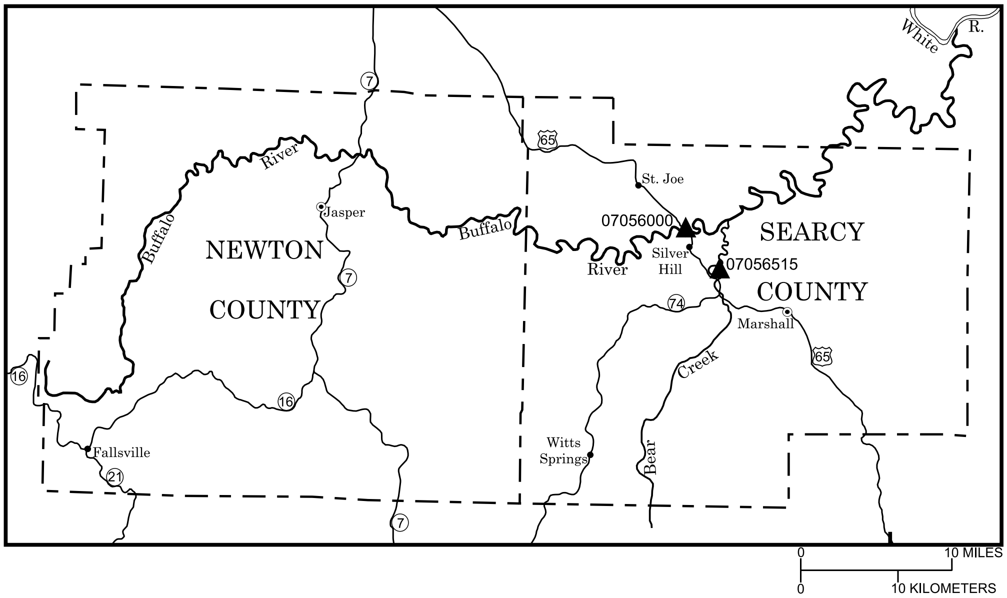
HYDROLOGIC CHARACTERISTICS OF BEAR CREEK NEAR SILVER HILL AND BUFFALO RIVER NEAR ST. JOE, ARKANSAS, 1999-2000

Water-Resources Investigations Report 02-4024



U.S. Department of the Interior
U.S. Geological Survey

HYDROLOGIC CHARACTERISTICS OF BEAR CREEK NEAR SILVER HILL AND BUFFALO RIVER NEAR ST. JOE, ARKANSAS, 1999-2000

By James C. Petersen[1], Brian E. Haggard[2], and W. Reed Green[1]

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 02-4024

Little Rock, Arkansas
2002

[1]U.S. Geological Survey, Little Rock, AR 72211
[2]U.S. Department of Agriculture—Agricultural Research Service, 203 Engineering Hall, University of Arkansas, Fayetteville, AR 72701

U.S. DEPARTMENT OF THE INTERIOR
GALE A. NORTON, Secretary

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

For additional information
write to:

District Chief
U.S. Geological Survey, WRD
401 Hardin Road
Little Rock, Arkansas 72211

Copies of this report can be
purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver Federal Center
Denver, Colorado 80225

CONTENTS

ILLUSTRATIONS

TABLES

CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
pound per year (lb/yr)	4.536	kilogram per year
pound per year per square mile ($lb/yr/mi^2$)	1.751	kilogram per year per square kilometer
degree Celsius (°C)	1.8 x °C + 32	degree Fahrenheit

HYDROLOGIC CHARACTERISTICS OF BEAR CREEK NEAR SILVER HILL AND BUFFALO RIVER NEAR ST. JOE, ARKANSAS, 1999-2000

By James C. Petersen, Brian E. Haggard, and W. Reed Green

ABSTRACT

The Buffalo River and its tributary Bear Creek are in the White River Basin in the Ozark Plateaus in north-central Arkansas. Analysis of streamflow measurements and water-quality samples at a site on Bear Creek and a site on the Buffalo River in Searcy County, Arkansas, quantify differences between the two sites during calendar years 1999 and 2000. Streamflow and water quality also vary seasonally at each site. Mean annual streamflow was substantially larger at the Buffalo River site (836 and 719 cubic feet per second in 1999 and 2000) than at the Bear Creek site (56 and 63 cubic feet per second). However, during times of low flow, discharge of Bear Creek comprises a larger proportion of the flow of the Buffalo River. Concentrations of nutrients, fecal-indicator bacteria, dissolved organic carbon, and suspended sediment generally were greater in samples from Bear Creek than in samples from the Buffalo River. Statistically significant differences were detected in concentrations of nitrite plus nitrate, total nitrogen, dissolved phosphorus, orthophosphorus, total phosphorus, fecal coliform bacteria, and suspended sediment. Loads varied between sites, hydrologic conditions, seasons, and years. Loads were substantially higher for the Buffalo River than for Bear Creek (as would be expected because of the Buffalo's higher streamflow). Loads contributed by surface runoff usually comprised more than 85 percent of the annual load. Constituent yields (loads divided by drainage area) were much more similar between sites than were loads. Flow-weighted concentrations and dissolved constituent yields generally were greater for Bear Creek than yields for the Buffalo River and flow-weighted concentrations yields were higher than typical flow-weighted concentrations and yields in undeveloped basins, but lower than flow-weighted concentrations and yields at a site in a more developed basin.

INTRODUCTION

The Buffalo River and its tributary, Bear Creek, are in the White River Basin in the Ozark Plateaus physiographic province (Fenneman, 1946) in north-central Arkansas (fig. 1). Most of the Buffalo River and a part of Bear Creek near its confluence with the Buffalo River lie within the boundaries of the Buffalo National River. A better understanding of the hydrology of this area is of interest to many, including the National Park Service, which administers the Buffalo National River. To contribute to this understanding, the U.S. Geological Survey (USGS) conducted a study to describe and compare streamflow and water-quality characteristics for a site on Bear Creek and a nearby site on the Buffalo River. This study is part of the National Park Service (NPS)/USGS Water-Quality Monitoring and Assessment Partnership. Studies conducted as part of the Water-Quality Monitoring and Assessment Partnership are designed to contribute information that would enhance the understanding of NPS water-quality management issues.

Because Bear Creek is one of the larger tributaries of the Buffalo River it can have a substantial effect on water quality and streamflow of the Buffalo River, and therefore on water-quality management issues. Immediately downstream from the confluence of Bear Creek and the Buffalo River, 9.8 percent of the Buffalo River's drainage area is contributed by the Bear Creek Basin. Relative to many other tributaries of the Buffalo River a large part (28 percent) of the Bear Creek Basin is cleared land (Panfil and Jacobson, 2001). Previous investigations (Mott, 1997; Steele and Mott, 1998) have indicated that Bear Creek (and other nearby tributaries with relatively large percentages of clear land within their basins) may contribute to elevated concentrations of nitrate in the middle section of the Buffalo River (a water-quality management issue). The recent decision (August 2001) of the U.S. Army Corps of Engineers to issue a federal permit, in response to an

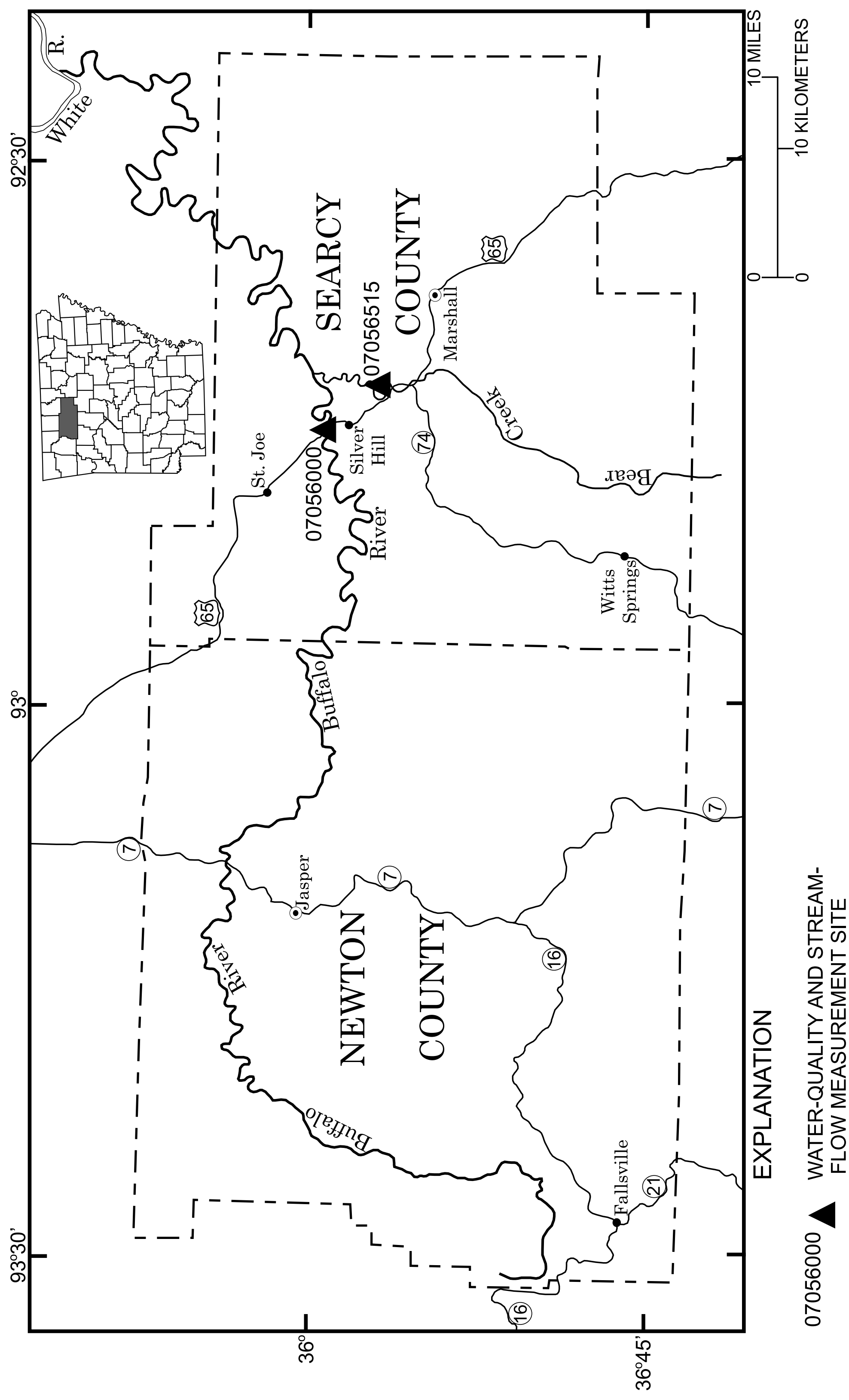


Figure 1. Location of Bear Creek and Buffalo River sampling sites.

application from the Searcy County Regional Water District, that would allow the District to build a 0.14 mi^2 water supply reservoir in the upper reaches of Bear Creek is related to water-quality and other management issues (U.S. Army Corps of Engineers, 2001). The proposed dam site is approximately 26 miles up Bear Creek from its confluence with the Buffalo River. The area upstream from the proposed dam constitutes about 12 percent of the total Bear Creek watershed and about 1 percent of that part of the Buffalo River watershed that is upstream from the mouth of Bear Creek (U.S. Army Corps of Engineers, 2001).

Purpose and Scope

The purpose of this report is to describe and compare streamflow and water-quality characteristics for a site on Bear Creek (drainage area of 83.1 mi^2) and a site on the Buffalo River (drainage area of 829 mi^2) upstream from the confluence of Bear Creek and the Buffalo River (fig. 1, table 1). Comparisons of streamflow and water-quality characteristics of the two sites are of interest because of the influence of Bear Creek upon the hydrology of the Buffalo River. Both the Bear Creek and Buffalo River sites are in Searcy County, Arkansas. The study area primarily is limited to these two sites; however, related information for the area upstream from each site and downstream to the influence of Bear Creek and the Buffalo River also is presented.

Stage was measured continuously and water samples were collected periodically at both sites from January 1999 through September 2001; selected data for calendar years 1999 and 2000 are described in this report. Data for January 1999 through September 2001 are listed in the appendix. Streamflow data for the Buffalo River site are available since October 1939; these data also are summarized and used to describe streamflow conditions for the Buffalo River. Water samples were analyzed for several properties and constituents, including specific conductance, dissolved oxygen, pH, alkalinity, fecal-indicator bacteria, nutrients, organic carbon, and suspended sediment. Annual and seasonal loads and yields were estimated for nutrients, organic carbon, and suspended sediment. Yields and flow-weighted concentrations of selected nutrients were estimated and compared with yields and flow-weighted concentrations for undisturbed and developed basins for the purpose of evaluating the water-quality characteristics of Bear Creek and the Buffalo River relative to other sites.

Description of Study Area

Bear Creek and the Buffalo River are in the southern Ozark Plateaus physiographic province. An overview of the environmental and hydrologic setting of the Ozark Plateaus can be found in Adamski and others (1995). Data and descriptions of the geology, physiography, land use, and stream habitat of Bear Creek and other streams in the Buffalo River Basin can be found in Panfil and Jacobson (2001).

Table 1. Sampling site information

Site name	U.S. Geological Survey station identification number	Drainage area (square miles)	Distance upstream from Bear Creek-Buffalo River confluence (river miles)
Bear Creek near Silver Hill, Arkansas	07056515	83.1	8
Buffalo River near St. Joe, Arkansas	07056000	829	5

Karst topography caused by caves, sinkholes, springs, and underground drainage resulting from dissolution of limestone has a major effect on the hydrology of the area. Within the study area much of the downstream sections of both streams lies within the Boone Formation, a geologic formation composed mainly of limestone. Enlarged fractures within the limestone allow rapid infiltration into the ground water; losing stream reaches and seasonally dry sections occur in both streams.

Bear Creek is a major tributary of the Buffalo River in north-central Arkansas (fig. 1). Bear Creek originates southeast of Witts Springs, Arkansas, in the Boston Mountains physiographic section. It flows northward into the Springfield Plateau physiographic section and empties into the Buffalo River north of Marshall, Arkansas. The drainage area of Bear Creek at its mouth is 91.6 mi^2 (Sullavan, 1974 revised). Bear Creek's drainage area comprises nearly 10 percent of the Buffalo River's drainage area at the location just below the confluence of Bear Creek and the Buffalo River. The $7Q_{10}$ (the minimum daily-mean streamflow for 7 consecutive days expected to occur an average of once every 10 years) for Bear Creek near Marshall at Highway 65 (fig. 1) (drainage area 77.9 mi^2) is estimated to be 2.0 ft^3/s (Ludwig, 1992).

Land use in the Bear Creek Basin primarily is a mixture of forest and pasture. Approximately 33 percent of the land in the basin is pasture (Scott and Hofer, 1995). The town of Marshall (population approximately 1,300) lies partially within the basin and effluent from the wastewater-treatment plant (treatment includes sedimentation, trickling filtration, activated sludge, and chlorine disinfection) (D.E. Ramsey, Arkansas Department of Environmental Quality, written commun., 2001) is discharged into Forest Creek, a tributary of Bear Creek (Arkansas Department of Environmental Quality, 2000; Steele and Mott, 1998). Except during wet periods of the year, it is likely that Forest Creek discharges most or all of its flow to ground water before reaching Bear Creek and it has not been determined if this ground water later resurfaces in the Forest Creek Basin or in adjacent basins (D.N. Mott, National Park Service, oral commun., 2001; Bob Singleton, Arkansas Department of Environmental Quality, oral commun., 2002).

