Analysis of Suspended-Sediment Concentrations and Discharges at Four Long-Term Sediment Stations in Central and Southern Illinois, 1975–92 Water Years

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CONVERSION FACTORS AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
mile (mi)	1.609	meter
square mile (mi^2)	2.590	square kilometer
foot per second (ft/s)	0.3048	meter per second
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
ton	907.2	kilogram
	0.9072	megagram

Abbreviated water-quality units used in this report:

milligram per liter (mg/L)
ton per day (ton/d)
ton per square mile per day [(ton/mi^2)/d]
milligram per liter per year [(mg/L)/yr]
ton per day per year [(ton/d)/yr]
ton per square mile per year [(ton/mi^2)/yr]
cubic foot per second per year [(ft^3/s)/yr]

Water year: Water year is the 12-month period from October to September. The water year is designated by the year in which it ends; thus, the year ending September 30, 1975, is called the "1975 water year." Years are water years in this report unless designated otherwise.

Analysis of Suspended-Sediment Concentrations and Discharges at Four Long-Term Sediment Stations in Central and Southern Illinois, 1975–92 Water Years

By Paul J. Terrio

Abstract

The U.S. Geological Survey and the U.S. Army Corps of Engineers, St. Louis District, have jointly operated four sediment stations in central and southern Illinois since May 1975—Illinois River at Valley City, Kaskaskia River at Cooks Mills, Kaskaskia River near Venedy Station, and Big Muddy River at Murphysboro. A comprehensive analysis of the historical data from these sediment stations was done to determine changes in the concentrations or amounts of suspended sediment transported in the streams.

Generally, the highest suspended-sediment concentrations were found in the Illinois River at Valley City (the station with the largest drainage area), and the lowest concentrations were in the Kaskaskia River at Cooks Mills (the station with the smallest drainage area). Suspended-sediment concentrations were typically high in the spring and summer (March through August) and low in the fall or winter (September through February). The seasonal Kendall test for trends indicated a statistically significant downward trend in suspended-sediment concentrations at three of the sediment stations, including a downward trend of 5.50 milligrams per liter per year in the Illinois River at Valley City.

Median suspended-sediment discharges at the four sediment stations ranged from 47.1 to 3,260 tons per day and corresponded to the size of the drainage areas. The largest median suspended-sediment yield, 0.12 tons per square mile per day, was in the Illinois River at Valley City. Suspended-sediment discharges during the spring were larger than during other seasons. The seasonal Kendall test for trends indicated a statistically significant downward trend in suspended-sediment discharges at two of the sediment stations (Kaskaskia River at Cooks Mills and Big Muddy River at Murphysboro).

INTRODUCTION

Suspended sediment has been defined as sediment that moves in suspension in water and is maintained in suspension by the upward components of turbulent currents or by colloidal suspension (Colby and others, 1953). Suspended-sediment concentration, discharge, and yield are important factors affecting the quality and use of a stream. Suspended-sediment discharge, as used in this report, refers to the quantity of sediment transported in suspension in a stream. Excess concentrations of suspended sediment can restrict biological activity (Talkington, 1991), limit light penetration, reduce reservoir capacities (Demisse and Bhowmik, 1985; Fitzpatrick and Keefer, 1988), create an unaesthetic appearance, and add cost to the treatment and use of the stream water. In addition, phosphorus and trace metals associate with sediment particles (Kelly and Hite, 1984; Carmen and others, 1986), and the transport of sediment affects the fate of these constituents in stream systems.

Background

Soil erosion and sedimentation often has been cited as a primary nonpoint-source contamination concern in Illinois (Illinois Environmental Protection Agency, 1992; Talkington, 1991). Talkington (1991) indicated that sedimentation is the most important issue concerning the Illinois River, and the Illinois Environmental Protection Agency (1992) identified silting as one of the primary causes that many Illinois streams and rivers did not fully support their designated uses. Bonini and others (1983) identified several needs for long-term sediment studies, including the identification of sediment-related problems, the evaluation of past management strategies and water-use activities, and the acquisition of information for planning future strategies and uses.

The U.S. Army Corps of Engineers, St. Louis District (District), is responsible for maintaining the navigability of the Mississippi River and major tributaries, for monitoring and protecting the water quality of rivers and streams, and for maintaining and operating manmade reservoirs within the District's jurisdiction. Four sediment stations on three major Illinois tributaries to the Mississippi River (Illinois, Kaskaskia, and Big Muddy Rivers) have been operated cooperatively by the District and the U.S. Geological Survey (USGS) since May 1975 and January 1979. Two of these stations are located on the Kaskaskia River (Cooks Mills and Venedy Station), one station is on the Big Muddy River (Murphysboro), and one station is on the Illinois River (Valley City) (fig. 1). These long-term sediment stations provide data that can be used to address the needs identified by Bonini and others (1983) and to provide guidance for the management of the reservoirs and streams in the District. Information from the operation of these sediment stations includes measured suspended-sediment concentration data, measured streamflow data, and computed suspended-sediment discharge data. Background information for the four sediment stations is given in table 1.

A comprehensive analysis of trends in suspended-sediment concentrations and suspended-sediment discharges at the four sediment stations was needed to determine possible increases or decreases in the concentrations and amounts of suspended sediment transported in the streams over the 18-year period from May 1975 through September 1992. The identification of trends, or lack of trends, in suspended-sediment concentrations and discharges provides information on the results of historical management practices and information useful for the assessment of current water-quality conditions of the streams and reservoirs in central and southern Illinois.

Purpose and Scope

This report provides statistical information and results of trend analyses for suspended-sediment concentrations and suspended-sediment discharges at four long-term sediment stations in central and southern Illinois from May 1975 through September 1992. Suspended-sediment concentration and streamflow data collected from the Illinois River at Valley City, the Kaskaskia River at Cooks Mills, the Kaskaskia River near Venedy Station, and the Big Muddy River at Murphysboro were used in the analyses. Data-set distributions are depicted using boxplots, differences among data sets or time periods are identified using Wilcoxon-Mann-Whitney rank-sum tests, and temporal trends are evaluated using the seasonal Kendall test for trends.

DATA-BASE COMPILATION

The District and the USGS have cooperatively supported four sediment stations in Illinois since May 1975. The characteristics of this data-collection program varied over the 18-year period from May 1975 through September 1992. Few analyses of these data had been done prior to this study.

The period of data record and frequency of data collection varied among the four sediment stations (table 2). Suspended-sediment data were collected on an approximately monthly frequency from May 1975 through April 1980 at three of the sediment stations—Illinois River at Valley City, Kaskaskia River near Venedy Station, and Big Muddy River at Murphysboro. Daily suspended-sediment data were collected beginning in January 1979 at Kaskaskia River at Cooks Mills and beginning in the first 4 months of 1980 at the other three sediment stations. Variations in sample-collection frequencies prior to 1981 resulted because of changes in funding, perceived needs for the frequency of suspended-sediment data at specific sediment stations, and changes in data-collection personnel.

A comprehensive data set with constant statistical variance for the 1975–92 water years was needed for analysis. The availability of only monthly data from May 1975 through April 1980 at most of the sediment

