SUSPENDED SEDIMENT IN THE ST. FRANCIS RIVEF AT ST. FRANCIS, ARKANSAS, 1986-95

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ABSTRACT

Daily suspended-sediment concentrations were analyzed from the St. Francis River at St. Francis, Arkansas during 1986 through 1995. Suspended-sediment particle size distribution was measured in selected samples from 1978 through 1998. These data are used to assess changes in suspended-sediment concentrations and loads through time. Suspended-sediment concentrations were positively related to discharge. At higher flows, percent silt-clay was negatively related to discharge. Nonparametric trend analysis (Mann-Kendall test) of suspended-sediment concentration over the period of record indicated a slight decrease in concentration. Flow-adjusted residuals of suspended-sediment concentration also decreased slightly through the same period. No change was identified in annual suspended-sediment load or annual flow-weighted concentration. Continued monitoring of daily-suspended-sediment concentrations at this site and others, and similar data analysis at other sites where data are available will provide a better understanding of sediment transport within the St. Francis River.

INTRODUCTION

The St. Francis River drains 8,416 square miles of primarily agricultural land in southeastern Missouri and northeastern Arkansas (fig. 1). Many of the stream channels within the St. Francis River Basin have been modified for flood control in support of agricultural purposes. The St. Francis River system, both naturally and as a result of channel modifications, typically transports large quantities of sediment. The U.S. Geological Survey (USGS) and U.S. Army Corps of Engineers (USACE) have monitored streamflow and sediment discharge in the St. Francis River Basin since 1969. Streamflow and suspended-sediment discharge are being monitored in the St. Francis River Basin to gather information for use in water-resource planning and management.

A study was conducted to assess changes in suspended-sediment concentrations and loads through time from samples collected in the St. Francis River at St. Francis, Arkansas (USGS station 07040100). Daily-suspended-sediment concentrations were evaluated for the 1986-95 period of record. Particle size distributions (percent of total suspended sediment consisting of silt and clay) were evaluated in selected samples for the 1978-98 period of record. All data were collected and analyzed by the USGS in cooperation with the USACE. Presented in this report are the results of the study.

APPROACH

Daily streamflow discharge was monitored at St. Francis River at St. Francis, Arkansas, following methods described by Rantz and others (1982). Daily suspended-sediment samples were collected using an automatic pumping sampler with the fixed-point intake located about 1 meter above the bottom at the deepest point in the stream cross section. Samples were collected about 12:00 noon on each day. Daily automatic samples were analyzed for suspended-sediment concentration following methods described by Guy (1969). Periodic (monthly and storm event) cross-sectional- and depth-integrated composite suspended-sediment samples were collected following equal width increment (EWI) methods described by Guy and Norman (1970) and Edwards and Glysson (1988). Instantaneous discharge also was measured for each EWI suspended-sediment sample collected. The periodic

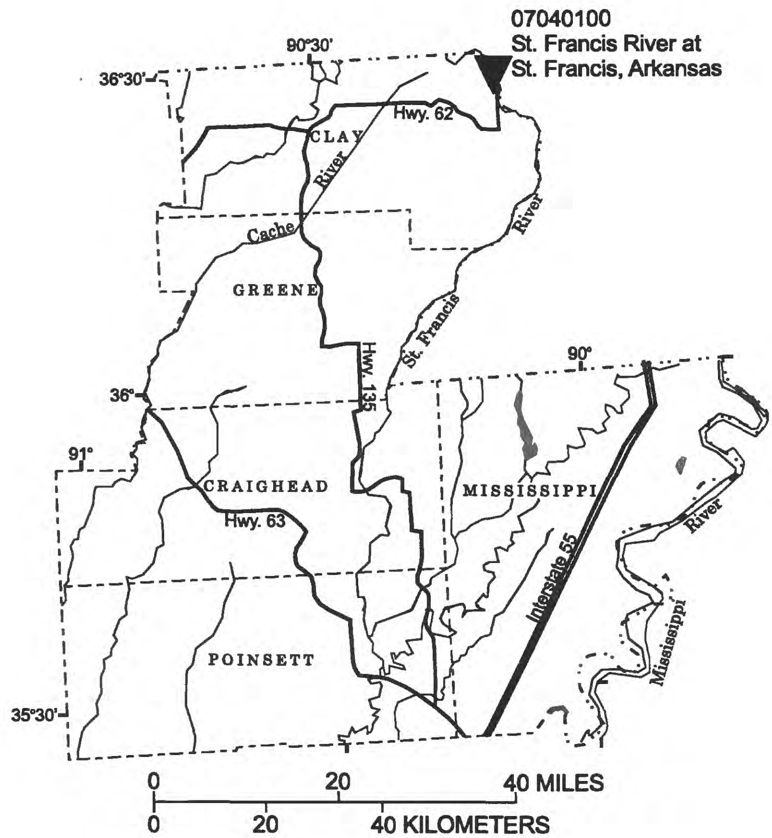

Figure 1. Location of study site showing daily suspended sediment station at St. Francis River at St. Francis, Arkansas.

