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U.S. Department of the Interior
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Front Cover: Photograph of Bear Creek looking upstream from Arkansas State Highway 74 bridge near Snowball, Arkansas, November 2004. Photograph by Joel M. Galloway, U.S. Geological Survey.

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Hydrologic and Water-Quality Characteristics for Bear Creek near Silver Hill, Arkansas, and Selected Buffalo River Sites, 1999-2004

By Joel M. Galloway and W. Reed Green

Abstract

The purpose of this report is to describe and compare the hydrologic and water-quality characteristics of Bear Creek near Silver Hill, Arkansas, to two sites on the Buffalo River upstream from the confluence of Bear Creek, to a site on Calf Creek, a smaller tributary to the Buffalo River, to selected undeveloped sites across the Nation, and to a developed site in Arkansas. A better understanding of the hydrology and water quality of Bear Creek is of interest to many, including the National Park Service, which administers the Buffalo National River, to evaluate its effects on the hydrology and water quality of the Buffalo River.

The streamflow at Bear Creek near Silver Hill varied seasonally and annually from January 1999 to March 2004. The mean annual streamflow at Bear Creek for calendar years 1999 to 2003 was 86.0 cubic feet per second. The highest annual mean streamflow occurred in 2002 (158 cubic feet per second) and the lowest annual mean streamflow occurred in 1999 (56.4 cubic feet per second). The mean annual streamflow for calendar years 1999 to 2003 at the Buffalo River near Boxley and Buffalo River near St. Joe was 102 and 881 cubic feet per second, respectively.

Concentrations of nitrogen measured for Bear Creek generally were greater than concentrations measured at the two Buffalo River sites and were similar to concentrations measured at Calf Creek. Concentrations of phosphorus measured at Bear Creek generally were greater than concentrations measured at the two Buffalo River sites and were similar to concentrations measured at Calf Creek. Fecal indicator bacteria concentrations generally were greater at Bear Creek than concentrations measured at the Buffalo River and similar to concentrations at Calf Creek. Bear Creek had significantly greater suspended-sediment concentrations than the Buffalo River near Boxley and the Buffalo River near St. Joe and similar concentrations to Calf Creek.

Nutrients, dissolved organic carbon, and suspended-sediment loads at Bear Creek and two Buffalo River sites varied because of differences in land use and contributing drainage area for each site. In general, the Buffalo River near St. Joe had the greatest annual loads of nutrients, dissolved organic carbon, and suspended sediment. The Buffalo River near Boxley had the least annual nutrient and suspended-sediment loads among the three sites. Buffalo River near Boxley had lesser annual loads than the other two sites probably because of the higher percentage of forested land in the basin and smaller contributing drainage area.

Mean annual nutrient, dissolved organic carbon, and suspended-sediment yields computed for Bear Creek were greater than yields computed for both of the Buffalo River sites. Bear Creek had greater median annual nutrient yields than selected undeveloped basins across the Nation and less median annual nutrient yields than the Illinois River south of Siloam Springs, Arkansas, which is representative of a developed basin.

Bear Creek had greater median annual flow-weighted nutrient concentrations than the Buffalo River near St. Joe, the Buffalo River near Boxley, and selected undeveloped sites across the Nation. Bear Creek had less median flow-weighted nutrient concentrations than the Illinois River.

Introduction

The Buffalo River and its tributary, Bear Creek, are in the White River Basin in the Ozark Plateaus physiographic province (Fenneman, 1938) in north-central Arkansas (fig. 1). The Buffalo River is a 150-mile long free-flowing stream famous for its scenic beauty and for canoeing, fishing, and other recreational activities. Eleven percent of the Buffalo River Basin lies within the boundaries of the Buffalo National River. Outside the boundary of the Buffalo National River, activities such as animal production and logging have increased, especially in the middle portion of the Buffalo River Basin (U.S. Department of Agriculture, 1995). Previous investigations indicated that nutrient and fecal-indicator bacteria concentrations and loads were elevated in Bear Creek and nearby Calf Creek (Mott, 1997; Petersen and others, 1998; Petersen and others, 2002; Steele and Mott, 1998; Galloway and Green, 2004). Increases in nutrients in the Buffalo River can lead to eutrophication of the stream that can be unfavorable for aesthetics and detrimental to the aquatic health of the stream. Increases in bacteria in the stream can pose a threat to humans that commonly come in contact with the waters for recreation. A better understanding of the hydrology and water quality of Bear Creek is of interest to many, including the National Park Service, which administers the Buffalo National River, to evaluate its effects on the hydrology and water quality of the Buffalo River. This report is part of the

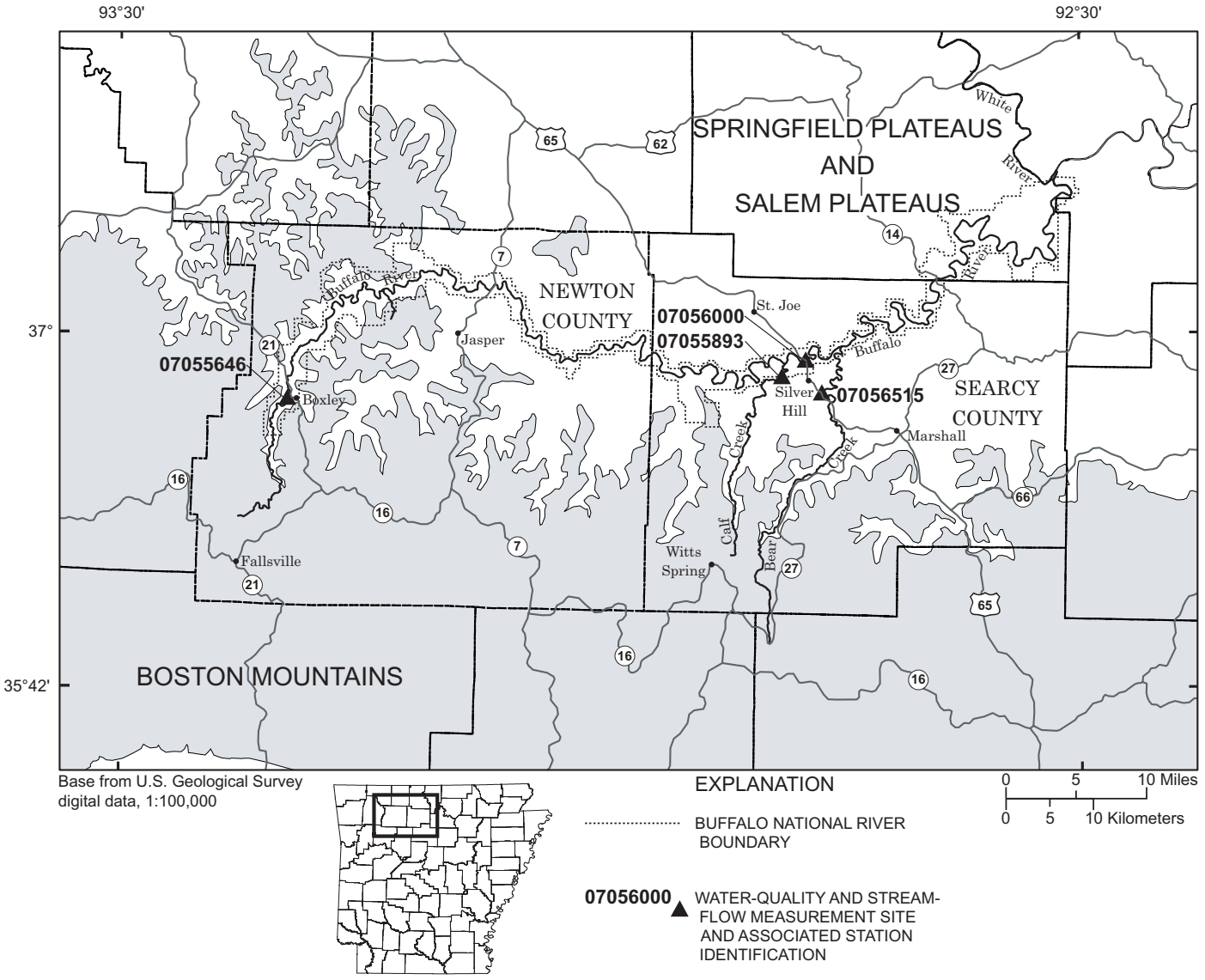

Figure 1. Locations of the Buffalo River, Bear Creek, and Calf Creek.

National Park Service/U.S. Geological Survey Water-Quality Monitoring and Assessment Partnership.

Purpose and Scope

The purpose of this report is to describe and compare the hydrologic and water-quality characteristics of Bear Creek near Silver Hill, Arkansas, to two sites on the Buffalo River upstream from the confluence of Bear Creek, to a site on Calf Creek, a smaller tributary to the Buffalo River, to selected undeveloped sites across the Nation, and to a developed site in Arkansas. Stream stage was measured continuously to compute streamflow, and water-quality samples were collected monthly and during selected storm events. Data from February 1999 through March 2004 are described in this report. Water samples were analyzed for several field parameters and constituents, including specific conductance, dissolved oxygen, water temperature, pH, alkalinity, fecal indicator bacteria, nutrients, organic carbon, and suspended sediment. Yields and loads of nutrients, dissolved organic carbon, and suspended sediment were estimated for Bear Creek and compared with yields and loads at sites on the Buffalo River upstream from its confluence with Bear Creek for calendar years 1999 through 2003. Flow-weighted concentrations were calculated from mean annual streamflow and estimated annual loads for comparison with other developed and undeveloped basins.

Description of Study Area

The Buffalo River originates north of Fallsville, Arkansas, in the Boston Mountains and flows eastward into the Springfield and Salem Plateaus to the White River (fig. 1). The drainage area of the Buffalo River at its mouth is 1,340 square miles (Sullavan, 1974). The drainage area upstream from the Buffalo River near Boxley streamflow gaging station (07055646) is approximately 57 square miles and upstream from the Buffalo River near St. Joe streamflow gaging station (07056000) is 829 square miles (Porter and others, 2001). Land use in the Buffalo River Basin is primarily a mixture of forest and pasture. Approximately 11 percent of the land is agricultural (mostly pasture) upstream from the Buffalo River near St. Joe. Only approximately 4 percent of the land is used for agriculture upstream from the Buffalo River near Boxley (Davis and Bell, 1998).

Bear Creek lies in the middle part of the Buffalo River Basin and originates near Witts Spring, Arkansas, flowing northward to the Buffalo River (fig. 1). The Bear Creek drainage area is about 91.6 square miles at its mouth or about 10 percent of the Buffalo River drainage area just downstream from the confluence of Bear Creek (Petersen and others, 2002). Land use in the Bear Creek Basin includes forest (70 percent), pasture and hay (29 percent), and recreation (1 percent within the Buffalo National River boundary) (U.S. Geological Survey, 2002). The Bear Creek Basin shares a boundary to the west with the Calf Creek Basin (49.6 square miles). Land use in the Calf Creek Basin is 69 percent forest land and 31 percent pasture and hay (U.S. Geological Survey, 2002).

Methods

Streamflow

Stream stage was measured continuously at a site on Bear Creek (07056515) and two sites on the Buffalo River (fig. 1). Stream stage was also measured continuously at a site on Calf Creek near Silver Hill, Arkansas (07055893) (Galloway and Green, 2004). Stage and instantaneous discharge were measured to compute the continuous streamflow from stage-discharge rating curves using methods described in Rantz and others (1982).

Streamflow was separated using the Base Flow Index (BFI) hydrograph separation computer program to identify base-flow and surface-runoff components (Wahl and Wahl, 1995). The BFI program uses the Institute of Hydrology method of base-flow separation, which divides the water year into increments and identifies the minimum flow for each increment. A 3-day increment was used for Bear Creek and the Buffalo River near Boxley, and a 5-day increment was used for the Buffalo River near St. Joe because it has a larger drainage area. Minimums are compared to adjacent minimums to determine turning points on the base-flow hydrograph. If 90 percent of a given minimum is less than both adjacent minimums, then that minimum is a turning point. Straight lines are drawn between the turning points to define the base-flow hydrograph (Wahl and Wahl, 1995). The area beneath the hydrograph is the estimate of the volume of base flow for the period. The ratio of the base-flow volume to total flow volume is the base-flow index.

Water Quality

Water-quality samples were collected periodically at Bear Creek from February 1999 to March 2004. Samples were collected monthly and during 20 supplemental high-flow events during the period. Samples were collected periodically at the Buffalo River near Boxley site from April 1994 to April 2004 and at the Buffalo River near St. Joe site from April 1974 to April 2004. Samples also were collected monthly at the Buffalo River sites. Supplemental high-flow samples were collected only at the Buffalo River near St. Joe site during calendar years 2001 to 2004. Samples were collected from January 2001 to March 2003 at Calf Creek near Silver Hill (07055893); 15 samples were collected during high-flow conditions and 15 samples were collected during base-flow conditions (Galloway and Green, 2004).

Water-quality samples were collected following equal-width increment methods using depth-integrated samplers and processed using protocols described in Wilde and Radke (1998), Wilde and others (1998a, 1998b, 1998c, 1999a, and 1999b), and Meyers and Wilde (1999). Samples were analyzed

for nutrients (total ammonia plus organic nitrogen, dissolved nitrite plus nitrate, total nitrogen, dissolved phosphorus, dissolved orthophosphorus, and total phosphorus), dissolved organic carbon, fecal indicator bacteria (fecal coliform, fecal streptococci, and *E. coli*), and suspended sediment. Field parameters, including water temperature, dissolved-oxygen concentration, alkalinity, pH, and specific conductance, also were collected with each sample following protocols described in Wilde and Radke (1998). Nutrient and dissolved organic carbon analyses were conducted at the U.S. Geological survey (USGS) National Water Quality Laboratory in Denver, Colorado, following procedures described in Fishman (1993). Samples were analyzed for fecal indicator bacteria in the field by USGS personnel, following procedures described in Meyers and Wilde (1999). Suspended sediment analyses were conducted at the USGS laboratory in Rolla, Missouri, following procedures described in Guy (1969).

To maintain proper quality assurance and control (QA/QC) of water-quality data, protocols for instrument calibration (Wilde and Radke, 1998) and equipment cleaning (Wilde and others, 1998c) were followed. Associated blank and replicate water-quality samples also were collected periodically. Results indicated that cleaning procedures were adequate in preventing cross-contamination of samples and that the laboratory results were reproducible. QA/QC sample data were stored in the USGS National Water Information System (NWIS) database.