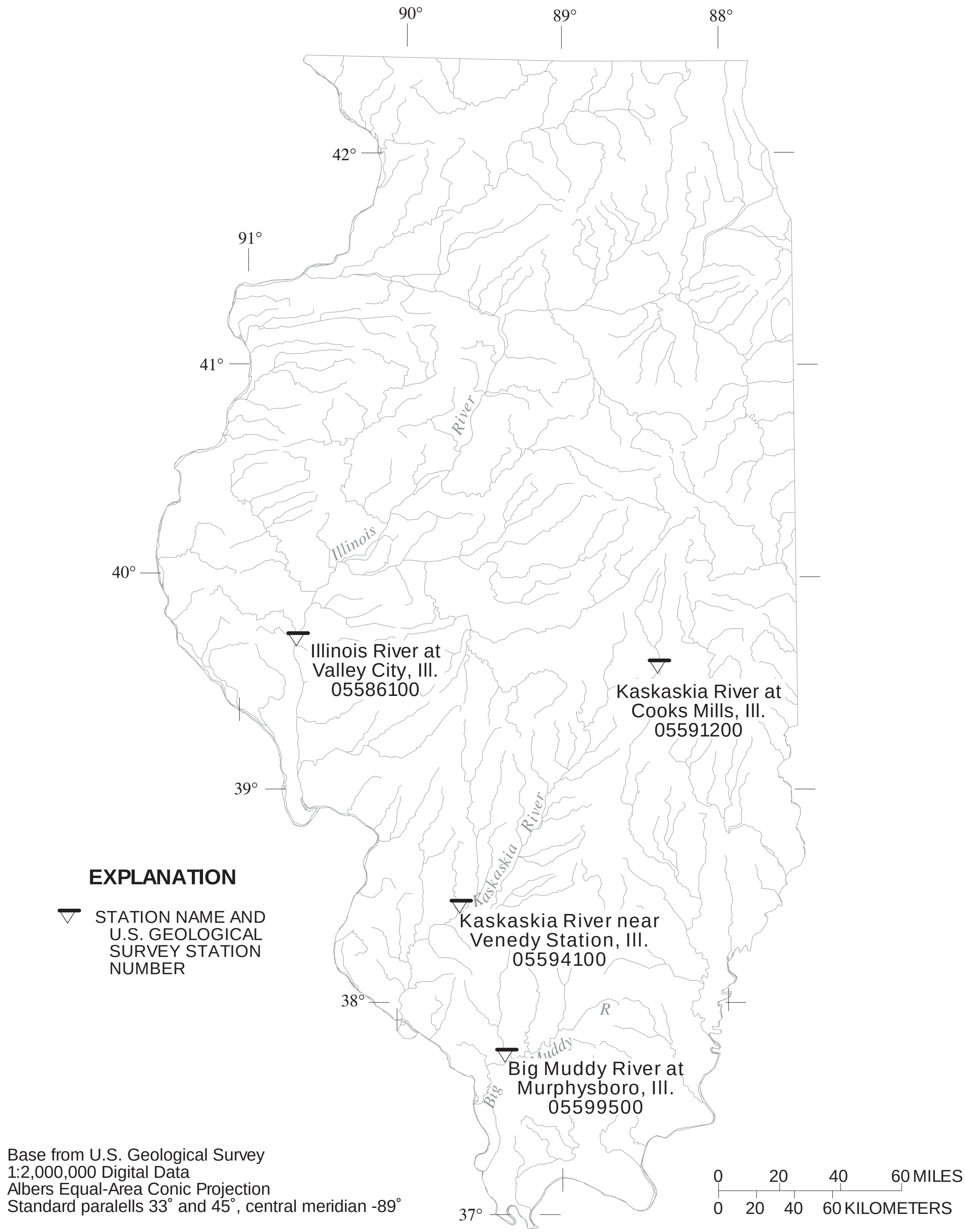

Figure 1. Location of four long-term sediment stations in central and southern Illinois.

Table 1. Background information for four long-term sediment stations in central and southern Illinois

[Land-use data from U.S. Geological Survey (1990). mi^2, square mile; ft^3/s, cubic foot per second]

Station name and number (fig. 1)	Drainage area (mi^2)	Period of daily streamflow record (water years)	Period of suspended-sediment record (water years)	Annual mean streamflow for the period of record (ft^3/s)	Land use (percentage of total drainage area)				
					Agricul-tural	Urban	Water	Forest	Other[1]
Illinois River at Valley City, Ill. (05586100)	26,742	1938–92	1975–92	22,110	83	6	2	1	8
Kaskaskia River at Cooks Mills, Ill. (05591200)	473	1970–92	1979–92	441	95	3	.5	.7	.8
Kaskaskia River near Venedy Station, Ill. (05594100)	4,393	1969–92	1975–92	3,596	84	2	2	12	0
Big Muddy River at Murphysboro, Ill. (05599500)	2,169	1916–92	1975–92	1,978	75	4	2	13	6

[1]Other land uses include barren land, rangeland, and wetland.

Table 2. Data-collection frequencies at four long-term sediment stations in central and southern Illinois, 1975–92 water years

Station name and number (fig. 1)	Time period	Collection frequency
Illinois River at Valley City, Ill. (05586100)	June 1975 through January 1980	Once per month.
	February 1980 through September 1992	Daily, plus more frequently during storms.
Kaskaskia River at Cooks Mills, Ill. (05591200)	January 1979 through September 1992	Daily, plus more frequently during storms.
Kaskaskia River near Venedy Station, Ill. (05594100)	May 1975 through April 1980	Monthly to bimonthly.
	May 1980 through September 1992	Daily, plus more frequently during storms.
Big Muddy River at Murphysboro, Ill. (05599500)	May 1975 through April 1980	Approximately once per month.
	May 1980 through September 1992	Daily, plus more frequently during storms.

stations dictated that the data set consist of monthly data. A long-term data set was compiled from the monthly suspended-sediment samples collected by USGS personnel from May 1975 through April 1980 and from approximately monthly suspended-sediment samples collected by USGS personnel from May 1980 through September 1992. No monthly suspended-sediment data were available for several periods during 1980–92. These periods were typically only 1 month long; however, there were some instances of several consecutive months with no data. These gaps in the data set were filled with data collected by observers. Most of the monthly suspended-sediment data for May 1975 through April 1980 were collected between the 8th and 22nd day of each month. Data collected by observers or daily concentrations calculated from the collected data, from the 15th day of each month, were used to represent concentrations for months when no data collected by USGS personnel were available. These data were combined with the monthly data collected by the USGS from May 1975 through September 1992 to produce a comprehensive data set with constant statistical variance for the 1975–92 water years. Between two and five high suspended-sediment concentration values were excluded from the data set because they were considered to be outliers not representative of actual suspended-sediment concentrations in the stream. These data could have resulted from improper sampling, sample contamination, or excessive algal growth in the sample prior to analysis.

Suspended-sediment concentration analyses were done at three laboratories as given below.

Period of analyses	Laboratory
October 1975–September 1981, October 1987–September 1991	U.S. Geological Survey, Iowa City, Iowa
October 1982–September 1987	Illinois State Water Survey, Champaign, Illinois
October 1991–September 1992	U.S. Geological Survey, Louisville, Kentucky

The Wilcoxon-Mann-Whitney rank-sum test was used to determine variances in concentrations among the samples analyzed at the laboratories. The rank-sum test is a nonparametric test to determine whether one group tends to produce larger observations than the second group (Helsel and Hirsch, 1992). Restrictions on the distributions of the two groups of data compared are not made in the application of the test. The rank-sum test was used to assess whether concentrations determined at one laboratory were significantly different from concentrations determined at another laboratory. The results of the rank-sum tests are given in table 3. A total of 12 intralaboratory comparisons were done; results of three comparisons indicated decreases in results of concentrations from one laboratory to another laboratory, results of one comparison indicated an increase in concentration, and results of eight comparisons indicated no statistically significant differences among concentrations determined by different laboratories.

Two factors complicated interpreting the rank-sum test results. First, if there were changes or trends in suspended-sediment concentrations over time, then the differences in reported concentrations between laboratories, as indicated by the rank-sum test, could result at least in part from in-stream changes and not from laboratory differences. Second, substantial changes were made in the sampling program from 1975 to 1992.

Pertaining to the first factor, the USGS laboratory in Iowa City, Iowa, was used from October 1975 through September 1981 and again from October 1987 through September 1991. The rank-sum test was used to compare suspended-sediment concentrations from the two periods when the Iowa City laboratory was used (results not included in table 3). Only one statistically significant difference in concentrations was found; concentrations from the latter period were higher than the concentrations from the earlier period at one sediment station. This result was opposite from most of the results of the intralaboratory comparisons given in table 3. No changes were made in sample-collection techniques or the methodology used at the Iowa City laboratory between the two periods. For most of the comparisons, there were no statistically significant differences in sediment concentrations between the two periods when the Iowa City laboratory was used for sediment analyses.

Pertaining to the second factor, a major change to the sampling program was to increase sampling frequency and to emphasize collecting samples during storms when the instream sediment discharges are typically large. This change possibly affected the characteristics of samples sent to the laboratories for analyses. Although results from the rank-sum tests indicated statistically significant differences among suspended-sediment concentrations determined at the three laboratories, the differences might have been caused by actual changes in concentrations (trends) and changes to the sampling program and not as a result of differences among laboratories. The differences in laboratory methods and analytical results among the three laboratories were assumed to be negligible for the purposes of this study.

RESULTS OF DATA ANALYSIS

The results of analyses of suspended-sediment concentration and suspended-sediment discharge data collected at the four sediment stations are presented in this section. These analyses include time-series plots, data-set distribution characteristics, seasonal analyses, trend analyses, and analyses of relations among suspended-sediment concentration, suspended-sediment discharge, and streamflow.

Suspended-Sediment Concentration

Time-series plots of monthly suspended-sediment concentration and streamflow data at the four sediment stations for the 1975–92 water years are shown in figure 2. Boxplots showing the distributions of the suspended-sediment concentration data at each of the four stations are provided in figure 3. Median suspended-sediment concentrations at the four sediment stations ranged from 75 to 124 mg/L. The highest median suspended-sediment concentration was from the Illinois River at Valley City, and the lowest median suspended-sediment concentration was from the Kaskaskia River at Cooks Mills. The highest suspended-sediment concentration sampled (1,400 mg/L) was from the Illinois River at Valley City, and the lowest suspended-sediment concentrations sampled (5 to 6 mg/L) were found at all three of the other stations. Overall, suspended-sediment concentrations from the Kaskaskia River at Cooks Mills were lowest, and suspended-sediment concentrations were higher, respectively, from the Kaskaskia River near Venedy Station, the Big Muddy River at Murphysboro, and the Illinois River at Valley City (fig. 3). Suspended-sediment concentrations from the Kaskaskia River at Cooks Mills generally were about one-half of the suspended-sediment concentrations from the Illinois River at Valley City.

