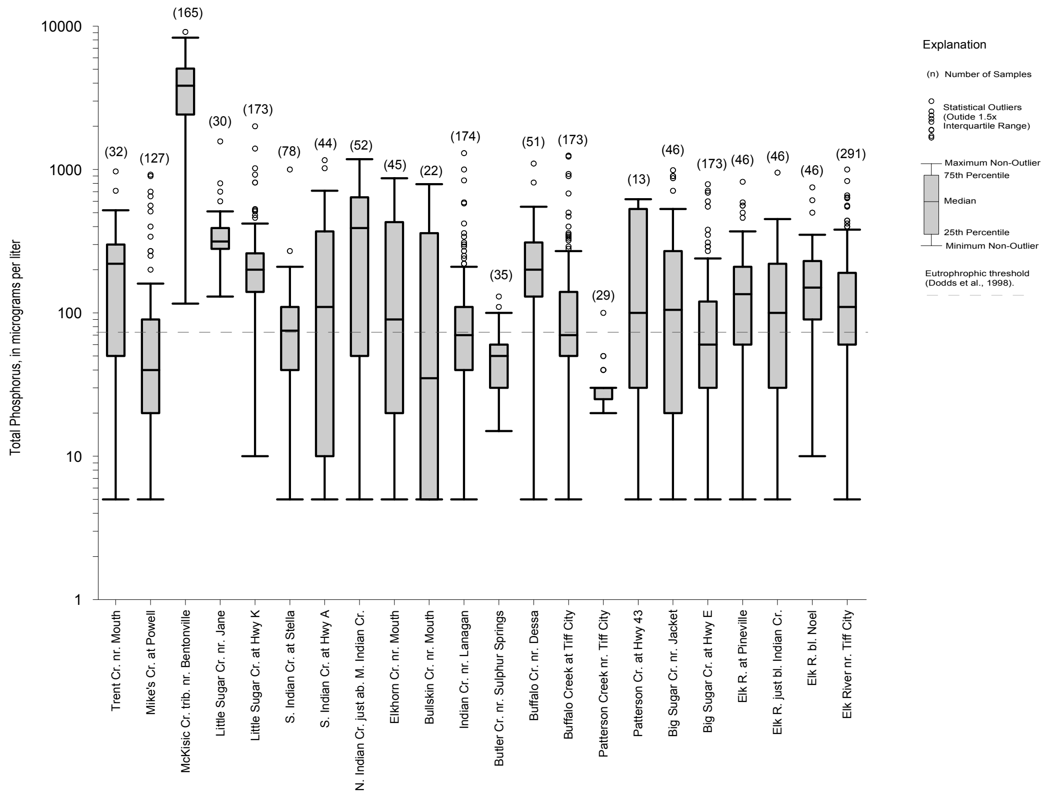

FIGURE 18. Box Plot of Total Phosphorus Levels in the Elk River Basin

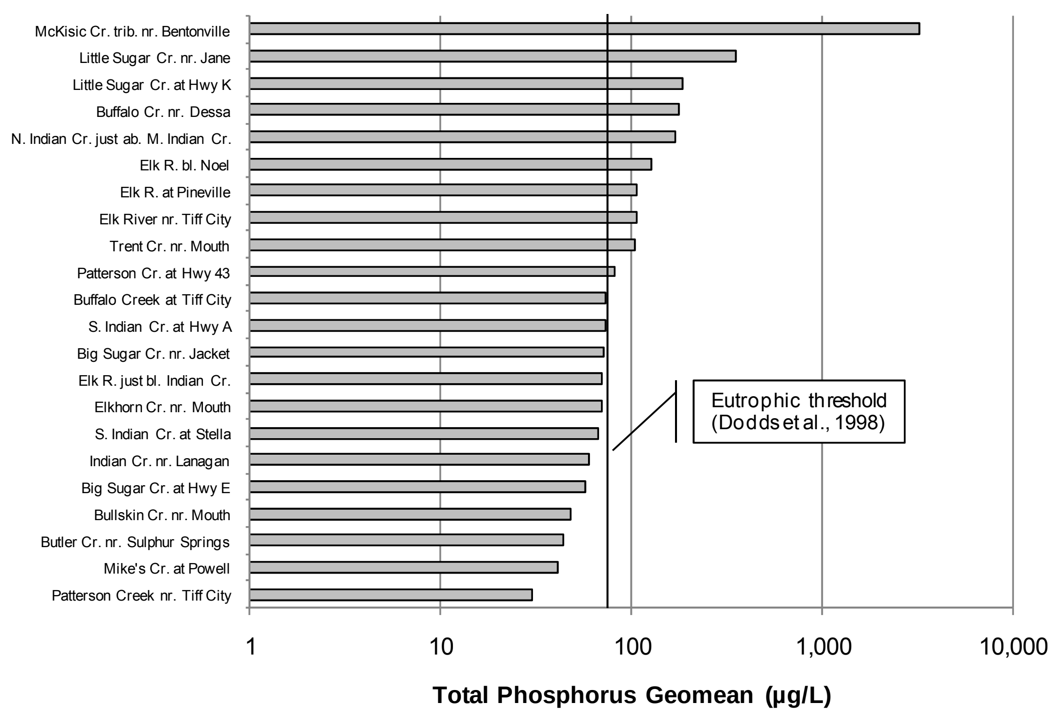

FIGURE 19. Bar Chart of Total Phosphorus Geomeans in the Elk River Basin

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[9] 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).

4.1.2.1. Total Nitrogen

A trend analysis was conducted using data from the Elk River near Tiff City station. Though the Tiff City station had the most complete long-term TN recordset of any station in the Elk River basin, no data were available from the late 1970s through the

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

1980s. Based on the available data, no clear trend could be observed. However, annual TN geomeans may be increasing based on data from 1990 through 2004, but a more rigorous statistical analysis would be required to confirm this trend (Figure 20).

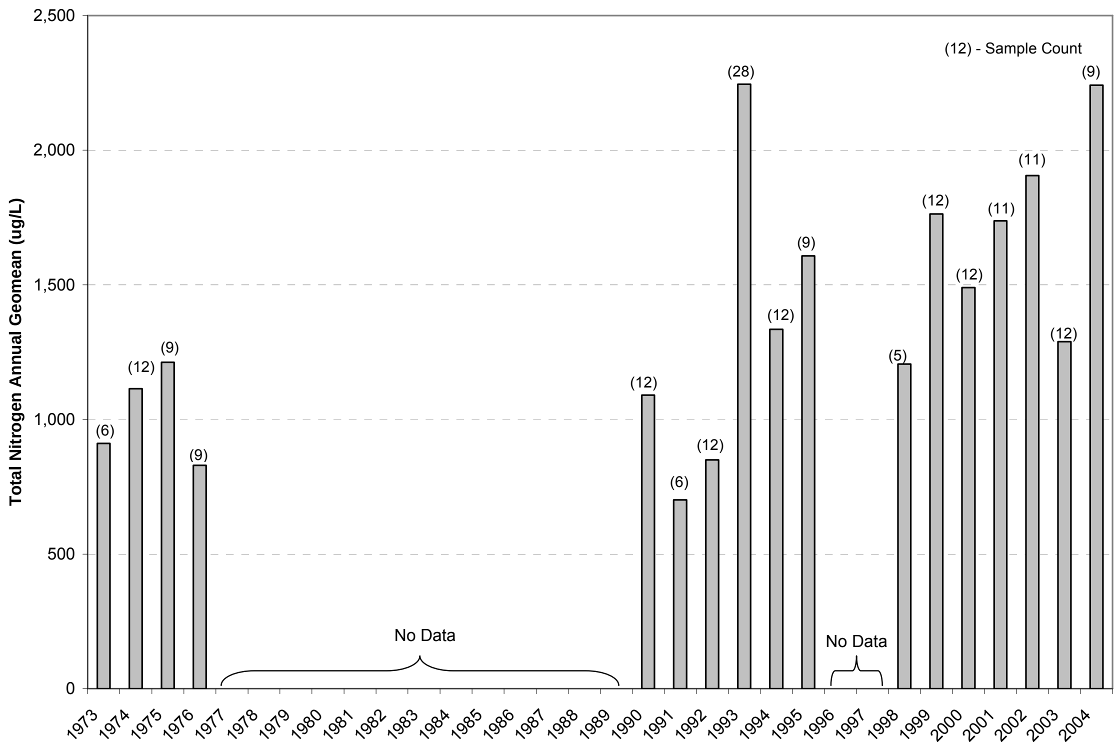

FIGURE 20. Total Nitrogen Annual Geometric Means Measured at the Elk River near Tiff City Station

As with phosphorus, the highest levels of TN geomeans in the Elk River basin were observed in the McKisic Creek tributary near Bentonville. TN levels in the McKisic Creek tributary ranged from 2,000 μg/L to 18,000 μg/L (Table 8 and Figure 21). But once again, because point source data for the gap analysis has been restricted to Missouri, the nitrogen loading sources for McKisic Creek are unclear. The four monitoring sites on the Elk River have TN geomeans ranging from 1,247 to 1,521 μg/L. The lowest TN geomean (913 μg/L) occurred on Mikes Creek at Powell and the next lowest (941 μg/L) occurred on the Little Sugar Creek near Jane.

A boxplot comparison of TN geomean values shows 10 of the 20 water quality samples collected in the Elk River basin exceed the Dodds *et al.* (1998) eutrophic threshold value of 1,500 μg/L (Figures 22 and 23). However, when comparing the interquartile range of each of the samples, only two sites exceed the threshold completely. All of the sites with geomeans exceeding the eutrophic threshold occurred on tributaries to the Elk River; none of the Elk River sites themselves exceeded the TN threshold.