Water-quality samples were separated into those collected under base-flow or high-flow conditions. Base-flow water-quality samples were collected on days when the estimated base flow was greater than or equal to 70 percent of the total daily mean flow. High-flow samples were defined as water-quality samples collected on days when the surface-runoff component was greater than 30 percent of total daily mean flow. Water-quality samples collected for Calf Creek were separated into those collected under base-flow or high-flow conditions using the same methods (Galloway and Green, 2004).

The resulting streamflow and water-quality data were analyzed or summarized using several statistical and graphical techniques. Boxplots were used to compare concentrations of selected water-quality constituents among sites for data collected from February 1999 to March 2004. Concentrations reported as less than a laboratory reporting limit were converted to one-half the reporting limit for preparation of boxplots, calculation of total nitrogen concentrations (the sum of nitrite plus nitrate and ammonia plus organic nitrogen), and statistical analyses. The Wilcoxon rank sum test (Helsel and Hirsch, 1992) was used to test for differences in selected water-quality constituents among sites.

Water-quality constituent loads and yields were calculated from concentrations and streamflow measured at each site. A longer period of data for the Buffalo River near Boxley (1994 to 2004) and near St. Joe (1990 to 2004) was used for calculating loads and yields than for Bear Creek (1999 to 2004). Constituent load (L) is a function of the volumetric rate of water passing a point in the stream (Q) and the constituent concentration within the water (C). Regression methods used to estimate constituent loads use the natural logarithm (ln) transformed relation between Q and C to estimate daily C (or L) of the constituent (Cohn and others, 1989; Cohn and others, 1992; Cohn, 1995). The regression method can account for non-normal data distributions, seasonal and long-term cycles, censored data, biases associated with using logarithmic transformations, and serial correlations of the residuals (Cohn, 1995). The regression method uses discrete water-quality samples often collected over several years and a daily streamflow hydrograph. A typical log-linear regression model for estimating load can be expressed as:

$$\ln(L) = \beta_o + \beta_1 \ln(Q) + \beta_2 \ln(Q^2) + \beta_3 T + \beta_4 T^2 + \beta_5 \sin(2\pi T) + \beta_6 \cos(2\pi T) \quad (1)$$

where L represents the constituent load, in pounds per day;
β_o is the regression constant;
β_1, β_2, β_3, β_4, β_5, and β_6 are regression coefficients;
Q represents daily streamflow, in cubic feet per second; and
T represents decimal time.

However, no significant relations between seasonality or time to constituent concentration were found for the three sites. Therefore, only the relations between natural logarithmic-transformed L and Q were used:

$$\ln(L) = \beta_o + \beta_1 \ln(Q) \quad (2)$$

Transforming the results of the model from logarithmic space to real space was accomplished using two methods: an adjusted maximum likelihood estimator (AMLE) and a least absolute deviation (LAD) (Cohn and others, 1992). The AMLE method was used if the constituent had censored values and the LAD method was used to transform the results if no censored values were included in the data or if outliers in the residuals were present. The S-LOADEST computer program (David Lorenz, U.S. Geological Survey, written commun., 2003) was used to estimate annual and seasonal constituent loads at the three sites for calendar years 1999 through 2003.

Annual yields (pounds per square mile) also were calculated from estimated annual loads at each site. The yield was calculated by dividing the annual load (pounds per year) by the drainage area (square miles) contributing flow at the location of the sampling site.

Flow-weighted concentrations also were calculated from the estimated annual loads. Flow-weighted concentrations were calculated by dividing the annual load by annual mean flow, and applying appropriate conversion factors for dimensional units:

$$C_{FW} = \left[\frac{L}{Q_{Annual}}\right] \times 5.08 \times 10^{-4} \quad (3)$$

where C_{FW} represents the flow-weighted concentration, in milligrams per liter,
L represents the annual constituent load in pounds per year, and
Q_{Annual} represents the annual mean streamflow, in cubic feet per second.

Hydrologic Characteristics

Streamflow at Bear Creek near Silver Hill varied annually and seasonally from January 1999 to March 2004 (fig. 2 and table 1). The mean annual streamflow for Bear Creek for calendar years 1999 through 2003 was 86.0 cubic feet per second (ft^3/s). The highest annual mean streamflow occurred in 2002 (158 ft^3/s) and the lowest annual mean streamflow occurred in 1999 (56.4 ft^3/s). The highest streamflows occurred in the winter (December, January, and February) and spring (March through May). The lowest streamflows occurred in the summer (June through August) and fall (September through November). Additional daily mean streamflow data and summary statistics are presented in Porter and others (2001, 2002), Brossett and Evans (2003), and Evans and others (2004).

The streamflow at the Buffalo River near Boxley, the Buffalo River near St. Joe, and Calf Creek near Silver Hill also varied annually and seasonally (fig. 2 and table 1). The mean annual streamflow for calendar years 1999 through 2003 at the Buffalo River near Boxley and the Buffalo River near St. Joe were 102 ft^3/s and 881 ft^3/s, respectively (table 1). At both sites, the highest annual mean streamflow occurred in 2002 and the lowest annual mean streamflow occurred in 2003. Mean annual streamflow at Calf Creek was 58.9 ft^3/s for calendar years 2001 and 2002. Seasonal streamflow patterns at the Buffalo River and Calf Creek sites were similar to the patterns at the Bear Creek site.

The Bear Creek drainage basin composes approximately 10 percent of the Buffalo River drainage basin at the confluence of Bear Creek and the Buffalo River. On an annual basis, the streamflow measured at the gaging station at Bear Creek near Silver Hill, which represents approximately 90 percent of Bear Creek drainage basin, was about 9 percent of the streamflow measured at the Buffalo River near St. Joe for calendar years 1999 through 2003. In 1999, the streamflow at Bear Creek was about 7 percent of the streamflow measured at the Buffalo River near St. Joe and in 2002 the streamflow was about 12 percent of the streamflow measured at the Buffalo River near St. Joe. During periods of predominately base-flow conditions (August through November), the streamflow at Bear Creek was about 14 to 16 percent of the streamflow measured at the Buffalo River near St. Joe, and during periods of high flow (February through June) the streamflow at Bear Creek was about 7 to 13 percent of the streamflow measured at the Buffalo River near St. Joe. Gains or losses in streamflow between the Bear Creek near Silver Hill gaging station and the mouth of Bear Creek (a distance of about 8 river miles) and between the Buffalo River near St. Joe gaging station and the confluence of the Buffalo River and Bear Creek (a distance of about 5 miles) are unknown.

Much of the total streamflow for Bear Creek, the Buffalo River near Boxley, and the Buffalo River near St. Joe occurred during relatively few days from January 1999 through March 2004 (fig. 3). Fifty percent of the streamflow passed the gaging station at Bear Creek in 97 days (5 percent of the period) and the gaging stations at the Buffalo River near Boxley and the Buffalo River near St. Joe in 78 days (4 percent of the period). This suggests that during a typical year, the upper 50 percent of the streamflow passes the gaging station at Bear Creek in about 18 days and passes the gaging stations at the Buffalo River near Boxley and the Buffalo River near St. Joe in about 15 days. If concentrations of materials transported were constant, regardless of the magnitude of flow, season, and other variables, more than one-half of the material transported past the site in a given year would occur over a period of less than 3 weeks.

The streamflow for Bear Creek and the two Buffalo River sites demonstrated a considerable amount of base flow that varied annually and seasonally (fig. 2). Bear Creek had the greatest percentage of base flow for the 5-year period (1999 through 2003) with approximately 38 percent of the total streamflow contributed by base flow. The Buffalo River near Boxley had approximately 28 percent of the total streamflow contributed by base flow and the Buffalo River near St. Joe had approximately 35 percent of the total streamflow contributed by base flow for the same period. The amount of base-flow contribution to the total annual streamflow for Bear Creek varied from 27 percent (2001) to 58 percent (2003). The contribution of base flow to the total annual streamflow ranged from 24 percent (2000 and 2001) to 34 percent (2003) of the total annual streamflow for the Buffalo River near Boxley and ranged from 28 percent (2000) to 43 percent (1999) of the total annual streamflow for the Buffalo River near St. Joe. Seasonally, Bear Creek had a greater contribution of base flow during late summer and fall (August through November) with a percent contribution ranging from 39 to 97 percent of the total monthly streamflow. The least percent contribution of base flow to Bear Creek generally occurred in the winter (December, January, and February) with a range of 10 to 70 percent of the total monthly streamflow. Although the least percent contribution of base flow to Bear Creek occurred in the winter, the greatest volume of base flow occurred in the late winter and early spring and the least volume of base flow occurred in the summer and early fall because of seasonal patterns of precipitation, evapotranspiration, and ground-water recharge in the basin. Similar seasonal patterns occurred for the two Buffalo River sites, although the Buffalo River near Boxley had the least percent contribution of base flow to the total monthly flow in May and June in addition to the winter months.

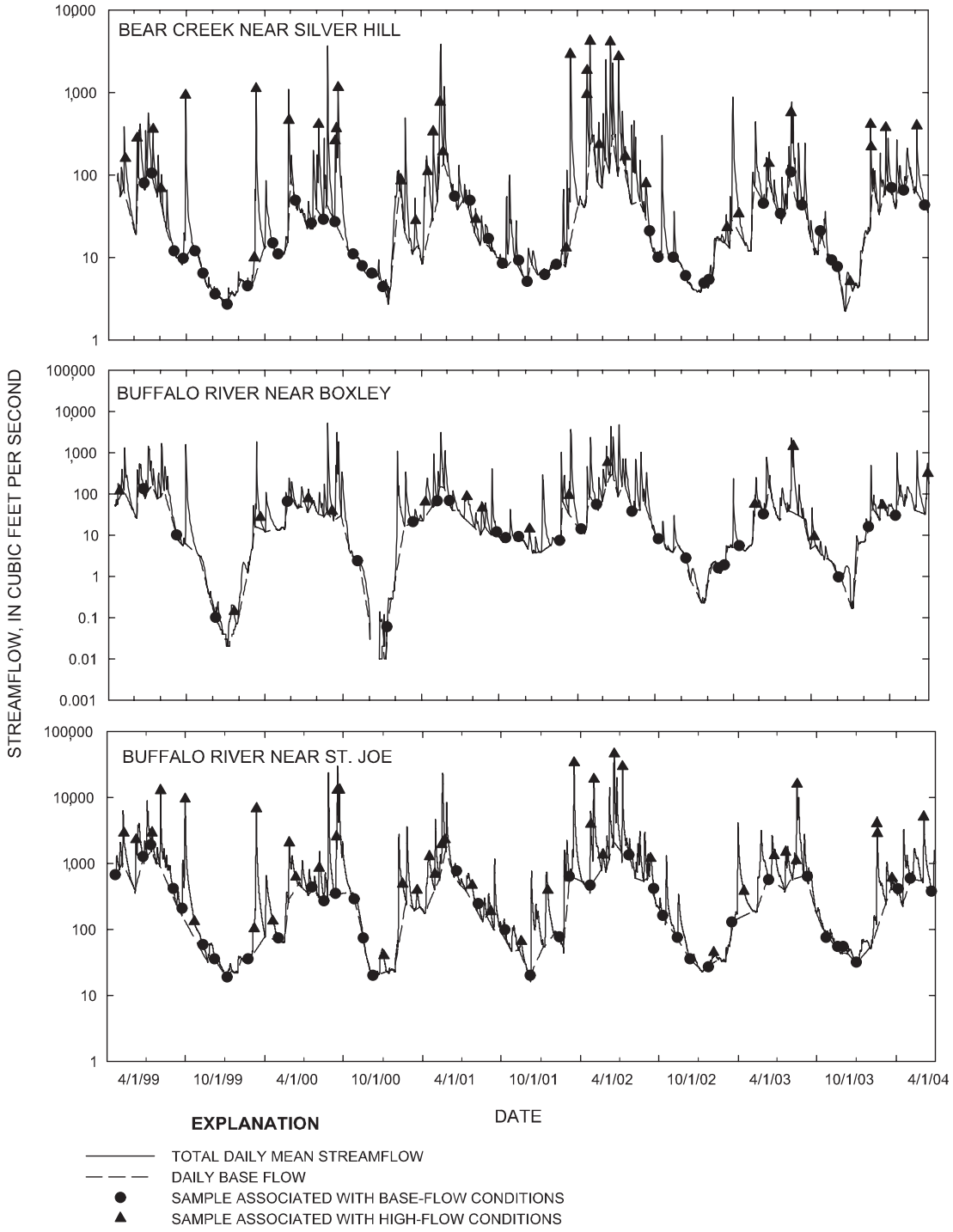

Figure 2. Daily base flow and total daily mean streamflow and water-quality sample times from January 1999 through March 2004 for Bear Creek near Silver Hill, the Buffalo River near Boxley, and the Buffalo River near St. Joe, Arkansas.

Table 1. Annual and monthly streamflow statistics for Bear Creek near Silver Hill, the Buffalo River near Boxley, and the Buffalo River near St. Joe, 1999-2003, and Calf Creek near Silver Hill, Arkansas, 2001-2002.