Suspended-sediment concentration data were examined for seasonal variation. Seasonality in

Table 3. Results of Wilcoxon-Mann-Whitney rank-sum tests for differences among suspended-sediment concentrations determined at three laboratories used to analyze samples from four sediment stations in central and southern Illinois, 1975–92 water years

[Underlining indicates test results with an attained significance level of less than 0.10; <, less than]

Station name and number (fig. 1)	Number of analyses		Mean rank		Attained significance level
Comparison of U.S. Geological Survey, Iowa City, Iowa (Lab 1), to Illinois State Water Survey, Champaign, Illinois (Lab 2)					
	Lab 1	Lab 2	Lab 1	Lab 2	
Illinois River at Valley City, Ill. (05586100)	66	69	75.6	60.8	0.0270
Kaskaskia River at Cooks Mills, Ill. (05591200)	36	69	54.7	52.1	.6854
Kaskaskia River near Venedy Station, Ill. (05594100)	78	69	70.8	77.6	.3394
Big Muddy River at Murphysboro, Ill. (05599500)	79	69	40.5	104.3	<.0001
Comparison of Illinois State Water Survey, Champaign, Illinois (Lab 2), to U.S. Geological Survey, Iowa City, Iowa (Lab 3)					
	Lab 2	Lab 3	Lab 2	Lab 3	
Illinois River at Valley City, Ill. (05586100)	69	48	65.3	50.0	.0167
Kaskaskia River at Cooks Mills, Ill. (05591200)	69	48	59.5	58.3	.8593
Kaskaskia River near Venedy Station, Ill. (05594100)	69	48	67.8	46.4	.0008
Big Muddy River at Murphysboro, Ill. (05599500)	69	48	57.1	61.7	.4782
Comparison of U.S. Geological Survey, Iowa City, Iowa (Lab 3), to U.S. Geological Survey, Louisville, Kentucky (Lab 4)					
	Lab 3	Lab 4	Lab 3	Lab 4	
Illinois River at Valley City, Ill. (05586100)	48	12	29.8	33.3	.5298
Kaskaskia River at Cooks Mills, Ill. (05591200)	48	12	31.9	24.9	.2156
Kaskaskia River near Venedy Station, Ill. (05594100)	48	12	28.9	36.8	.1602
Big Muddy River at Murphysboro, Ill. (05599500)	48	12	33.1	20.1	.0209

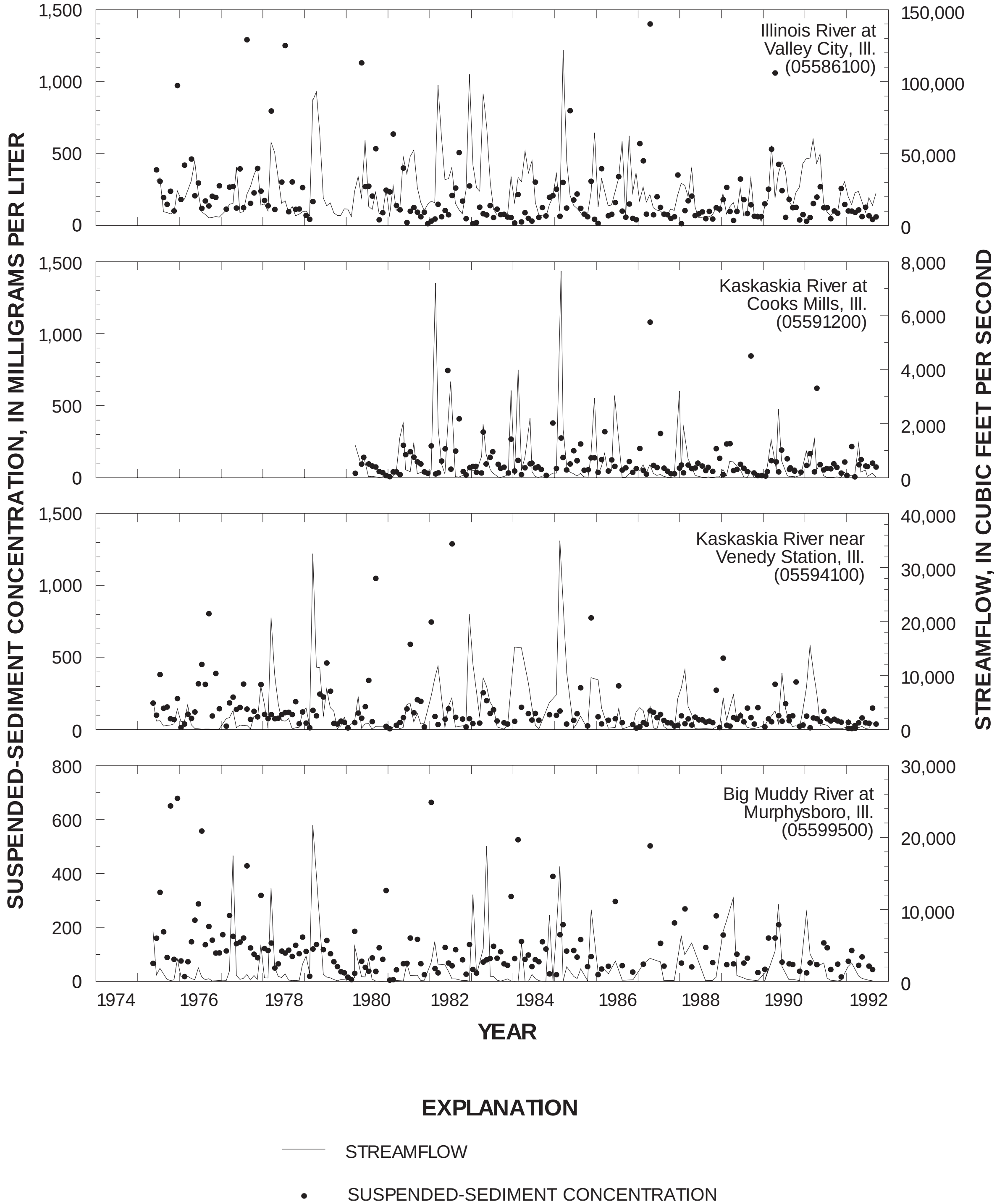

Figure 2. Suspended-sediment concentrations and streamflow at four sediment stations in central and southern Illinois, 1975–92 water years.

suspended-sediment concentrations can be caused by natural seasonal factors, such as plant-growth cycles, soil freezing, and fluctuations of the climatic and hydrologic cycles, and by anthropogenic (human-related) factors including land-use practices, construction activity, and recreation. Four seasons per year were used in the seasonal analysis, representing the four climatic seasons of winter, spring, summer, and fall. A Wilcoxon-Mann-Whitney rank-sum test was used to determine statistically significant differences

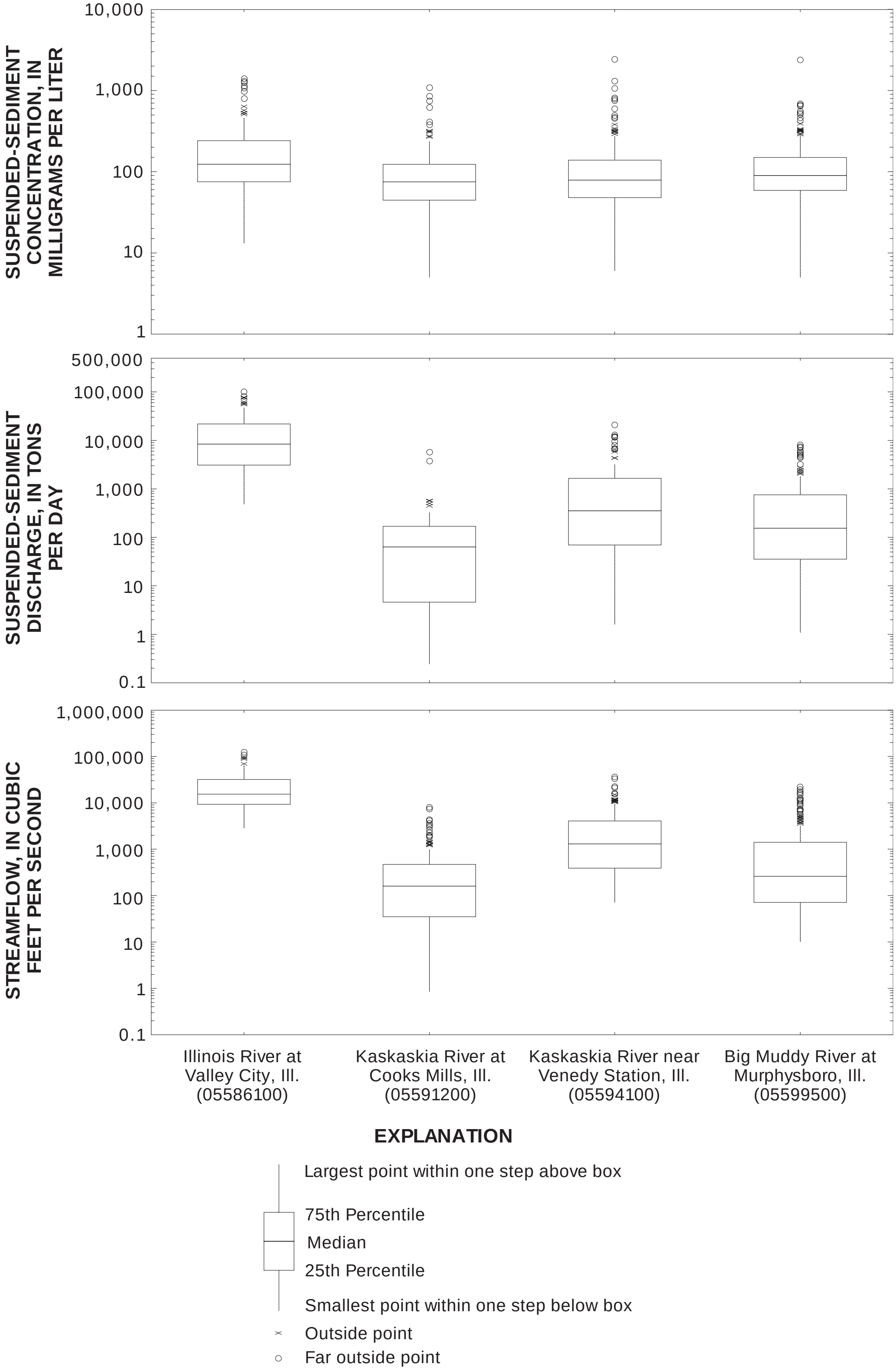

Figure 3. Distributions of suspended-sediment concentrations, suspended-sediment discharges, and streamflows at four sediment stations in central and southern Illinois, 1975–92 water years.