TABLE 8. Total Nitrogen Statistics for the Elk 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)
3250/24.9/0.1	Trent Cr. nr. Mouth	1/3/1990	1/20/1994	29	2,120	3,045	1,912	170	7,950	2,516	490	1,030	5,305	6,528
7188660	Mike's Cr. at Powell	1/3/1990	5/18/1995	45	1,020	1,328	913	130	5,130	1,207	212	620	1,500	3,140
7188800	McKisic Cr. trib. nr. Bentonville	10/24/1989	7/11/2006	115	6,800	7,475	6,681	2,000	18,000	3,524	3,686	4,478	9,528	12,304
3249/7.7	Little Sugar Cr. nr. Jane	1/3/1990	9/8/1992	27	1,150	1,144	941	210	2,270	620	282	720	1,580	2,010
3249/0.7	Little Sugar Cr. at Hwy K	1/3/1990	11/18/1993	42	1,535	1,989	1,360	190	8,410	1,752	291	720	2,260	4,572
3259/3.3	S. Indian Cr. at Hwy A	1/3/1990	11/18/1993	41	2,140	2,846	2,015	230	8,470	2,259	760	1,250	3,560	6,740
3260/3.0	N. Indian Cr. just ab. M. Indian Cr.	1/3/1990	11/18/1993	42	2,265	3,401	2,363	270	11,020	2,747	699	1,525	4,805	7,415
3257/0.2	Elkhorn Cr. nr. Mouth	1/3/1990	11/18/1993	41	1,660	2,377	1,681	180	7,520	2,015	710	1,190	2,770	6,150
3264/0.5	Bullskin Cr. nr. Mouth	1/3/1990	3/2/1994	19	1,020	1,348	1,029	200	6,540	1,336	602	838	1,440	1,812
7188885	Indian Cr. nr. Lanagan	1/3/1990	9/15/2004	43	1,590	1,995	1,497	210	6,680	1,541	574	1,045	2,365	3,598
3273/5.2	Buffalo Cr. nr. Dessa	1/3/1990	11/18/1993	42	1,670	2,285	1,637	210	8,160	1,851	466	1,200	3,178	3,899
7189100	Buffalo Creek at Tiff City	1/3/1990	11/18/1993	42	1,440	2,230	1,528	200	10,090	2,100	444	1,073	2,448	4,830
7188950	Patterson Creek nr. Tiff City	11/2/1999	9/14/2004	29	3,600	3,784	3,703	2,270	6,150	836	3,064	3,250	4,020	5,126
3268/2.7/0.5	Patterson Cr. at Hwy 43	1/3/1990	9/12/1991	11	1,250	1,452	1,159	260	2,800	870	310	1,005	2,005	2,730
3250/33.8	Big Sugar Cr. nr. Jacket	1/3/1990	11/18/1993	42	1,785	2,251	1,613	200	6,940	1,686	384	1,123	3,180	4,911
3250/19	Big Sugar Cr. at Hwy E	1/3/1990	11/18/1993	42	1,445	2,084	1,412	180	7,280	1,788	346	987	2,310	5,307
3246/20.8	Elk R. at Pineville	1/3/1990	10/28/1993	41	1,430	1,846	1,280	200	6,680	1,687	340	770	1,820	4,770
3246/14.7	Elk R. just bl. Indian Cr.	1/3/1990	11/18/1993	40	1,425	1,832	1,247	180	6,430	1,604	287	825	1,863	4,278
3246/X	Elk R. bl. Noel	1/3/1990	11/18/1993	41	1,400	1,895	1,362	230	6,610	1,515	400	880	2,460	3,940
7189000	Elk River nr. Tiff City	1/3/1990	9/14/2004	151	1,680	1,788	1,521	190	5,730	1,016	770	1,135	2,100	2,980

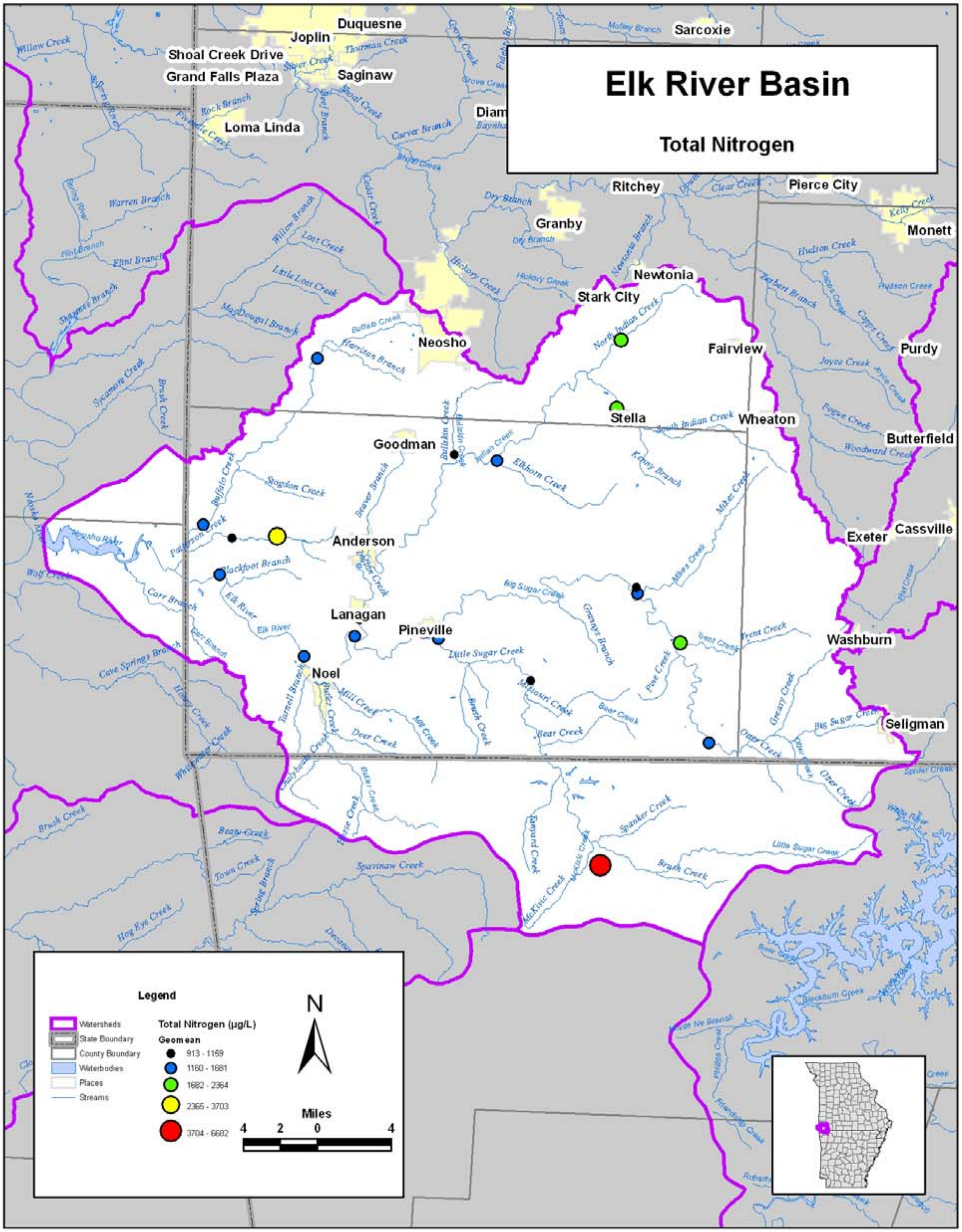

FIGURE 21. Graduated Symbol Map of Total Nitrogen Geometric Means in the Elk River