Previous investigations indicated that nutrient and fecal-indicator bacteria concentrations and loads generally were elevated in Bear Creek relative to concentrations and loads in streams in basins containing smaller percentages of pasture and less effluent from wastewater-treatment plants (Mott, 1997; Petersen and others, 1998; Steele and Mott, 1998).

The Buffalo River originates north of Fallsville, Arkansas, in the Boston Mountains. It flows eastward into the Springfield and Salem Plateaus. The drainage area of the Buffalo River below its confluence with Bear Creek is 935 mi^2 (Sullavan, 1974 revised). The $7Q_{10}$ for the Buffalo River near St. Joe, Arkansas, (approximately 5 river miles upstream from the confluence of the Buffalo River and Bear Creek, 829 mi^2) is estimated to be 17 ft^3/s (Ludwig, 1992).

Land use in the Buffalo River Basin (upstream from Highway 65) primarily is a mixture of forest and pasture. Approximately 13 percent of the land is agricultural (mostly pasture) (Davis and Bell, 1998).

Previous investigations indicated that nutrient and bacteria concentrations at the Buffalo River near St. Joe were lower than concentrations at a group of selected sites with larger percentages of agricultural land use or with major municipal wastewater streamflows in their basins (Davis and Bell, 1998). However, dissolved organic carbon and suspended sediment concentrations were not lower than concentrations at the same group of selected sites.

METHODS

Stream stage was measured continuously at a site on Bear Creek and a site on the Buffalo River (fig. 1, table 1). Stage and instantaneous surface runoff were measured and continuous streamflow data were computed from stage-discharge rating curves using methods described in Buchanan and Somers (1968), Carter and Davidian (1968), Buchanan and Somers (1969), and Kennedy (1984). Stage has been measured continually from January 22, 1999 to present (2002) at Bear Creek and from October 1939 to present (2002) at the Buffalo River site. Because stage was not measured on January 1-21, 1999, at the Bear Creek site, the mean daily flow for 1999 was used for estimates of load for this period in this study.

Water samples were collected periodically at both sites from January 1999 through September 2001. Samples were collected monthly and during six supplemental high-flow storm events per year. High-flow samples for Bear Creek were collected at the Highway 74 bridge approximately 2.9 river miles upstream from the streamflow measurement and low-flow water-quality sampling site. Water samples were collected using depth integrated, equal width increment sampling methods described in Edwards and Glysson (1999).

The resulting streamflow and water-quality data were analyzed or summarized using several graphical and statistical techniques. Boxplots were used to compare streamflow and concentrations of selected constituents between sites for data collected during calendar years 1999 and 2000. Concentrations reported as less than a reporting limit were converted to one-half the reporting limit for preparation of box plots, 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 between sites.

Streamflow was separated using a hydrograph separation computer program, Base Flow Index (BFI), to identify base-flow and surface-runoff components (Institute of Hydrology, 1980a, 1980b; Wahl and Wahl, 1995). Base flow is the sustained fair weather flow of the stream; in most streams, base flow is composed largely of ground-water flow (Langbein and Iseri, 1960). Surface runoff was defined as total flow minus base flow. Base flow contributions were analyzed using a method proposed by the Institute of Hydrology (1980a, 1980b). The minimum flow in 5-day increments is identified, and minimum flows less than 90 percent of adjacent minimum flows are defined as turning points (Wahl and Wahl, 1988, Wahl and Tortorelli, 1997). The BFI program estimates the volume of base flow from successive turning points; straight lines drawn between turning points estimate the baseflow hydrograph.

Water-quality samples were divided into those collected under base-flow or surface-runoff conditions. Base-flow water-quality samples were collected on days when the estimated base flow was greater than or equal to 70 percent of total flow. Surface-runoff samples were defined as water-quality samples collected on days when surface runoff was greater than 30 percent of total flow. Simple linear regression was used to assess relations between concentrations and total streamflow during base-flow or surface-runoff conditions.

Constituent load (L) is a function of 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 logarithmic (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. This study used the simple relation between natural logarithm-transformed L and Q:

$$\ln(L) = \beta_o + \beta_1 \ln(Q) \quad (1)$$

where L represents the constituent load, β_o is the regression constant, β_1 is the regression coefficient, and Q represents daily streamflow.

In this model, constituent loads are based solely on the relations between L and Q; the β_1 coefficient will be significantly different from zero if a relation exists between L and Q. A minimum variance unbiased estimator was used to transform the results from logarithmic space to real space (Cohn and others, 1989; Cohn and others, 1992). The LOADEST2 computer program (Crawford, 1991; 1996) was used to estimate constituent loads in these streams under base-flow and surface-runoff conditions. LOADEST2 is functionally equivalent to the ESTIMATOR computer program (Cohn and others, 1989), except LOADEST2 gives estimates of constituent loads using the rating curve with parametric and non-parametric transformations. Loads were estimated for calendar year 1999 and calendar year 2000.

In this report, base-flow loads refer to the load transported on days when base flow is greater than or equal to 70 percent of total flow. Surface-runoff loads refer to the load transported on days when surface runoff is greater than 30 percent of total flow.

Yields were calculated for each load. Yield was calculated by dividing the load by the drainage area of the sampling site. For selected constituents a second yield estimate was calculated from a second load estimate computed from a subset of the water-quality samples—those samples collected at monthly intervals. The loads and yields based on the monthly (or fixed-interval) samples were derived for a comparison of Bear Creek and the Buffalo River with a group of sites in undisturbed basins. The undisturbed-basin sites typically had been sampled at fixed-intervals.

Flow-weighted concentrations also were calculated from the loads derived from the fixed-interval samples. Flow-weighted concentrations were calculated by dividing the annual load by total annual flow, and applying appropriate conversion factors for dimensional units.

HYDROLOGIC CHARACTERISTICS

This section describes the streamflow and water-quality characteristics of Bear Creek near Silver Hill and Buffalo River near St. Joe. Most of the description is based upon data collected from January 1999 through December 2000. However, streamflow data for the Buffalo River near St. Joe measured prior to January 1999 also are described.

Streamflow

Streamflow for Bear Creek near Silver Hill varied annually and seasonally (fig. 2). The mean streamflow for calendar years 1999 and 2000 was 56 and 65 ft^3/s, respectively (table 2). Mean daily streamflow ranged from 2.7 to 3,650 ft^3/s. The maximum mean daily streamflow for 2000 (3,650 ft^3/s) was more than three times the maximum for 1999 (1,110 ft^3/s). Median and mean flows generally were greatest in January through June and lowest in August through October. Monthly median values ranged from 3.5 to 131 ft^3/s; monthly mean values ranged from 3.5 to 257 ft^3/s. Additional summary statistics for January 1999 through September 2000 are reported in Porter and others (2001).

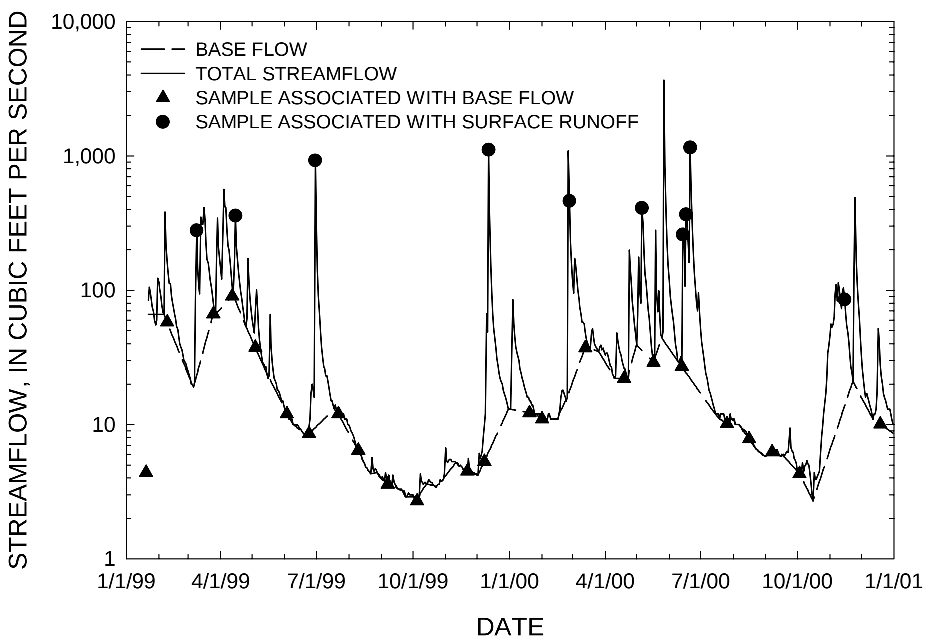


Figure 2. Daily base flow and total streamflow and associated water-quality sample times during calendar years 1999 and 2000 for Bear Creek near Silver Hill, Arkansas.

Table 2. Annual and monthly streamflow statistics for Bear Creek near Silver Hill and Buffalo River near St. Joe, Arkansas, 1999-2000

[Values are in cubic feet per second]

			Annual	January	February	March	April	May	June	July	August	September	October	November	December
Bear Creek	1999														
		Minimum	2.7	55	26	19	54	14	8	10	4.0	2.9	2.7	4.3	4.2
		Median	14	79	67	119	131	27	10	15	5.3	3.5	3.6	5.0	20
		Mean	56	81	86	151	172	35	42	35	5.9	3.5	3.5	5.0	76
		Maximum	1,110	123	382	413	563	101	923	307	10	4.4	4.3	6.7	1,110
Bear Creek	2000														
		Minimum	2.7	11	11	35	22	29	27	10	5.8	5.1	2.7	21	10
		Median	21	16	12	45	33	88	93	12	8.0	6.2	4.5	70	15
		Mean	65	23	78	62	46	257	170	17	8.1	6.3	8.3	88	18
		Maximum	3,650	85	1,090	172	199	3,650	1,150	50	11	9.4	38	490	52
Buffalo River	1999														
		Minimum	18	532	513	396	1,000	514	165	93	32	22	18	31	39
		Median	357	917	1,135	1,590	1,655	1,020	320	233	58	34	22	35	158
		Mean	836	1,203	1,472	1,699	2,409	1,624	467	737	57	34	23	36	617
		Maximum	12,800	4,450	5,230	4,020	8,430	12,800	3,210	9,520	90	58	30	43	6,770
Buffalo River	2000														
		Minimum	19	78	64	438	331	250	337	261	25	19	22	46	193
		Median	321	153	70	643	473	504	1,350	418	75	22	24	500	239
		Mean	719	211	306	711	491	1,724	3,542	512	108	27	28	730	273
		Maximum	28,700	647	2,050	1,250	786	17,900	28,700	1,350	318	50	48	2,920	501

Much of the total streamflow for Bear Creek during calendar years 1999 and 2000 occurred during relatively few days (fig. 3). For example, more than 10 percent of the streamflow occurred during 2 days and 50 percent of the streamflow occurred during 51 days (about 7 percent of the 2-year period).

Streamflow for Buffalo River near St. Joe also varied annually and seasonally (fig. 4). The mean streamflow for calendar years 1999 and 2000 was 836 and 719 ft^3/s, respectively (table 2). The maximum mean daily streamflow for 2000 (28,700 ft^3/s) was more than two times the maximum for 1999 (12,800 ft^3/s). Median and mean flows generally were greatest in January through May and lowest in August through October. Monthly median values ranged from 22 to 1,655 ft^3/s; monthly mean values ranged from 23 to 3,542 ft^3/s. Mean daily streamflow ranged from 18 to 28,700 ft^3/s.

Much of the total streamflow for the Buffalo River during calendar years 1999 and 2000 occurred during relatively few days (fig. 5). For example, more than 10 percent of the streamflow occurred during 3 days and 50 percent of the streamflow occurred during 57 days (about 8 percent of the 2-year period).

Additional summary statistics for the Buffalo River near St. Joe for October 1939 through September 2000 are reported in Porter and others (2001). The mean streamflow for this time period was 1,052 ft^3/s, compared to the means of 836 and 719 ft^3/s for calendar years 1999 and 2000. The maximum instantaneous streamflow for the time period is estimated to be 158,000 ft^3/s and the minimum instantaneous streamflow was 6.6 ft^3/s.

Streamflow for the Buffalo River near St. Joe generally is substantially greater than for Bear Creek near Silver Hill; however, during times of low flow, streamflow in Bear Creek comprises a larger proportion of the flow of the Buffalo River. During calendar years 1999 and 2000, median streamflow for the Buffalo River was 357 and 321 ft^3/s, respectively (fig. 6). Median streamflow for Bear Creek near Silver Hill was 14 and 21 ft^3/s in 1999 (beginning January 22) and 2000. The minimum mean daily streamflows during the 2 years were 18 ft^3/s for the Buffalo River and 2.7 ft^3/s for Bear Creek. The Bear Creek mean annual streamflows for 1999 and 2000 were about 7 and 9 percent of the mean annual streamflows for the Buffalo River. However, on 25 percent of the days in August through October (the 3 months of 1999 and 2000 with the lowest flows) Bear Creek flows comprised at least 18 percent (range 18.6 to 95.0 percent) of the same-day flow of the Buffalo River near St. Joe. On 23 consecutive days in September 2000, the flows at the Bear Creek site were at least 25 percent (range 25.7 to 33.7 percent) of the flows at the Buffalo River site.

Some users of this report may be more interested in streamflow (and loads) at the confluence of Bear Creek and the Buffalo River than at the two measurement sites. The comparisons discussed in the preceding paragraph provide considerable information that can be used to estimate the expected proportion of the volumetric rate of flow from Bear Creek into the Buffalo River to the volumetric rate of flow in the Buffalo River immediately downstream from Bear Creek. However, the changes in streamflow between the Bear Creek gaging site and the mouth of Bear Creek (a distance of about 8 river miles) and between the Buffalo River gaging site and the confluence of the Buffalo River and Bear Creek (about 5 river miles) are unknown. Reaches of Bear Creek and the Buffalo River upstream from the gaging sites lose and gain substantial volumes of water to and from subsurface flow and so reliability of a drainage area ratio to estimate streamflow at the mouth of Bear Creek and at the Buffalo River upstream from Bear Creek from streamflow at the gaging sites is uncertain. However, if streamflow does increase between the gaging sites and the downstream location in proportion to increase in drainage area, streamflow at the mouth of Bear Creek would be about 10 percent greater than at the Bear Creek gaging site and Buffalo River streamflow just upstream from Bear Creek would be about 2 percent greater than at the Buffalo River gaging site. Ratios of streamflow in Bear Creek to streamflow in Buffalo River, calculated using estimated streamflows at Buffalo River upstream from the confluence with Bear Creek and at the mouth of Bear Creek, were similar to ratios calculated using streamflows measured at the gaging sites; ratios generally were within 1 percent (as an absolute difference, not a percentage difference) of ratios calculated at the gaging sites.

Water Quality

Water quality for two sites on Bear Creek and the Buffalo River is described below in terms of concentration (in base flow samples and in samples from base flow and surface runoff), load, flow-weighted concentration (from base flow samples), and yield. Substantial differences between sites were indicated. Concentrations, flow-weighted concentrations, and yields generally were greater at the Bear Creek site.