[Values are mean streamflow in cubic feet per second]

Station	Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Bear Creek near Silver Hill	1999	80.9	86.3	151	172	35.0	41.5	35.2	5.94	3.50	3.52	4.98	75.7	56.4
	2000	22.9	77.9	62.2	46.1	257	170	17.3	8.12	6.26	8.28	87.8	18.2	65.0
	2001	85.7	516	86.3	53.5	21.4	14.3	21.0	10.6	8.50	6.76	12.2	291	91.2
	2002	322	265	713	319	118	32.6	31.1	12.2	5.61	4.34	11.0	66.0	158
	2003	59.0	70.0	88.0	51.0	173	71.0	17.0	13.2	5.09	6.22	65.0	99.0	60.0
	Mean for 1999-2003	**114**	**205**	**220**	**128**	**121**	**66.0**	**24.0**	**10.0**	**5.79**	**5.82**	**36.0**	**110**	**86.0**
	Mean for period of record (1999-2003)	**114**	**205**	**220**	**128**	**121**	**66.0**	**24.0**	**10.0**	**5.79**	**5.82**	**36.0**	**110**	**86.0**
Buffalo River near Boxley	1999	150	197	192	355	245	61.9	46.8	1.32	0.117	0.096	1.71	104	112
	2000	30.2	52.7	84.0	64.0	284	318	24.9	1.45	0.027	0.224	99.4	28.1	82.0
	2001	137	531	75.2	50.0	24.4	35.0	10.3	8.13	6.09	30.9	68.1	326	106
	2002	126	173	748	487	175	80.1	8.78	7.20	2.29	0.466	1.75	11.3	152
	2003	9.46	47.1	145	56.4	310	36.7	8.11	2.51	1.26	4.28	51.4	43.5	60.0
	Mean for 1999-2003	**90.7**	**200**	**249**	**202**	**208**	**106**	**19.8**	**4.12**	**1.96**	**7.19**	**44**	**103**	**102**
	Mean for period of record (1994-1995; 1997-2003)	**103**	**157**	**217**	**208**	**176**	**78.6**	**13.0**	**4.13**	**3.74**	**18.9**	**102**	**108**	**100**
Buffalo River near St. Joe	1999	1,200	1,470	1,700	2,410	1,620	467	737	57.0	34.3	23.0	36.0	617	861
	2000	211	306	712	491	1,720	3,540	512	108	27.7	27.7	741	269	720
	2001	775	3,640	882	489	201	229	83.0	52.7	148	192	299	2,880	805
	2002	1,270	2,320	6,800	3,450	1,200	643	251	125	38.7	26.2	36.8	206	1,360
	2003	565	752	1,080	796	2,690	715	126	61	45.7	53.9	525	512	661
	Mean for 1999-2003	**805**	**1,700**	**2,230**	**1,530**	**1,490**	**1,120**	**342**	**81**	**59**	**64**	**328**	**896**	**881**
	Mean for period of record (1940-2003)	**1,160**	**1,610**	**2,020**	**2,140**	**1,840**	**797**	**233**	**161**	**169**	**303**	**986**	**1,210**	**1,050**
Calf Creek near Silver Hill	2001	39.3	181	42.3	22.2	8.34	4.69	2.78	3.20	7.08	3.66	22.2	150	39.6
	2002	87.6	99.6	456	163	63.3	15.7	17	5.29	1.62	1.79	2.41	23.4	78.2
	Mean for 2001-2002	**63.4**	**140**	**249**	**92.6**	**35.8**	**10.2**	**9.89**	**4.25**	**4.35**	**2.73**	**12.3**	**86.5**	**58.9**
	Mean for period of record (2001-2002)	**63.4**	**140**	**249**	**92.6**	**35.8**	**10.2**	**9.89**	**4.25**	**4.35**	**2.73**	**12.3**	**86.5**	**58.9**

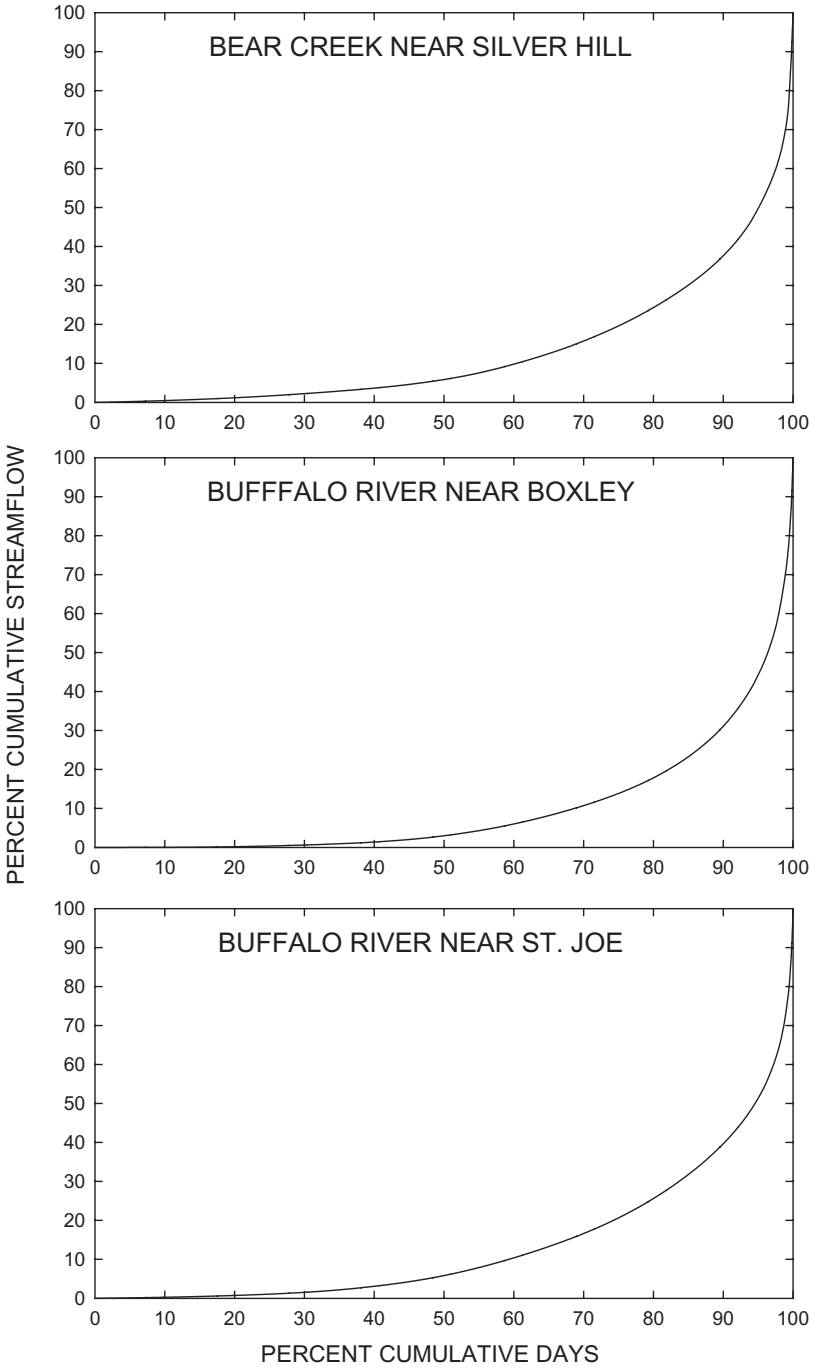

Figure 3. Flow accumulation curves for January 1999 through March 2004 for Bear Creek near Silver Hill, the Buffalo River near Boxley, and the Buffalo River near St. Joe, Arkansas.

Water-Quality Characteristics

The water-quality characteristics of Bear Creek are described below in terms of concentrations, annual and seasonal loads and yields, and annual flow-weighted concentrations. The water quality of Bear Creek is compared to two Buffalo River sites and one Calf Creek (a smaller tributary to the Buffalo River) site. Field parameters collected with samples from the four sites are summarized in table 2. In addition, the yields and flow-weighted concentrations also are compared to other selected developed and undeveloped sites.

Table 2. Field parameters measured for Bear Creek near Silver Hill, the Buffalo River near Boxley, the Buffalo River near St. Joe, 1999 -2004 and Calf Creek near Silver Hill, Arkansas, 2001-2003.

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; °C, degrees Celsius; $CaCO_3$, calcium carbonate; n, number of samples]

Station	Sample type	Statistic	Dissolved oxygen, in mg/L	Dissolved oxygen, percent saturation	pH, in standard units	Specific conductance, in µS/cm at 25 °C	Water temperature, in °C	Alkalinity, in mg/L as $CaCO_3$
Bear Creek near Silver Hill	High Flow (n=38)	Maximum	14	130	8.7	374	22	172
		Minimum	8.1	64	6.9	69.0	3.7	23
		Mean	9.8	93	7.5	159	13	66
		Median	9.4	93	7.6	131	12	54
	Base flow (n=44)	Maximum	13	118	8.3	433	29	188
		Minimum	5.0	53	6.9	123	6.0	53
		Mean	8.6	89	7.6	280	17	123
		Median	8.5	90	7.6	300	19	126
	All (n=82)	Mean	9.2	91	7.6	224	15	96
		Median	9.1	92	7.6	220	16	95
Buffalo River near Boxley	High Flow (n=17)	Maximum	13	106	8.1	194	24	92
		Minimum	7.3	73	6.7	39.0	2.7	14
		Mean	10	97	7.5	77.3	12	34
		Median	10	98	7.6	64.0	11	28
	Base flow (n=25)	Maximum	13	105	8.5	201	26	103
		Minimum	5.3	61	7.0	49.0	4.5	19
		Mean	9.5	90	7.7	112	14	51
		Median	9.3	96	7.5	112	11	48
	All (n=42)	Mean	9.8	93	7.6	97.9	13	44
		Median	10	96	7.6	76.0	11	32

Table 2. Field parameters measured for Bear Creek near Silver Hill, the Buffalo River near Boxley, the Buffalo River near St. Joe, 1999 -2004 and Calf Creek near Silver Hill, Arkansas, 2001-2003.—Continued

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; °C, degrees Celsius; $CaCO_3$, calcium carbonate; n, number of samples]

Station	Sample type	Statistic	Dissolved oxygen, in mg/L	Dissolved oxygen, percent saturation	pH, in standard units	Specific conductance, in µS/cm at 25 °C	Water temperature, in °C	Alkalinity, in mg/L as $CaCO_3$
Buffalo River near St. Joe	High Flow (n=43)	Maximum	16	140	8.4	277	29	132
		Minimum	6.4	65	6.5	62.0	1.9	5
		Mean	9.5	92	7.6	160	14	73
		Median	9.5	91	7.7	154	13	69
	Base flow (n=39)	Maximum	13	115	8.6	266	29	159
		Minimum	5.7	72	6.8	159	4.6	68
		Mean	8.8	94	7.9	214	19	102
		Median	8.8	92	8.0	219	21	102
	All (n=82)	Mean	9.2	92	7.8	186	16	87
		Median	9.3	91	7.9	186	15	88
Calf Creek near Silver Hill	High Flow (n=15)	Maximum	16	140	8.2	389	25	171
		Minimum	7.3	66	7.2	162	7.9	56
		Mean	11	99	7.7	241	12	106
		Median	11	95	7.8	236	11	98
	Base flow (n=15)	Maximum	13	154	8.6	365	25	178
		Minimum	7	69	7.5	246	9.8	100
		Mean	9.9	104	7.9	309	17	138
		Median	10	101	7.8	319	16	144
	All (n=30)	Mean	10	101	7.8	275	15	122
		Median	10	98	7.8	272	13	118

Concentrations

Concentrations of nitrogen in water samples collected at Bear Creek generally were greater than concentrations from the two Buffalo River sites and were similar to concentrations from Calf Creek (fig. 4). The median (50th percentile) total ammonia plus organic nitrogen concentration at Bear Creek was 0.12 milligrams per liter (mg/L) as nitrogen during base-flow conditions and 0.31 mg/L as nitrogen during high-flow conditions. Total ammonia plus organic nitrogen concentrations at Bear Creek were significantly greater ($p < 0.05$) than concentrations at both Buffalo River sites and Calf Creek during high-flow conditions and similar to the concentrations at the Buffalo River near St. Joe during base-flow conditions. The median nitrite plus nitrate concentration at Bear Creek was 0.47 mg/L as nitrogen during base-flow conditions and 0.38 mg/L as nitrogen during high-flow conditions. Bear Creek had nitrite plus nitrate concentrations that were greater than concentrations at both the Buffalo River sites regardless of the flow condition. However, the nitrite plus nitrate concentrations at Bear Creek were greater than concentrations at Calf Creek during base-flow conditions and similar to concentrations at Calf Creek during high-flow conditions (fig. 4).

Concentrations of phosphorus from water samples collected at Bear Creek generally were greater than concentrations at the two Buffalo River sites and were similar to concentrations at Calf Creek (fig. 5). Dissolved phosphorus and orthophosphorus concentrations were significantly greater at Bear and Calf Creeks than concentrations at the Buffalo River sites and did not noticeably differ with the flow condition. However, total phosphorus concentrations increased substantially during high-flow conditions at Bear Creek with a median concentration of 0.027 mg/L as phosphorus during base-flow conditions and 0.078 mg/L as phosphorus during high-flow conditions. Total phosphorus concentrations did not noticeably differ with flow conditions at Calf Creek.

Concentrations of dissolved organic carbon from samples collected at Bear Creek generally were greater than concentrations at the Buffalo River near St. Joe and at Calf Creek (fig. 6). Dissolved organic carbon concentrations at Bear Creek were more than three times higher during high-flow conditions than during base-flow conditions (with a median value of 3.25 mg/L and 1.00 mg/L as carbon, respectively). Concentrations during high-flow conditions at the Buffalo River near St. Joe and Calf Creek were nearly twice as great as concentrations during base-flow conditions. Water-quality samples at the Buffalo River near Boxley were not analyzed for dissolved organic carbon.

Fecal indicator bacteria concentrations from samples collected at Bear Creek generally were greater than concentrations at the Buffalo River and similar to concentrations at Calf Creek (fig. 7). Bear Creek had a median concentration of 57 colonies per 100 milliliters (col./100 mL) for fecal coliform for all of the samples collected which was nearly eight times greater than the median concentration for the Buffalo River near Boxley and more than three times greater than the median concentration at Buffalo River near St. Joe. The median concentration of fecal streptococci at Bear Creek was 97 col./100 mL for all of the samples collected, which was about four times greater than the median concentrations at both Buffalo River sites. Bear Creek had a median *E. coli* concentration of 45 col./100 mL for all of the samples collected, which was more than seven times greater than the median concentration at the Buffalo River near Boxley and more than three times greater than median concentration at the Buffalo River near St. Joe.

Concentrations of fecal indicator bacteria were substantially greater at Bear Creek during high-flow conditions than during base-flow conditions (fig. 7). The fecal coliform concentrations during high-flow conditions at Bear Creek were 13 times greater than concentrations during base-flow conditions and fecal streptococci concentrations were more than 15 times greater during high-flow conditions. *E. coli* concentrations at Bear Creek were 21 times higher during high-flow conditions than during base-flow conditions.

Bear Creek had significantly greater suspended-sediment concentrations in all samples than the Buffalo River near Boxley and the Buffalo River near St. Joe, and similar concentrations to Calf Creek (fig. 8). Median concentrations of suspended sediment at Bear Creek did not substantially vary between samples collected at high-flow and base-flow conditions and were more than three times greater than median concentrations measured at the Buffalo River near Boxley regardless of the flow conditions (fig. 8).