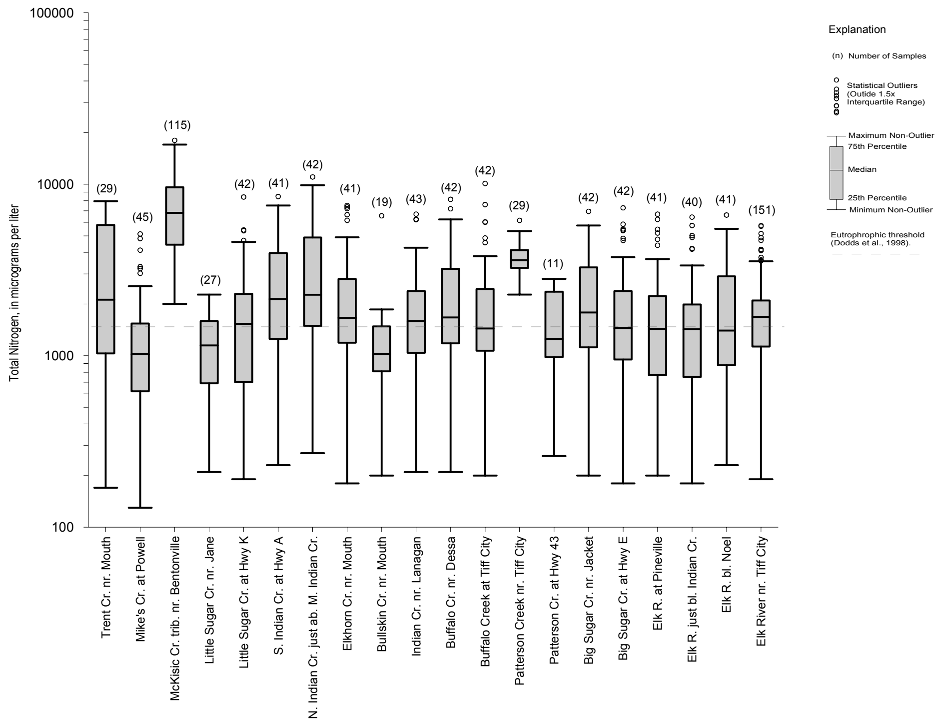

FIGURE 22. Box Plot of Total Nitrogen Levels in the Elk River Basin

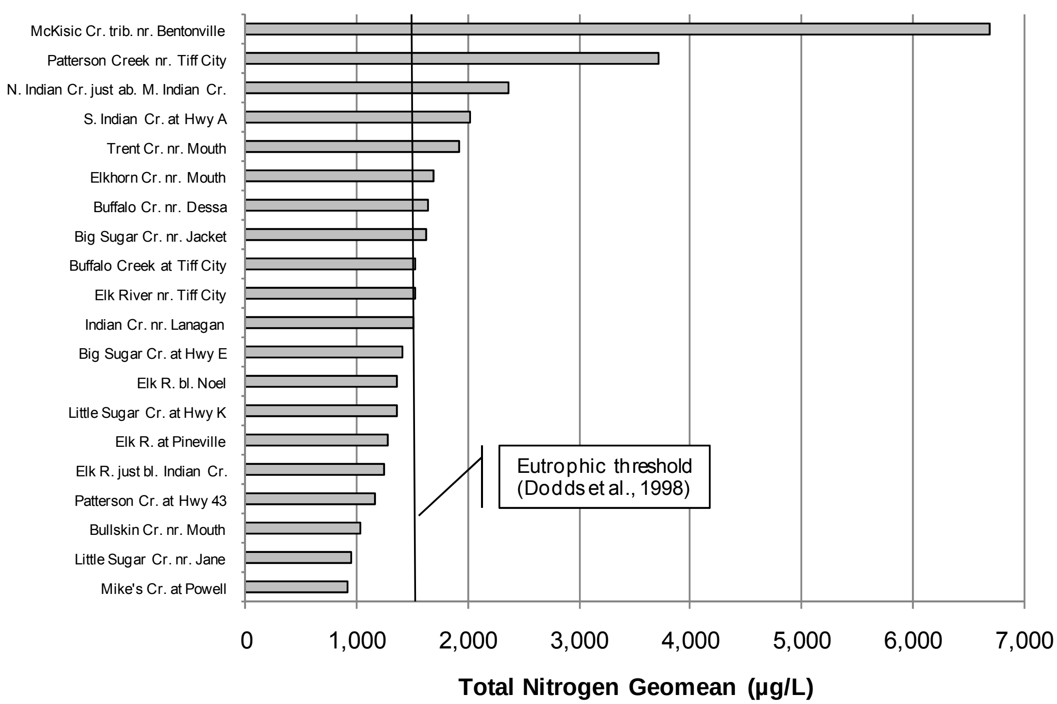

FIGURE 23. Bar Chart of Total Nitrogen Geomeans in the Elk River Basin

4.1.2.2. Nitrate plus Nitrite Nitrogen

A trend analysis was conducted using data from the Elk River near Tiff City station. The Tiff City station had the most complete long-term NO_3+NO_2 recordset of any station in the Elk River basin. Annual geomean NO_3+NO_2 levels indicated no apparent trend in the 1970s and 1980s. However, annual geomean NO_3+NO_2 levels appeared to trend upwards throughout the 1990s into 2004 (Figure 24).

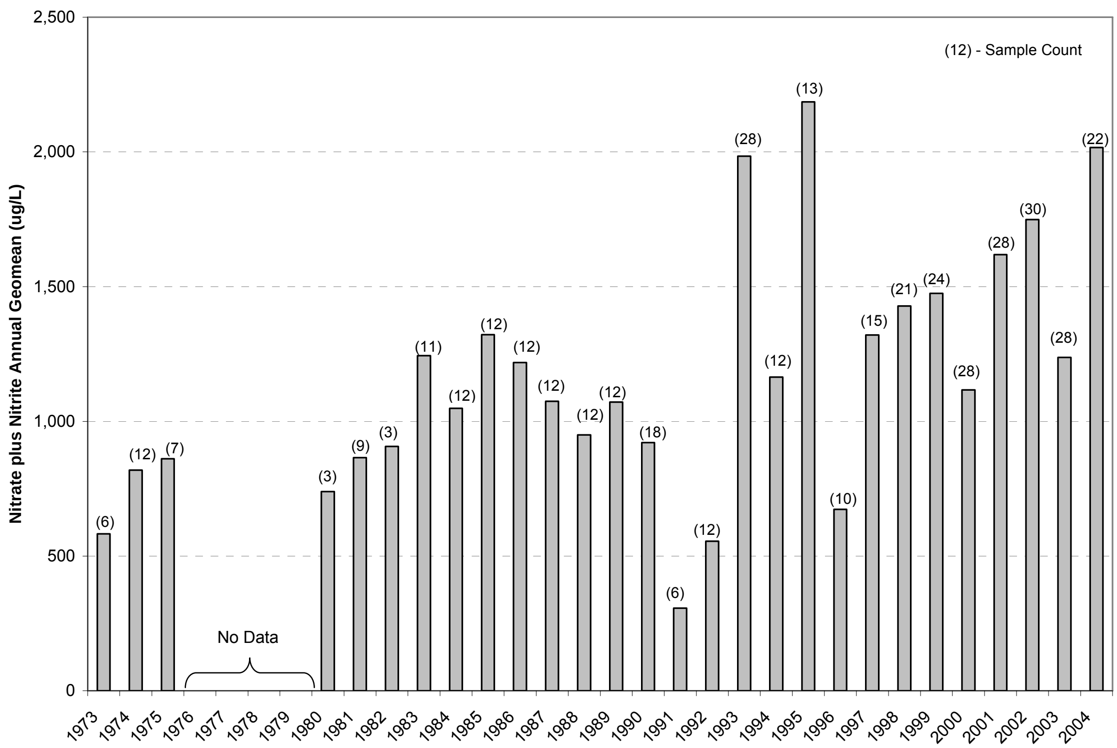

FIGURE 24. Nitrate plus Nitrite Annual Geometric Means Measured at the Elk River near Tiff City Station

As with TN, the highest levels of NO_3+NO_2 were observed in the McKisic Creek tributary near Bentonville where concentrations ranged from 1,000 to 16,000 µg/L with a geomean of 6,116. (Table 9 and Figure 25). NO_3+NO_2 geomeans along the Elk River ranged from 852 µg/L just below Indian Creek to 1,338 µg/L near Tiff City, the farthest downstream site. Along Indian Creek geomeans were among the highest in the basin ranging from 1,498 µg/L at Highway A to 2,961 µg/L at Stella. NO_3+NO_2 geomeans were generally the lowest along the mainstem of the Elk River with concentrations ranging from 852 to 1,338 µg/L. The lowest value in the basin was recorded on Little Sugar Creek near Jane.

Concentrations of NO_3+NO_2 in the Elk River show no obvious spatial trend, suggesting highly local influences on these concentrations (Figures 26 and 27). Also, despite the elevated levels at a couple of the sites, the range of values for all NO_3+NO_2 sites shows relatively little variability as compared to other water quality parameters.

TABLE 9. Nitrate plus Nitrite Nitrogen Statistics for the Elk 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)
3250/24.9/0.1	Trent Cr. nr. Mouth	1/3/1990	1/20/1994	29	2,020	2,579	1,320	40	7,700	2,349	258	700	4,950	5,764
7188660	Mike's Cr. at Powell	1/3/1990	8/13/2004	123	900	1,066	782	30	5,050	806	224	600	1,300	1,880
7188800	McKisic Cr. trib. nr. Bentonville	10/24/1989	7/11/2006	169	6,477	6,835	6,116	1,000	16,000	3,089	3,186	4,275	8,790	11,020
3249/7.7	Little Sugar Cr. nr. Jane	1/3/1990	9/8/1992	27	840	884	599	70	2,000	602	90	455	1,150	1,740
3249/0.7	Little Sugar Cr. at Hwy K	1/3/1990	8/13/2004	171	1,400	1,669	1,266	10	10,400	1,293	540	1,000	1,950	2,800
3259/3.8	S. Indian Cr. at Stella	4/10/2000	8/13/2004	78	3,050	3,071	2,961	1,400	6,300	822	2,180	2,700	3,400	4,000
3259/3.3	S. Indian Cr. at Hwy A	1/3/1990	11/18/1993	41	1,550	2,497	1,498	90	8,300	2,263	470	900	3,400	6,200
3260/3.0	N. Indian Cr. just ab. M. Indian Cr.	1/3/1990	11/29/2005	47	2,000	4,624	2,073	110	28,300	6,569	408	940	5,050	8,668
3257/0.2	Elkhorn Cr. nr. Mouth	1/3/1990	11/18/1993	42	1,350	2,061	1,270	50	7,300	1,860	443	1,000	2,527	5,190
3264/0.5	Bullskin Cr. nr. Mouth	1/3/1990	7/26/2005	21	800	1,375	779	60	7,904	1,879	310	600	1,300	1,800
7188885	Indian Cr. nr. Lanagan	1/3/1990	9/15/2004	171	1,800	2,055	1,654	50	11,200	1,362	800	1,200	2,600	3,300
7188910	Butler Cr. nr. Sulphur Springs	10/24/1989	5/11/1993	33	1,300	1,492	1,381	700	3,790	667	896	1,100	1,600	2,240
3273/5.2	Buffalo Cr. nr. Dessa	1/3/1990	12/20/2005	47	1,400	2,403	1,266	30	8,000	2,318	180	790	3,505	6,340
7189100	Buffalo Creek at Tiff City	1/3/1990	8/13/2004	170	1,380	1,634	1,245	10	12,000	1,315	672	1,000	2,000	2,410
7188950	Patterson Creek nr. Tiff City	11/2/1999	9/14/2004	29	3,520	3,647	3,565	2,170	5,890	823	2,968	3,090	3,920	4,960
3268/2.7/0.5	Patterson Cr. at Hwy 43	1/3/1990	9/12/1991	12	1,150	1,196	795	50	2,600	766	137	815	1,625	2,150
3250/33.8	Big Sugar Cr. nr. Jacket	1/3/1990	11/18/1993	42	1,275	1,939	1,126	40	6,600	1,645	118	985	2,600	4,360
3250/19	Big Sugar Cr. at Hwy E	1/3/1990	8/13/2004	171	1,600	1,808	1,359	10	11,200	1,349	600	1,000	2,200	3,000
3246/20.8	Elk R. at Pineville	1/3/1990	11/18/1993	42	1,100	1,568	888	40	5,580	1,570	109	568	1,675	4,330
3246/14.7	Elk R. just bl. Indian Cr.	1/3/1990	11/18/1993	40	1,100	1,525	852	40	5,900	1,529	79	567	1,580	4,170
3246/X	Elk R. bl. Noel	1/3/1990	11/18/1993	42	1,200	1,532	894	30	5,970	1,399	107	600	1,900	3,636
7189000	Elk River nr. Tiff City	10/11/1989	9/14/2004	298	1,515	1,651	1,338	10	6,130	967	614	1,000	2,000	2,700