EWI samples were analyzed for suspended-sediment concentration and particle size distribution following methods described by Guy (1969). Sediment discharge was estimated using box and coefficient methods described by Porterfield (1972) and Edwards and Glysson (1988). Daily suspended-sediment discharge (load) was tabulated and summed over the entire water year (October through September) to provide annual load.

Relations between discharge and concentration and discharge and percent silt-clay (by weight) were identified using a locally weighted scatterplot smoothing (LOWESS) technique described by Cleveland (1979). The LOWESS technique was used because of the nonlinearity of the relation between discharge and concentration. Temporal trend over the period of record for suspended-sediment concentrations were assessed using the nonparametric Mann-Kendall test described by Helsel and Hirsch (1992). The Mann-Kendall test determines whether the variable of interest (concentration or percent silt-clay) tends to increase or decrease with time (monotonic change). Observed suspended-sediment concentrations were adjusted for flow using residuals between observed concentration and estimated LOWESS concentration (observed value minus LOWESS value). Flow-adjusted residuals of concentration were plotted against time and temporal changes over the period of record were assessed using the Mann-Kendall trend test (Helsel and Hirsch, 1992). Annual suspended-sediment load (sum of daily loads) was divided by annual discharge (and converting units) to provide annual flow-weighted concentration. Changes in annual suspended-sediment load and flow-weighted concentration were assessed using the Mann-Kendall test (Helsel and Hirsch, 1992).

SUSPENDED-SEDIMENT CONCENTRATION AND LOAD

Relations of Suspended-Sediment Concentration and Percent Silt-Clay to Streamflow

A positive relation existed between suspended-sediment concentration and discharge (fig. 2A) whereas a negative relation existed between percent silt-clay and discharge (fig. 2B). Little change in suspended-sediment concentration occurred between 70 and about 400 cubic feet per second (ft^3/s). The rate increased slightly between about 400 and 3,000 ft^3/s. The rate of change was greatest in excess of about 3,000 ft^3/s, conditions whereby sand transport became significant (fig. 2B). Percent of total suspended-sediment consisting of silt and clay varied little with increasing discharge to about 3,000 ft^3/s. In excess of about 3,000 ft^3/s, percent silt-clay decreased with increasing discharge due to greater quantities of sand transport.

Temporal Distribution of Suspended-Sediment Concentrations

Temporal distribution of suspended-sediment concentrations (fig. 3) indicated a strong seasonal influence. Lowest concentrations occurred during late summer and early autumn months, highest in early spring, similar to streamflow variability. A slight decrease in concentration over the period of record (1986-95) was identified by the Mann-Kendall test (Kendall's Tau = -0.031, P = 0.005). Adjusting concentrations for variability that was explained by flow (flow-adjusted residuals from the LOWESS fit) and plotting residuals through time (fig. 4) showed a slight decrease in flow-adjusted suspended-sediment concentration (Kendall's Tau = -0.081, P = <0.0001).

Suspended-Sediment Load

Total annual suspended-sediment loads were estimated by summing daily loads within the given water year (table 1). Total annual load varied year to year through the period of record (fig. 5). Annual discharge also varied over the same time period suggesting that the higher load was a result of discharge. The Mann-Kendall test for trend indicated that no trend (Kendall's Tau = 0.156, P = 0.531) in annual load occurred over the period of record (1986-95). To better assess change in annual load over time, annual load was divided by annual discharge to give annual flow-weighted suspended-sediment concentration (fig. 6, table 1). Flow-weighted suspended-sediment concentration varied over the period of record and no significant trend was identified (Kendall's Tau = -0.289, P = 0.245).