among suspended-sediment concentrations during adjacent climatic seasons. Generally, suspended-sediment concentrations were high in the spring and summer (March–August) and low in the fall or winter (September–February) (table 4). Suspended-sediment concentrations during the summer (June–August) were significantly higher than suspended-sediment concentrations during the fall at all four sediment stations (fig. 4). There were significant differences in suspended-sediment concentrations between consecutive seasons in samples from the Kaskaskia River near Venedy Station; the highest suspended-sediment concentrations were during the summer, and the lowest suspended-sediment concentrations were during the winter.

Seasonal variation in suspended-sediment concentrations also was related to seasonal variation in streamflow. Seasonality in streamflow was evident at all four sediment stations (figs. 4 and 5). Streamflow in Illinois is generally high in the spring because of seasonal precipitation patterns. Also, summer thunderstorms often produce high streamflow. Thunderstorms producing intense rainfall often cause substantial increases in streamflow in a relatively short period. Both the precipitation in the spring and the thunderstorm activity in the summer can result in increases in streamflow and associated increases in suspended-sediment concentrations and sediment discharge. Streamflows are typically low in the fall because of seasonal precipitation patterns.

Streamflows during the winter months were higher than during the fall but lower than during the spring or summer, except at Big Muddy River at Murphysboro where streamflows during the winter were higher than during the spring and summer. Winter precipitation is often in the form of snow or ice in the drainage areas of the four sediment stations, producing a more gradual runoff than rainfall. Snow does not remain frozen on the ground through winter in central and southern Illinois. Winter precipitation falls as snow and ice less frequently at the Big Muddy River at Murphysboro sediment station than at the other three stations. This factor, combined with land use, topography, and soil characteristics of the basin, contributes to the lack of seasonal differences in suspended-sediment concentrations at this station.

The drainage basins for all four sediment stations are predominately agricultural, and growing and non-growing seasons can affect the seasonality of suspended-sediment concentrations. Corn and soybeans are the principal crops grown in central and southern Illinois. The growing season for these crops is generally from late May through September, or the summer and early fall seasons. Suspended-sediment concentrations were found to be highest during the growing season, a result somewhat unexpected because runoff and sediment transport from barren fields are typically greater than from fields with an actively growing crop cover. Other factors, including agitation and loosening of the soil from planting and crop-maintenance activities, thunderstorm activity, construction activity, recreation, and soil freezing during the winter months, possibly contribute to the higher suspended-sediment concentrations during the summer.

The seasonal Kendall test for trends (Helsel and Hirsch, 1992) was used to determine monotonic time trends in suspended-sediment concentrations and sediment discharges. The seasonal Kendall test is a nonparametric test for trend detection applicable to data sets with seasonality (Hirsch and others, 1982). The test eliminates the effect of seasonal variation by comparing observations from the same season of different years as defined by the user. The seasonal Kendall test is monotonic and designed to provide a single summary statistic for the entire period of record. The attained significance level of the trend is computed to indicate the probability of erroneously rejecting the null hypothesis that no trend is present. An attained significance level of 0.10 was used to determine whether a test result was statistically significant. The seasonal Kendall slope estimator is an estimate of the magnitude of the slope of the trend line expressed as the change per year because of the trend. The estimate is unaffected by seasonality because the slopes are computed between values that are multiples of 12 months (Hirsch and others, 1982). Helsel and Hirsch (1992) suggested that "...seasons should be just long enough so that there is some data available for most of the seasons in most of the years of record...if the data are primarily collected at a monthly frequency, the seasons should be defined to be the 12 months." Twelve "seasons" per year (monthly values) were used for the trend analyses described in this report to ensure that effects from seasonal variability in sediment concentrations were minimized.

An evaluation of the relations between suspended-sediment concentrations and streamflow at the four sediment stations was done prior to the trend analyses because streamflow directly affects suspended-sediment concentrations and sediment discharges. As

Table 4. Results of Wilcoxon-Mann-Whitney rank-sum tests for differences among suspended-sediment concentrations during four climatic seasons at four sediment stations in central and southern Illinois, 1975–92 water years

[Winter, December through February; spring, March through May; summer, June through August; fall, September through November. Shading indicates test results with an attained significance level of less than 0.10]

Station name and number (fig. 1)	Number of analyses		Mean rank		Attained significance level
	Winter to Spring				
	Winter	Spring	Winter	Spring	
Illinois River at Valley City, Ill. (05586100)	47	45	43.8	49.4	0.3155
Kaskaskia River at Cooks Mills, Ill. (05591200)	36	38	35.8	39.1	.5164
Kaskaskia River near Venedy Station, Ill. (05594100)	41	48	36.8	52.0	.0056
Big Muddy River at Murphysboro, Ill. (05599500)	53	51	48.1	57.1	.1265
	Spring to Summer				
	Spring	Summer	Spring	Summer	
Illinois River at Valley City, Ill. (05586100)	45	48	46.1	47.9	.7468
Kaskaskia River at Cooks Mills, Ill. (05591200)	38	39	35.4	42.5	.1689
Kaskaskia River near Venedy Station, Ill. (05594100)	48	53	42.7	58.5	.0069
Big Muddy River at Murphysboro, Ill. (05599500)	51	54	54.0	52.1	.7437
	Summer to Fall				
	Summer	Fall	Summer	Fall	
Illinois River at Valley City, Ill. (05586100)	48	48	54.5	42.5	.0361
Kaskaskia River at Cooks Mills, Ill. (05591200)	39	37	48.0	28.5	.0001
Kaskaskia River near Venedy Station, Ill. (05594100)	53	41	55.0	37.8	.0025
Big Muddy River at Murphysboro, Ill. (05599500)	54	52	58.7	48.1	.0757
	Fall to Winter				
	Fall	Winter	Fall	Winter	
Illinois River at Valley City, Ill. (05586100)	48	47	46.8	49.3	.6551
Kaskaskia River at Cooks Mills, Ill. (05591200)	37	36	34.7	39.3	.3568
Kaskaskia River near Venedy Station, Ill. (05594100)	41	41	47.2	35.8	.0303
Big Muddy River at Murphysboro, Ill. (05599500)	52	53	53.2	52.8	.9387