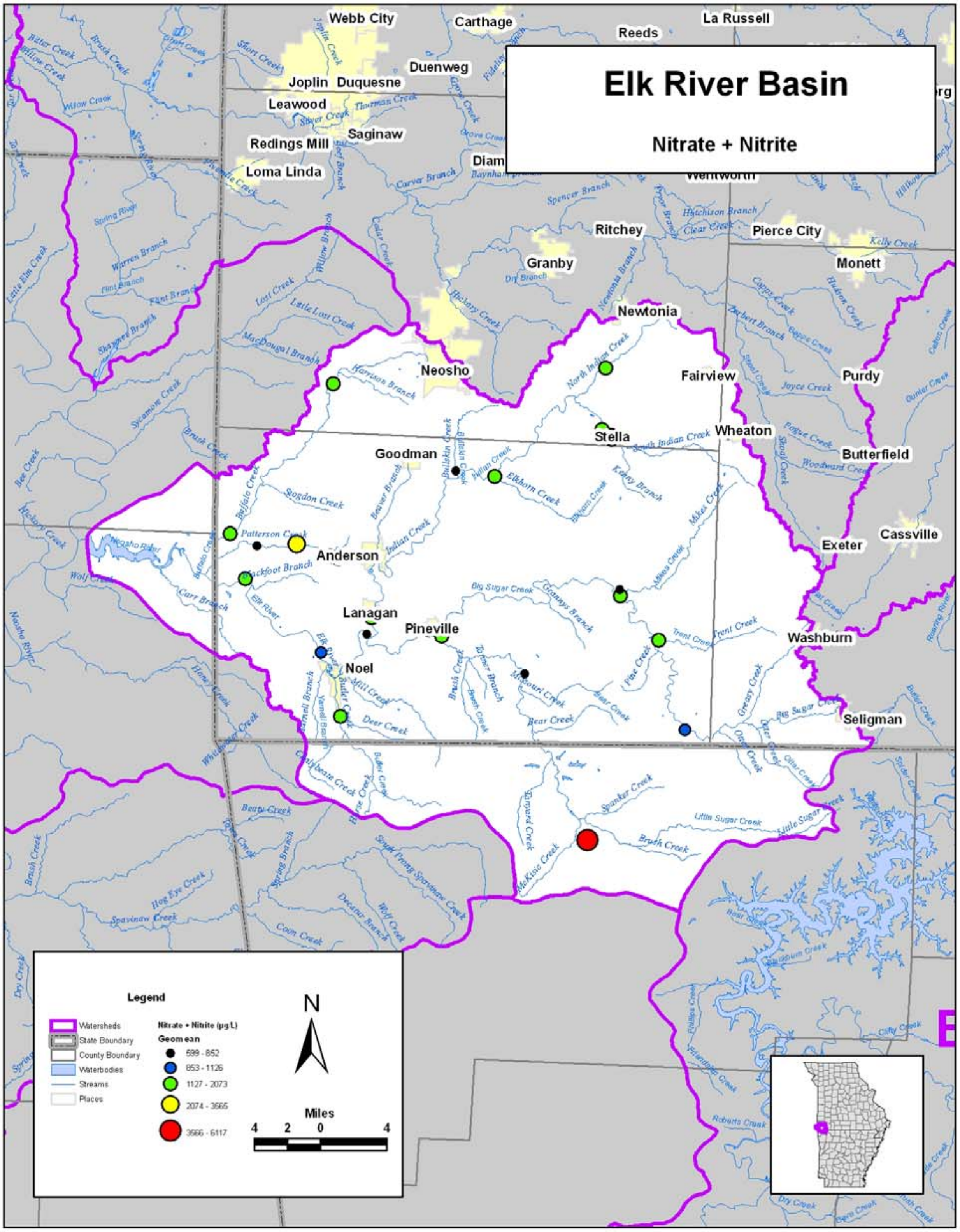

FIGURE 25. Graduated Symbol Map of Nitrate plus Nitrite Geometric Means in the Elk River Basin

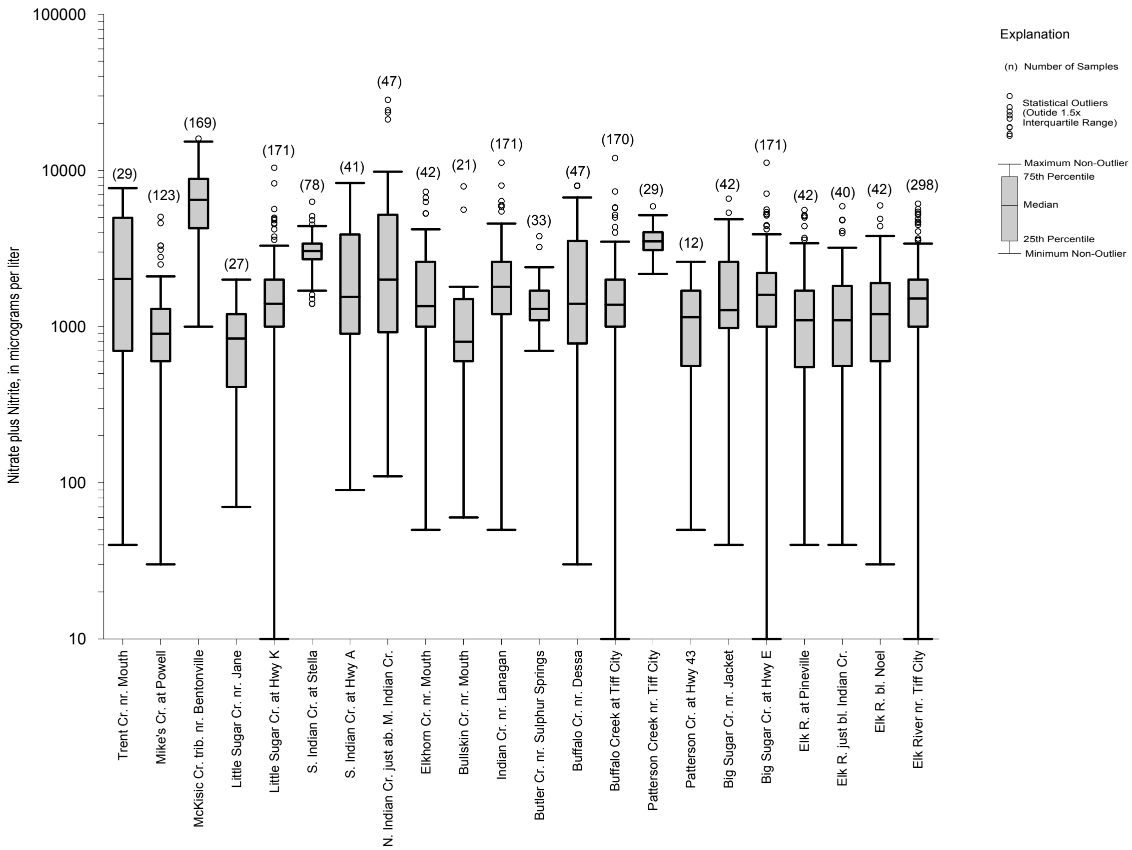

FIGURE 26. Box Plot of Nitrite plus Nitrate Levels in the Elk River Basin

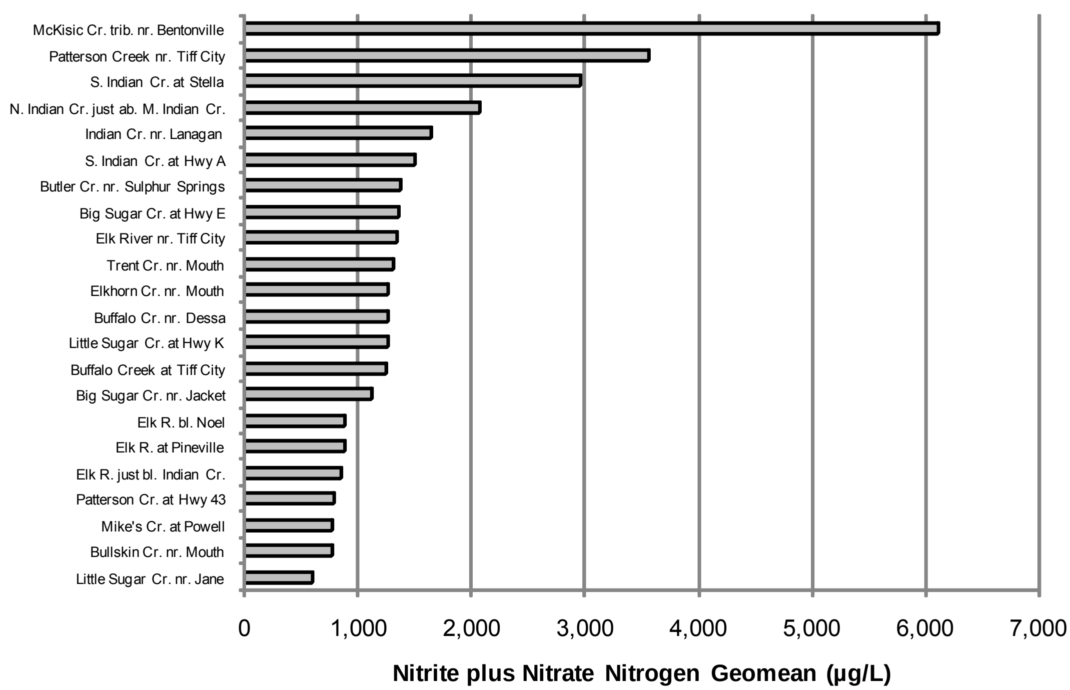

FIGURE 27. Bar Chart of Nitrite plus Nitrate Geomeans in the Elk River Basin

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 "firstcut" 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 Elk River basin, if nutrients are in fact limiting (Table 10). Data suggests that at a majority of the sites, nutrient limitations are not as significant an issue. Many of the sites have ratios slightly below 10 suggesting a possible nitrogen limitation. An obvious nitrogen limitation is seen in Little Sugar Creek near Jane, with a TN:TP ratio of 2.98 as well as the McKisic Creek tributary site near Bentonville with a ratio of 1.56. The Patterson Creek site near Tiff City shows a relatively high ratio of 116.13 suggesting a significant phosphorus limitation. All of the Elk River sites appear to have no nutrient limitations with the exception of the Noel site, which only suggests a very slight nitrogen limitation.