Loads and Yields

Nutrients, dissolved organic carbon, and suspended-sediment loads and yields for Bear Creek and the two Buffalo River sites (table 3) varied because of differences in land use and contributing drainage area for each site. In general, the Buffalo River near St. Joe had the greatest annual loads of nutrients, dissolved organic carbon, and suspended sediment (fig. 9). The Buffalo River near Boxley had the least annual nutrient and suspended-sediment loads among the three sites. Greater loads would be expected at the Buffalo River near St. Joe because of the higher volume of streamflow that occurs at the site. Buffalo River near Boxley had lesser annual loads than the other two sites probably because of the smaller contributing area (lower volume of streamflow), and the higher percentage of forested land in the basin. Also, fewer samples representing high-flow events were collected at the Buffalo River near Boxley when generally most of the constituent load is delivered in a stream, which may affect the load computation for the site.

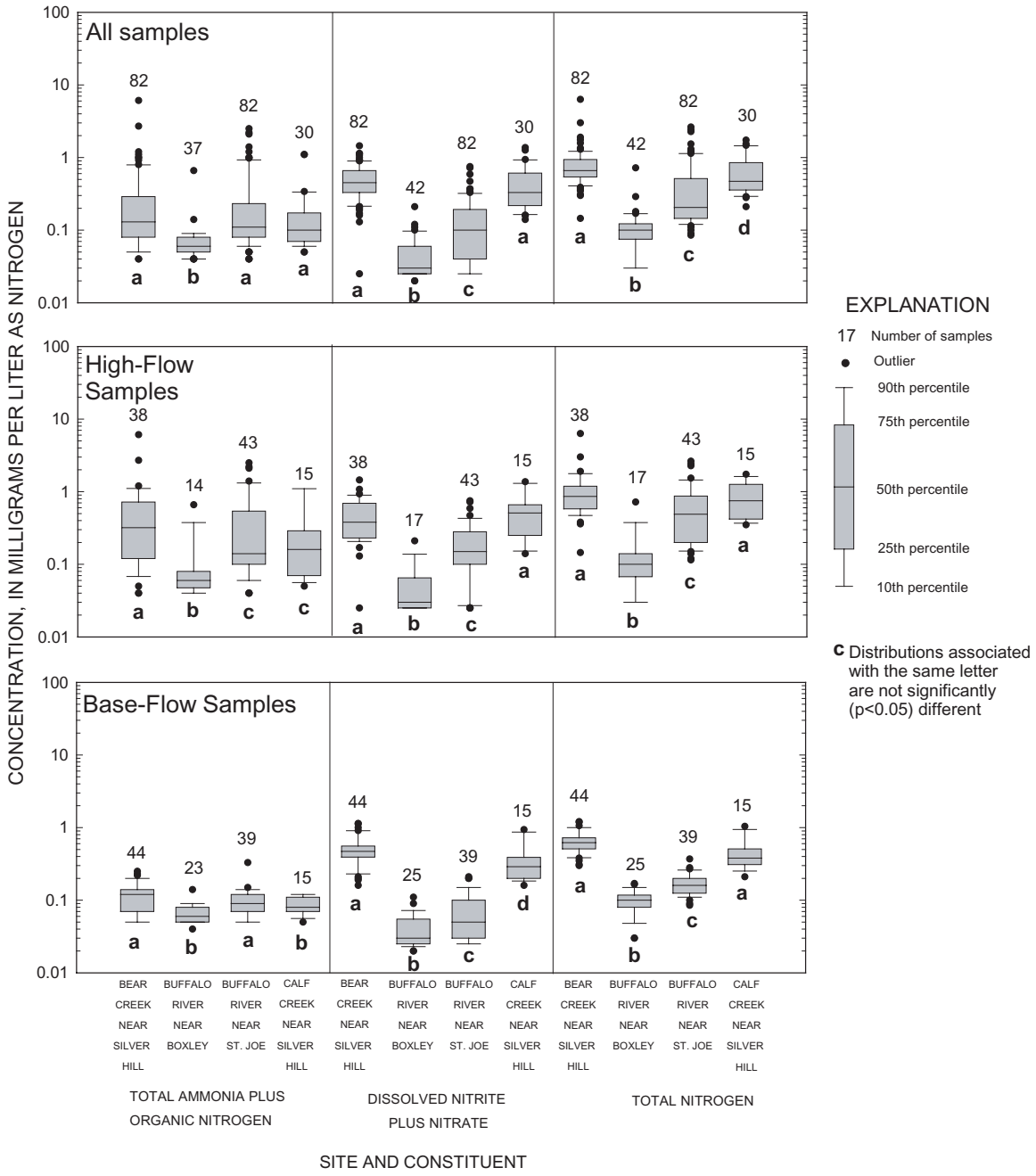

Figure 4. Distribution of nitrogen concentrations for Bear Creek near Silver Hill, the Buffalo River near Boxley, and the Buffalo River near St. Joe, 1999-2004 and Calf Creek near Silver Hill, Arkansas, 2001-2003.

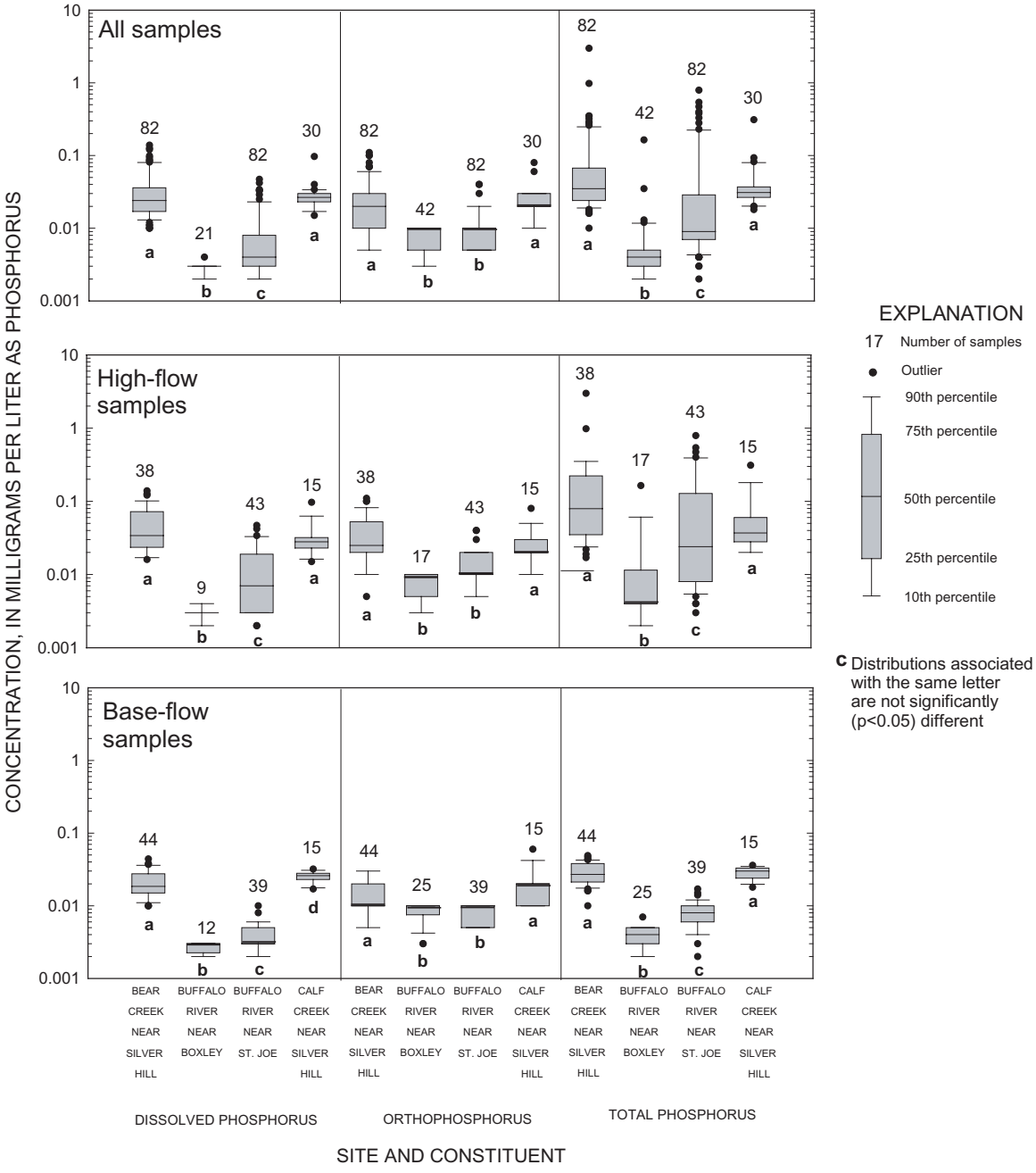

Figure 5. Distribution of phosphorus concentrations for Bear Creek near Silver Hill, the Buffalo River near Boxley, and the Buffalo River near St. Joe, 1999-2004 and Calf Creek near Silver Hill, Arkansas, 2001-2003.

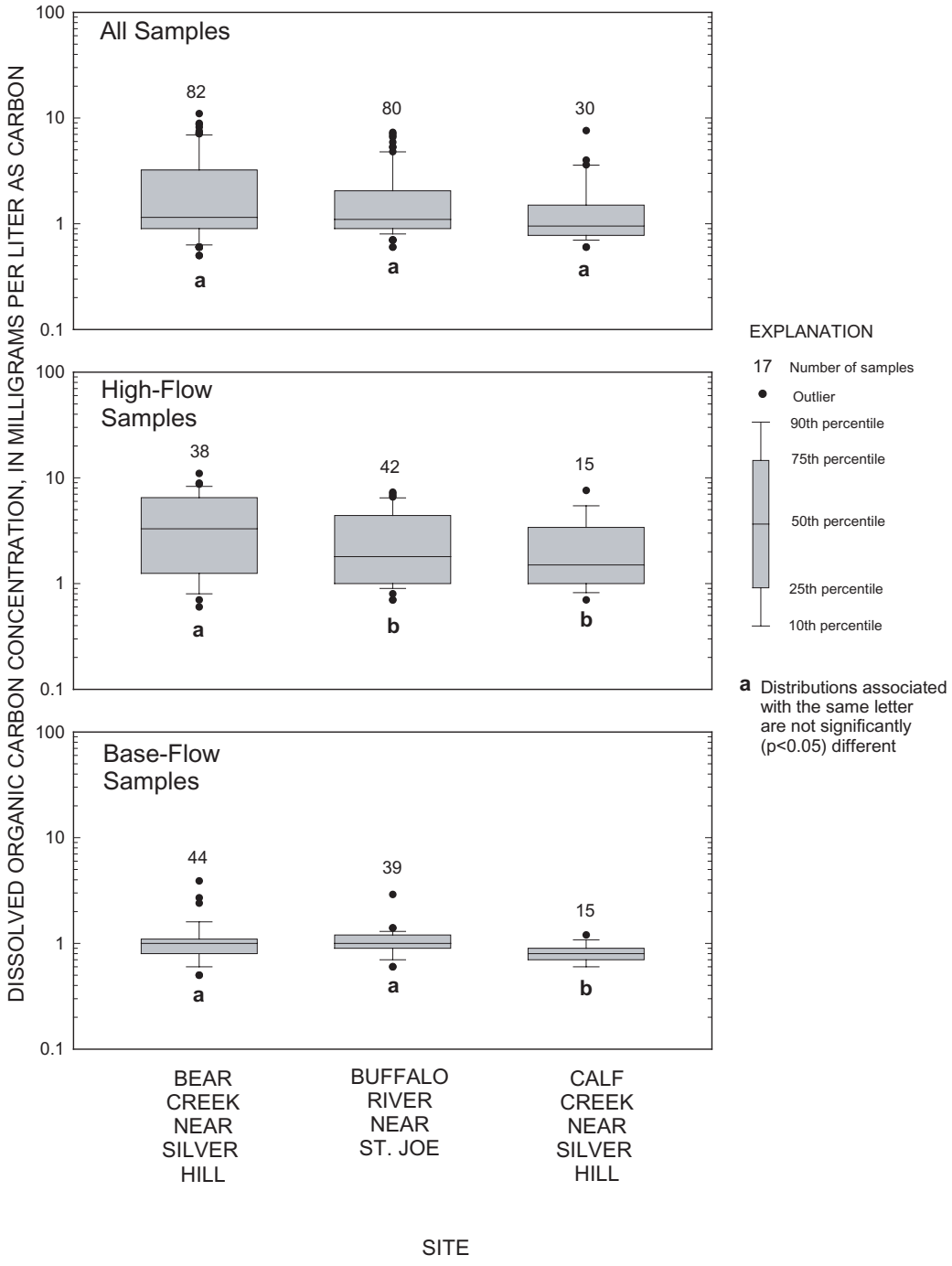

Figure 6. Distribution of dissolved organic carbon concentrations for Bear Creek near Silver Hill and the Buffalo River near St. Joe, 1999-2004 and Calf Creek near Silver Hill, Arkansas, 2001-2003.