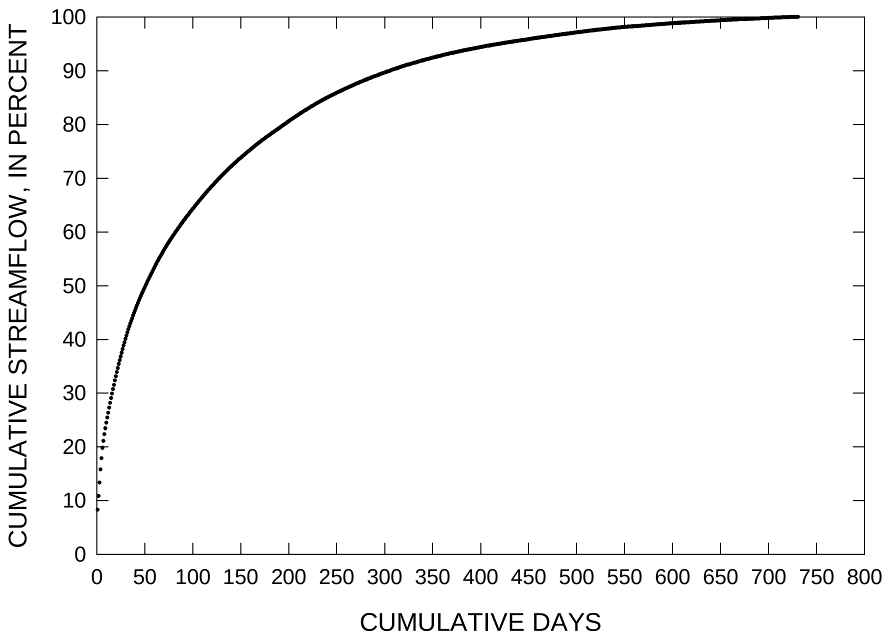


Figure 3. Flow-accumulation curve for Bear Creek near Silver Hill, Arkansas, January 1, 1999 to December 31, 2000.

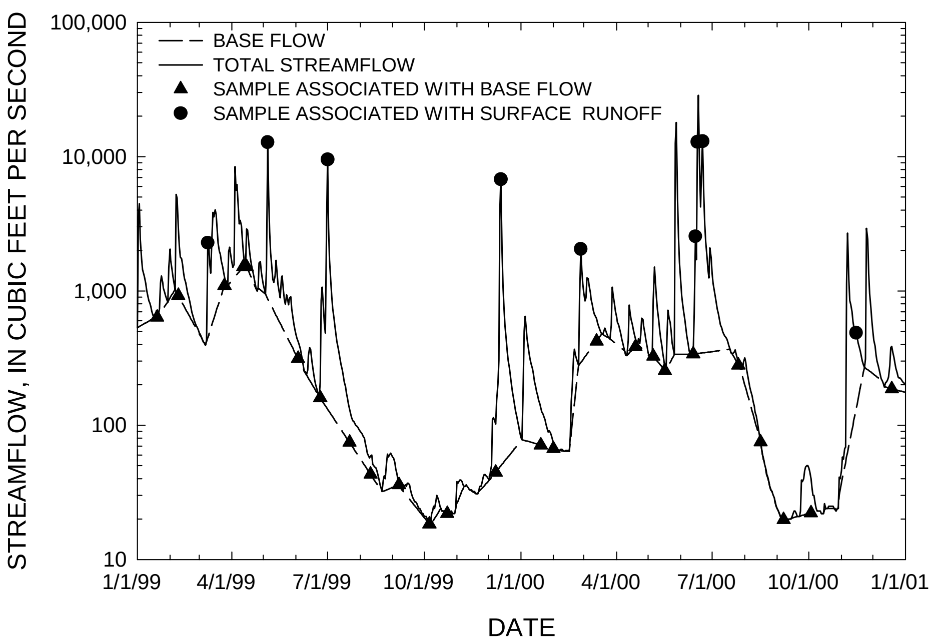


Figure 4. Daily base flow and total streamflow and associated water-quality sample times during calendar years 1999 and 2000 for Buffalo River near St. Joe, Arkansas.

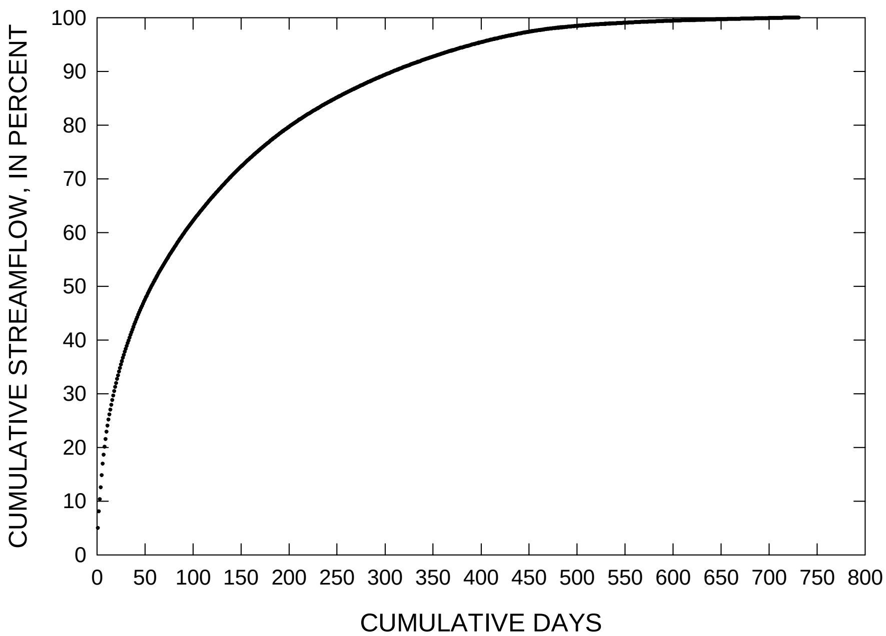


Figure 5. Flow-accumulation curve for Buffalo River near St. Joe, Arkansas, January 1, 1999 to December 31, 2000.

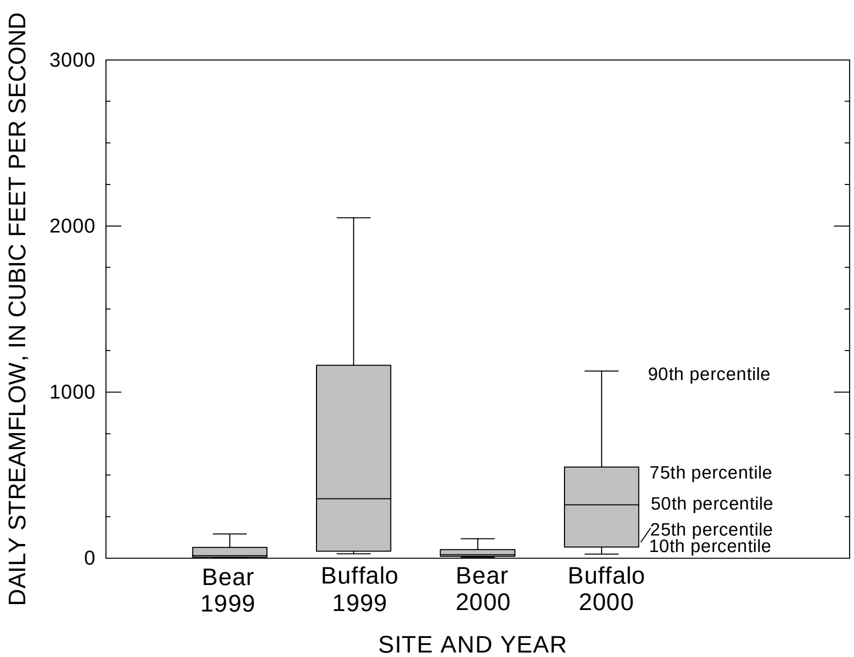


Figure 6. Daily streamflow for Bear Creek near Silver Hill and Buffalo River near St. Joe, Arkansas, in 1999 and 2000.

During 1999 and 2000 a difference occurred in the timing of the high-flow storm-event samples from the two sites relative to the time of the maximum streamflow for storm events. Bear Creek samples typically were collected about 2 to 10 hours after the maximum streamflow. Buffalo River samples typically were collected about 10 hours before to 10 hours after the maximum streamflow. Although variable, suspended sediment concentrations of streams most commonly peak before the streamflow peak (Guy, 1970). Phosphorus concentration may increase rapidly and peak before the streamflow peak and then slowly decrease in concentration (for example, see Richards and others, 2001; Richards and Holloway, 1987; Thomas, 1988). Therefore, because the Buffalo River storm-event samples were more likely than the Bear Creek samples to be collected before the streamflow peak, concentrations of suspended constituents collected during storm events may be biased toward higher concentrations for the Buffalo River relative to concentrations for Bear Creek.

Concentrations

Nutrient concentrations in samples from Bear Creek generally were greater than in samples from the Buffalo River (figs. 7 and 8). Statistically significant ($p<0.05$) differences between sites were detected in concentrations of ammonia plus organic nitrogen (during base flow only), nitrite plus nitrate, total nitrogen, dissolved phosphorus, orthophosphorus (during base flow only), and total phosphorus.

At each site nutrients generally increased as streamflow increased (see appendix). However, ammonia concentrations remained relatively constant as streamflow increased. Nitrate concentrations generally decreased as streamflow increased at the Bear Creek site and appeared to increase and then decrease as streamflow increased at the Buffalo River site.

Concentrations of fecal-indicator bacteria also generally were higher in Bear Creek samples than in samples from the Buffalo River (fig. 9). The differences were most apparent at the upper percentiles of the distributions for each site. For example, the concentrations that were between the 75th and 90th percentile for *Escherichia coli (E. coli)* and fecal coliform bacteria for Bear Creek were substantially higher than for the Buffalo River. However, statistically significant differences were detected only for fecal coliform bacteria. At each site bacteria concentrations generally increased as streamflow and suspended sediment concentrations increased (see appendix).

Dissolved organic carbon concentrations often were higher in samples from Bear Creek than in samples from the Buffalo River; however, median concentrations were similar (fig. 10). As with bacteria, it was often the higher concentrations at each site that were more dissimilar. Concentration differences were not statistically significant. At each site dissolved organic carbon concentrations generally increased as streamflow increased (see appendix).

Suspended sediment concentrations generally were higher in samples from Bear Creek than in samples from the Buffalo River (fig. 11). However, many of the highest concentrations were in samples from the Buffalo River. Statistically significant differences were detected. At each site suspended sediment concentrations generally increased as streamflow increased (see appendix).

Loads

Annual

Estimated base flow and surface runoff loads of nitrite plus nitrate, total nitrogen, dissolved phosphorus, orthophosphorus, total phosphorus, dissolved organic carbon, and suspended sediment for 1999 and 2000 at the Buffalo River and Bear Creek sites indicate substantial differences between sites, hydrologic conditions, seasons, years, and constituents. Loads were substantially higher for the Buffalo River than for Bear Creek (as would be expected because of the Buffalo's higher streamflow). Loads were substantially higher on days when flow included a substantial amount (30 percent or more) of surface runoff ; on an annual basis, loads associated with days with a substantial amount of surface runoff always comprised 85 percent or more of the total annual load. For Bear Creek and the Buffalo River, loads generally were less in 1999 than in 2000.

Annual loads for the Buffalo River site typically were 5 to 10 times higher than loads for the Bear Creek site (table 3). However, in 1999 the dissolved phosphorus load for the Buffalo River was only 4.2 times greater than the Bear Creek load. In 2000, it was only 3.2 times greater. These 2 years of data indicate that Bear Creek contributes a proportionately larger part of the dissolved phosphorus load than loads of other constituents to the Buffalo River; although some of this load could be attributed to the wastewater effluent, concentrations usually increased as streamflow increased

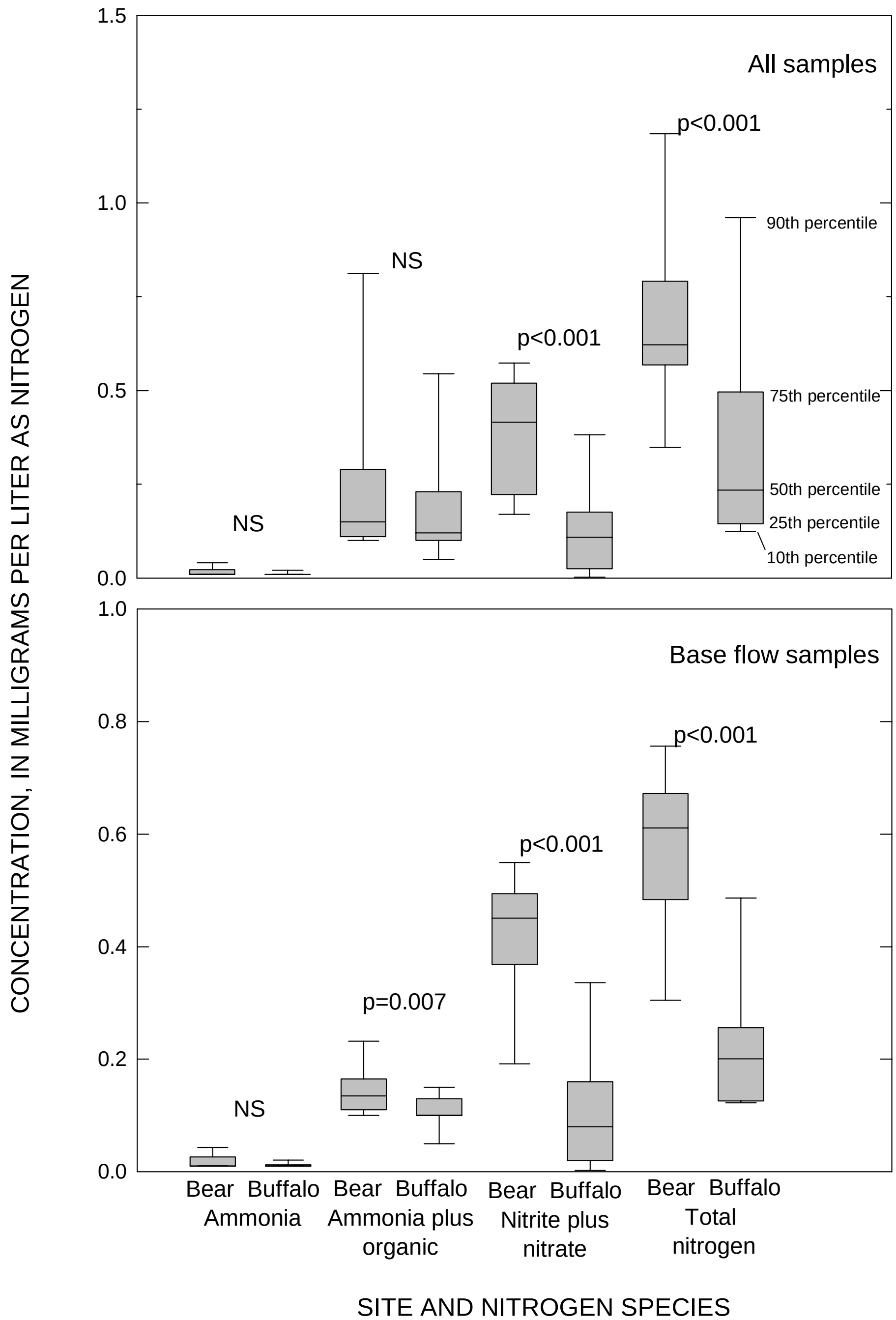


Figure 7. Distribution of nitrogen concentrations for Bear Creek near Silver Hill and Buffalo River near St. Joe, Arkansas, 1999-2000. The p-value is the probability that the median concentrations at the two sites are equal. NS indicates the probability exceeds 0.05. Several total nitrogen values were calculated from the sum of individual nitrogen species concentrations that included estimated concentrations set equal to one-half the reporting limit. For example, a nitrite plus nitrate concentration of <0.050 mg/L was converted to 0.025 mg/L.