TABLE 10. TN:TP Ratios for Monitoring Sites in the Elk River Basin

Site Number	Station Name	TN:TP (Average)	Count	Period of Record
3246/14.7	Elk R. just bl. Indian Cr.	12.6	40	1/3/1990-11/18/1993
3246/20.8	Elk R. at Pineville	11.1	41	1/3/1990-10/28/1993
3246/X	Elk R. bl. Noel	9.9	41	1/3/1990-11/18/1993
3249/7.7	Little Sugar Cr. nr. Jane	3.0	27	1/3/1990-9/8/1992
3250/19	Big Sugar Cr. at Hwy E	16.5	42	1/3/1990-11/18/1993
3250/24.9/0.1	Trent Cr. nr. Mouth	13.8	28	1/3/1990-1/20/1994
3250/33.8	Big Sugar Cr. nr. Jacket	9.9	42	1/3/1990-11/18/1993
3257/0.2	Elkhorn Cr. nr. Mouth	10.6	40	1/3/1990-11/18/1993
3259/3.3	S. Indian Cr. at Hwy A	11.1	39	1/3/1990-11/18/1993
3260/3.0	N. Indian Cr. just ab. M. Indian Cr.	9.3	42	1/3/1990-11/18/1993
3264/0.5	Bullskin Cr. nr. Mouth	9.0	19	1/3/1990-3/2/1994
3268/2.7/0.5	Patterson Cr. at Hwy 43	8.5	11	1/3/1990-9/12/1991
3273/5.2	Buffalo Cr. nr. Dessa	9.3	42	1/3/1990-11/18/1993
7188660	Mike's Cr. at Powell	13.3	45	1/3/1990-5/18/1995
7188800	McKisic Cr. Trib. nr. Bentonville	1.6	136	10/24/1989-7/11/2006
7188885	Indian Cr. nr. Lanagan	11.4	43	1/3/1990-9/15/2004
7188950	Patterson Creek nr. Tiff City	116.1	29	11/2/1999-9/14/2004
7189000	Elk River nr. Tiff City	14.4	186	1/3/1990-9/14/2004
7189100	Buffalo Creek at Tiff City	8.0	56	1/3/1990-11/18/1993

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, the MDNR developed *E. coli* criteria for Missouri's recreational waters. The 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[10], 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 Elk River near Tiff City station. The Tiff City station had the most complete long-term *E. coli* recordset of any station in the Elk River basin. Annual geomean *E. coli* levels indicated no apparent trend. Although *E. coli* levels appeared to decline after 1996, this did not necessarily reflect an actual trend in the data (Figure 28).

[10] 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.

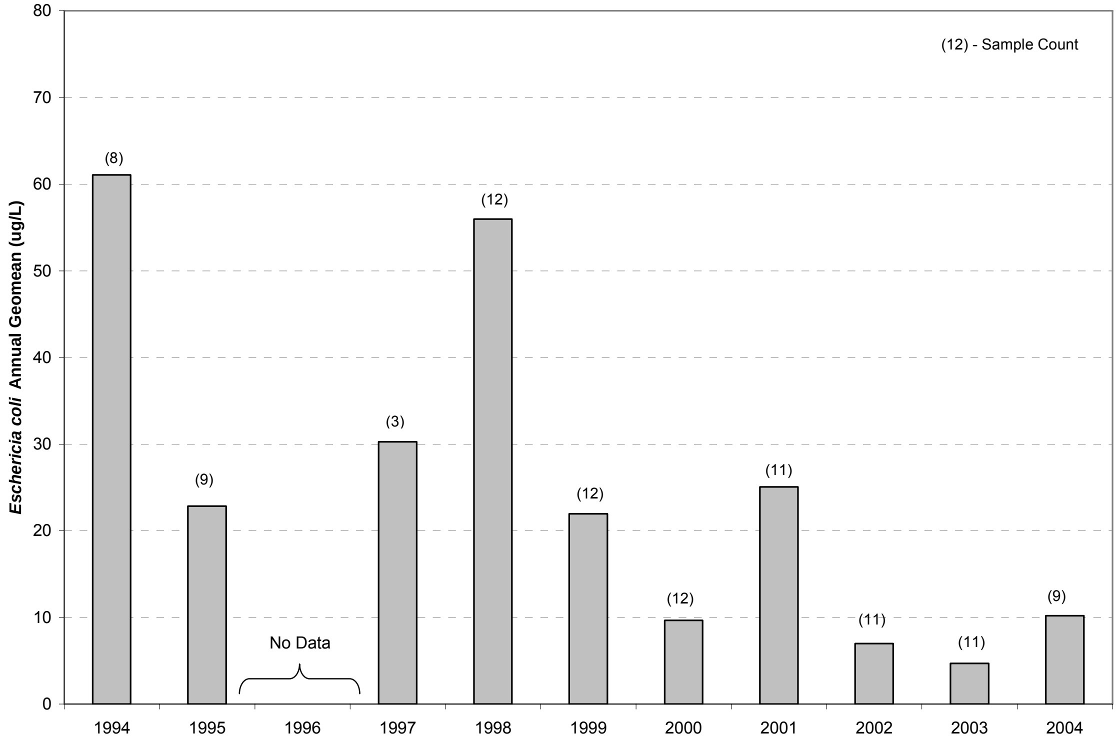

FIGURE 28. *E. coli* Annual Geometric Means Measured at the Elk River near Tiff City Station

The *E. coli* data suggests many streams within the Indian Creek watershed are impaired for bacteria. Within the Indian Creek watershed there are six sampling stations in streams designated as WBCR Category A with *E. coli* geomeans in excess of their criterion of 126 cfu/100mL. These six sites are located on South Indian Creek (2 sites), a tributary to South Indian Creek (1 site), North Indian Creek (1 site), Middle Indian Creek (1 site) and Indian Creek (1 site) where *E. coli* geomeans range from 319 to 2,531 cfu/100mL (Table 11). It is important to reiterate that comparison to bacteria criteria is for reference purposes only and does not constitute an analysis of standards attainment. True tests for bacteria impairment would be limited to reacreational season data and would be based on one-sided upper confidence limits.

With limited spatial coverage, bacteria levels throughout most of the basin remain unknown (Figure 29). *E.coli* levels appear relatively high within the Indian Creek watershed, which corresponds to the greatest density of CAFOs (Figure 5). Outside the Indian Creek watershed the only water quality stations with *E. coli* data are in Patterson Creek and the Elk River. Both of these stations have *E. coli* geomeans below the WBCR Category A criteria of 126 cfu/100 mL (Figures 30 and 31).

TABLE 11. *E. coli* Statistics for the Elk 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)
3259/3.8	S. Indian Cr. at Stella	4/3/2007	6/20/2007	11	649	725	248	2,910	741	365	503	956	1,414
NEWTON_108	Trib. to S. Indian Cr. at Ozark St	4/3/2007	6/20/2007	11	2,323	2,531	1,527	4,839	1,286	1,600	1,662	3,759	4,839
3259/3.3	S. Indian Cr. at Hwy A	4/3/2007	6/20/2007	10	548	590	248	1,986	506	318	396	863	1,042
NEWTON_105	Trib. to S. Indian Cr. at Route O	4/3/2007	6/20/2007	11	7	7	1	73	20	2	3	13	14
3260/3.0	N. Indian Cr. just ab. M. Indian Cr.	6/6/2005	6/20/2007	18	278	319	91	4,839	1,087	117	186	488	743
NEWTON_31	Middle Indian Cr. at Hwy O	6/28/2005	6/20/2007	12	411	391	161	770	194	180	297	588	645
NEWTON_34	Indian Cr. at Hwy D	6/6/2005	6/20/2007	35	328	418	111	4,839	1,070	149	242	649	980
7188950	Patterson Creek nr. Tiff City	11/2/1999	9/14/2004	28	46	32	1	1,800	342	4	13	69	192
7189000	Elk River nr. Tiff City	5/18/1994	9/14/2004	98	16	17	1	3,000	338	2	7	37	130