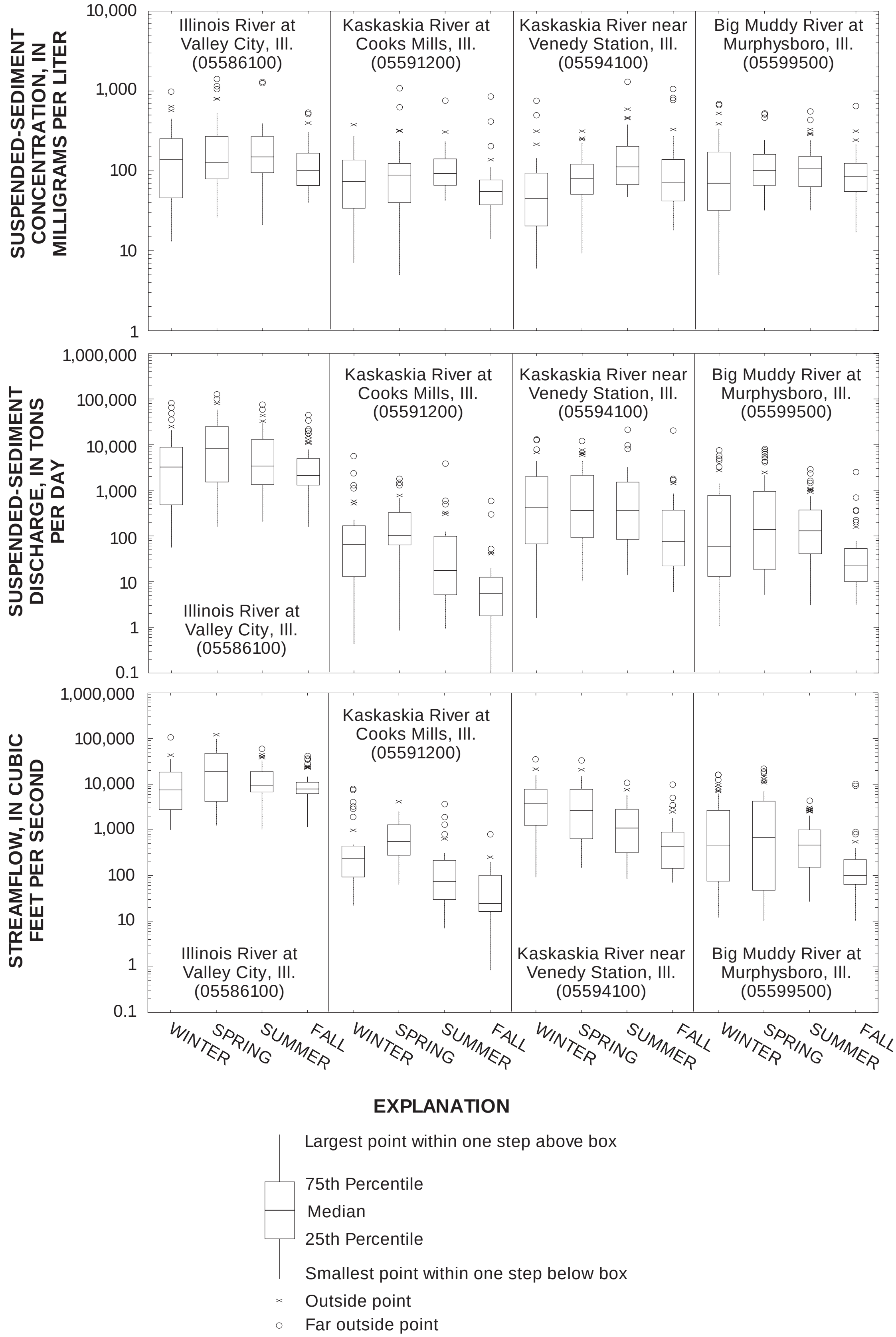

Figure 4. Distributions of suspended-sediment concentrations, suspended-sediment discharges, and streamflow during four climatic seasons at four sediment stations in central and southern Illinois, 1975–92 water years.

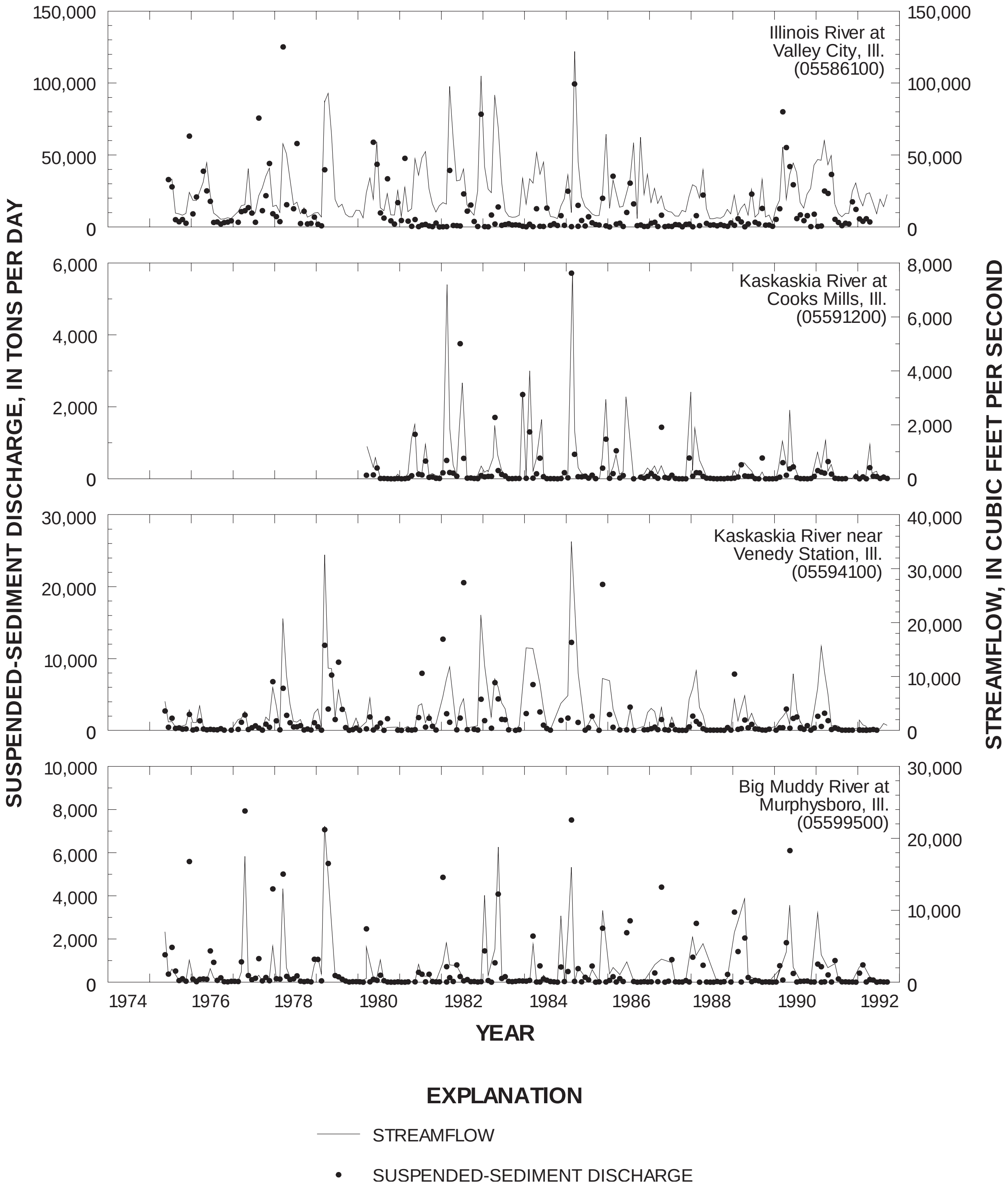

Figure 5. Suspended-sediment discharges and streamflow at four sediment stations in central and southern Illinois, 1975–92 water years.

streamflow increases, suspended-sediment concentration might increase because of additional erosion and transport of sediment to the stream. Conversely, suspended-sediment concentration may decrease because of dilution by the additional quantity of water. Sediment discharge typically increases with streamflow because additional material is transported to the stream, bed material is loosened and suspended, streambank and channel erosion is increased, and the capacity of the stream to carry sediment is increased. The effects of streamflow on suspended-sediment concentrations might change over time because of changes in land use, evolution of the drainage area, changes and fluctuation in climate, and anthropogenic activities.

A best-fit relation between suspended-sediment concentration and streamflow for each sediment station was derived through linear regression. Regressions between suspended-sediment concentrations and streamflow were done applying log, square, inverse, and two hyperbolic functions, as well as the actual suspended-sediment concentrations and streamflows. A statistically significant regression was defined as a regression with a correlation coefficient of at least 0.50 and an attained significance level less than or equal to 0.10. Results from the regression analyses indicate that streamflow accounted for less than 20 percent of the variation (correlation coefficient less than 0.20) in suspended-sediment concentrations at all four sediment stations. The same functions of streamflow and suspended-sediment concentration were used for regressions with only the highest 10 percent of the streamflows during the 18-year period of this study. These regressions were done because there is often a strong direct correspondence between high streamflow and high suspended-sediment concentrations. The results of these regressions indicated that streamflow accounted for less than about 25 percent of the variation in suspended-sediment concentrations at the four sediment stations during high streamflow periods.

Although statistically significant relations between suspended-sediment concentrations and streamflow and sediment discharge and streamflow were not indicated by the regression analyses, the relation between these characteristics generally is well known. The monthly samples might not adequately represent many of the high streamflow periods and did not adequately characterize suspended-sediment concentrations or sediment discharges during high-flow periods (fig. 2). An analysis of daily data would likely result in determining a more significant relation between sediment characteristics and streamflow.

The trend-test results indicated statistically significant decreases in suspended-sediment concentrations at three of the sediment stations (table 5). No significant trend in suspended-sediment concentrations was indicated for the Kaskaskia River at Cooks Mills. Suspended-sediment concentrations decreased by about 5.5 (mg/L)/yr in the Illinois River at Valley City and in the Kaskaskia River near Venedy Station, and by about 2.4 (mg/L)/yr in the Big Muddy River at Murphysboro. Trends in flow-adjusted suspended-sediment concentrations also are shown in table 5 and are similar to the results for nonadjusted trends. This similarity is because of the weak relation between suspended-sediment concentration and streamflow for the monthly samples, as indicated by the previously described regression analyses.

Trend analyses also were done for streamflow at the four sediment stations. The trend tests for streamflow were done using the same procedures used for the trend tests in suspended-sediment concentrations. The only statistically significant trend in streamflow was indicated for the Big Muddy River at Murphysboro. This was a downward trend of –5.33 (ft^3/s)/yr, with an attained significance level of 0.0475. No significant relation between streamflow and suspended-sediment concentration was found at this station.