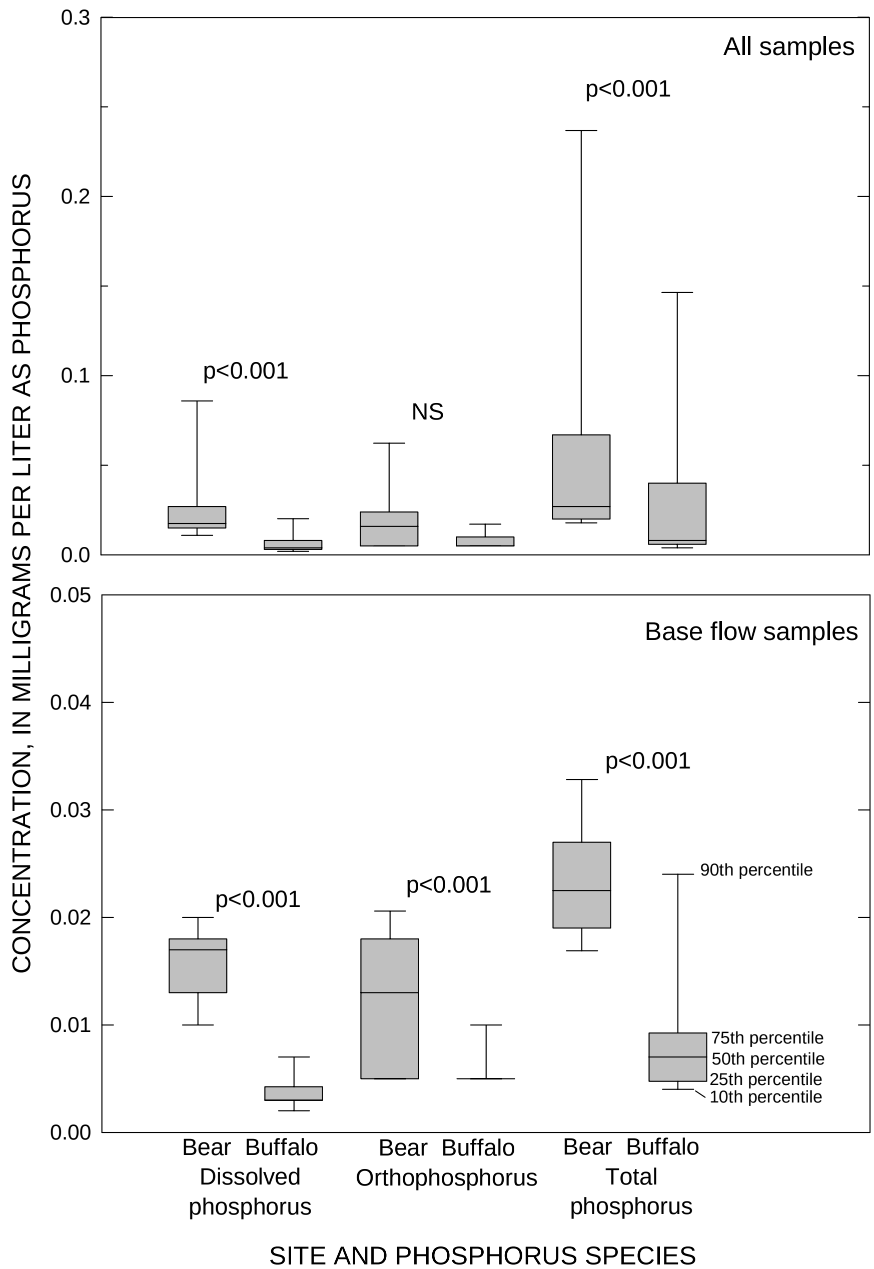


Figure 8. Distribution of phosphorus concentrations for Bear Creek near Silver Hill and Buffalo River near St. Joe, Arkansas, 1999-2000. The p-value is the probability that the median concentrations at the two sites are equal. NS indicates the probability exceeds 0.05.

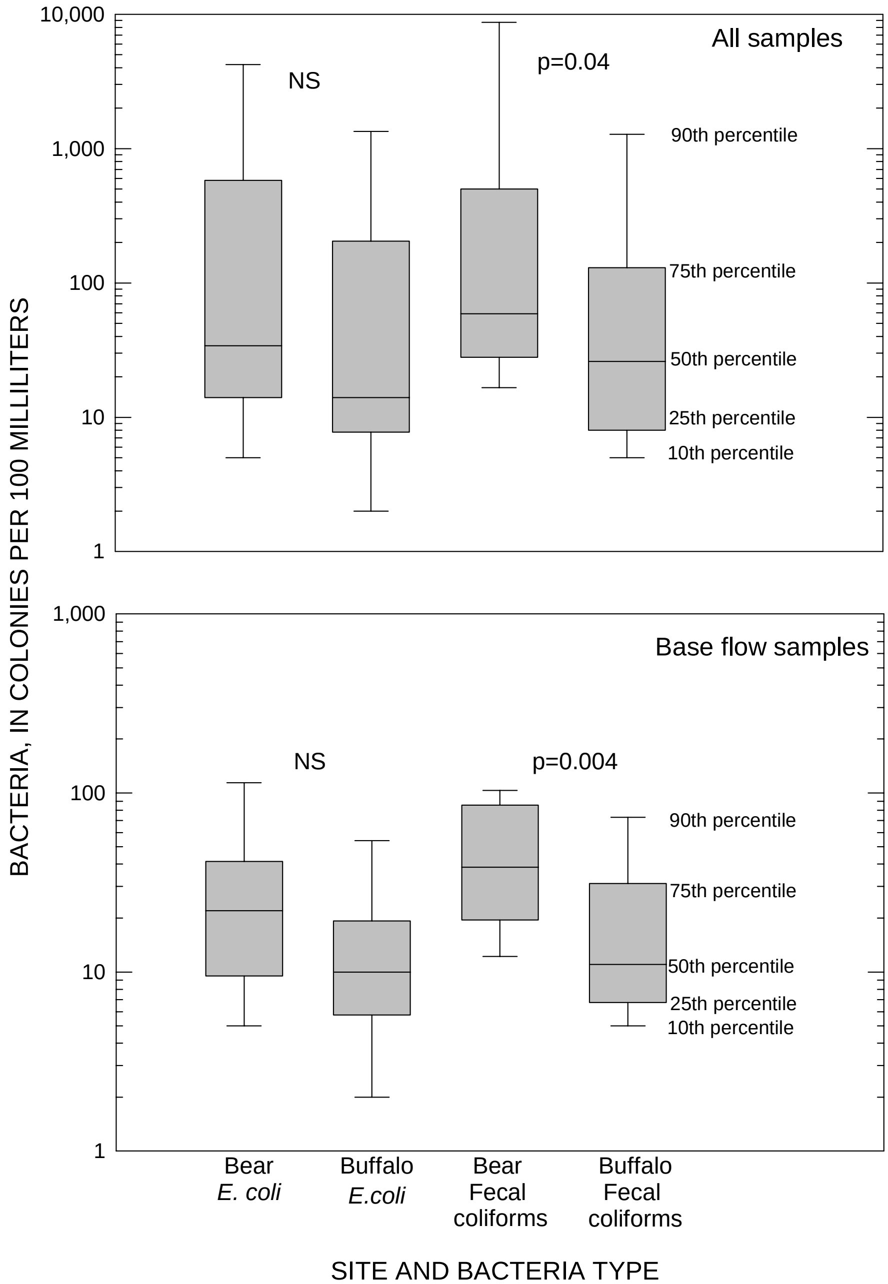


Figure 9. Distribution of bacteria concentrations for Bear Creek near Silver Hill and Buffalo River near St. Joe, Arkansas, 1999 and 2000. The p-value is the probability that the median concentrations are equal at the two sites. NS indicates the probability exceeds 0.05.

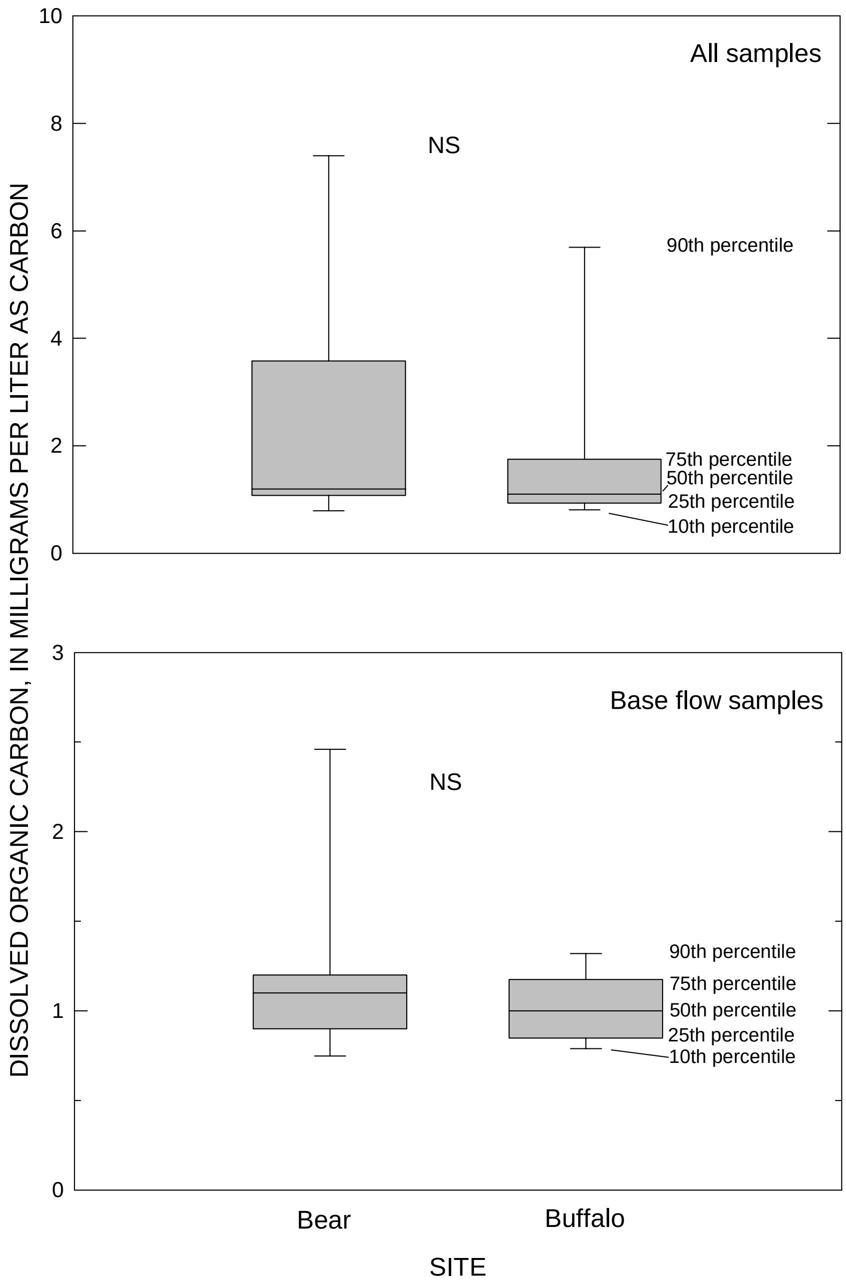


Figure 10. Distribution of dissolved organic carbon concentrations for Bear Creek near Silver Hill and Buffalo River near St. Joe, Arkansas, 1999-2000. The p-value is the probability that the median concentrations at the two sites are equal. NS indicates the probability exceeds 0.05.

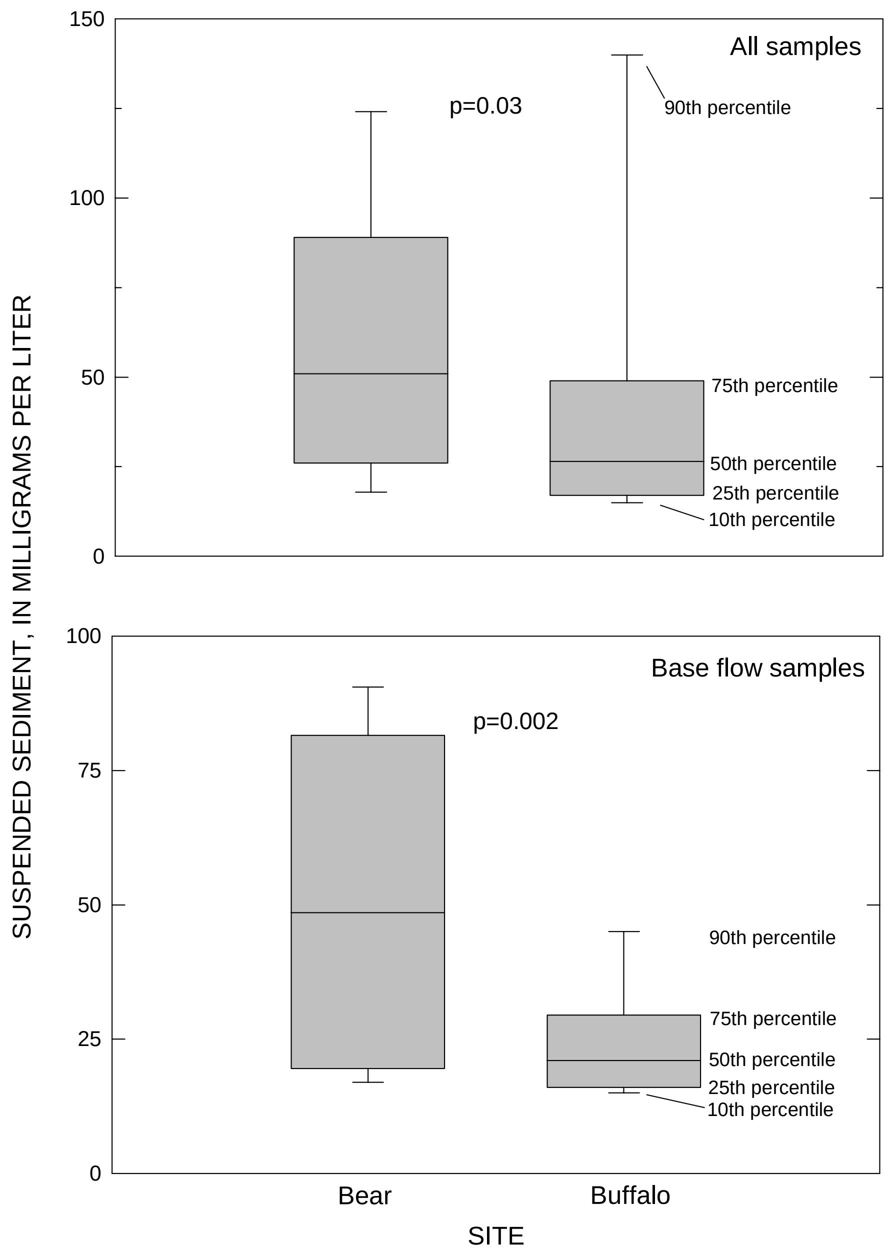


Figure 11. Distribution of suspended sediment concentrations for Bear Creek near Silver Hill and Buffalo River near St. Joe, Arkansas, 1999-2000. The p-value is the probability that the median concentrations at the two sites are equal. NS indicates the probability exceeds 0.05.

suggesting primarily nonpoint sources of dissolved phosphorus. Relative to other constituents, Bear Creek appears to contribute a smaller proportion of suspended sediment load to the Buffalo River; the suspended sediment load for the Buffalo River site was about 18 to 24 times greater than the load for the Bear Creek site.

At both sites, annual loads were largely contributed by daily loads occurring on days with a substantial amount of surface runoff (table 3). Although only 40 to 45 percent of the days each year included a substantial amount of surface runoff, most (usually more than 90 percent) of the annual load occurred on these days. For total phosphorus about 96 to 99 percent of the annual load occurred on these days.