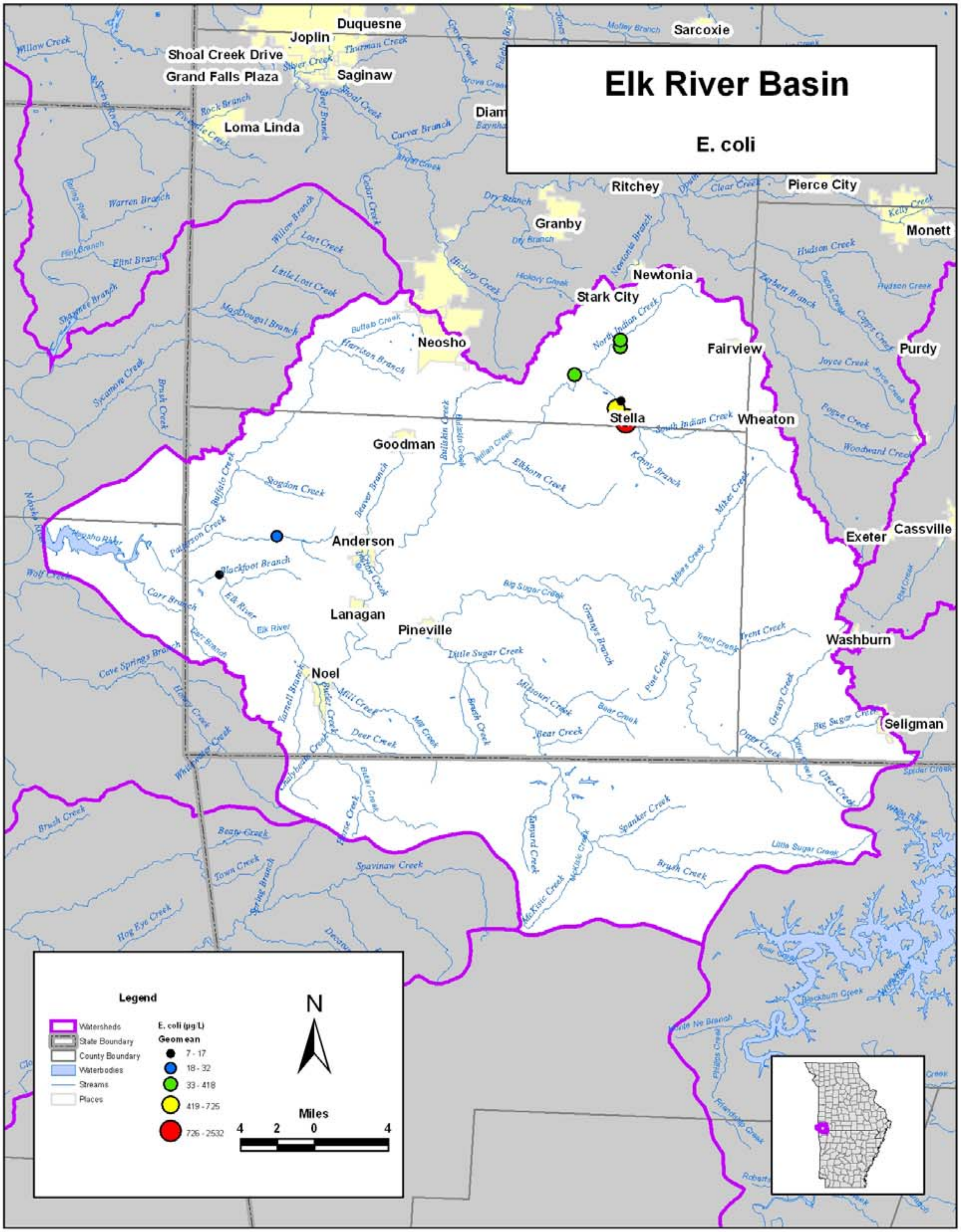

FIGURE 29. Graduated Symbol Map of *E. coli* Geometric Means in the Elk River Basin

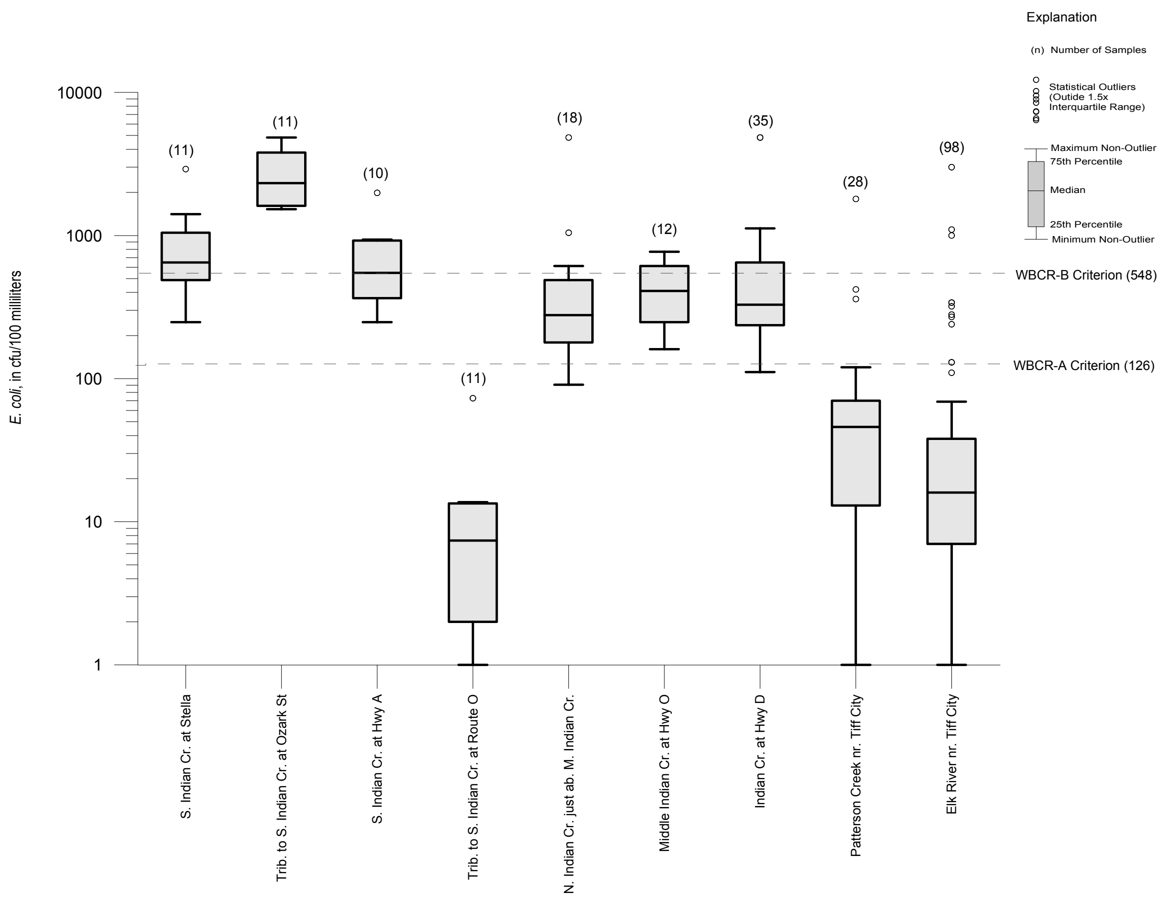

FIGURE 30. Box Plot of *E.coli* Levels in the Elk River Basin

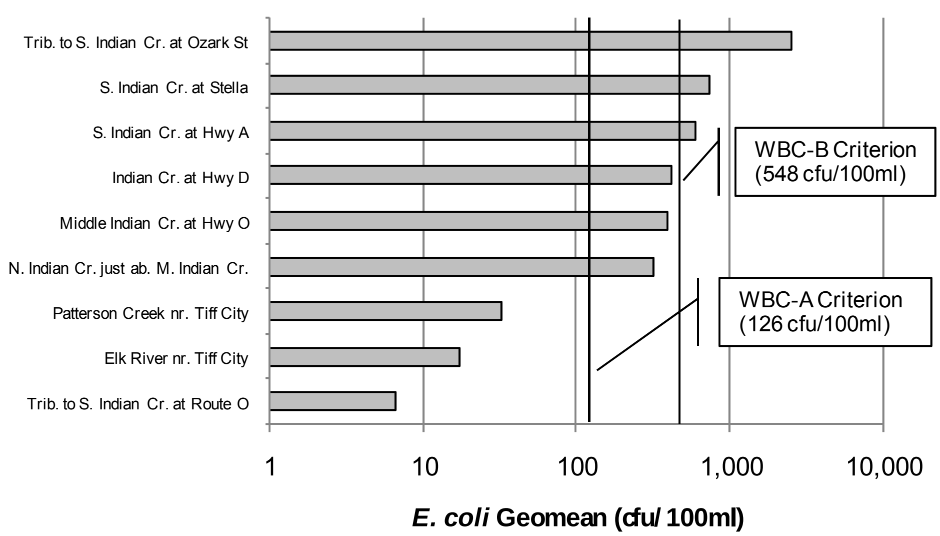

FIGURE 31. Bar Chart of *E. coli* in the Elk River Basin

V. BIOLOGICAL MONITORING

MDNR, the Missouri Department of Conservation (MDC), and the USGS have conducted multiple biological data collection efforts throughout the Elk River basin since the 1990s (Table 12). 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:

- The MDNR database includes 23 macroinvertebrate sampling locations in the Elk River basin on 4 waterbodies (Figure 32). All samples were collected between March of 1997 and March of 2001. Information included with these data are waterbody, latitude and longitude, the date collected and the sample number.

- The MDC database includes 6 fish sampling locations within the Elk River basin. These samples were collected between 1995 and August of 2004. Information included with this dataset are latitude and longitude, date collected, waterbody, and a variety of other data fields, some of which lack explanation.

- 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 Elk River basin.

TABLE 12. Summary of Digital Biological Databases for the Elk River Basin

Data Types	Collection Agency	Number of Sites	Collection Dates
Macro-Invertebrates	MDNR	23	1997-2001
Fish	MDC	6	1995-2004
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. However, MDNR has not completed any biological assessment reports for the Elk River basin.

Fish surveys in the Elk River basin suggest a healthy fish population, but there is evidence of declines in some species. Seventy species of fish have been collected in the Elk River basin since the 1930s. Eleven of these species have not been collected since 1965. Some of the absent species may be attributed to inadequate sampling or sampling error. The channel darter was last sampled prior to 1946 and likely no longer exists in the watershed. The bluntface shiners and wedgespot shiners are considered to be in decline, but are still present in the lower part of the basin (Horton, 2001).

There are several rare, threatened, and endangered species of flora and fauna within the Elk River basin. Federally endangered species include the gray bat (*Myotis grisescens*), running buffalo clover (*Trifolium stoloniferum*), peregrin falcon (*Falco peregrinus*), and the Indiana bat (*Myotis sodalist*). Federally threatened species include the Ozark cavefish (*Amblyopsis rosae*) and the bald eagle (*Haliaeetus leucocephalus*) (Horton, 2001).