Suspended-Sediment Discharge

Sediment discharge is computed by multiplying the streamflow and the suspended-sediment concentration and converting to the desired units. Daily sediment discharges have been computed for the four sediment stations since daily suspended-sediment concentration data collection began in 1980. These data have been published in annual USGS water-data reports for Illinois, such as Coupe and others (1989). For this analysis, a data set of monthly sediment discharges was computed by multiplying the monthly suspended-sediment concentration data (collected by USGS personnel or computed from data collected by observers) by the corresponding instantaneous streamflow or mean daily streamflow, respectively. Time-series plots of sediment discharges at the four sediment stations for the 1975–92 water years are shown in figure 5.

Boxplots showing the distributions of sediment discharges at the four sediment stations for water years 1975–92 (water years 1979–92 for Kaskaskia River at Cooks Mills) are shown in figure 3. The largest median sediment discharge (3,260 ton/d) was for the Illinois River at Valley City. The smallest median sediment discharge (47.1 ton/d) was for the Kaskaskia River at Cooks Mills. The largest daily sediment discharge was 125,000 ton/d at Illinois River at Valley City, and the smallest daily sediment discharge was 0.10 ton/d for the Kaskaskia River at Cooks Mills. The drainage area for the Illinois River at Valley City is the largest of the four sediment stations (26,742 mi^2), whereas the smallest drainage area is for the Kaskaskia River at Cooks Mills (473 mi^2).

Table 5. Results of seasonal Kendall test for trends in suspended-sediment concentrations at four sediment stations in central and southern Illinois, 1975–92 water years

[(mg/L)/yr, milligrams per liter per year; shading indicates result with an attained significance level less than or equal to 0.10]

Station name and number (fig. 1)	Number of observations	Nonadjusted concentrations			Flow-adjusted concentrations		
		Direction of trend	Trend slope (mg/L)/yr	Attained significance level[1]	Direction of trend	Trend slope (mg/L)/yr	Attained significance level[1]
Illinois River at Valley City, Ill. (05586100)	195	downward	–5.50	0.0330	downward	–6.44	0.0127
Kaskaskia River at Cooks Mills, Ill. (05591200)	165	downward	–1.12	.2242	downward	–1.10	.1864
Kaskaskia River near Venedy Station, Ill. (05594100)	206	downward	–5.07	.0021	downward	–4.66	.0041
Big Muddy River at Murphysboro, Ill. (05599500)	208	downward	–2.40	.0382	downward	–2.33	.0423

[1]Trend-test results are not considered statistically significant if the attained significance level is greater than 0.10.

Sediment yields are calculated by dividing sediment discharges by the upstream drainage area. Typically, yields are expressed in tons per square mile per day. Sediment yields can be used to compare sediment-discharge characteristics among stations with drainage areas of different sizes. No consistent relation between sediment yields and drainage-area size was found for the four sediment stations. The median sediment yield for the Illinois River at Valley City, 0.12 (ton/mi^2)/d, was similar to the sediment yield for the Kaskaskia River at Cooks Mills, 0.10 (ton/mi^2)/d. These two stations have the largest and smallest drainage areas, respectively. The lowest median yield was for the Big Muddy River at Murphysboro, 0.03 (ton/mi^2)/d. At all four stations, the largest sediment yields corresponded to high-flow periods and represented sediment-transport characteristics during periods when most of the suspended sediment is transported. The highest sediment yield, 38.3 (ton/mi^2)/d, was determined for the Illinois River at Valley City, the sediment station with the largest drainage area. Sediment yields generally were largest for the Illinois River at Valley City, except for occasional high sediment yields associated with storm periods. The large sediment loads and yields for the Illinois River at Valley City indicate tributary streams with loads and yields larger than those measured at the other three sediment stations. Historical data from other USGS and Illinois State Water Survey sediment stations indicate that suspended-sediment concentrations, discharges, and yields are substantially larger for streams in the western part of Illinois, including several major tributaries to the Illinois River upstream from Valley City (Bonini and others, 1983).

Seasonality of sediment discharges at the four sediment stations also was examined. Boxplots of sediment discharges at the sediment stations during the four climatic seasons are shown in figure 4. Typically, there were statistically significant differences in sediment discharges between adjacent climatic seasons. In general, sediment discharges were largest in the spring and smallest in the fall and closely corresponded with the seasonal variation in streamflow.

The seasonal Kendall test for trends was used to determine trends in sediment discharges at the four sediment stations for the 1975–1992 water years. Statistically significant trends in sediment discharges were indicated for the Kaskaskia River at Cooks Mills and the Big Muddy River at Murphysboro (table 6). These trends were both downward and about 1 (ton/d)/yr. There were statistically significant downward trends in both suspended-sediment concentrations and streamflow (the factors composing sediment discharge) for the Big Muddy River at Murphysboro. Kaskaskia River at Cooks Mills, however, was the only sediment station for which no significant trend in suspended-sediment concentrations was found. A significant downward trend in streamflow, however, was indicated for this station.

Bar charts of annual mean streamflows, annual mean suspended-sediment concentrations, and annual mean suspended-sediment discharges at the four sediment stations for the 1980–92 water years are shown in figures 6–9. The annual mean values were computed from daily data for the 1980–92 water years. Although relations among streamflow, suspended-sediment concentrations, and sediment discharges vary among sediment stations and temporally for a given station, some general observations can be made. Sediment discharge typically increased substantially during a year with high streamflow, particularly when preceeded by a year or two of low streamflow. This observation was not unexpected. Sediment discharge often increased during a year in which the streamflow was higher than during the previous year, regardless of whether the mean annual streamflow was low or high for the particular station. A general tendency was for relatively small sediment discharges in years subsequent to a year with substantially high streamflow, even though there also may be relatively high streamflow in the subsequent year. This reduced sediment discharge likely results from resuspension and removal of sediment from the drainage basin and streambed during the initial year of high streamflow and a resultant lack of sediment source the second year. These effects were observed for the Kaskaskia River near Venedy Station (1980–84), the Big Muddy River at Murphysboro (1980–85 and 1988–91), and for the Kaskaskia River at Cooks Mills (1979–85). The specific and variable storms and conditions that have a large effect on suspended-sediment concentrations and sediment discharges are not accounted for in the annual mean statistics.

SUMMARY

The U.S. Geological Survey (USGS), in cooperation with the U.S. Army Corps of Engineers, St. Louis District, has operated four sediment stations on three streams in central and southern Illinois since

Table 6. Results of seasonal Kendall test for trends in suspended-sediment discharges and streamflow at four sediment stations in central and southern Illinois, 1975–92 water years

[ton/d)/yr, tons per day per year; (ft^3/s)/yr, cubic feet per second per year; shading indicates result with an attained signifcance level less than or equal to 0.10]

Station name and number (fig. 1)	Number of observations	Suspended-sediment discharge			Streamflow		
		Direction of trend	Trend slope (ton/d)/yr	Attained significance level	Direction of trend	Trend slope (ft^3/s)/yr	Attained significance level
Illinois River at Valley City, Ill. (05586100)	188	downward	−136	0.1828	downward	−211	0.2374
Kaskaskia River at Cooks Mills, Ill. (05591200)	144	downward	−1.12	.0517	downward	−2.25	.1728
Kaskaskia River near Venedy Station, Ill. (05594100)	183	downward	−8.54	.1781	downward	−12.2	.7169
Big Muddy River at Murphysboro, Ill. (05599500)	210	downward	−1.19	.0184	downward	−5.33	.0475