Table 3. Annual nitrogen, phosphorus, dissolved organic carbon, and suspended sediment loads and yields for Bear Creek near Silver Hill and Buffalo River near St. Joe, Arkansas, 1999-2000

[lb/yr is pounds per year; lb/yr/mi^2 is pounds per year per square mile; SD is standard deviation; NA is not available (not calculated by the model). Yields and surface runoff load percentages were calculated before loads were rounded to two significant figures]

	Total load (lb/yr)	Total yield (lb/yr/mi^2)	Base-flow load (±SD) (lb/yr)	Base-flow yield (lb/yr/mi^2)	Surface-runoff load (±SD) (lb/yr)	Surface-runoff yield (lb/yr/mi^2)	Load contri-buted by surface runoff (percent)
Ammonia plus organic nitrogen, as nitrogen							
Bear-1999	43,000	520	2,900 ±400	35	40,000 ±8,800	480	93
Bear-2000	83,000	1,000	2,600 ±400	31	80,000 ±29,000	970	97
Buffalo-1999	660,000	800	40,000 ±3,000	48	620,000 ±140,000	750	94
Buffalo-2000	790,000	950	24,000 ±1,100	29	770,000 ±220,000	920	97
Nitrite plus nitrate, as nitrogen							
Bear-1999	56,000	670	8,400 ±1,500	100	47,000 ±7,700	570	85
Bear-2000	58,000	700	7,300 ±1,000	88	51,000 ±8,800	610	88
Buffalo-1999	420,000	500	55,000 ±10,000	66	360,000 ±10,000	440	87
Buffalo-2000	350,000	420	20,000 ±3,000	24	330,000 ±10,000	400	94
Total nitrogen							
Bear-1999	91,000	1,100	10,000 ±1,100	120	80,000 ±8,800	970	89
Bear-2000	130,000	1,500	9,100 ±700	110	120,000 ±16,000	1,400	93
Buffalo-1999	NA	NA	NA	NA	1,100,000 ±23,000	1,300	NA
Buffalo-2000	NA	NA	NA	NA	1,100,000 ±310,000	1,400	NA
Dissolved phosphorus							
Bear-1999	4,700	57	350 ±20	4.2	4,400 ±690	53	93
Bear-2000	7,200	87	280 ±15	3.4	6,900 ±2,000	83	96
Buffalo-1999	20,000	24	1,600 ±130	1.9	18,000 ±3,400	22	92
Buffalo-2000	23,000	28	910 ±51	1.1	22,00 ±5,500	26	96

Table 3. Annual nitrogen, phosphorus, dissolved organic carbon, and suspended sediment loads and yields for Bear Creek near Silver Hill and Buffalo River near St. Joe, Arkansas, 1999-2000--Continued

[lb/yr is pounds per year; lb/yr/mi^2 is pounds per year per square mile; SD is standard deviation; NA is not available (not calculated by the model). Yields and surface runoff load percentages were calculated before loads were rounded to two significant figures]

	Total load (lb/yr)	Total yield (lb/yr/mi^2)	Base-flow load (±SD) (lb/yr)	Base-flow yield (lb/yr/mi^2)	Surface-runoff load (±SD) (lb/yr)	Surface-runoff yield (lb/yr/mi^2)	Load contributed by surface runoff (percent)
Orthophosphorus							
Bear-1999	3,600	44	280 ±40	3.4	3,400 ±550	40	92
Bear-2000	5,700	69	230 ±29	2.8	5,500 ±1,000	66	96
Buffalo-1999	NA	NA	NA	NA	20,000 ±4,000	24	NA
Buffalo-2000	NA	NA	NA	NA	20,000 ±5,100	25	NA
Total phosphorus							
Bear-1999	11,000	140	510 ±40	6.1	11,000 ±2,400	130	96
Bear-2000	25,000	300	440 ±29	5.3	25,000 ±9,500	300	98
Buffalo-1999	160,000	200	2,600 ±400	3.1	160,000 ±58,000	190	98
Buffalo-2000	270,000	320	1,500 ±110	1.8	270,000 ± 140,000	320	99
Dissolved organic carbon							
Bear-1999	430,000	5,100	25,000 ±3,000	300	400,000 ±6,200	4,800	94
Bear-2000	790,000	9,500	21,000 ±2,000	250	770,000 ±190,000	9,200	97
Buffalo-1999	4,400,000	5,300	400,000 ±31,000	480	4,000,000 ±58,000	4,800	91
Buffalo-2000	4,600,000	5,600	230,000 ±14,000	280	4,400,000 ±84,000	5,300	95
Suspended sediment							
Bear-1999	6,600,000	80,000	770,000 ±91,000	9,200	5,800,00 ±120,000	70,000	88
Bear-2000	11,000,000	130,000	690,000 ±80,000	8,300	9,900,000 ± 310,000	120,000	93
Buffalo-1999	160,000,000	190,000	7,700,000 ±120,000	9,200	150,000,000 ± 44,000,000	180,000	95
Buffalo-2000	190,000,000	230,000	5,100,000 ±590,000	6,200	180,000,000 ±66,000,000	220,000	97

Total loads generally were greater in 2000 than in 1999 for Bear Creek and the Buffalo River (table 3). Loads for 2000 generally were about 1.2 to 1.8 times the loads for 1999. Differences were greater between years for Bear Creek than for the Buffalo River; loads for 2000 were almost always less than 1.3 times the 1999 loads for the Buffalo River. Mean streamflow for Bear Creek in 2000 was about 1.2 times the 1999 mean streamflow. Mean streamflow for the Buffalo River in 2000 was about 0.9 times the 1999 streamflow.

Seasonal

Daily loads varied seasonally at both sites (table 4). At both sites and during both years, daily base-flow loads generally were greatest in the spring, although spring and winter loads were often nearly equal at Bear Creek in 1999. These results are similar to those of Steele and Mott (1998). Daily surface-runoff loads were related to times of greatest streamflow and were greatest in the spring (March through May) or summer (June through August). In 1999, daily surface-runoff loads were greatest in the spring at both sites. In 2000, daily runoff loads were greatest in the spring at Bear Creek, but greatest in the summer at the Buffalo River. The higher daily runoff loads for the Buffalo River in the summer of 2000 were largely the result of high flows in mid to late June.

Table 4. Seasonal nitrogen, phosphorus, dissolved organic carbon, and suspended sediment loads for Bear Creek near Silver Hill and Buffalo River near St. Joe, Arkansas, 1999-2000

[Values are loads in pounds per day, plus or minus the standard deviation. Significant figures of reported values vary, depending on streamflow and constituent concentration. NA is not available (not calculated by the model). Ammonia loads for 1999 were not calculated because of the high frequency of concentrations less than the reporting limit. Spring is March through May, summer is June through August, fall is September through November, and winter is January, February, and December]

Constituent	Site	Annual	Spring	Summer	Fall	Winter
			Base flow (1999)			
Ammonia plus organic nitrogen as nitrogen	Bear	8 ±1	12 ±1	6 ±0	4 ±0	12 ±1
	Buffalo	110 ±7	230 ±16	42 ±2	17 ±1	160 ±9
Nitrite plus nitrate as nitrogen	Bear	23 ±4	33 ±7	17 ±2	10 ±2	33 ±6
	Buffalo	150 ±28	360 ±76	31 ±4	5 ±1	190 ±34
Total nitrogen	Bear	28 ±3	39 ±5	21 ±2	13 ±2	40 ±5
	Buffalo	NA	NA	NA	NA	NA
Dissolved phosphorus	Bear	0.96±0.06	1.5 ±0.12	0.59 ±0.03	0.31 ±0.02	1.5 ±0.11
	Buffalo	4.4 ±35	9.4 ±.87	1.5 ±.09	.55 ±.05	6.2 ±48
Orthophosphorus	Bear	0.77 ±11	1.2 ±21	.48 ±.06	.25 ±.04	1.2 ±20
	Buffalo	NA	NA	NA	NA	NA
Total phosphorus	Bear	1.4 ±11	2.2 ±.21	.89 ±.06	.48 ±.04	2.1 ±20
	Buffalo	7 ±1	13 ±2	3 ±0	1 ±0	9 ±1
Dissolved organic carbon	Bear	69 ±7	100 ±13	45 ±4	25 ±3	100 ±13
	Buffalo	1,100 ±86	2,200 ±210	400 ±23	160 ±15	1,500 ±120
Suspended sediment	Bear	2,100 ±250	2,300 ±390	2,000 ±230	1,500 ±260	2,500 ±380
	Buffalo	21,000 ±3,200	41,000 ±7,500	8,800 ±970	4,400 ±720	29,000 ±4,500
			Base flow (2000)			
Ammonia plus organic nitrogen as nitrogen	Bear	7 ±1	12 ±2	7 ±0	3 ±0	7 ±0
	Buffalo	67 ±3	120 ±6	81 ±4	17 ±1	45 ±2
Nitrite plus nitrate as nitrogen	Bear	20 ±3	34 ±6	19 ±3	8.0 ±1	20 ±3
	Buffalo	54 ±7	120 ±17	65 ±9	8.0 ±1	28 ± 3
Total nitrogen	Bear	25 ±2	41 ±5	24 ±2	10 ±1	24 ±2
	Buffalo	NA	NA	NA	NA	NA
Dissolved phosphorus	Bear	0.78 ±.04	1.5 ±.10	.71 ±.04	.26 ±.01	.71 ±.04
	Buffalo	2.5 ±.14	4.7 ±.30	3.0 ±17	.58 ±.04	1.6 ±.09
Orthophosphorus	Bear	0.64 ±.08	1.2 ±.19	.58 ±.07	.21 ±.03	.58 ±.07
	Buffalo	NA	NA	NA	NA	NA

Table 4. Seasonal nitrogen, phosphorus, dissolved organic carbon, and suspended sediment loads for Bear Creek near Silver Hill and Buffalo River near St. Joe, Arkansas, 1999-2000--Continued

[Values are loads in pounds per day, plus or minus the standard deviation. Significant figures of reported values vary, depending on streamflow and constituent concentration. NA is not available (not calculated by the model). Ammonia loads for 1999 were not calculated because of the high frequency of concentrations less than the reporting limit. Spring is March through May, summer is June through August, fall is September through November, and winter is January, February, and December]

Constituent	Site	Annual	Spring	Summer	Fall	Winter
Total phosphorus	Bear	1.2 ±.08	2.1 ±.18	1.1 ±.07	.39 ±.03	1.1 ±.07
	Buffalo	4 ±.31	7.3 ±.64	4.8 ±38	1 ±.09	2.7 ±.20
Dissolved organic carbon	Bear	58 ±5	100 ±12	53 ±4	20 ±2	54 ±4
	Buffalo	630 ±38	1,200 ±78	770 ±45	160 ±10	430 ±24
Suspended sediment	Bear	1,900 ±220	2,500 ±400	2,000 ±220	1,000 ±140	2,000 ±220
	Buffalo	14,000 ±1,600	24,000 ±3,100	16,000 ±1,900	3,900 ±500	9,700 ±1,000
				Surface runoff (1999)		
Ammonia plus organic nitrogen as nitrogen	Bear	110 ±24	240 ±48	67 ±17	0.02 ±0.01	140 ±31
	Buffalo	1,700 ±380	4,100 ±930	830 ±190	1 ±0	1,900 ±400
Nitrite plus nitrate as nitrogen	Bear	130 ±21	280 ±47	54 ±9	0 ±0	170 ±30
	Buffalo	1,000 ±300	2,300 ±690	520 ±140	3 ±2	1,200 ±350
Total nitrogen	Bear	220 ±24	500 ±54	110 ±13	0 ±0	280 ±30
	Buffalo	2,900 ±640	6,800 ±1,600	1,400 ±310	3 ±1	3,400 ±710
Dissolved phosphorus	Bear	12 ±1.9	26 ±4.1	6.2 ±1.2	.00 ±.00	14 ±2.4
	Buffalo	50 ±9.3	120 ±23	24 ±4.6	.03 ±.01	57 ±9.9
Orthophosphorus	Bear	9.2 ±1.5	20 ±3.2	5.0 ±1.0	.00 ±.00	11 ±1.9
	Buffalo	55 ±11	130 ±27	27 ±5.4	.07 ±.03	65 ±13
Total phosphorus	Bear	30 ±6.7	64 ±13	19 ±5.1	.00 ±.00	39 ±9.2
	Buffalo	440 ±160	1,100 ±400	220 ±85	.05 ±.03	450 ±150
Dissolved organic carbon	Bear	1,100 ±170	2,400 ±370	640 ±120	0 ±0	1,400 ±220
	Buffalo	11,000 ±1,600	26,000 ±3,900	5,200 ±770	8.0 ±2.0	12,000 ±1,700
Suspended sediment	Bear	16,000 ±3,300	36,000 ±7,200	8,800 ±2,200	5 ±3	20,000 ±4,200
	Buffalo	420,000 ±120,000	990,000 ±280,000	200,000 ±57,000	210 ±99	470,000 ±120,000
				Surface runoff (2000)		
Ammonia plus organic nitrogen as nitrogen	Bear	220 ±79	580 ±250	170 ±40	50 ±10	100 ±26
	Buffalo	2,100 ±600	2,500 ±680	5,200 ±1,600	410 ±77	230 ±44
Nitrite plus nitrate as nitrogen	Bear	140 ±24	250 ±47	150 ±25	95 ±20	82 ±14
	Buffalo	900 ±290	1,100 ±360	1,800 ±700	340 ±94	270 ±81
Total nitrogen	Bear	320 ±45	690 ±120	300 ±34	130 ±15	160 ±20
	Buffalo	3,100 ±850	3,800 ±1,000	7,300 ±2,200	780 ±150	500 ±100
Dissolved phosphorus	Bear	19 ±5	45 ±14	16 ±3	6 ±1	9 ±2
	Buffalo	60 ±15	72 ±17	150 ±39	12 ±2	7 ±1
Orthophosphorus	Bear	15 ±4	36 ±11	13 ±2	5 ±1	7 ±1
	Buffalo	56 ±14	69 ±17	130 ±36	16 ±3	11 ±2
Total phosphorus	Bear	68 ±26	180 ±83	47 ±12	13 ±3	29 ±8
	Buffalo	730 ±370	830 ±390	2,000 ±1,000	76 ±23	34 ±10
Dissolved organic carbon	Bear	2,100 ±520	5,100 ±1,600	1,600 ±280	520 ±86	940 ±180
	Buffalo	12,000 ±2,300	15,000 ±2,700	30,000 ±6,200	2,700 ±360	1,700 ±230
Suspended sediment	Bear	27,000 ±8,400	64,000 ±25,000	23,000 ±5,200	8,000 ±1,700	13,000 ±3,200
	Buffalo	500,000 ±180,000	600,000 ±210,000	1,200,000 ±490,000	98,000 ±24,000	55,000 ±14,000

Flow-Weighted Concentrations

Flow-weighted concentrations (table 5) for Bear Creek and the Buffalo River were compared to flow-weighted concentrations in 82 undeveloped basins identified across the nation, including two basins in the Ozark Plateaus (Clark and others, 2000), and to a more developed basin (Green and Haggard, 2001). The flow-weighted concentrations for Bear Creek and the Buffalo River were calculated from loads calculated using water-quality data collected at fixed intervals. These data were a subset of the water-quality data collected and used to calculate the loads in tables 3 and 4; data from the supplemental high-flow storm events were not included. The data associated with the supplemental storm events were omitted because the data for the undeveloped basins generally included small amounts of supplemental high-flow storm event data. The flow-weighted concentrations for the developed basin were calculated from loads computed from data that included some storm event data.