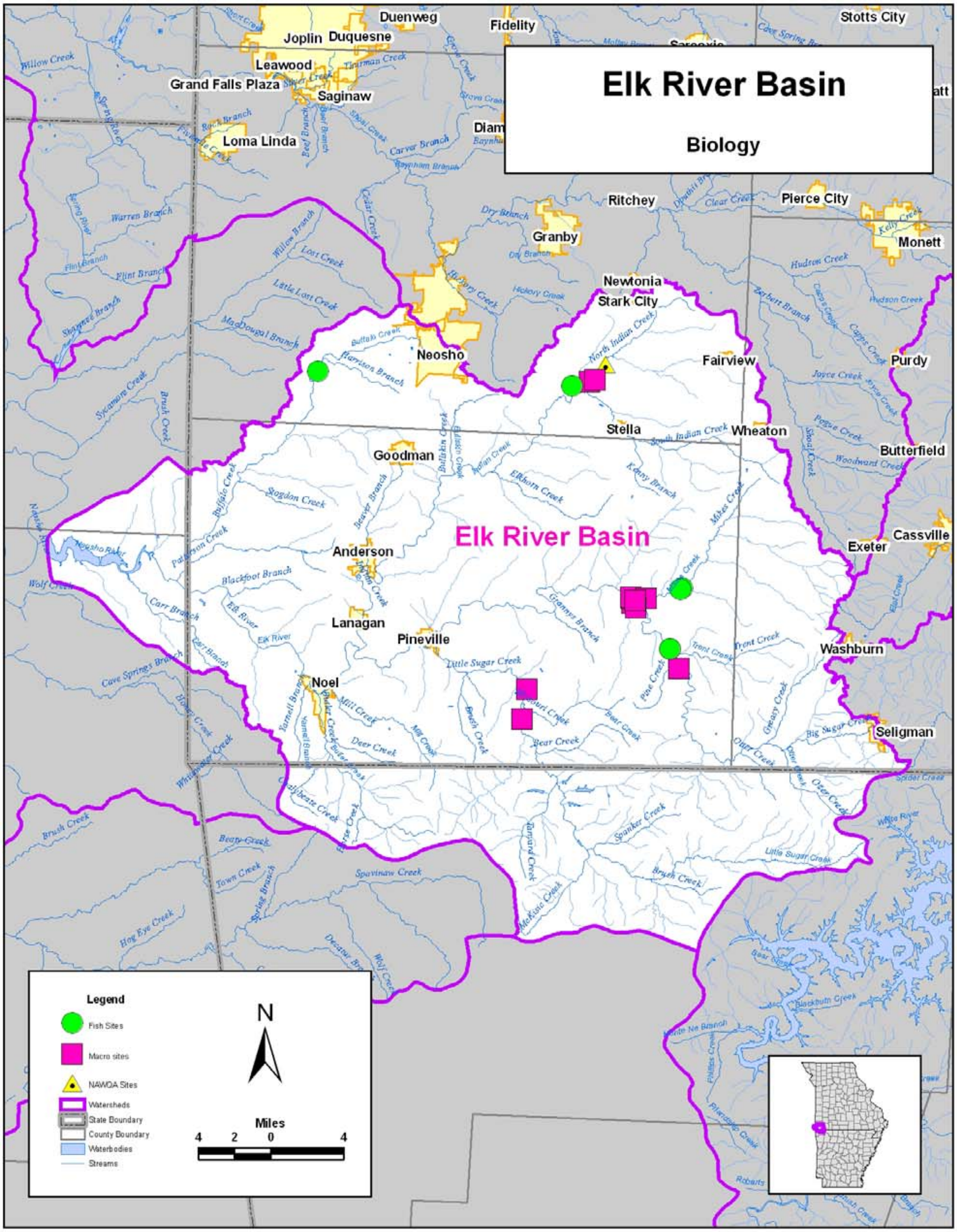

FIGURE 32. Biological Monitoring Sites in the Elk River Basin

VI. DATA GAPS

A data gap is defined here as a lack of information necessary to the goals of WQIP. Within the Elk 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 Elk 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 and bacteria. It should be noted that although this gap analysis is limited to the 26 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 Elk 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 Elk River basin appears to be sufficient to address the goals of the WQIP. The 26 sampling stations, while fewer than other WQIP basins, are located along all of the major tributaries to the Elk River and are relatively well spaced capturing conditions above and below major tributary inputs. The only locations where coverage may be lacking are the central portions of Indian Creek, near Anderson, as well as Little Sugar Creek, upstream of Bear Creek. Also, it would advantageous to have a site located on the Elk River downstream of its final significant tributary, Buffalo Creek, but upstream of Grand Lake, in order to capture accurate cumulative conditions prior to entering the Lake. Although spatial distribution of sampling sites appears fairly comprehensive, the database would only be improved by filling the minor spatial gaps that exist.

With respect to improving the spatial distribution of sites, 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 Elk 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.

- Elk River Nutrient TMDL identified the following waterbodies as nutrient impaired:
    - Buffalo Creek;
    - Elk River;
    - Indian Creek;
    - Middle Indian Creek;
    - North Indian Creek;
    - South Indian Creek;
    - Patterson Creek;
    - Big Sugar Creek; and
    - Little Sugar Creek.

- Indian Creek Watershed
    - High Density of CAFOs
    - Relatively high *E. coli* values were observed

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 Elk River basin are discussed below.

There is a lack of long-term monitoring data within the Elk River basin. Long-term monitoring data could help address any of the WQIP goals; however, it is most critical for addressing regional and temporal trends. The only clear long-term monitoring stations include Elk River near Tiff City and McKisic Creek tributary near Bentonville, which are run by the USGS and the Arkansas Department of Environmental Quality. The Elk River and McKisik Creek stations date back to approximately 1960 and 1983, respectively (Figure 29). A few other stations have data dating back to the 1960s, but are too intermittent or appear to have been discontinued. Crowder College has some monitoring stations dating back to around 1990, which have the potential to produce valuable long-term monitoring data if monitoring efforts continue on a more regular and frequent basis.

Many of the WQIP goals do not necessarily require long-term data but may be addressed by short-term studies. Short-term studies are defined here as generally less than a season but may be repeated over multiple years. They can be effective for characterizing reference conditions or impacts from pollutant sources. Available data suggest Crowder College conducted short-term studies throughout much of Elk River basin in the early 1990s. More recently, the Newton County Health Department appears to be conducting some studies primarily in the Indian Creek subwatershed (Figure 33). However, more short-term studies are needed to better understand existing loading sources and reference conditions throughout the basin.

The observed sampling frequency in the Elk River basin can vary by site and collection entity. 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 Elk River basin were sampled monthly, however, this sampling frequency only continued for a short time.

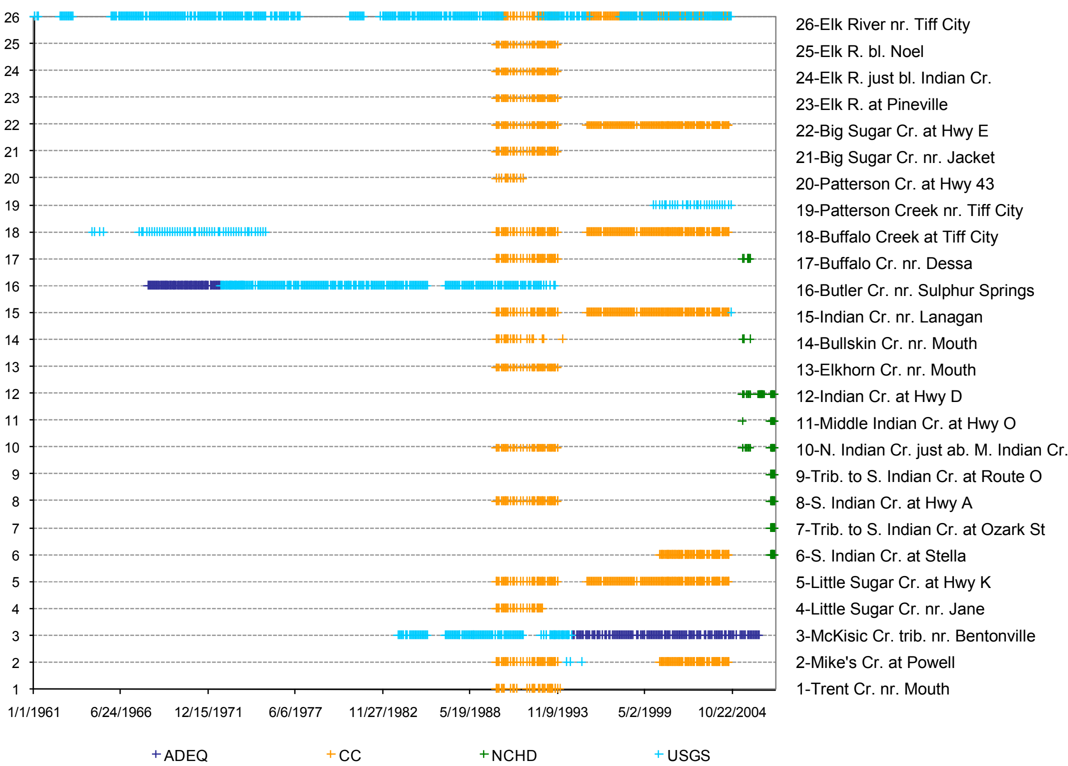

FIGURE 33. Monitoring Visits by Collection Entity from January 1961 to June 2007

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, $NO_3 + NO_2$, and flow. A summary of parameters, and how often they were collected is given in Table 13.

There were some inconsistencies in terms of which nutrient parameters were collected during the sampling events. TP data were available for all but two stations collectively 85% of the time. NO_3+NO_2 data were available for at all but three stations collectively 78% of the time. TN data, however, were generally lacking from most sampling events. TN data were available from 20 of the 26 stations collectively on average only 36% of the time.

Chlorophyll *a* data are lacking from the Elk River basin. Although excessive algal growth is the primary concern with excessive nutrification, chlorophyll *a* data (i.e., a measure of algal growth) are nonexistent in the Elk 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.