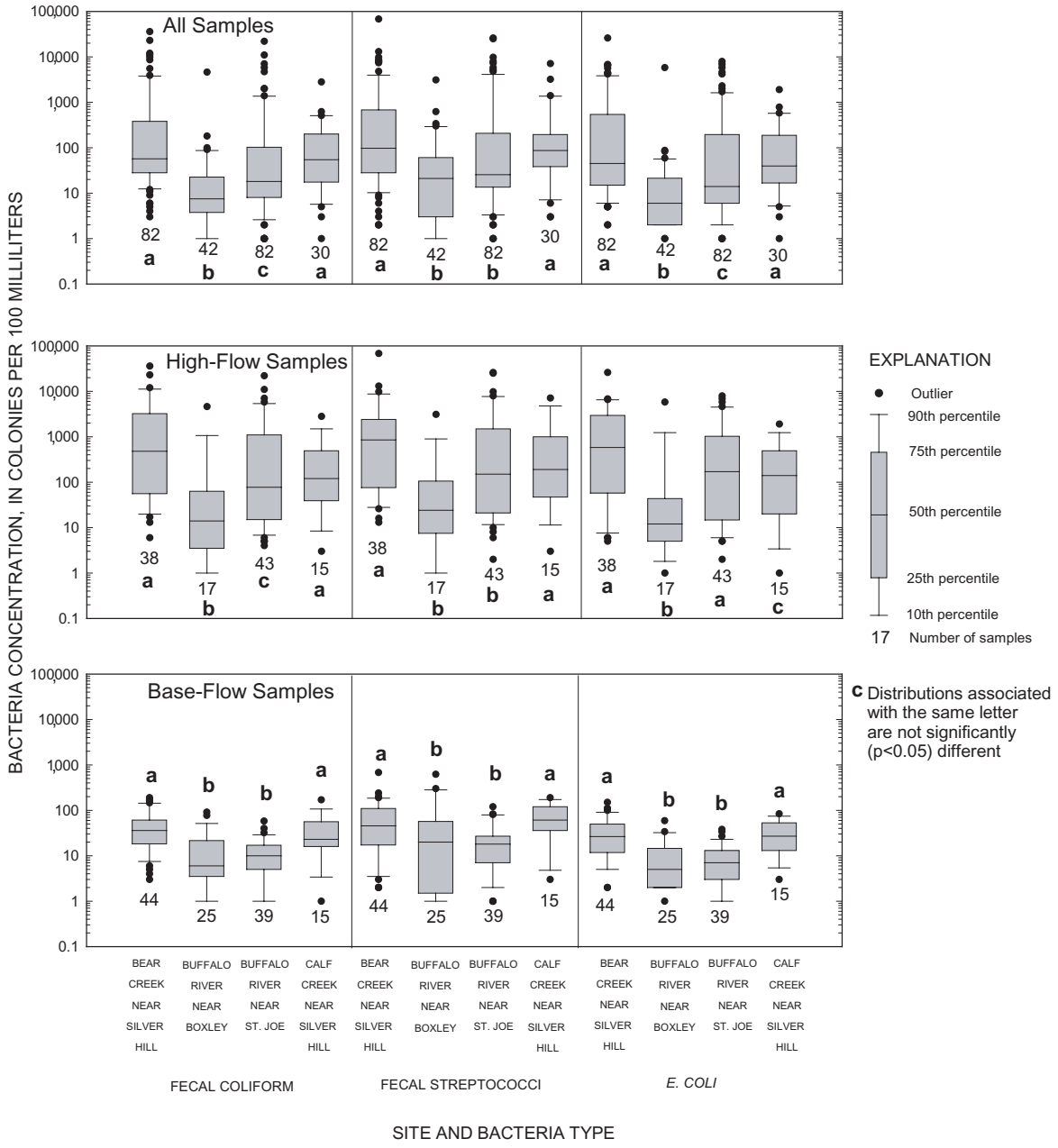

Figure 7. Distribution of fecal indicator bacteria concentrations for Bear Creek near Silver Hill, the Buffalo River near Boxley, and the Buffalo River near St. Joe, 1999-2004 and Calf Creek near Silver Hill, Arkansas, 2001-2003.

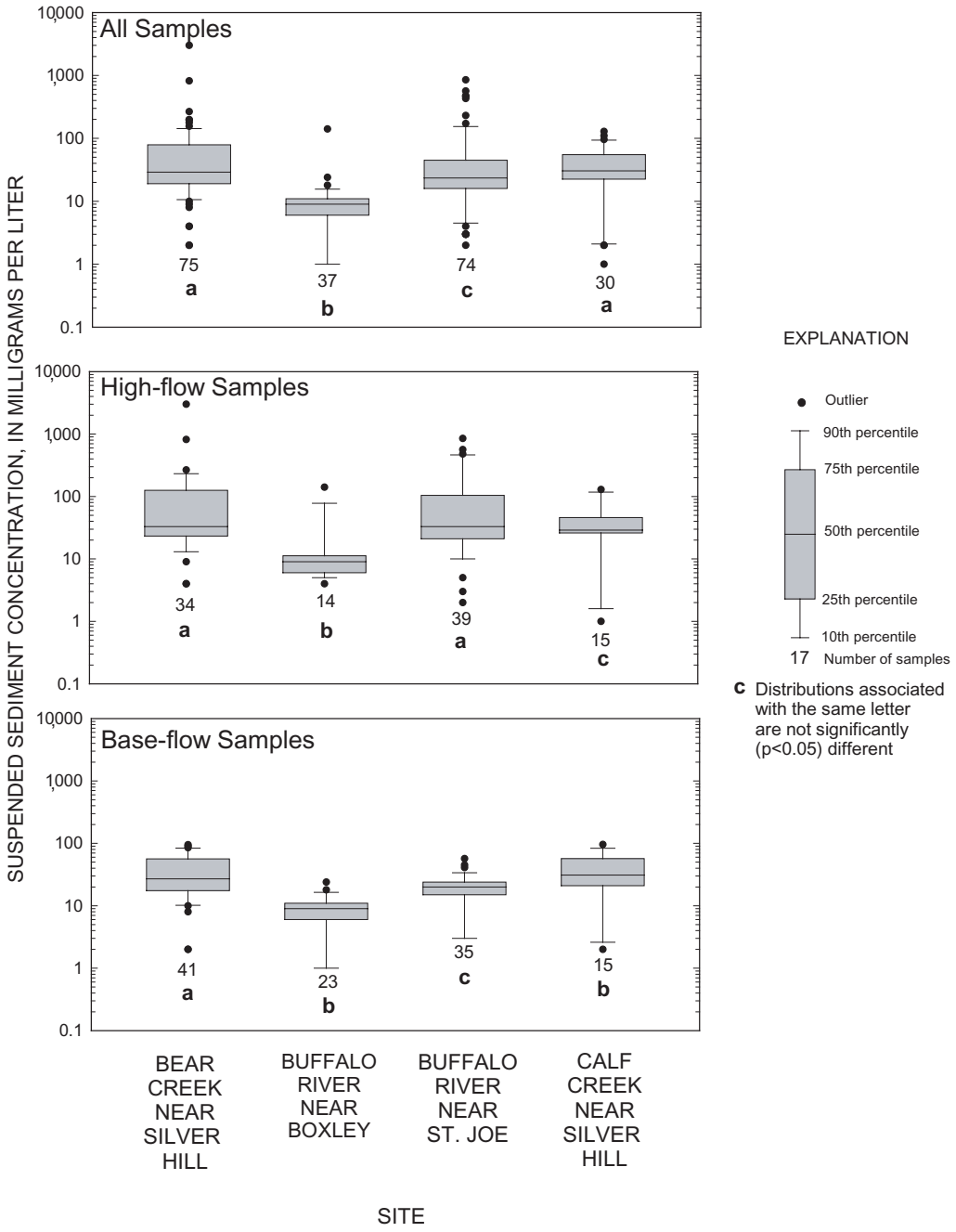

Figure 8. Distribution of suspended-sediment concentrations for Bear Creek near Silver Hill, the Buffalo River near Boxley, and the Buffalo River near St. Joe, 1999-2004 and Calf Creek near Silver Hill, Arkansas, 2001-2003.

Table 3. Regression models applied to estimate constituent loads.

[Water-quality data collected between January 1994 and March 2004 for the Buffalo River near Boxley, January 1990 and March 2004 for the Buffalo River near St. Joe, and February 1999 and March 2004 for Bear Creek near Silver Hill. N is nitrogen, P is phosphorus, C is carbon, Regression model described by the equation $\ln(L) = \beta_o + \beta_1 \ln Q$, where L is load in pounds per day, Q is discharge, in cubic feet per second, β_o is a regression constant, and β_1 is a regression coefficient; --, not calculated]

Constituent	Site	Number of samples	Regression constant (β_0)	Regression coefficient (β_1)	Coefficient of determination (R^2)
Total ammonia plus organic nitrogen as N	Buffalo River near Boxley	82	2.22	1.07	97
	Buffalo River near St. Joe	113	5.77	1.32	94
	Bear Creek near Silver Hill	82	2.81	1.38	93
Nitrite plus nitrate as N	Buffalo River near Boxley	86	1.52	1.08	93
	Buffalo River near St. Joe	113	5.36	1.26	89
	Bear Creek near Silver Hill	82	3.88	0.89	91
Total nitrogen as N	Buffalo River near Boxley	--	--	--	--
	Buffalo River near St. Joe	113	6.42	1.28	95
	Bear Creek near Silver Hill	82	4.27	1.12	95
Dissolved phosphorus as P	Buffalo River near Boxley	--	--	--	--
	Buffalo River near St. Joe	113	2.64	1.28	94
	Bear Creek near Silver Hill	82	1.01	1.42	96
Orthophosphorus as P	Buffalo River near Boxley	--	--	--	--
	Buffalo River near St. Joe	113	2.73	1.26	94
	Bear Creek near Silver Hill	82	0.666	1.22	94
Total phosphorus as P	Buffalo River near Boxley	85	-0.218	1.11	89
	Buffalo River near St. Joe	160	3.7	1.46	85
	Bear Creek near Silver Hill	82	1.52	1.42	95
Dissolved organic carbon as C	Buffalo River near Boxley	--	--	--	--
	Buffalo River near St. Joe	107	8.15	1.22	96
	Bear Creek near Silver Hill	81	5.04	1.35	96
Suspended sediment	Buffalo River near Boxley	86	7.14	1.02	84
	Buffalo River near St. Joe	110	10.94	1.38	86
	Bear Creek near Silver Hill	74	8.07	1.23	83

Annual loads for 1999 through 2003 showed substantial variability among the three sites and through time (fig. 9 and table 4). Annual loads of total ammonia plus organic nitrogen for Bear Creek ranged from 35,700 pounds of nitrogen per year (lbs/yr) in 2003 to 192,000 lbs/yr in 2002. The greater loads in 2002 can be attributed to the higher volume of streamflow in 2002. The total ammonia plus organic nitrogen loads for the Buffalo River near St. Joe were 5 to more than 10 times greater than the loads for Bear Creek, and the loads for the Buffalo River near Boxley were one-sixth to one-half the loads for Bear Creek. Similarly, nitrite plus nitrate loads for the Buffalo River near St. Joe were four to six times greater than Bear Creek, and the Buffalo River near Boxley had loads that were one-sixth to one-third the loads for Bear Creek. Total nitrogen loads for Bear Creek ranged from 103,000 lbs/yr in 2003 to 302,000 lbs/yr in 2002. Total phosphorus loads for Bear Creek ranged from 9,920 lbs/yr in 2003 to 52,800 lbs/yr in 2002. The total phosphorus loads for the Buffalo River near St. Joe were 5 to 11 times greater than Bear Creek and the loads for the Buffalo River near Boxley were one-twelfth to one-third the loads for Bear Creek. The dissolved organic carbon loads for Bear Creek ranged from 301,000 lbs/yr in 2003 to 1,540,000 lbs/yr in 2002. The dissolved organic carbon loads for the Buffalo River near St. Joe were 4 to more than 10 times greater than loads for Bear Creek. Samples collected for the Buffalo River near Boxley were not analyzed for dissolved organic carbon. Suspended-sediment loads for Bear Creek ranged from 10,000,000 lbs/yr in 2003 to 40,200,000 lbs/yr in 2002. The Buffalo River near St. Joe had suspended-sediment loads that were 6 to 11 times greater than the loads for Bear Creek and the Buffalo River near Boxley had loads that were one-ninth to one-third the loads for Bear Creek.

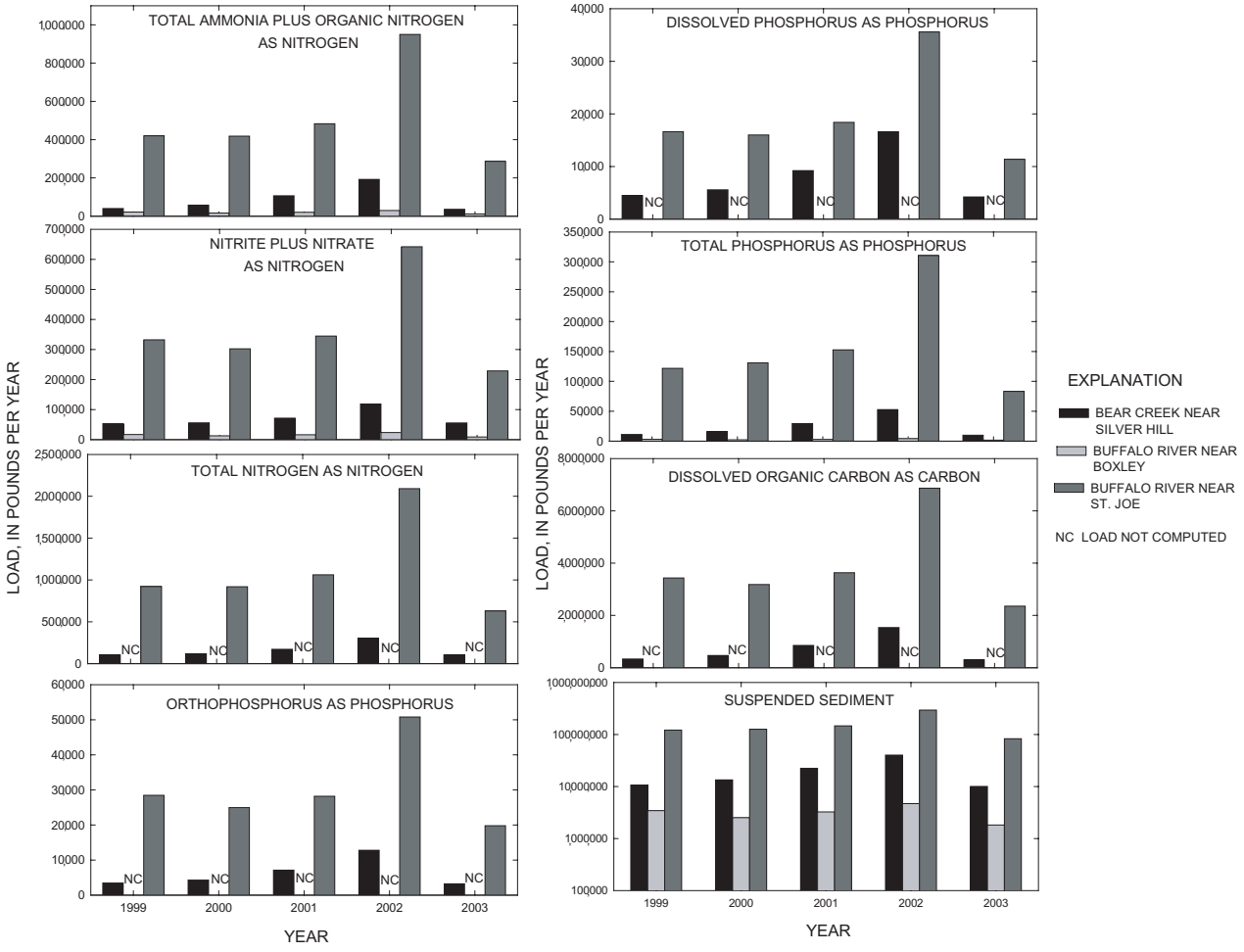

Figure 9. Annual loads of nutrients, dissolved organic carbon, and suspended sediment for Bear Creek near Silver Hill, the Buffalo River near Boxley, and the Buffalo River near St. Joe, Arkansas, 1999-2003.