Flow-weighted concentrations for Bear Creek generally were higher than for concentrations for the Buffalo River; flow-weighted concentrations for both sites were higher than concentrations at undisturbed sites but lower than concentrations at a site in a more developed basin. Nitrite plus nitrate concentrations were approximately 4 times (Buffalo River) and 5 times (Bear Creek) higher than the median concentration for undeveloped basins (Clark and others, 2000). Total phosphorus concentrations were approximately 3 (Buffalo River) and 5 to 6 times (Bear Creek) higher than the median concentration for undeveloped basins. Total phosphorus concentrations for Bear Creek also were substantially higher than the 75th percentiles of concentrations for the undeveloped basins. Flow-weighted concentrations of nitrite plus nitrate, total nitrogen, orthophosphorus, and total phosphorus were about 3 to 8 times higher at a site on the Illinois River (Green and Haggard, 2001) than at the Bear Creek and Buffalo River sites. The Illinois River site is downstream from several wastewater-treatment plants and also is affected by pasture land and poultry waste (Arkansas Department of Environmental Quality, 2000).

Table 5. Comparison of Bear Creek and Buffalo River flow-weighted concentrations with flow-weighted concentrations for undeveloped basins and the Illinois River, Arkansas

[Values are in milligrams per liter. Bear Creek and Buffalo River concentrations are calculated from loads computed from fixed-interval sampling data. Values for undeveloped basins are from Clark and others (2000). Values for North Sylamore Creek and Paddy Creek are from data compiled and summarized by Clark and others (2000). Values from Clark and others (2000) primarily are derived from fixed-interval sampling data. Values for the Illinois River are based on data in Green and Haggard (2001) and includes some data collected during high-flow storm events. NA is not available]

	Dissolved nitrite plus nitrate, as nitrogen	Total nitrogen	Dissolved ortho-phosphorus, as phosphorus	Total phosphorus
Bear Creek-1999	0.46	0.82	0.03	0.09
Bear Creek-2000	0.46	0.88	0.04	0.13
Buffalo River-1999	0.35	0.75	NA	0.05
Buffalo River-2000	0.39	0.93	NA	0.06
Undeveloped basin median	0.09	0.26	0.01	0.02
Undeveloped basin 75th percentile	0.21	0.50	0.01	0.04
North Sylamore Creek, Arkansas (undeveloped)	0.10	0.23	<0.01	0.03
Paddy Creek, Missouri (undeveloped)	0.04	<0.20	<0.01	0.04
Illinois River, Arkansas	2.4	3.4	0.22	0.40

Yields

Constituent yields (annual load divided by drainage area) at the two sites were much more similar than loads, because the effect of drainage area size is removed. Yields of dissolved constituents (dissolved nitrite plus nitrate, dissolved phosphorus, and dissolved orthophosphorus) generally were greater at the Bear Creek site (table 3). Yields of most other constituents (particularly total phosphorus and suspended sediment) more often were greater at the Buffalo River site (table 3).

Yields (table 6) for Bear Creek and the Buffalo River were compared to yields in 82 undeveloped basins identified across the nation, including two basins in the Ozark Plateaus (Clark and others, 2000), and to a more developed basin (Green and Haggard, 2001). The yields for Bear Creek and the Buffalo River were calculated from loads calculated using water-quality data collected at fixed intervals. These data were a subset of the water-quality data collected and used to calculate the loads in tables 3 and 4; data from the supplemental high-flow storm events were not included. The data associated with the supplemental storm events were omitted because the data for the undeveloped basins generally did not include supplemental high-flow storm event data. The yields for the developed basin were calculated from loads computed from data that included some storm event data. Nitrite plus nitrate yields were approximately 4 to 5 times (Buffalo River and Bear Creek) higher than the median yield for undeveloped basins (Clark and others, 2000). Total phosphorus yields were approximately 2 times (Buffalo River) and 2 to 4 times (Bear Creek) higher than the median yield for undeveloped basins. Yields for Bear Creek and the Buffalo River also were often substantially higher than the 75th percentiles of yields for the undeveloped basins; phosphorus yields were the most elevated relative to the 75th percentiles. Nutrient yields were about 5 to 10 times higher at a site on the Illinois River (Haggard and Green, 2001) than at the Bear Creek and Buffalo River sites. The Illinois River site is downstream from several wastewater-treatment plants and also is affected by pasture land and poultry waste (Arkansas Department of Environmental Quality, 2000).

Table 6. Comparison of Bear Creek and Buffalo River yields with yields for undeveloped basins and the Illinois River, Arkansas

[Values are in pounds per year per square mile. Bear Creek and Buffalo River yields are calculated from loads computed from fixed-interval sampling data. Values for undeveloped basins are from Clark and others (2000). Values for North Sylamore Creek and Paddy Creek are from data compiled and summarized by Clark and others (2000). Values from Clark and others (2000) primarily are derived from fixed-interval sampling data. Values for the Illinois River are based on data in Green and Haggard (2001) and included some data collected during high-flow storm events. NA is not available]

	Nitrite plus nitrate, as nitrogen	Total nitrogen	Dissolved ortho-phosphorus, as phosphorus	Total phosphorus
Bear Creek-1999	610	1,100	44	120
Bear Creek-2000	700	1,400	61	190
Buffalo River-1999	700	1,500	NA	97
Buffalo River--2000	660	1,600	NA	100
Undeveloped basin median	150	490	16	49
Undeveloped basin 75th percentile	500	1,300	27	69
North Sylamore Creek, Arkansas (undeveloped)	170	390	7.4	43
Paddy Creek, Missouri (undeveloped)	80	360	9.1	74
Illinois River, Arkansas	5,900	8,600	540	960

SUMMARY

Analyses of streamflow measurements and water-quality samples at a site on Bear Creek and a site on the Buffalo River in Searcy County, Arkansas, quantify differences between the two sites during calendar years 1999 and 2000. Streamflow and water quality also vary seasonally at each site.

Mean annual streamflow was substantially larger at the Buffalo River site (836 and 719 ft^3/s in 1999 and 2000) than at the Bear Creek site (56 and 65 ft^3/s). Drainage areas of the Buffalo River and Bear Creek sites are 2,147 and 215 km^2, respectively. However, during times of low flow streamflow of Bear Creek comprises a larger proportion of the flow of the Buffalo River. For example, on 23 consecutive days in September 2000 the flows at the Bear Creek site were 25 percent or more of the flows at the Buffalo River site. At both sites streamflow varied seasonally. Flows generally were greatest in January through June and least in August through October.

Concentrations of nutrients, fecal-indicator bacteria, dissolved organic carbon, and suspended sediment generally were greater in samples from Bear Creek than in samples from the Buffalo River. Statistically significant ($p<0.05$) differences were detected in concentrations of nitrite plus nitrate, total nitrogen, dissolved phosphorus, orthophosphorus, total phosphorus, fecal coliform bacteria, and suspended sediment.

Loads varied between sites, hydrologic conditions, years, and seasons. Loads were substantially higher for the Buffalo River than for Bear Creek (as would be expected because of the Buffalo's higher streamflow). Loads contributed by surface runoff always comprised 85 percent or more of the total annual load.

Loads generally were greater in 2000 than in 1999 for Bear Creek and the Buffalo River. Loads for 2000 generally were about 1.2 to 1.8 times the loads for 1999. Differences were greater between years for Bear Creek than for the Buffalo River; loads for 2000 were always less than 1.3 times the 1999 loads for the Buffalo River.

Daily loads varied seasonally at both sites. At both sites and during both years, daily baseflow loads generally were greatest in the spring. Daily surface-runoff loads were greatest in the spring or summer. In 1999, daily surface-runoff loads were greatest in the spring at both sites. In 2000, daily runoff loads were greatest in the spring at Bear Creek, but greatest in the summer at the Buffalo River.

Flow-weighted concentrations generally were higher for Bear Creek than the Buffalo River. Concentrations for both streams were higher than typical flow-weighted concentrations for undeveloped basins, but lower than concentrations at a site in a more developed basin.

Yields for the two sites were much more similar because the effect of drainage area size is removed. Yields of dissolved constituents generally were greater at Bear Creek; yields of other constituents generally were greater at the Buffalo River. Yields of nutrients were higher than typical yields in undeveloped basins, but lower than yields at a site in a more developed basin.

REFERENCES

Adamski, J.C., Petersen, J.C., Freiwald, D.A., and Davis. J.V., 1995, Environmental and hydrologic setting of the Ozark Plateaus study unit, Arkansas, Kansas, Missouri, and Oklahoma: U.S. Geological Survey Water-Resources Investigations Report 94-4022, 69 p.

Arkansas Department of Environmental Quality, 2000, Water quality inventory report, 2000: Arkansas Department of Environmental Quality, variously paginated.

Buchanan, T.J., and Somers, W.P., 1968, Stage measurements at gaging stations: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. A7, 28 p.

——— 1969, Discharge measurements at gaging stations: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. A9, 27 p.

Carter, R.W., and Davidian, Jacob, 1968, General procedure for gaging streams: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. A6, 13 p.

Clark, G.M., Mueller, D.K., and Mast, M.A., 2000, Nutrient concentrations and yields in undeveloped stream basins of the United States: Journal of American Water Resources Association, no. 36, v. 4, p. 849-867.

Cohn, T.A., 1995, Recent advances in statistical methods for the estimation of sediment and nutrient transport in rivers, U.S. National Report to the International Union Geodesy and Geophysics 1991-1994: Reviews of Geophysics, Supplement 33, p. 1117-1123.

Cohn, T.A., Caulder, D.L., Gilroy, E.J., Zynjuk, L.D., and Summers, R.M., 1992, The validity of a simple log-linear model for estimating fluvial constituent loads: An empirical study involving nutrient loads entering Chesapeake Bay: Water Resources Research, v. 28, no. 9, p. 2353-2363.

Cohn, T.A., DeLong, L.L., Gilroy, E.J., Hirsch, R.M. and Wells, D.K., 1989, Estimating constituent loads: Water Resources Research, v. 25, no. 5, p. 937-942.

Crawford, C.G., 1991, Estimation of suspended-sediment rating curves and mean suspended-sediment loads: Journal of Hydrology, v. 129, p. 331-348.

———1996, Estimating mean constituent loads in rivers by the rating-curve and flow-duration, rating-curve methods: Bloomington, Indiana, Indiana University, Ph.D. Dissertation.

Davis, J.V., and Bell, R.W., 1998, Water-quality assessment of the Ozark Plateaus study unit, Arkansas, Kansas, Missouri, and Oklahoma—Nutrients, bacteria, organic carbon, and suspended sediment in surface water, 1993-95: U.S. Geological Survey Water-Resources Investigations Report 98-4164, 56 p.

Edwards, T.K., and Glysson, G.D., 1999, Field methods for measurement of fluvial sediment, U.S. Geological Survey Techniques of Water Resources Investigations, book 3, chap. C2, 89 p.

Fenneman, N.M., 1938, Physiography of eastern United States: New York, McGraw-Hill Book Co., Inc., 714 p.

Green, W.R., and Haggard, B.E., 2001, Phosphorus and nitrogen loading at Illinois River south of Siloam Springs, Arkansas, 1997-1999: U.S. Geological Survey Water-Resources Investigations Report 01-4217, 12 p.

Guy, H.P., 1970, Fluvial sediment concepts: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. C1, 55 p.

Helsel, D.R., and Hirsch, R.M., 1992, Statistical methods in water resources: Amsterdam, Netherlands, Elsevier, 522 p.

Institute of Hydrology, 1980a, Low flow studies: Wallingford, Oxon, United Kingdom, Report No. 1, 21 p.

——— 1980b, Low flow studies: Wallingford, Oxon, United Kingdom, Report No. 3, p. 12-19.

Kennedy, E.J., 1983, Computation of continuous records of streamflow: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. A13, 53 p.

——— 1984, Discharge ratings at gaging stations: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. A10, 59 p.

Langbein, W.B., and Iseri, K.T., 1960, General introductions and hydrologic definitions: U.S. Geological Survey Water-Supply Paper 1541-A, 29 p.

Ludwig, A.H., 1992, Flow duration and low-flow characteristics of selected Arkansas streams: U.S. Geological Survey Water-Resources Investigations Report 92-4026, 57 p.

Mott, D.N., 1997, Buffalo National River, Arkansas - Ten years of water quality monitoring: Department of the Interior, National Park Service, Harrison, Arkansas, 35 p.

Panfil, M.S., and Jacobson, R.B., 2001, Relations among geology, physiography, land use, and stream habitat conditions in the Buffalo and Current River systems, Missouri and Arkansas: USGS/BRD/BSR-2001-0005, 111 p. (This report also can be accessed via the internet at: http://www.cerc.usgs.gov/pubs/center/pdf docs/BSR2001-0005.pdf).

Petersen, J.C., Adamski, J.C., Bell, R.W., Davis, J.V., Femmer, S.R., Freiwald, D.A., and Joseph, R.L., 1998, Water quality in the Ozark Plateaus, Arkansas, Kansas, Missouri, and Oklahoma, 1992-95: U.S. Geological Survey Circular 1158, 33 p.

Porter, J.E., Evans, D.A., and Remsing, L.R., 2001, Water resources data, Arkansas, water year 2000: U.S. Geological Survey Water-Data Report AR-00-1, 403 p.

Richards, R.P., and Holloway, J., 1987, Monte Carlo studies of sampling strategies for estimating tributary loads: Water Resources Research, v. 23, p. 1939-1948.

Richards, R.P., Baker, D.B., Kramer, J.W., Ewing, D.E., Merryfield, E.J., and Miller, N.L., 2001, Storm discharge, loads, and average concentrations in northwest Ohio rivers, 1975-1995: Journal of the American Water Resources Associations, v. 37, p. 423-438.

Scott, H.D., and Hofer, K.R., 1995, Spatial and temporal analysis of the morphological and land use characteristics of the Buffalo River watershed: University of Arkansas Water Resources Center Publication No. 170, 61 p.

Steele, K.F., and Mott, D.N., 1998, Storm and base flow water quality for Bear, Calf, and Tomahawk Creeks: University of Arkansas Water Resources Center Publication No. 255, unpaginated.

Sullavan, J.N., 1974, Drainage areas of streams in Arkansas, White River Basin: U.S. Geological Survey Open-File Report, 123 p.

Thomas, R.B., 1988, Monitoring baseline suspended sediment in forested basins: The effects of sampling on suspended sediment rating curves: Hydrologic Science, v. 33, p. 499-514.

U.S. Army Corps of Engineers, 2001, Searcy County Regional Water District: accessed August 15, 2001 at URL http://www.swl.usace.army.mil/regulatory/searcyco.html.

Wahl, K.L., and Tortorelli, R.L., 1997, Changes in flow in the Beaver - North Canadian River Basin upstream from Canton Lake, western Oklahoma: U.S. Geological Survey Water-Resources Investigations Report 96-4304, 58 p.

Wahl, K.L., and Wahl, T.L., 1988, Effects of regional ground-water level declines on streamflow in the Oklahoma Panhandle: Proceedings of Water-Use Data for Water Resources Management, American Water Resources Association, August 1988, p. 239-249.

——— 1995, Determining the flow of Comal Springs at New Braunfels, Texas, *in* Texas Water '95: American Society of Civil Engineers, San Antonio, Texas, August 6-17, 1995, p. 77-86.