E. coli is an important parameter to investigate in this basin due to the relatively high concentration of CAFOs. However, *E. coli* data were only available from a relatively few number of stations primarily located in the Indian Creek sub basin. Collectively at all sites *E. coli* data were sampled 9% of the time and are only available from 13 of 26 stations.

Better efforts at characterizing flow conditions during monitoring events are needed in the future. Flow data were collected 47% of time when summed over all sample events and were completely lacking at 5 of the 26 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). It should also be noted, as discussed in Section 2.5, there are five USGS gaging stations in the Elk River basin. Discharge data from these USGS gaging stations could potentially be used in analyzing existing ambient water quality data in the Elk River basin.

Finally, the general lack of parameter characterization found throughout the Elk River basin may be addressed in the future by collecting additional parameters during sampling events. Although some parameters such as TP and $NO_3 + NO_2$ are sampled for relatively frequently, other critical parameters such as TN, *E. coli*, and chlorophyll a are not. Sampling agencies could better address the goals of the WQIP by collecting for all the parameters of interest during their sample events.

TABLE 13. Percent of Time Parameters were Collected During Site Visits

Station Name	Total Visits	TP	TN	NO_3+NO_2	*E. coli*	Flow
Trent Cr. nr. Mouth	34	94%	85%	85%	0%	85%
Mike's Cr. at Powell	127	100%	35%	97%	2%	33%
McKisic Cr. trib. nr. Bentonville	250	86%	59%	90%	3%	1%
Little Sugar Cr. nr. Jane	31	97%	87%	87%	0%	94%
Little Sugar Cr. at Hwy K	177	98%	24%	97%	0%	22%
S. Indian Cr. at Stella	89	88%	0%	88%	12%	0%
Trib. to S. Indian Cr. at Ozark St	11	0%	0%	0%	100%	0%
S. Indian Cr. at Hwy A	56	79%	73%	73%	18%	70%
Trib. to S. Indian Cr. at Route O	11	0%	0%	0%	100%	0%
N. Indian Cr. just ab. M. Indian Cr.	64	81%	66%	73%	28%	61%
Middle Indian Cr. at Hwy O	12	8%	0%	0%	100%	0%
Indian Cr. at Hwy D	35	17%	0%	14%	100%	0%
Elkhorn Cr. nr. Mouth	46	98%	89%	91%	0%	85%
Bullskin Cr. nr. Mouth	26	85%	73%	81%	12%	65%
Indian Cr. nr. Lanagan	178	98%	24%	96%	1%	22%
Butler Cr. nr. Sulphur Springs	367	54%	0%	40%	1%	63%
Buffalo Cr. nr. Dessa	53	96%	79%	89%	11%	74%
Buffalo Creek at Tiff City	231	91%	24%	80%	0%	39%
Patterson Creek nr. Tiff City	29	100%	100%	100%	97%	100%
Patterson Cr. at Hwy 43	13	100%	85%	92%	0%	38%
Big Sugar Cr. nr. Jacket	46	100%	91%	91%	0%	85%
Big Sugar Cr. at Hwy E	177	98%	24%	97%	0%	22%
Elk R. at Pineville	46	100%	89%	91%	0%	85%
Elk R. just bl. Indian Cr.	46	100%	87%	87%	0%	85%
Elk R. bl. Noel	46	100%	89%	91%	0%	80%
Elk River nr. Tiff City	561	85%	33%	75%	17%	72%
Total of all stations	2,762	85%	36%	78%	9%	47%

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.

Relatively high phosphorus detection limits from at least one site prevent an accurate determination of ambient stream conditions. Approximately 45% of the phosphorus samples collected by the USGS from the Patterson Creek near Tiff City site are below detection limits. Phosphorus detection limits at this site range from 40 to 60 µg/L (Table 14), which exceed this site's geomean of 31 µg/L (Table 5). This site could potentially be used for establishing reference conditions due to its low concentration of TP. However, the site's current dataset is insufficient for establishing TP levels due to the relatively high detection limits.

TABLE 14. Total Phosphorus Sample Results Reported Below Detection Limit

Agency	Station Name	Sample Count	Samples Below Detection Limit	Percent Below Detection Limit	Detection Limit[1]
CC	Trent Cr. nr. Mouth	32	4	13%	0(4)
CC	Mike's Cr. at Powell	124	15	12%	0(15)
USGS	Mike's Cr. at Powell	3	3	100%	10(3)
USGS	McKisic Cr. trib. nr. Bentonville	90	0	0%	NA
CC	Little Sugar Cr. nr. Jane	30	0	0%	NA
CC	Little Sugar Cr. at Hwy K	173	0	0%	NA
CC	S. Indian Cr. at Stella	78	1	1%	0(1)
CC	S. Indian Cr. at Hwy A	44	10	23%	0(10)
CC	N. Indian Cr. just ab. M. Indian Cr.	46	6	13%	0(6)
NCHD	N. Indian Cr. just ab. M. Indian Cr.	6	0	0%	NA
NCHD	Middle Indian Cr. at Hwy O	1	0	0%	NA
NCHD	Indian Cr. at Hwy D	6	0	0%	NA
CC	Elkhorn Cr. nr. Mouth	45	10	22%	0(10)
CC	Bullskin Cr. nr. Mouth	20	6	30%	0(6)
NCHD	Bullskin Cr. nr. Mouth	2	0	0%	NA
CC	Indian Cr. nr. Lanagan	173	13	8%	0(13)
USGS	Indian Cr. nr. Lanagan	1	0	0%	NA
ADEQ	Butler Cr. nr. Sulphur Springs	4	0	0%	NA
USGS	Butler Cr. nr. Sulphur Springs	196	29	15%	10(22), 30(7)
CC	Buffalo Cr. nr. Dessa	46	1	2%	0(1)
NCHD	Buffalo Cr. nr. Dessa	5	3	60%	50(3)
CC	Buffalo Creek at Tiff City	174	9	5%	0(9)
USGS	Buffalo Creek at Tiff City	36	3	8%	0(2), 10(1)
USGS	Patterson Creek nr. Tiff City	29	13	45%	40(2), 50(3), 60(8)
CC	Patterson Cr. at Hwy 43	13	3	23%	0(3)
CC	Big Sugar Cr. nr. Jacket	46	10	22%	0(10)
CC	Big Sugar Cr. at Hwy E	173	12	7%	0(12)
CC	Elk R. at Pineville	46	3	7%	0(3)
CC	Elk R. just bl. Indian Cr.	46	6	13%	0(6)
CC	Elk R. bl. Noel	46	0	0%	NA
CC	Elk River nr. Tiff City	173	2	1%	0(2)
USGS	Elk River nr. Tiff City	305	17	6%	0(2), 10(4), 30(2), 50(4), 80(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).

Detection limits do not appear to be an issue for nitrogen values in the Elk River basin. Only four $NO_3 + NO_2$ samples in the WQIP database were reported to be below the detection limit. These samples identified as below the detection limit represent no more than 8% of the total samples at any site (Table 15). The highest reported detection limit for NO_3+NO_2 was a relatively low 100 µg/L; whereas $NO_3 + NO_2$ geomeans ranged from 599 to 6,116 µg/L at all the sites. Additionally, no TN samples were identified below laboratory detection limits. However, it should be noted that this discussion of TN detection limits only concerns directly reported TN values (i.e., not TN values calculated by summing $NO_3 + NO_2$ and TKN).

TABLE 15. 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]
CC	Trent Cr. nr. Mouth	29	0	0%	NA
CC	Mike's Cr. at Powell	120	0	0%	NA
USGS	Mike's Cr. at Powell	3	0	0%	NA
USGS	McKisic Cr. trib. nr. Bentonville	95	0	0%	NA
CC	Little Sugar Cr. nr. Jane	27	0	0%	NA
CC	Little Sugar Cr. at Hwy K	171	0	0%	NA
CC	S. Indian Cr. at Stella	78	0	0%	NA
CC	S. Indian Cr. at Hwy A	41	0	0%	NA
CC	N. Indian Cr. just ab. M. Indian Cr.	42	0	0%	NA
NCHD	N. Indian Cr. just ab. M. Indian Cr.	5	0	0%	NA
NCHD	Indian Cr. at Hwy D	5	0	0%	NA
CC	Elkhorn Cr. nr. Mouth	42	0	0%	NA
CC	Bullskin Cr. nr. Mouth	19	0	0%	NA
NCHD	Bullskin Cr. nr. Mouth	2	0	0%	NA
CC	Indian Cr. nr. Lanagan	170	0	0%	NA
USGS	Indian Cr. nr. Lanagan	1	0	0%	NA
ADEQ	Butler Cr. nr. Sulphur Springs	13	1	8%	0(1)
USGS	Butler Cr. nr. Sulphur Springs	135	0	0%	NA
CC	Buffalo Cr. nr. Dessa	42	0	0%	NA
NCHD	Buffalo Cr. nr. Dessa	5	0	0%	NA
CC	Buffalo Creek at Tiff City	171	0	0%	NA
USGS	Buffalo Creek at Tiff City	13	1	8%	100(1)
USGS	Patterson Creek nr. Tiff City	29	0	0%	NA
CC	Patterson Cr. at Hwy 43	12	0	0%	NA
CC	Big Sugar Cr. nr. Jacket	42	0	0%	NA
CC	Big Sugar Cr. at Hwy E	171	0	0%	NA
CC	Elk R. at Pineville	42	0	0%	NA
CC	Elk R. just bl. Indian Cr.	40	0	0%	NA
CC	Elk R. bl. Noel	42	0	0%	NA
CC	Elk River nr. Tiff City	171	0	0%	NA
USGS	Elk River nr. Tiff City	252	2	1%	100(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 who 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 4 sampling sites in the Elk River basin with no geographic coordinates. These 4 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 Elk 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;
- 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 leveraged better.

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 Elk 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 Elk 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 Elk River basin do not fully address the WQIP goals. A well designed monitoring network that clearly addresses the goals of the WQIP is needed.

Nonpoint 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 lack 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).

Although significant nutrient data are available for the Elk River basin, 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 Elk 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.

Continue to Populate Database with Historical Data

Much water quality data in the Elk 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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