Table 4. Annual nitrogen, phosphorus, dissolved organic carbon, and suspended-sediment loads and yields for Bear Creek near Silver Hill, the Buffalo River near Boxley, and the Buffalo River near St. Joe, Arkansas, 1999-2003.

[Loads and yields were rounded to three significant figures; lbs/yr, pounds per year; lbs/yr/mi^2, pounds per year per square mile; SD, standard deviation; N, nitrogen; P, phosphorus; C, carbon; --, not calculated]

		Total ammonia plus organic nitrogen as N		Nitrite plus nitrate as N		Total nitrogen as N	
Site	Year	Load (lbs/yr) (+/-SD)	Yield (lbs/yr/mi^2)	Load (lbs/yr) (+/-SD)	Yield (lbs/yr/mi^2)	Load (lbs/yr) (+/-SD)	Yield (lbs/yr/mi^2)
Bear Creek near Silver Hill	1999	40,100+/-101	234	53,100+/-130	309	104,000+/-223	605
	2000	57,500+/-191	335	55,700+/-162	324	117,000+/-270	680
	2001	107,000+/-425	621	71,400+/-298	416	172,000+/-448	999
	2002	192,000+/-755	1,120	118,000+/-591	690	302,000+/-817	1,760
	2003	35,700+/-83	208	55,500+/-113	323	103,000+/-212	600
	Mean	**86,400**	**503**	**70,800**	**413**	**160,000**	**929**
	Median	**57,500**	**335**	**55,700**	**324**	**117,000**	**680**
Buffalo River near Boxley	1999	21,900+/-771	174	17,000+/-107	135	--	--
	2000	16,000+/-613	128	12,500+/-80	100	--	--
	2001	20,700+/-812	164	16,200+/-105	129	--	--
	2002	29,800+/-1,316	237	23,500+/-159	187	--	--
	2003	11,600+/-356	92	8,930+/-54	71	--	--
	Mean	**20,000**	**159**	**15,600**	**124**	--	**--**
	Median	**20,700**	**164**	**16,200**	**129**	--	**--**
Buffalo River near St. Joe	1999	420,000+/-1,932	230	332,000+/-1,874	182	921,000+/-5,263	504
	2000	418,000+/-2,315	229	302,000+/-1,737	165	919,000+/-5,514	503
	2001	483,000+/-2,750	264	344,000+/-1,995	188	1,060,000+/-6,466	581
	2002	950,000+/-5,922	520	642,000+/-3,837	351	2,090,000+/-13,432	1,140
	2003	287,000+/-1,315	157	228,000+/-1,287	125	629,000+/-3,587	344
	Mean	**512,000**	**280**	**370,000**	**202**	**1,120,000**	**614**
	Median	**420,000**	**230**	**332,000**	**182**	**921,000**	**504**

Table 4. Annual nitrogen, phosphorus, dissolved organic carbon, and suspended-sediment loads and yields for Bear Creek near Silver Hill, the Buffalo River near Boxley, and the Buffalo River near St. Joe, Arkansas, 1999-2003.—Continued

[Loads and yields were rounded to three significant figures; lbs/yr, pounds per year; lbs/yr/mi^2, pounds per year per square mile; SD, standard deviation; N, nitrogen; P, phosphorus; C, carbon; --, not calculated]

Site	Year	Dissolved phosphorus as P		Orthophosphorus as P		Total phosphorus as P	
		Load (lbs/yr) (+/-SD)	Yield (lbs/yr/mi^2)	Load (lbs/yr) (+/-SD)	Yield (lbs/yr/mi^2)	Load (lbs/yr) (+/-SD)	Yield (lbs/yr/mi^2)
Bear Creek near Silver Hill	1999	4,480+/-7	26	3,440+/-7	20	11,100+/-46	65
	2000	5,570+/-10	32	4,280+/-11	25	15,900+/-90	92
	2001	9,220+/-21	54	7,110+/-21	41	29,300+/-204	171
	2002	16,600+/-38	97	12,800+/-39	74	52,800+/-363	307
	2003	4,220+/-6	25	3,230+/-6	19	9,920+/-36	58
	Mean	**8,010**	**47**	**6,170**	**36**	**23,800**	**139**
	Median	**5,570**	**32**	**4,280**	**25**	**15,900**	**92**
Buffalo River near Boxley	1999	--	--	--	--	3,030+/-79	24
	2000	--	--	--	--	2,240+/-64	18
	2001	--	--	--	--	2,900+/-84	23
	2002	--	--	--	--	4,240+/-139	34
	2003	--	--	--	--	1,590+/-36	13
	Mean	--	**--**	--	**--**	**2,800**	**22**
	Median	--	**--**	--	**--**	**2,900**	**23**
Buffalo River near St. Joe	1999	16,600+/-72	9	28,400+/-160	16	122,000+/-931	67
	2000	16,000+/-82	9	24,900+/-142	14	131,000+/-1,164	72
	2001	18,400+/-97	10	28,200+/-163	15	153,000+/-1,388	84
	2002	35,600+/-207	19	50,800+/-307	28	310,000+/-3,009	170
	2003	11,400+/-48	6	19,800+/-111	11	83,300+/-641	46
	Mean	**19,600**	**11**	**30,400**	**17**	**160,000**	**87**
	Median	**16,600**	**9**	**28,200**	**15**	**131,000**	**72**

Table 4. Annual nitrogen, phosphorus, dissolved organic carbon, and suspended-sediment loads and yields for Bear Creek near Silver Hill, the Buffalo River near Boxley, and the Buffalo River near St. Joe, Arkansas, 1999-2003.—Continued

[Loads and yields were rounded to three significant figures; lbs/yr, pounds per year; lbs/yr/mi^2, pounds per year per square mile; SD, standard deviation; N, nitrogen; P, phosphorus; C, carbon; --, not calculated]

		Dissolved organic carbon as C		Suspended sediment	
Site	Year	Load (lbs/yr) (+/-SD)	Yield (lbs/yr/mi^2)	Load (lbs/yr) (+/-SD)	Yield (lbs/yr/mi^2)
Bear Creek near Silver Hill	1999	335,000+/-613	1,950	10,700,000+/-70,630	62,200
	2000	468,000+/-1,047	2,730	13,400,000+/-99,982	78,000
	2001	854,000+/-2,238	4,970	22,400,000+/-188,504	130,000
	2002	1,540,000+/-3,998	8,950	40,200,000+/-342,395	234,000
	2003	301,000+/-522	1,760	10,000,000+/-62,674	58,400
	Mean	**699,000**	**4,070**	**19,300,000**	**112,000**
	Median	**468,000**	**2,730**	**13,400,000**	**78,000**
Buffalo River near Boxley	1999	--	--	3,430,000+/-44,987	27,300
	2000	--	--	2,520,000+/-34,082	20,000
	2001	--	--	3,250,000+/-44,785	25,800
	2002	--	--	4,700,000+/-69,451	37,400
	2003	--	--	1,820,000+/-22,023	14,400
	Mean	--	**--**	**3,140,000**	**25,000**
	Median	--	**--**	**3,250,000**	**25,800**
Buffalo River near St. Joe	1999	3,430,000+/-10,307	1,880	121,000,000+/-982,852	66,300
	2000	3,180,000+/-11,148	1,740	126,000,000+/-1,220,933	69,000
	2001	3,640,000+/-13,111	1,990	146,000,000+/-1,454,759	80,200
	2002	6,870,000+/-27,555	3,760	295,000,000+/-3,148,407	161,000
	2003	2,360,000+/-6,927	1,290	82,600,000+/-674,175	45,200
	Mean	**3,900,000**	**2,130**	**154,000,000**	**84,300**
	Median	**3,430,000**	**1,880**	**126,000,000**	**69,000**

Estimated nutrient, dissolved organic carbon, and suspended-sediment loads computed for Bear Creek and the Buffalo River varied seasonally for the period of 1999 to 2003 (fig. 10 and table 5). The greatest loads for all three sites occurred in the winter and spring and the least loads occurred in the summer and fall. Mean daily total nitrogen loads for Bear Creek ranged from 69.6 pounds per day (lbs/d) in the fall to 795 lbs/d in the spring. Mean daily total phosphorus loads for Bear Creek ranged from 5.37 lbs/d in the fall to 121 lbs/d in the spring. Dissolved organic carbon mean daily loads for Bear Creek ranged from 165 lbs/d in the fall to 3,540 lbs/d in the spring, and suspended-sediment mean daily loads ranged from 5,940 lbs/d in the fall to 97,600 lbs/d in the spring.

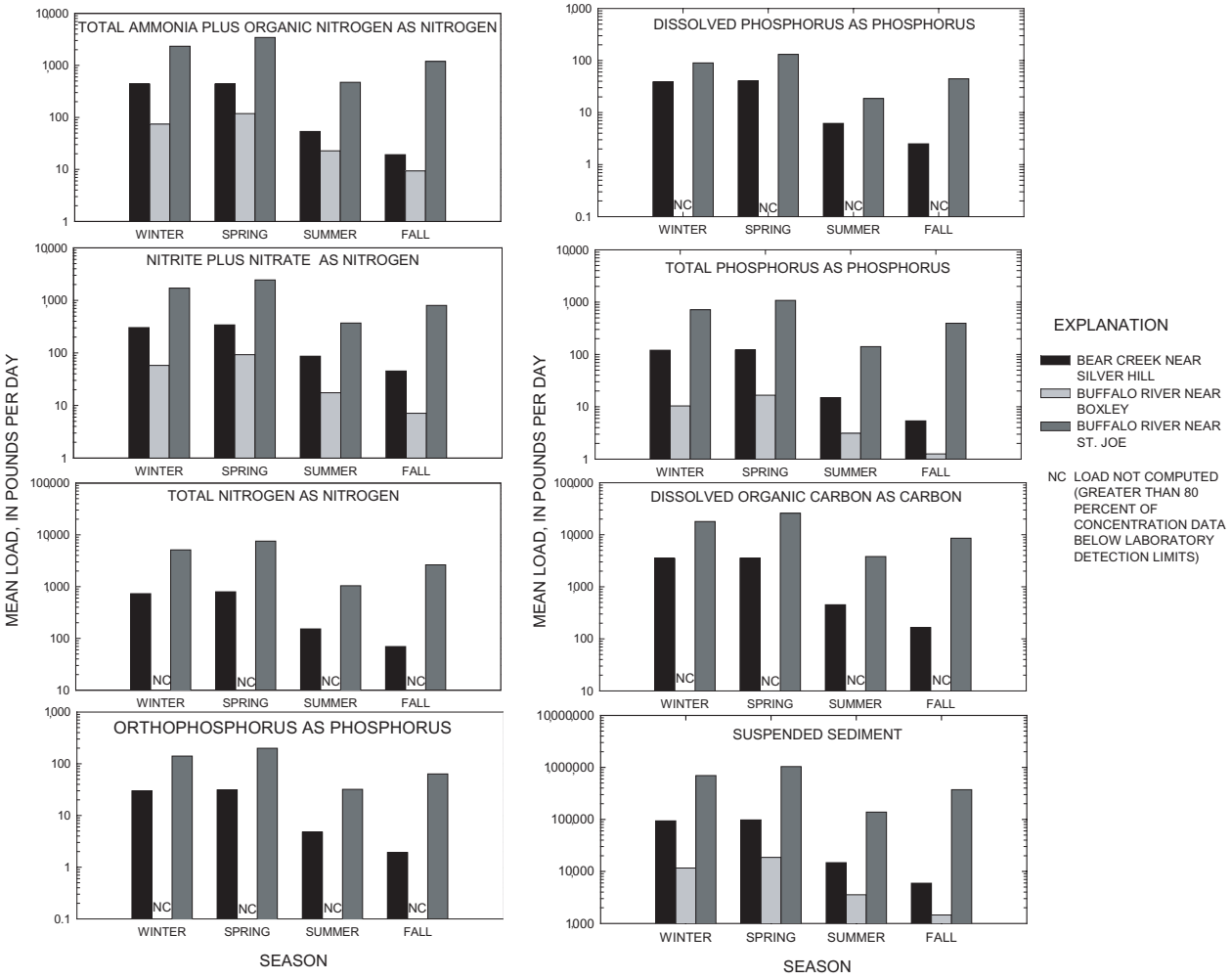

Figure 10. Mean daily seasonal loads of nutrients, dissolved organic carbon, and suspended sediment for Bear Creek near Silver Hill, the Buffalo River near Boxley, and the Buffalo River near St. Joe, Arkansas, 1999-2003.

Table 5. Seasonal nitrogen, phosphorus, dissolved organic carbon, and suspended-sediment loads and yields for Bear Creek near Silver Hill, the Buffalo River near Boxley, and the Buffalo River near St. Joe, Arkansas, 1999-2003.