Appendix - Water-quality data for Buffalo River near St. Joe and Bear Creek near Silver Hill, Arkansas

[Five digit numbers in parentheses are U.S. Environmental Protection Agency STORET data management system parameter codes. ft^3/s, cubic feet per second; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; C, carbon; mm, millimeter; --, no data; E, estimated, <, less than; K, plate count outside ideal range, >, greater than]

Date (yyyymmdd)	Time	Discharge, instantaneous (ft^3/s) (00061)	Oxygen, dissolved (percent saturation) (00301)	Oxygen, dissolved (mg/L) (00300)	pH, field standard units (00400)	Specific conductance (µS/cm) (00095)	Temperature (°C) (00010)	Acid neutralizing capacity, field (mg/L as $CaCO_3$) (00410)	Ammonia, dissolved (mg/L as N) (00608)	Ammonia plus organic nitrogen dissolved (mg/L as N) (00623)	Ammonia plus organic nitrogen, total (mg/L as N) (00625)	Nitrogen, dissolved (mg/L as N) (00602)	Nitrite plus nitrate, dissolved (mg/L as N) (00631)	Nitrogen total (mg/L as N) (00600)	Nitrite, dissolved (mg/L as N) (00613)
Buffalo River near St. Joe, Arkansas															
19990120	1045	673	98	12.2	7.4	181	5.5	78	<0.020	E0.07	E0.07	--	0.196	--	<0.010
19990209	1030	2,910	104	11.5	7.3	141	10	57	.020	E.05	.15	--	.336	.48	<.010
19990309	1205	2,940	91	10.2	7.8	145	9.9	66	<.020	.11	.32	.29	.176	.49	<.010
19990325	845	1,290	90	9.8	8.3	168	11.2	159	<.020	E.05	<.10	--	.151	--	<.010
19990412	1350	1,890	104	10	8	163	17.3	68	<.020	E.07	E.09	--	.139	--	<.010
19990415	830	2,740	90	9.3	7.3	185	12.8	81	<.020	E.06	.13	--	.187	.32	<.010
19990505	1045	17,600	96	9.2	6.5	114	15.5	52	.045	.31	2.1	.48	.165	2.2	<.010
19990603	940	422	88	7.2	6.8	225	24	102	.032	E.09	0.12	--	.106	.23	<.010
19990624	1215	159	113	9.3	8	239	24.3	108	.020	<.20	<.20	--	.08	--	<.010
19990701	830	12,100	89	8	7.4	121	19.8	61	<.020	.25	1.4	.39	.138	1.5	<.010
19990722	900	122	83	6.4	7.5	232	28.5	105	<.020	.20	.13	--	<.050	--	<.010
19990811	835	53	74	5.7	7.8	231	28.6	103	<.020	.19	.12	--	<.050	--	<.010
19990907	1200	35	107	8.5	7.5	250	26.5	112	<.020	E.05	E.05	--	<.050	--	<.010
19991006	830	20	--	--	8.2	262	14	100	<.020	E.06	E.10	--	<.050	--	<.010
19991123	830	37	89	8.8	7.7	266	14.7	119	<.020	<.10	E.10	--	<.050	--	<.010
19991208	1215	467	87	9.8	7.9	277	9.1	132	<0.020	<0.10	.10	--	0.722	0.82	<0.010

Appendix - Water-quality data for Buffalo River near St. Joe and Bear Creek near Silver Hill, Arkansas--Continued

[Five digit numbers in parentheses are U.S. Environmental Protection Agency STORET data management system parameter codes. ft^3/s, cubic feet per second; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; C, carbon; mm, millimeter; --, no data; E, estimated, <, less than; K, plate count outside ideal range, >, greater than]

Date (yyyymmdd)	Time	Discharge, instantaneous (ft^3/s) (00061)	Oxygen, dissolved (percent saturation) (00301)	Oxygen, dissolved (mg/L) (00300)	pH, field standard units (00400)	Specific conductance (µS/cm) (00095)	Temperature (°C) (00010)	Acid neutralizing capacity, field (mg/L as $CaCO_3$) (00410)	Ammonia, dissolved (mg/L as N) (00608)	Ammonia plus organic nitrogen dissolved (mg/L as N) (00623)	Ammonia plus organic nitrogen, total (mg/L as N) (00625)	Nitrogen, dissolved (mg/L as N) (00602)	Nitrite plus nitrate, dissolved (mg/L as N) (00631)	Nitrogen total (mg/L as N) (00600)	Nitrite, dissolved (mg/L as N) (00613)
19991213	1130	6,360	86	9.5	6.9	113	10.2	42	<.020	.25	0.43	0.72	.466	.89	<.010
20000120	810	152	92	10.8	7.4	210	8.0	94	<.020	E.05	E.09	--	.107	--	<.010
20000201	945	88	95	12.4	8.1	214	4.6	99	<.020	<.10	<.10	--	.076	--	<.010
20000227	945	2,050	88	9.8	7.6	109	11.1	44	<.020	.12	.23	.28	.156	.38	<.010
20000313	1225	650	93	10.1	7.7	164	11.7	92	<.020	E.07	.13	--	<.050	--	<.010
20000419	1145	550	111	9.7	7.8	170	20.6	76	<.020	E.06	.10	--	<.050	--	<.010
20000506	1715	1,170	100	8.8	7.6	166	19.6	76	<.020	E.08	.24	--	<.050	--	<.010
20000517	1125	273	103	9.0	7.9	168	20.9	76	<.020	.11	.16	--	<.050	--	<.010
20000613	900	356	89	7.5	7.9	216	23.6	86	<.020	.14	E.08	.24	.101	--	<.010
20000615	830	2,640	91	8.2	7.3	104	19.9	45	<.020	.14	.44	.25	.11	.55	<.010
20000617	1830	27,300	95	8.8	7.7	88	18.5	40	<.020	.29	2.5	.42	.133	2.6	<.010
20000622	900	15,000	90	8.3	7.2	110	18.3	46	<.020	.17	.45	.32	.147	.60	<.010
20000726	1010	294	93	7.7	7.7	244	23.8	113	<.020	E.06	.14	--	.09	.23	<.010
20000816	905	120	76	5.9	8.1	234	27.4	117	<.020	.11	.11	--	<.050	--	<.010
20000907	1020	20	88	7.1	7.4	241	24.4	128	.02	E.10	.12	--	<.050	--	<.010
20001003	740	40	78	6.9	7.9	251	20.8	117	.024	E.07	.11	--	.591	.70	<.010
20001115	1220	492	140	15.5	8.2	215	10.1	98	<.041	<.10	<.08	--	.373	--	<.006
20001219	940	403	65	8.9	8.0	222	1.9	102	<.041	E.08	<.08	--	.331	--	<.006
20010116	1400	1,240	77	9.4	8.4	152	6.4	68	<.041	<.10	<.08	--	.287	--	<.006

Appendix - Water-quality data for Buffalo River near St. Joe and Bear Creek near Silver Hill, Arkansas--Continued

[Five digit numbers in parentheses are U.S. Environmental Protection Agency STORET data management system parameter codes. ft^3/s, cubic feet per second; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; C, carbon; mm, millimeter; --, no data; E, estimated, <, less than; K, plate count outside ideal range, >, greater than]

Date (yyyymmdd)	Time	Discharge, instantaneous (ft^3/s) (00061)	Oxygen, dissolved (percent saturation) (00301)	Oxygen, dissolved (mg/L) (00300)	pH, field standard units (00400)	Specific conductance (µS/cm) (00095)	Temperature (°C) (00010)	Acid neutralizing capacity, field (mg/L as $CaCO_3$) (00410)	Ammonia, dissolved (mg/L as N) (00608)	Ammonia plus organic nitrogen dissolved (mg/L as N) (00623)	Ammonia plus organic nitrogen, total (mg/L as N) (00625)	Nitrogen, dissolved (mg/L as N) (00602)	Nitrite plus nitrate, dissolved (mg/L as N) (00631)	Nitrogen total (mg/L as N) (00600)	Nitrite, dissolved (mg/L as N) (00613)
20010129	1815	774	99	11.8	8.0	183	7.1	--	<.041	.20	.56	.56	.366	1.2	E.003
20010214	645	1,590	91	10.6	7.9	146	8.7	64	<.041	<.10	--	--	.302	.43	<.006
20010221	815	2,240	92	10.6	7.6	156	9.4	68	<.041	E.06	--	--	.754	.87	.009
20010320	1300	750	107	11.9	8.3	172	11.0	74	<.041	<.10	--	--	.150	.25	<.006
20010425	815	477	71	7.0	6.9	176	16.2	79	<.041	E.09	--	--	E.040	--	<.006
20010509	1100	244	94	8.5	8.1	210	20.7	95	<.041	E.09	.12	--	0.096	0.22	E0.003
20010607	740	176	99	8.2	7.5	202	24.0	94	<.040	E.07	E.07	--	.053	--	<.006
20010710	1145	94	84	6.4	8.0	219	28.6	99	<.040	E.09	.14	--	E.036	--	E.003
20010817	710	94	64	5.2	7.5	236	24.8	145	<.040	E.09	.09	--	<.050	--	<.006
20010906	945	21	81	6.6	8.1	241	25.8	109	<.040	E.08	.11	--	E.031	--	<.006

Appendix - Water-quality data for Buffalo River near St. Joe and Bear Creek near Silver Hill, Arkansas--Continued

[Five digit numbers in parentheses are U.S. Environmental Protection Agency STORET data management system parameter codes. ft^3/s, cubic feet per second; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; C, carbon; mm, millimeter; --, no data; E, estimated, <, less than; K, plate count outside ideal range, >, greater than]

Date	Time	Phosphorus dissolved (mg/L as P) (00666)	Orthophosphorus, dissolved (mg/L as P) (00671)	Phosphorus, total (mg/L as P) (00665)	Solids, residue at 180 °C, dissolved (mg/L) (70300)	*E. coli* (colonies per 100 mL) (31633)	Fecal coliforms (colonies per 100 mL) (31625)	Fecal streptococci (colonies per 100 mL) (31673)	Organic carbon, dissolved (mg/L as C) (00681)	Sediment, suspended (mg/L) (80154)	Sediment, suspended (percent finer than 0.062 mm) (70331)
Buffalo River near St. Joe, Arkansas											
19990120	1045	<0.004	<0.010	<0.004	99	<1	K1	K1	1.3	15	98
19990209	1030	.007	.016	.024	85	54	73	56	--	27	88
19990309	1205	.004	.017	.049	90	220	140	190	2.1	52	79
19990325	845	.005	<.010	.006	--	K13	K8	K12	.8	16	100
19990412	1350	.006	<.010	.010	--	K10	K5	K9	.9	15	96
19990415	830	.007	<.010	.024	--	200	210	150	1.0	28	78
19990505	1045	.033	.035	.537	76	800	500	540	6.6	565	83
19990603	940	<.004	.010	.007	142	K2	K7	21	1.2	21	96
19990624	1215	<.020	<.010	<.020	142	38	58	79	.6	23	99
19990701	830	.023	.019	.376	106	2,300	K22,000	K2,500	6.8	463	55
19990722	900	<.004	<.010	.008	133	K11	8	15	1.4	17	95
19990811	835	<.004	<.010	.008	129	K12	K9	83	1.1	16	99
19990907	1200	<.004	<.010	.006	146	K4	K14	K7	1.3	22	96
19991006	830	E.004	<.010	.008	149	K5	K10	120	1.0	41	90
19991123	830	<.006	<.010	E.007	142	K18	K19	24	.83	18	91
19991208	1215	E.003	.016	E.004	152	K6	K5	41	.81	34	87
19991213	1130	.020	.014	.088	61	1,100	1,100	4,800	4.1	49	92
20000120	810	E.003	<.010	.021	113	35	31	20	--	16	93

Appendix - Water-quality data for Buffalo River near St. Joe and Bear Creek near Silver Hill, Arkansas--Continued

[Five digit numbers in parentheses are U.S. Environmental Protection Agency STORET data management system parameter codes. ft^3/s, cubic feet per second; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; C, carbon; mm, millimeter; --, no data; E, estimated, <, less than; K, plate count outside ideal range, >, greater than]

Date	Time	Phosphorus dissolved (mg/L as P) (00666)	Orthophosphorus, dissolved (mg/L as P) (00671)	Phosphorus, total (mg/L as P) (00665)	Solids, residue at 180 °C, dissolved (mg/L) (70300)	*E. coli* (colonies per 100 mL) (31633)	Fecal coliforms (colonies per 100 mL) (31625)	Fecal streptococci (colonies per 100 mL) (31673)	Organic carbon, dissolved (mg/L as C) (00681)	Sediment, suspended (mg/L) (80154)	Sediment, suspended (percent finer than 0.062 mm) (70331)
20000201	945	<.006	<.010	E.004	118	K8	K7	K7	.82	16	93
20000227	945	0.008	<0.010	0.051	61	250	130	350	2.8	39	84
20000313	1225	<.006	<.010	E.005	89	K9	31	K2	1.1	12	100
20000419	1145	E.003	<.010	<.008	96	23	32	K8	1.1	21	98
20000506	1715	.013	<.010	.04	99	150	77	450	.94	51	85
20000517	1125	E.004	<.010	E.006	93	K2	K2	K20	1.1	14	92
20000613	900	E.004	<.010	E.005	118	K8	21	81	1.4	19	98
20000615	830	.018	<.010	.109	67	5,800	>2,000	K26,000	5.3	102	66
20000617	1830	.047	.033	.791	71	4,600	11,000	K25,000	7.1	852	79
20000622	900	.016	.01	.121	73	K1,000	K1,200	5,800	4.1	104	82
20000726	1010	<.006	<.010	.009	134	K7	K16	23	.93	57	92
20000816	905	<.006	<.010	E.007	131	K14	40	30	1.2	45	89
20000907	1020	E.004	<.010	.008	140	K2	K5	20	1.1	28	97
20001003	740	E.003	<.010	E.004	136	K10	K6	K14	.94	45	92
20001115	1220	E.003	<.018	.006	121	--	51	70	1.3	26	99
20001219	940	E.003	<.018	E.002	123	K17	K11	K8	.74	22	100
20010116	1400	E.005	<.018	.008	83	K6	K4	K17	1.3	21	93
20010129	1815	.042	.036	.284	102	1,700	2,000	7,300	3.3	172	98
20010214	645	E.004	<.018	.019	86	240	210	260	1.4	28	89
20010221	815	.006	<.018	.020	84	120	52	58	.96	33	83
20010320	1300	<.006	<.018	.005	100	<1	K2	K2	.97	20	94

Appendix - Water-quality data for Buffalo River near St. Joe and Bear Creek near Silver Hill, Arkansas--Continued

[Five digit numbers in parentheses are U.S. Environmental Protection Agency STORET data management system parameter codes. ft^3/s, cubic feet per second; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; C, carbon; mm, millimeter; --, no data; E, estimated, <, less than; K, plate count outside ideal range, >, greater than]

Date	Time	Phosphorus dissolved (mg/L as P) (00666)	Orthophosphorus, dissolved (mg/L as P) (00671)	Phosphorus, total (mg/L as P) (00665)	Solids, residue at 180 °C, dissolved (mg/L) (70300)	*E. coli* (colonies per 100 mL) (31633)	Fecal coliforms (colonies per 100 mL) (31625)	Fecal streptococci (colonies per 100 mL) (31673)	Organic carbon, dissolved (mg/L as C) (00681)	Sediment, suspended (mg/L) (80154)	Sediment, suspended (percent finer than 0.062 mm) (70331)
20010425	815	E.003	<.018	.007	--	78	110	27	.92	16	96
20010509	1100	E.003	<.018	.008	130	K4	K10	21	.97	19	99
20010607	740	<.006	<.020	.009	10,000	K14	K12	38	1.1	22	95
20010710	1145	<.006	<.020	.008	--	K11	K13	21	1.2	23	96
20010817	710	<.006	<.020	.007	69	K9	K5	35	1.9	29	96
20010906	945	E.003	<.020	.007	144	27	29	E18	1.4	23	100

Appendix - Water-quality data for Buffalo River near St. Joe and Bear Creek near Silver Hill, Arkansas--Continued