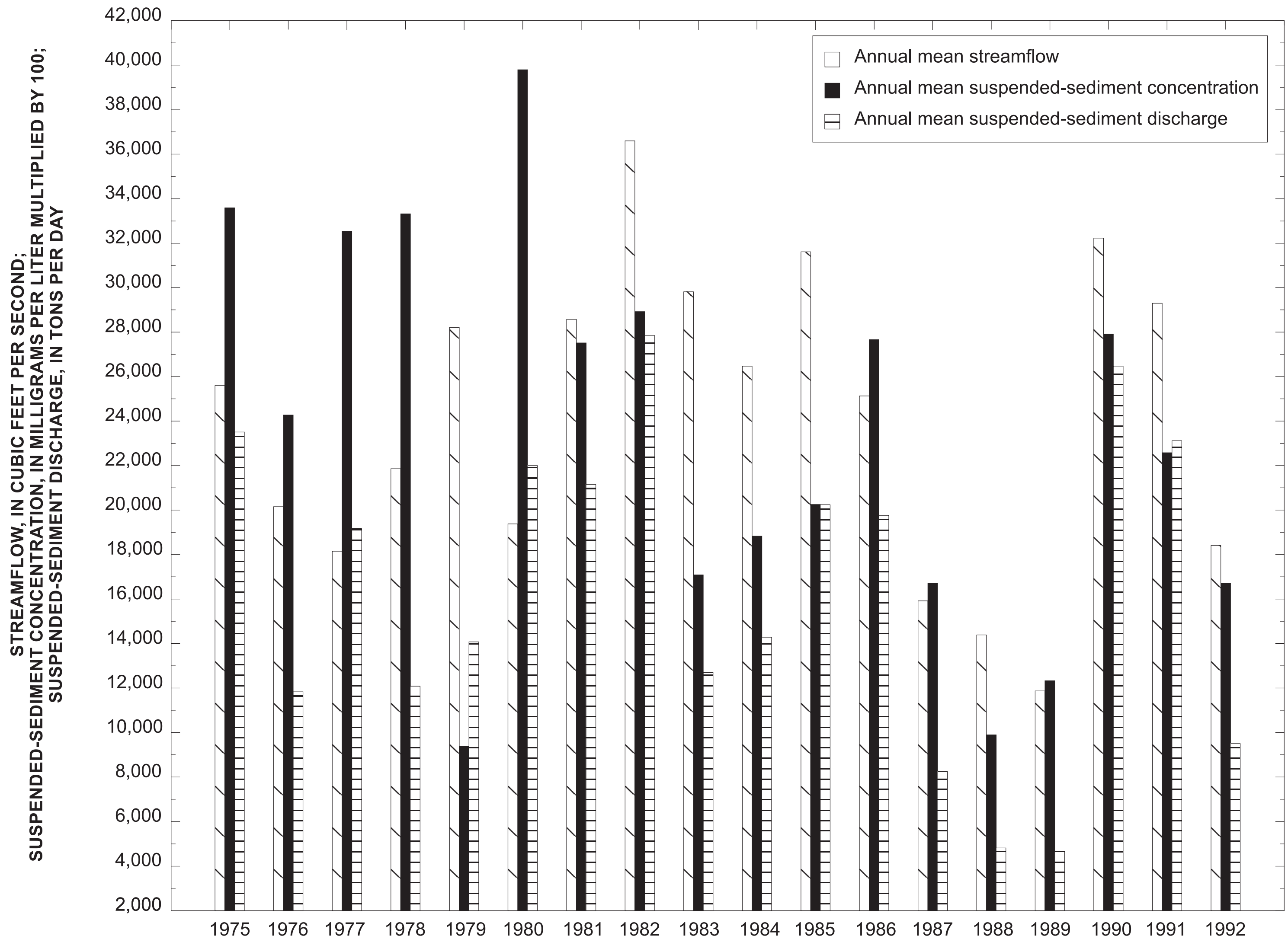

Figure 6. Annual mean streamflow, annual mean suspended-sediment concentration, and annual mean suspended-sediment discharge for Illinois River at Valley City, Illinois, 1975–92 water years.

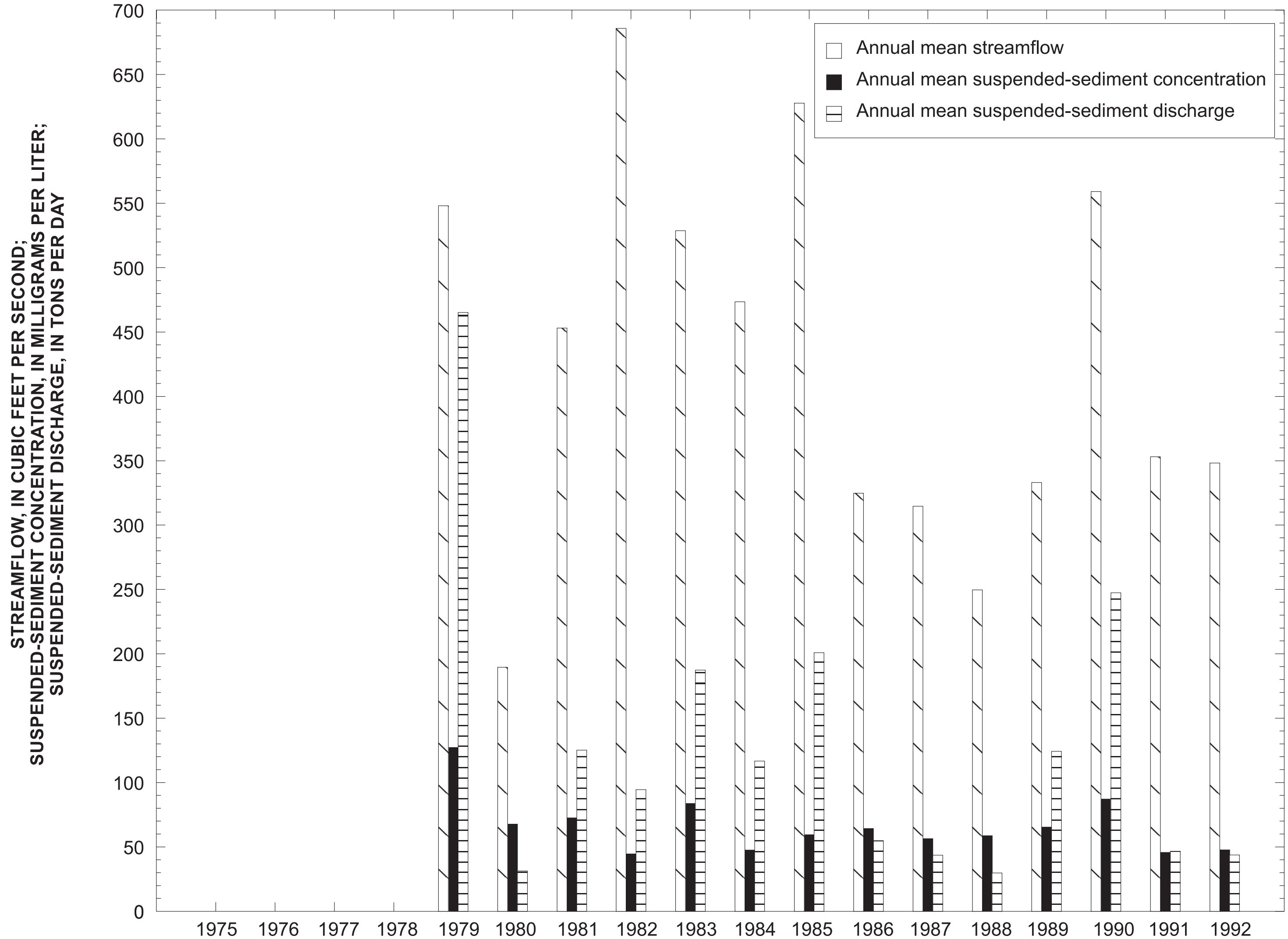

Figure 7. Annual mean streamflow, annual mean suspended-sediment concentration, and annual mean suspended-sediment discharge for Kaskaskia River at Cooks Mills, Illinois, 1979–92 water years.

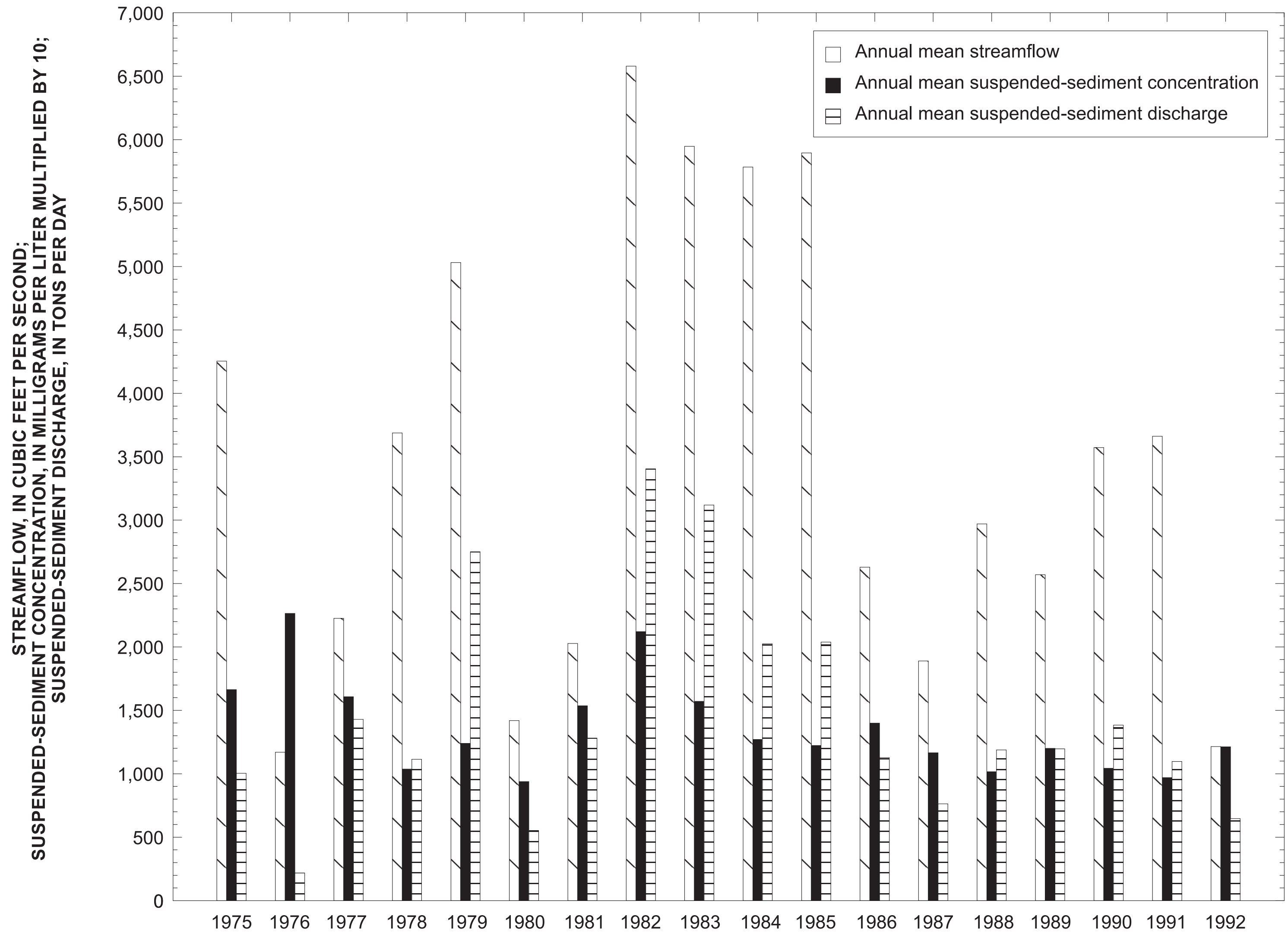

Figure 8. Annual mean streamflow, annual mean suspended-sediment concentration, and annual mean suspended-sediment discharge for Kaskakia River near Venedy Station, Illinois, 1975–92 water years.