[Values are loads in pounds per day; N is nitrogen; P is phosphorus; C is carbon; winter defined as December through February; spring defined as March through May; summer defined as June through August; fall defined as September through November; values were rounded to three significant figures; --, not calculated]

		Total ammonia plus organic nitrogen as N				Nitrite plus nitrate as N				Total nitrogen as N			
Site	Year	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Bear Creek near Silver Hill	1999	150	222	53.0	1.69	238	282	69.9	15.0	446	572	129	15.1
	2000	137	365	134	49.1	136	269	152	89.1	287	624	310	155
	2001	694	68.0	12.5	5.87	396	144	47.6	30.5	1,040	242	64.1	36.8
	2002	1,080	1,350	28.1	3.90	579	761	71.9	24.0	1,570	2,040	110	27.3
	2003	127	187	40.7	35.4	166	253	91.2	67.7	324	496	148	114
	Mean	**437**	**438**	**53.7**	**19.2**	**303**	**342**	**86.4**	**45.3**	**732**	**795**	**152**	**69.6**
	Median	**150**	**222**	**40.7**	**5.87**	**238**	**269**	**71.9**	**30.5**	**446**	**572**	**129**	**36.8**
Buffalo River near Boxley	1999	94.3	141	19.5	0.320	72.6	110	15.1	0.220	--	--	--	--
	2000	33.2	78.0	60.6	17.5	25.4	61.2	47.8	13.5	--	--	--	--
	2001	120	26.0	9.12	18.5	93.8	19.3	6.69	14.1	--	--	--	--
	2002	113	254	16.5	0.740	89.1	202	12.3	0.510	--	--	--	--
	2003	11.4	91.9	8.03	9.83	8.46	71.6	5.89	7.34	--	--	--	--
	Mean	**74.4**	**118**	**22.8**	**9.38**	**57.9**	**92.8**	**17.6**	**7.13**	**--**	**--**	**--**	**--**
	Median	**94.3**	**91.9**	**16.5**	**9.83**	**72.6**	**71.6**	**12.3**	**7.34**	**--**	**--**	**--**	**--**
Buffalo River near St. Joe	1999	1,530	2,710	514	10.4	1,270	2,100	414	14.6	3,360	5,940	1,130	22.7
	2000	430	1,460	2,620	274	359	1,080	1,770	239	943	3,200	5,760	600
	2001	2,590	475	72.6	171	1,830	442	79.3	166	5,690	1,040	159	375
	2002	3,970	8,140	282	11.6	2,730	5,300	270	16.1	8,740	17,900	618	25.4
	2003	424	2,180	236	211	368	1,640	219	183	929	4,790	516	462
	Mean	**1,790**	**2,990**	**745**	**136**	**1,310**	**2,110**	**550**	**124**	**3,930**	**6,570**	**1,640**	**297**
	Median	**1,530**	**2,180**	**282**	**171**	**1,270**	**1,640**	**270**	**166**	**3,360**	**4,790**	**618**	**375**

Table 5. Seasonal nitrogen, phosphorus, dissolved organic carbon, and suspended-sediment loads and yields for Bear Creek near Silver Hill, the Buffalo River near Boxley, and the Buffalo River near St. Joe, Arkansas, 1999-2003.--Continued

[Values are loads in pounds per day; N is nitrogen; P is phosphorus; C is carbon; winter defined as December through February; spring defined as March through May; summer defined as June through August; fall defined as September through November; values were rounded to three significant figures; --, not calculated]

		Dissolved phosphorus as P				Orthophosphorus as P				Total phosphorus as P			
Site	Year	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Bear Creek near Silver Hill	1999	18.1	24.9	5.62	0.360	13.9	19.1	4.31	0.270	41.7	61.5	14.7	0.490
	2000	13.6	32.4	14.1	6.04	10.5	25.0	10.8	4.63	37.8	101	37.1	13.7
	2001	58.4	9.01	1.98	1.03	45.0	6.89	1.51	0.780	191	19.0	3.55	1.68
	2002	89.6	115	3.86	0.727	69.1	88.5	2.95	0.551	296	370	7.89	1.12
	2003	14.0	21.2	5.40	4.40	10.8	16.3	4.13	3.37	35.3	51.9	11.4	9.88
	Mean	**38.7**	**40.4**	**6.19**	**2.51**	**29.9**	**31.1**	**4.75**	**1.92**	**120**	**121**	**14.9**	**5.37**
	Median	**18.1**	**24.9**	**5.40**	**1.03**	**13.9**	**19.1**	**4.13**	**0.78**	**41.7**	**61.5**	**11.4**	**1.68**
Buffalo River near Boxley	1999	--	--	--	--	--	--	--	--	12.9	19.6	2.70	0.040
	2000	--	--	--	--	--	--	--	--	4.51	11.1	8.59	2.39
	2001	--	--	--	--	--	--	--	--	16.9	3.37	1.17	2.50
	2002	--	--	--	--	--	--	--	--	16.1	36.5	2.15	0.090
	2003	--	--	--	--	--	--	--	--	1.48	12.8	1.03	1.29
	Mean	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**10.4**	**16.7**	**3.13**	**1.26**
	Median	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**12.9**	**12.8**	**2.15**	**1.29**
Buffalo River near St. Joe	1999	61.6	106	20.4	0.500	111	177	36.2	1.69	429	795	149	2.02
	2000	17.3	56.3	98.0	11.2	31.9	90.8	140	21.6	121	446	854	74.2
	2001	98.4	19.9	3.20	7.24	148	41.3	8.10	15.9	819	122	16.9	43.3
	2002	150	301	11.9	0.550	218	409	25.7	1.86	1,280	2,720	71.4	2.28
	2003	17.3	84.8	9.83	8.59	33.2	138	20.5	16.7	115	657	61.2	57.6
	Mean	**68.9**	**114**	**28.7**	**5.62**	**108**	**171**	**46.1**	**11.6**	**553**	**948**	**231**	**35.9**
	Median	**61.6**	**84.8**	**11.9**	**7.24**	**111**	**138**	**25.7**	**15.9**	**429**	**657**	**71.4**	**43.3**

Table 5. Seasonal nitrogen, phosphorus, dissolved organic carbon, and suspended-sediment loads and yields for Bear Creek near Silver Hill, the Buffalo River near Boxley, and the Buffalo River near St. Joe, Arkansas, 1999-2003.--Continued

[Values are loads in pounds per day; N is nitrogen; P is phosphorus; C is carbon; winter defined as December through February; spring defined as March through May; summer defined as June through August; fall defined as September through November; values were rounded to three significant figures; --, not calculated]

		Dissolved organic carbon as C				Suspended sediment			
Site	Year	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Bear Creek near Silver Hill	1999	1,270	1,860	439	16.1	43,000	59,400	13,500	828
	2000	1,120	2,930	1,110	418	32,700	78,400	33,700	14,400
	2001	5,530	588	112	53.7	142,000	21,300	4,650	2,410
	2002	8,560	10,800	244	36.1	218,000	278,000	9,120	1,690
	2003	1,060	1,570	352	302	33,500	50,600	12,800	10,400
	Mean	**3,510**	**3,540**	**451**	**165**	**93,700**	**97,600**	**14,700**	**5,940**
	Median	**1,270**	**1,860**	**352**	**53.7**	**43,000**	**59,400**	**12,800**	**2,410**
Buffalo River near Boxley	1999	--	--	--	--	14,800	22,100	3,050	47.2
	2000	--	--	--	--	5,180	12,300	9,540	2,730
	2001	--	--	--	--	18,800	4,020	1,410	2,880
	2002	--	--	--	--	17,800	40,200	2,550	111
	2003	--	--	--	--	1,760	14,500	1,240	1,530
	Mean	**--**	**--**	**--**	**--**	**11,700**	**18,600**	**3,560**	**1,460**
	Median	**--**	**--**	**--**	**--**	**14,800**	**14,500**	**2,550**	**1,530**
Buffalo River near St. Joe	1999	13,000	21,800	4,250	132	432,000	788,000	148,000	2,270
	2000	3,660	11,300	18,900	2,410	121,000	433,000	811,000	75,500
	2001	19,400	4,400	760	1,630	787,000	127,000	18,000	45,100
	2002	29,100	57,200	2,670	146	1,220,000	2,560,000	74,400	2,550
	2003	3,720	17,200	2,180	1,850	117,000	643,000	63,200	58,400
	Mean	**13,800**	**22,400**	**5,750**	**1,230**	**535,000**	**910,000**	**223,000**	**36,800**
	Median	**13,000**	**17,200**	**2,670**	**1,630**	**432,000**	**643,000**	**74,400**	**45,100**

Annual nutrient, dissolved organic carbon, and suspended-sediment yields computed for Bear Creek were greater than yields computed for both of the Buffalo River sites (table 4). Bear Creek had a mean annual total ammonia plus organic nitrogen (as nitrogen) yield for 1999 to 2003 of 503 pounds per year per square mile (lbs/yr/mi^2). The mean annual total ammonia plus organic nitrogen yields at the Buffalo River near St. Joe and Buffalo River near Boxley were 280 and 159 lbs/yr/mi^2, respectively. The mean annual nitrite plus nitrate (as nitrogen) yield for Bear Creek was 413 lbs/yr/mi^2, which was approximately twice the mean annual yield at the Buffalo River near St. Joe and three times the mean annual yield at the Buffalo River near Boxley. The mean annual total nitrogen yield at Bear Creek was 929 lbs/yr/mi^2 compared to 614 lbs/yr/mi^2 at the Buffalo River near St. Joe. Bear Creek had a mean annual total phosphorus yield of 139 lbs/yr/mi^2, which was slightly greater than the mean annual yield at the Buffalo River near St. Joe (87 lbs/yr/mi^2) and more than six times the mean annual yield at the Buffalo River near Boxley (22 lbs/yr/mi^2). The mean annual dissolved organic carbon yield at Bear Creek (4,070 lbs/yr/mi^2) was nearly double the mean annual yield for the Buffalo River near St. Joe (2,130 lbs/yr/mi^2), and the mean annual suspended-sediment yield at Bear Creek (112,000 lbs/yr/mi^2) also was greater than the mean annual yield at the Buffalo River near St. Joe (84,300 lbs/yr/mi^2). The mean annual suspended-sediment yield at Bear Creek was more than four times the mean annual yield at the Buffalo River near Boxley.

Annual yields of nutrients for Bear Creek and the two Buffalo River sites for 1999 through 2003 were compared to yields for Calf Creek for 2001 through 2002 (Galloway and Green, 2004), and to yields for 82 sites representing undeveloped basins throughout the Nation for 1990 through 1995 (Clark and others, 2000). One site that is included in Clark and others (2000), North Sylamore Creek near Fifty-Six, Arkansas, located in the Ozark Plateaus, also was used for comparison, with annual yields recomputed with data for 1990 to 2002. Annual yields also were compared to a site representative of a developed basin that is affected by both point and non-point sources of nutrients, dissolved organic carbon, and suspended sediment, the Illinois River south of Siloam Springs, Arkansas (Green and Haggard, 2001), with annual yields recomputed with data for 1996 through 2002.

Median annual nutrient yields for Bear Creek generally were greater than yields for undeveloped basins (including North Sylamore Creek), and the Buffalo River near Boxley, but lower than values for Calf Creek and the Illinois River (developed basin) (fig. 11). Median annual nitrite plus nitrate, total nitrogen, and orthophosphorus yields for Bear Creek and the Buffalo River near St. Joe were less than the 75th percentile of yields for the undeveloped basins, and the median annual total phosphorus yields for both sites were greater than the 75th percentile of yields for the undeveloped basins. The median annual nitrite plus nitrate and total nitrogen yields for Bear Creek were less than one-thirteenth and one-ninth the yields for the Illinois River, respectively. The median annual orthophosphorus and total phosphorus yields for Bear Creek were less than one-eighteenth and one-eighth the yields for the Illinois River, respectively.

Flow-Weighted Concentrations

Bear Creek had greater mean annual nutrient, dissolved organic carbon, and suspended-sediment flow-weighted concentrations than both the Buffalo River near St. Joe and the Buffalo River near Boxley (table 6). The mean annual total ammonia plus organic nitrogen flow-weighted concentration for Bear Creek was 0.46 mg/L as nitrogen, which was 1.6 times the mean flow-weighted concentration for Buffalo River near St. Joe and nearly five times the flow-weighted concentration for Buffalo River near Boxley. The mean annual nitrite plus nitrate flow-weighted concentration for Bear Creek was twice the mean annual flow-weighted concentration for the Buffalo River near St. Joe and more than five times the flow-weighted concentration for the Buffalo River near Boxley. Bear Creek had a mean annual total nitrogen concentration that was 1.5 times the mean annual flow-weighted concentration for the Buffalo River near St. Joe. Although the mean annual dissolved phosphorus flow-weighted concentration for Bear Creek was four times the flow-weighted concentration for the Buffalo River near St. Joe, the mean annual orthophosphorus and total phosphorus flow-weighted concentrations were similar between the two sites. The mean annual total phosphorus flow-weighted concentration for Bear Creek was 13 times the flow-weighted concentration for the Buffalo River near Boxley. Bear Creek had a mean annual dissolved organic carbon flow-weighted concentration of 3.78 mg/L as carbon, which was 1.7 times the mean annual flow-weighted concentration at the Buffalo River near St. Joe. The mean annual suspended-sediment flow-weighted concentration for Bear Creek was similar to the mean annual concentration at the Buffalo River near St. Joe and seven times the mean annual flow-weighted concentration for the Buffalo River near Boxley. In general, the Buffalo River near Boxley had the least flow-weighted concentration of total phosphorus and suspended sediment probably because land use in the basin upstream from the site has a higher percentage of forested land than in the Bear Creek Basin and in the basin upstream from the Buffalo River near St. Joe, and because fewer samples were collected during high-flow conditions.

Annual flow-weighted concentrations of nutrients at Bear Creek and the two Buffalo River sites for 1999 through 2003 were compared to flow-weighted concentrations at Calf Creek for 2001 and 2002 (Galloway and Green, 2004), and to flow-weighted concentrations for 82 sites representing undeveloped basins throughout the Nation for 1990 through 1995 (Clark and others, 2000). One site that is included in Clark and others (2000), North Sylamore Creek near Fifty-Six, Arkansas, located in the Ozark Plateaus, also was used for comparison, with annual flow-weighted concentrations recomputed with data for 1990 to 2002. Annual flow-weighted concentrations also were compared to a site representative of a developed basin that is affected by both point and non-point sources of nutrients,

dissolved organic carbon, and suspended sediment, the Illinois River south of Siloam Springs, Arkansas (Green and Haggard, 2001), with annual flow-weighted concentrations recomputed with data for 1996 through 2002.

Median annual flow-weighted concentrations of nutrients at Bear Creek generally were greater than flow-weighted concentrations for the two sites on the Buffalo River, North Sylamore Creek, and other sites in undeveloped basins; median annual flow-weighted concentrations of nutrients at Bear Creek were less than concentrations for the Illinois River (fig. 12). The median flow-weighted concentrations for nitrite plus nitrate, orthophosphorus, and total phosphorus at Bear Creek were greater than the 75th percentile of the flow-weighted concentrations for undeveloped basins. Bear Creek also had the greatest median total
phosphorus flow-weighted concentrations among all of the sites with the exception of the Illinois River. Median nitrite plus nitrate and total nitrogen flow-weighted concentrations at Bear Creek were less than one-fifth and one-third the flow-weighted concentrations at the Illinois River, respectively. Median orthophosphorus and total phosphorus flow-weighted concentrations at Bear Creek were less than one-seventh and one-third the flow-weighted concentrations at the Illinois River, respectively.