[Five digit numbers in parentheses are U.S. Environmental Protection Agency STORET data management system parameter codes. ft^3/s, cubic feet per second; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; C, carbon; mm, millimeter; --, no data; E, estimated, <, less than; K, plate count outside ideal range, >, greater than]

Date	Time	Discharge, instantaneous (ft^3/s) (00061)	Oxygen, dissolved (percent saturation) (00301)	Oxygen, dissolved (mg/L) (00300)	pH, field standard units (00400)	Specific conductance (µS/cm) (00095)	Temperature (°C) (00010)	Acid neutralizing capacity, field (mg/L as $CaCO_3$) (00410)	Ammonia, dissolved (mg/L as N) (00608)	Ammonia plus organic nitrogen dissolved (mg/L as N) (00623)	Ammonia plus organic nitrogen, total (mg/L as N) (00625)	Nitrogen, dissolved (mg/L as N) (00602)	Nitrite plus nitrate, dissolved (mg/L as N) (00631)	Nitrogen total (mg/L as N) (00600)	Nitrite, dissolved (mg/L as N) (00613)
Bear Creek near Silver Hill, Arkansas															
19990120	1000	4.4	105	12.9	7.3	206	6.0	78	<0.020	0.11	0.11	0.66	0.548	0.66	<0.010
19990209	1318	150	107	11.2	7.1	145	12.5	53	<.020	E.08	.13	--	.452	.58	<.010
19990309	1045	254	92	10.6	7.3	99	8.9	56	<.020	.17	.27	.50	.334	.60	<.010
19990325	935	74	93	9.9	8.0	184	12.3	95	<.020	E.06	E.07	--	.361	--	<.010
19990412	1245	95	118	11.3	7.9	175	17.2	66	.02	.12	.13	.46	.345	.48	<.010
19990415	730	390	91	9.3	7.2	131	13.0	49	<.020	.18	.36	.41	.223	.58	<.010
19990504	2345	175	99	9.2	6.9	180	17.0	80	.044	.33	.92	.71	.376	1.3	<.010
19990603	1035	12	102	8.8	8.1	299	21.6	126	.075	.20	.22	.67	.466	.69	.012
19990624	1130	8.5	98	8.4	7.9	316	22.0	137	.040	<.20	<.20	--	.520	--	.010
19990630	1700	1,360	92	8.1	7.1	88	20.8	33	.020	.36	1.0	.58	.222	1.3	<.010
19990722	945	12	107	9.4	7.6	313	21.5	138	.031	.23	.17	.70	.465	.64	<.010
19990810	1400	6.3	98	7.4	7.6	321	28.9	132	.043	.17	.23	.56	.388	.61	<.010
19990907	1045	3.7	90	7.6	7.2	344	22.8	139	.020	E.08	.15	--	.454	.60	.012
19991005	1130	2.7	72	7.5	8.3	355	13.0	169	<.020	.11	.12	.51	.403	.52	<.010
19991122	1350	4.5	108	10.5	7.7	353	16.0	154	<.020	E.07	.25	--	.449	.70	<.010
19991208	1120	8.6	75	8.2	7.6	374	9.9	166	<.020	<.10	.12	--	<.050	--	<.010

Appendix - Water-quality data for Buffalo River near St. Joe and Bear Creek near Silver Hill, Arkansas--Continued

[Five digit numbers in parentheses are U.S. Environmental Protection Agency STORET data management system parameter codes. ft^3/s, cubic feet per second; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; C, carbon; mm, millimeter; --, no data; E, estimated, <, less than; K, plate count outside ideal range, >, greater than]

Date	Time	Discharge, instantaneous (ft^3/s) (00061)	Oxygen, dissolved (percent saturation) (00301)	Oxygen, dissolved (mg/L) (00300)	pH, field standard units (00400)	Specific conductance (µS/cm) (00095)	Temperature (°C) (00010)	Acid neutralizing capacity, field (mg/L as $CaCO_3$) (00410)	Ammonia, dissolved (mg/L as N) (00608)	Ammonia plus organic nitrogen dissolved (mg/L as N) (00623)	Ammonia plus organic nitrogen, total (mg/L as N) (00625)	Nitrogen, dissolved (mg/L as N) (00602)	Nitrite plus nitrate, dissolved (mg/L as N) (00631)	Nitrogen total (mg/L as N) (00600)	Nitrite, dissolved (mg/L as N) (00613)
19991212	1700	2,560	96	10.7	7.3	76	9.7	23	<.020	.29	1.1	.95	.657	1.7	<.010
20000120	840	16	85	10.2	7.2	261	7.4	108	<.020	<.10	E.07	--	.523	--	<.010
20000201	1030	11	101	12.3	8.2	273	7.2	117	<0.020	<0.10	E0.06	--	.468	--	<.010
20000227	845	480	87	10	7.1	103	9.5	34	<.020	.16	.29	.69	.530	.82	<.010
20000313	1135	50	95	9.8	7.5	188	13.5	99	<.020	E.07	.14	--	.213	.35	<.010
20000419	1030	27	111	10	7.7	208	19.1	88	.025	E.09	.14	--	.161	.30	<.010
20000506	1615	577	94	8.7	7.0	99	17.2	36	<.020	.25	.47	.38	.131	.60	<.010
20000517	1000	31	80	7.1	7.6	209	20.1	88	<.020	.10	.11	.30	.195	.31	<.010
20000613	815	27	82	7.4	8.0	265	19.9	102	<.020	.15	.11	.53	.382	.50	<.010
20000614	2230	607	91	8.1	7.4	140	20.1	56	.024	.34	.80	.72	.380	1.2	<.010
20000617	1730	880	94	8.4	7.8	114	20.1	45	<.020	.32	.58	.53	.211	.80	<.010
20000621	1430	2,380	90	8.1	7.2	98	19.6	48	<.020	.41	.70	.58	.171	.87	<.010
20000726	920	11	99	8.8	7.4	327	19.7	141	<.020	E.08	.14	--	.564	.70	<.010
20000816	1030	7.2	102	8.5	8.2	327	23.9	151	.022	.15	.16	.62	.466	.63	<.010
20000907	940	6.7	106	9.1	7.3	348	21.6	169	.028	.12	.15	.55	.428	.58	<.010
20001003	1000	5.6	81	7.4	7.9	360	19.7	160	<0.020	0.11	0.20	0.64	0.526	0.72	<0.010
20001115	1115	85	130	14.3	8.0	243	10.2	96	<.041	E.06	<.08	--	.755	--	<.006
20001219	830	30	64	8.4	8.1	259	3.7	103	<.041	E.08	E.07	--	.929	--	<.006
20010116	1315	108	109	13.3	8.7	167	7.3	65	<.041	E.07	<.08	--	.842	--	<.006

Appendix - Water-quality data for Buffalo River near St. Joe and Bear Creek near Silver Hill, Arkansas--Continued

[Five digit numbers in parentheses are U.S. Environmental Protection Agency STORET data management system parameter codes. ft^3/s, cubic feet per second; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; C, carbon; mm, millimeter; --, no data; E, estimated, <, less than; K, plate count outside ideal range, >, greater than]

Date	Time	Discharge, instantaneous (ft^3/s) (00061)	Oxygen, dissolved (percent saturation) (00301)	Oxygen, dissolved (mg/L) (00300)	pH, field standard units (00400)	Specific conductance (µS/cm) (00095)	Temperature (°C) (00010)	Acid neutralizing capacity, field (mg/L as $CaCO_3$) (00410)	Ammonia, dissolved (mg/L as N) (00608)	Ammonia plus organic nitrogen dissolved (mg/L as N) (00623)	Ammonia plus organic nitrogen, total (mg/L as N) (00625)	Nitrogen, dissolved (mg/L as N) (00602)	Nitrite plus nitrate, dissolved (mg/L as N) (00631)	Nitrogen total (mg/L as N) (00600)	Nitrite, dissolved (mg/L as N) (00613)
20010129	1520	943	99	11.2	7.7	126	8.8	--	.061	.51	1.2	1.2	.702	1.9	E.005
20010214	845	607	91	10.4	7.5	130	9.5	46	.105	.26	.62	.99	.732	1.3	E.003
20010221	1030	186	93	10.6	7.7	178	9.9	66	<.041	E.08	.13	--	1.45	1.6	E.004
20010320	1000	43	112	12.3	8.2	210	11.1	84	<.041	<.10	.12	--	.487	.61	<.006
20010425	1035	36	73	7.3	6.9	193	15	81	<.041	.10	.13	.35	.253	.38	E.003
20010509	900	35	93	9.2	7.8	236	16	100	<.041	.10	.12	.46	.360	.48	.006
20010607	845	17	89	7.9	7.5	276	20.3	117	<.040	.11	.13	.48	.377	.50	.007
20010710	855	8.6	74	6.2	7.9	331	23.4	145	E.034	.10	.18	.58	.475	.65	.009
20010817	830	9.6	76	6.8	7.5	313	20.3	155	E.024	.14	.13	.69	.546	.67	E.004
20010906	1045	5.2	97	8.0	7.9	340	25.3	170	<.040	.13	.13	.65	.525	.66	.008

Appendix - Water-quality data for Buffalo River near St. Joe and Bear Creek near Silver Hill, Arkansas--Continued

[Five digit numbers in parentheses are U.S. Environmental Protection Agency STORET data management system parameter codes. ft^3/s, cubic feet per second; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; C, carbon; mm, millimeter; --, no data; E, estimated, <, less than; K, plate count outside ideal range, >, greater than]

Date	Time	Phosphorus dissolved (mg/L as P) (00666)	Ortho-phosphorus, dissolved (mg/L as P) (00671)	Phosphorus, total (mg/L as P) (00665)	Solids, residue at 180 °C, dissolved (mg/L) (70300)	*E. coli* (colonies per 100 mL) (31633)	Fecal coliforms (colonies per 100 mL) (31625)	Fecal streptococci (colonies per 100 mL) (31673)	Organic carbon, dissolved (mg/L as C) (00681)	Sediment, suspended (mg/L) (80154)	Sediment, suspended (percent finer than 0.062 mm) (70331)
Bear Creek near Silver Hill, Arkansas											
19990120	1000	0.020	0.018	0.026	117	K5	K18	23	2.4	17	98
19990209	1318	.018	.020	.031	87	36	66	28	--	19	94
19990309	1045	.017	.026	.055	70	860	700	700	4.4	26	99
19990325	935	.017	<.010	.020	--	34	43	26	.9	18	100
19990412	1245	.020	.018	.027	--	K5	K30	K12	1.1	17	100
19990415	730	.031	.023	.082	--	K3,000	K17	1,500	3.3	28	92
19990504	2345	.099	.082	.281	112	400	500	460	6.5	123	98
19990603	1035	.019	.026	.031	194	K11	31	58	.9	51	71
19990624	1130	<.020	.020	<.020	188	K2	K3	K6	.5	46	85
19990630	1700	.079	.047	.292	102	4,400	K23,000	K2,700	11	156	90
19990722	945	.017	.013	.027	183	29	52	130	1.1	52	88
19990810	1400	.017	<.010	.027	175	110	94	150	1.2	54	83
19990907	1045	.013	<.010	.019	194	K7	K17	200	1.4	84	82
19991005	1130	.015	.016	.022	206	K9	K21	53	1.2	90	96
19991122	1350	.010	<.010	.018	--	K10	K5	52	.87	55	79
19991208	1120	.017	<.010	.019	211	K5	K13	170	.8	89	72
19991212	1700	.094	.074	.355	52	6,500	10,000	2,300	6.4	198	83
20000120	840	0.015	0.019	0.049	147	K15	30	38	0.74	20	99

Appendix - Water-quality data for Buffalo River near St. Joe and Bear Creek near Silver Hill, Arkansas--Continued

[Five digit numbers in parentheses are U.S. Environmental Protection Agency STORET data management system parameter codes. ft^3/s, cubic feet per second; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; C, carbon; mm, millimeter; --, no data; E, estimated, <, less than; K, plate count outside ideal range, >, greater than]

Date	Time	Phosphorus dissolved (mg/L as P) (00666)	Orthophosphorus, dissolved (mg/L as P) (00671)	Phosphorus, total (mg/L as P) (00665)	Solids, residue at 180 °C, dissolved (mg/L) (70300)	*E. coli* (colonies per 100 mL) (31633)	Fecal coliforms (colonies per 100 mL) (31625)	Fecal streptococci (colonies per 100 mL) (31673)	Organic carbon, dissolved (mg/L as C) (00681)	Sediment, suspended (mg/L) (80154)	Sediment, suspended (percent finer than 0.062 mm) (70331)
20000201	1030	.015	<.010	.019	150	K15	K18	K9	.75	25	96
20000227	845	.027	.024	.067	61	1,200	K640	390	3.2	28	97
20000313	1135	.010	<.010	.016	102	21	61	K2	2.7	17	94
20000419	1030	.015	.011	.023	116	K21	28	29	1.1	27	95
20000506	1615	.029	.017	.105	72	540	1,100	1,000	6.2	54	91
20000517	1000	.020	.013	.030	116	33	97	39	1.1	19	97
20000613	815	.018	.016	.025	148	51	97	100	1.1	27	93
20000614	2230	.121	.101	.232	93	K700	>2,000	7,400	8.2	99	94
20000617	1730	.065	.046	.173	83	6,600	8,600	9,800	7.2	95	91
20000621	1430	.085	.061	.224	81	4,200	K12,000	13,000	8.9	134	79
20000726	920	.017	.013	.023	181	23	34	55	1.1	95	86
20000816	1030	.011	<.010	.017	181	32	K57	26	1.3	85	83
20000907	940	.013	<.010	.020	202	47	91	56	1.0	79	93
20001003	1000	.011	.010	.018	202	150	160	110	1.2	51	92
20001115	1115	0.025	E.015	0.031	138	--	52	72	1.6	31	99
20001219	830	.018	E.014	.022	150	110	80	51	1.1	35	99
20010116	1315	.017	E.014	.024	97	K6	K6	K16	1.6	17	98
20010129	1520	.087	.071	.354	85	2,900	K3,100	4,800	8.7	196	90
20010214	845	.081	.073	.155	84	820	570	1,300	4.3	48	86
20010221	1030	.026	.023	.035	112	130	94	60	1.2	21	100
20010320	1000	.012	<.018	.016	120	25	K9	K8	1.0	24	97

Appendix - Water-quality data for Buffalo River near St. Joe and Bear Creek near Silver Hill, Arkansas--Continued

[Five digit numbers in parentheses are U.S. Environmental Protection Agency STORET data management system parameter codes. ft^3/s, cubic feet per second; mg/L, milligrams per liter; μS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; C, carbon; mm, millimeter; --, no data; E, estimated, <, less than; K, plate count outside ideal range, >, greater than]

Date	Time	Phos-phorus dis-solved (mg/L as P) (00666)	Ortho-phosphorus, dissolved (mg/L as P) (00671)	Phosphorus, total (mg/L as P) (00665)	Solids, residue at 180 °C, dissolved (mg/L) (70300)	*E. coli* (colonies per 100 mL) (31633)	Fecal coliforms (colonies per 100 mL) (31625)	Fecal strep-tococci (colonies per 100 mL) (31673)	Organic carbon, dissolved (mg/L as C) (00681)	Sediment, suspended (mg/L) (80154)	Sediment, suspended (percent finer than 0.062 mm) (70331)
20010425	1035	.013	<.018	.021	--	55	49	31	1.1	18	98
20010509	900	.016	E.009	.017	144	32	47	63	1.2	19	98
20010607	845	.021	<.020	.03	156	--	41	110	.96	39	48
20010710	855	.014	E.010	.022	--	23	36	180	1.0	76	90
20010817	830	.026	E.013	.033	91	49	61	110	3.9	78	78
20010906	1045	.018	<.020	.024	202	E28	60	110	.96	84	89