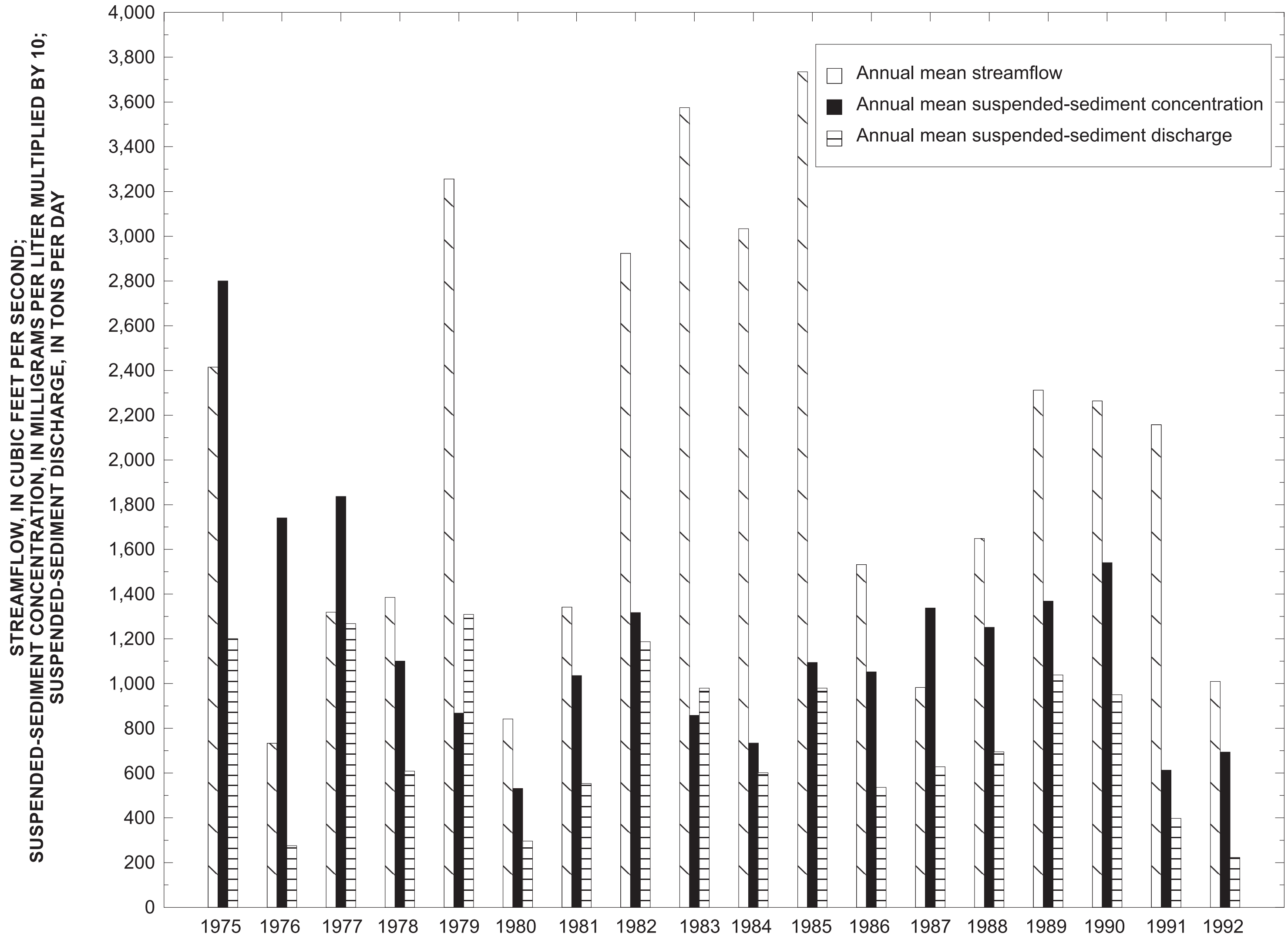

Figure 9. Annual mean streamflow, annual mean suspended-sediment concentration, and annual mean suspended-sediment discharge for Big Muddy River at Murphysboro, Illinois, 1975–92 water years.

May 1975—Illinois River at Valley City, Ill., Kaskaskia River at Cooks Mills, Ill., Kaskaskia River near Venedy Station, Ill., and Big Muddy River at Murphysboro, Ill. An analysis of the data from these sediment stations was done to determine increases or decreases in suspended-sediment concentrations or sediment discharges in the streams from May 1975 through September 1992.

Monthly suspended-sediment concentration and streamflow data were available for the four sediment stations from May 1975 through September 1992 (1979–92 for Kaskaskia River at Cooks Mills). Daily suspended-sediment concentration and streamflow data were available for the four sediment stations from February 1980 through September 1992 (1979–92 for Kaskaskia River at Cooks Mills). A comprehensive data set of monthly suspended-sediment concentrations and sediment discharges for the 1975–92 water years was compiled from monthly data collected by USGS personnel from 1975 through 1992 and from daily data either collected by observers or computed from daily data collected by observers from 1980 through 1992. Three laboratories were used to determine suspended-sediment concentrations in the water samples collected. After an analysis of the laboratory data, it was assumed that differences among the results from the three laboratories were negligible.

Median suspended-sediment concentrations at the four sediment stations ranged from 75 to 124 mg/L, which is typical for streams in Illinois. The highest median suspended-sediment concentration was from the Illinois River at Valley City, and the lowest median suspended-sediment concentration was from the Kaskaskia River at Cooks Mills. The highest single suspended-sediment concentration sampled (1,400 mg/L) also was from the Illinois River at Valley City. Generally, suspended-sediment concentrations were lowest from the Kaskaskia River at Cooks Mills, and suspended-sediment concentrations were highest from Illinois River at Valley City.

The suspended-sediment concentration data also were examined for seasonal variation. Suspended-sediment concentrations were typically highest in the spring and summer (March–August) and lowest in the fall and winter (September–February). Suspended-sediment concentrations were related to seasonal variations in streamflow.

The seasonal Kendall test was used to determine trends in suspended-sediment concentrations at the four sediment stations from May 1975 through September 1992. Regression equations of suspended-sediment concentrations and streamflow at the four sediment stations could not be utilized to explain the variation in suspended-sediment concentrations at the stations, so no adjustment of suspended-sediment concentrations for flow was done prior to the trend analyses. Statistically significant downward trends in suspended-sediment concentrations were identified at three of the stations—Illinois River at Valley City, Kaskaskia River near Venedy Station, and Big Muddy River at Murphysboro These downward trends ranged from 2.4 (mg/L)/yr for the Big Muddy River at Murphysboro to 5.5 (mg/L)/yr for the Illinois River at Valley City.

Analyses of sediment discharges at the four sediment stations for the 1975–92 water years (1979–92 for Kaskaskia River at Cooks Mills) indicated that the largest median sediment discharge (3,260 ton/d), was for the Illinois River at Valley City. The smallest median sediment discharge (47.1 ton/d) was for the Kaskaskia River at Cooks Mills. Median sediment yields were similar for the Illinois River at Valley City, 0.12 (ton/mi^2)/d, and for the Kaskaskia River at Cooks Mills, 0.10 (ton/mi^2)/d. The median yields at the other two sediment stations were smaller, 0.03 to 0.07 (ton/mi^2)/d.

Seasonality of sediment discharges also was examined for relations to climatic season. Sediment discharges were substantially larger during the spring and smaller during the fall. Seasonality of sediment discharges was somewhat similar to the seasonality for suspended-sediment concentrations and more directly related to the seasonality of streamflow.

The seasonal Kendall test also was used to determine trends in sediment discharges at the four sediment stations. Statistically significant downward trends in sediment discharge were determined only for the Kaskaskia River at Cooks Mills and the Big Muddy River at Murphysboro. These downward trends were each approximately 1 (ton/d)/yr.

Graphical analyses of the relations among streamflow, suspended-sediment concentrations, and sediment discharges at the four sediment stations indicate that sediment discharge often increased during a year in which the mean annual streamflow was higher than the previous year. This resulted regardless of whether the mean annual streamflow was considered low or high for the particular station. There also is a general tendency for relatively small sediment discharges in years subsequent to a year with substantially high streamflow, even though there also might be relatively high streamflow in the subsequent year.

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