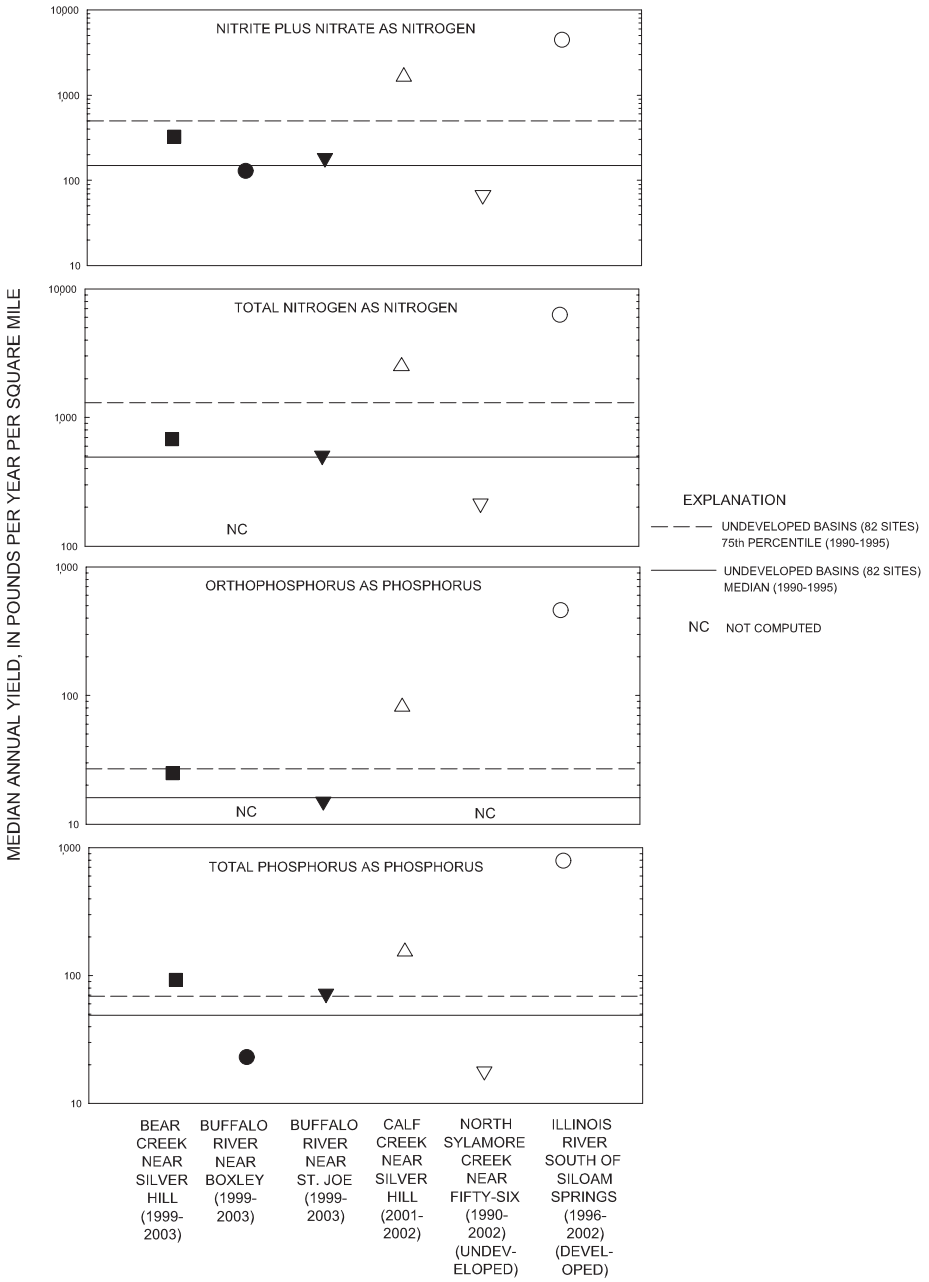

Figure 11. Median annual nutrient yields for Bear Creek near Silver Hill, the Buffalo River near Boxley, the Buffalo River near St. Joe, and other selected basins.

Table 6. Annual nitrogen, phosphorus, dissolved organic carbon, and suspended-sediment flow-weighted concentrations for Bear Creek near Silver Hill, the Buffalo River near Boxley, and the Buffalo River near St. Joe, Arkansas, 1999-2003.

[Values are in milligrams per liter; N, nitrogen; P, phosphorus; C, carbon; --, not calculated]

Site	Year	Total ammonia plus organic nitrogen as N	Nitrite plus nitrate as N	Total nitrogen as N	Dissolved phosphorus as P	Ortho-phosphorus as P	Total phosphorus as P	Dissolved organic carbon as C	Suspended sediment
Bear Creek near Silver Hill	1999	0.36	0.48	0.94	0.04	0.03	0.10	3.02	96.3
	2000	0.45	0.43	0.91	0.04	0.03	0.12	3.65	104
	2001	0.59	0.40	0.96	0.05	0.04	0.16	4.76	124
	2002	0.62	0.38	0.97	0.05	0.04	0.17	4.93	129
	2003	0.30	0.47	0.87	0.04	0.03	0.08	2.53	84.4
	Mean	**0.46**	**0.43**	**0.93**	**0.04**	**0.03**	**0.13**	**3.78**	**108**
	Median	**0.45**	**0.43**	**0.94**	**0.04**	**0.03**	**0.12**	**3.65**	**104**
Buffalo River near Boxley	1999	0.10	0.08	--	--	--	0.01	--	15.5
	2000	0.10	0.08	--	--	--	0.01	--	15.6
	2001	0.10	0.08	--	--	--	0.01	--	15.6
	2002	0.10	0.08	--	--	--	0.01	--	15.7
	2003	0.10	0.08	--	--	--	0.01	--	15.4
	Mean	**0.10**	**0.08**	**--**	**--**	**--**	**0.01**	**--**	**15.6**
	Median	**0.10**	**0.08**	**--**	**--**	**--**	**0.01**	**--**	**15.6**
Buffalo River near St. Joe	1999	0.25	0.20	0.54	0.01	0.02	0.07	2.02	71.4
	2000	0.29	0.21	0.65	0.01	0.02	0.09	2.24	88.8
	2001	0.30	0.22	0.67	0.01	0.02	0.10	2.29	92.5
	2002	0.35	0.24	0.78	0.01	0.02	0.12	2.56	110
	2003	0.22	0.18	0.48	0.01	0.02	0.06	1.81	63.5
	Mean	**0.28**	**0.21**	**0.63**	**0.01**	**0.02**	**0.09**	**2.19**	**85.3**
	Median	**0.29**	**0.21**	**0.65**	**0.01**	**0.02**	**0.09**	**2.24**	**88.8**

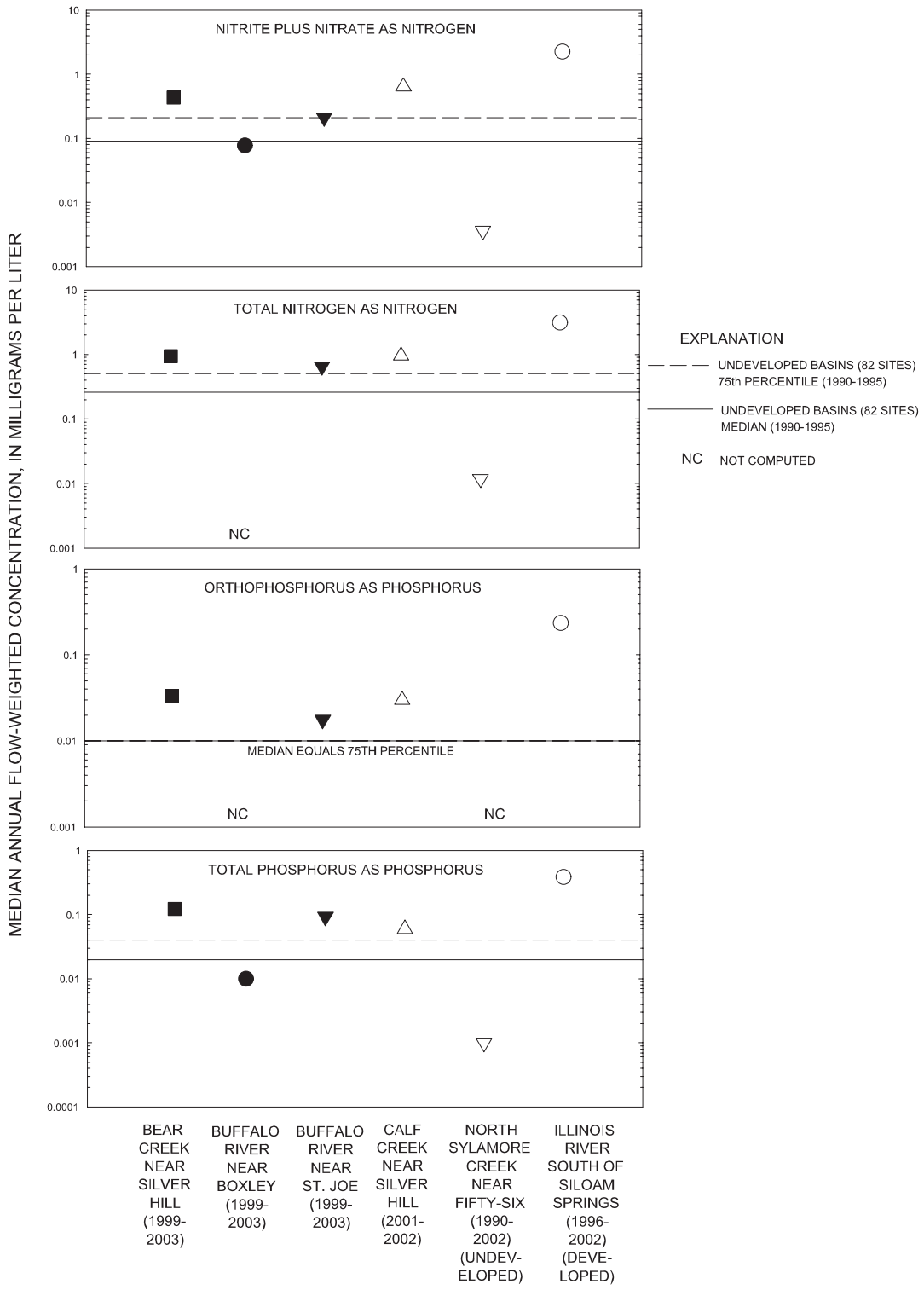

Figure 12. Median annual nutrient flow-weighted concentrations for Bear Creek near Silver Hill, the Buffalo River near Boxley, the Buffalo River near St. Joe, and other selected basins.

Summary

The purpose of this report is to describe and compare the hydrologic and water-quality characteristics of Bear Creek near Silver Hill, Arkansas, to two sites on the Buffalo River upstream from the confluence of Bear Creek, to a site on Calf Creek, a smaller tributary to the Buffalo River, to selected undeveloped sites across the Nation, and to a developed site in Arkansas. A better understanding of the hydrology and water quality of Bear Creek is of interest to many, including the National Park Service, which administers the Buffalo National River, to evaluate its effects on the hydrology and water quality of the Buffalo River.

The streamflow at Bear Creek near Silver Hill varied seasonally and annually from January 1999 to March 2004. The mean annual streamflow for Bear Creek for calendar years 1999 to 2003 was 86.0 ft^3/s. The highest annual mean streamflow occurred in 2002 (158 ft^3/s) and the lowest annual mean streamflow occurred in 1999 (56.4 ft^3/s).The highest streamflows occurred in the winter and spring and the lowest streamflows occurred in the summer and fall. The streamflow at the Buffalo River near Boxley, the Buffalo River near St. Joe, and Calf Creek near Silver Hill also varied annually and seasonally. The mean annual streamflow for calendar years 1999 to 2003 at the Buffalo River near Boxley and Buffalo River near St. Joe were 102 ft^3/s and 881 ft^3/s, respectively.

Concentrations of nitrogen measured at Bear Creek generally were greater than concentrations measured at the two Buffalo River sites and were similar to concentrations measured at Calf Creek. Concentrations of phosphorus measured at Bear Creek generally were greater than concentrations measured for the two Buffalo River sites and were similar to concentrations measured at Calf Creek. Fecal indicator bacteria concentrations generally were greater at Bear Creek than concentrations measured at the Buffalo River and similar to concentrations at Calf Creek. Concentrations of fecal indicator bacteria were substantially greater at Bear Creek during high-flow conditions than during base-flow conditions. Bear Creek had significantly greater suspended-sediment concentrations than the Buffalo River near Boxley and the Buffalo River near St. Joe, and similar concentrations to Calf Creek.

Nutrients, dissolved organic carbon, and suspended sediment loads for Bear Creek and two Buffalo River sites varied because of differences in land use and contributing drainage area for each site. In general, the Buffalo River near St. Joe had the greatest annual loads of nutrients, dissolved organic carbon, and suspended sediment. The Buffalo River near Boxley had less annual nutrient and suspended-sediment loads than Bear Creek and the Buffalo River near St. Joe. Greater loads would be expected at the Buffalo River near St. Joe because of the higher volume of streamflow that occurs at the site. Buffalo River near Boxley had lesser annual loads than the other two sites probably because of the higher percentage of forested land in the basin and a smaller contributing drainage area.

Mean annual nutrient, dissolved organic carbon and suspended-sediment yields computed for Bear Creek were greater than yields computed for both of the Buffalo River sites. Bear Creek had greater median annual nutrient yields than selected undeveloped basins across the Nation and less median annual nutrient yields than the Illinois River south of Siloam Springs, which is representative of a developed basin.

Bear Creek had greater mean annual flow-weighted nutrient concentrations than the Buffalo River near St. Joe and the Buffalo River near Boxley. Bear Creek also had greater median flow-weighted nutrient concentrations than selected undeveloped sites across the Nation and less median flow-weighted concentrations than the Illinois River south of Siloam Springs (developed basin).

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