Table 1. Suspended-sediment annual load and annual flow-weighted mean concentration at St. Francis River at St. Francis, Arkansas, 1986-95

Water year	Annual mean discharge (cubic feet per second)	Annual load (tons)	Annual flow-weighted concentration (milligrams per liter)
1986	2,183	683,672	317
1987	871	251,395	292
1988	1,707	689,482	410
1989	2,525	1,002,509	403
1990	2,194	742,462	343
1991	2,736	946,022	350
1992	1,645	510,692	315
1993	2,479	713,728	292
1994	3,070	985,168	325
1995	2,199	671,775	310

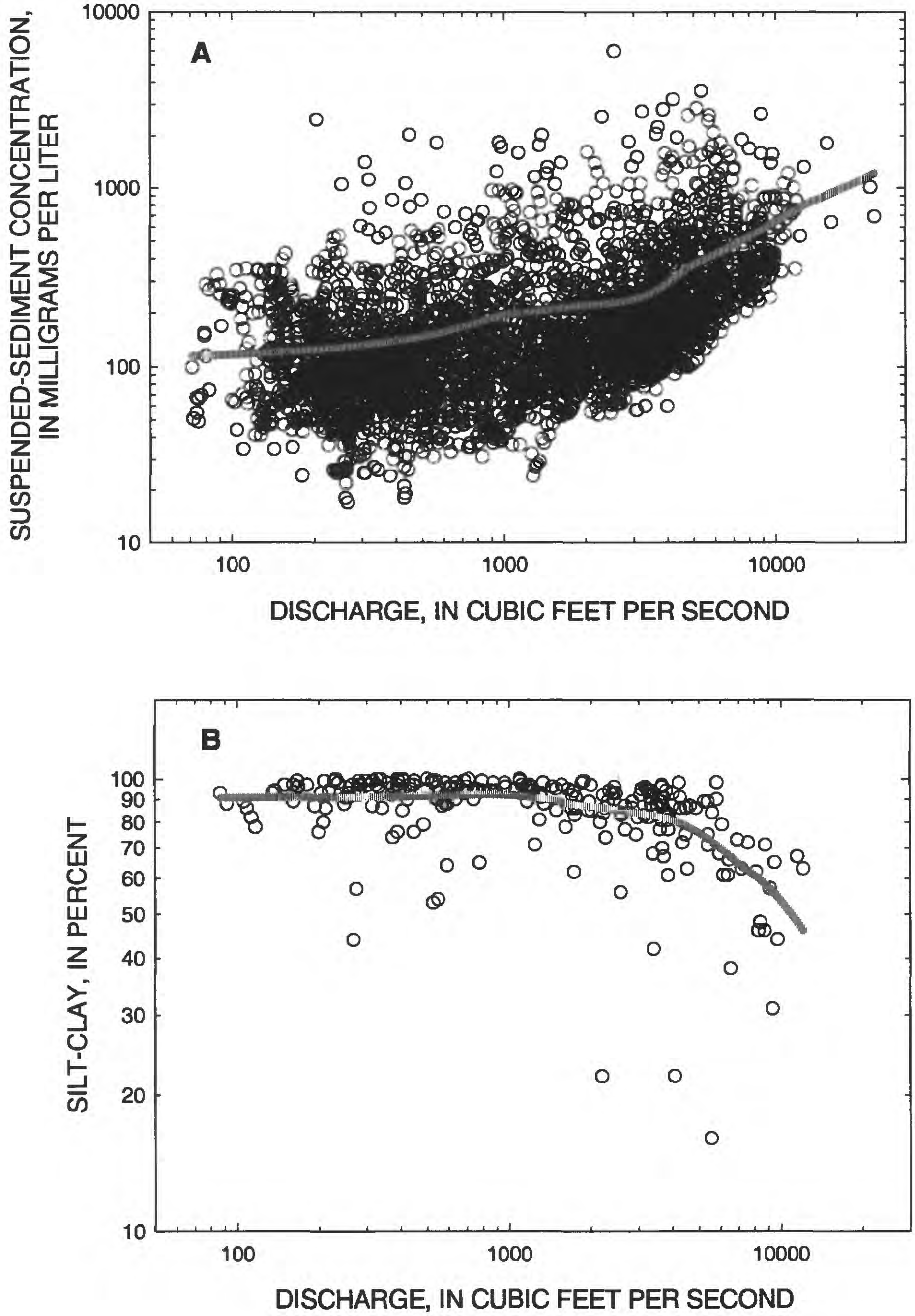

Figure 2. Relations between (A) streamflow and suspended-sediment concentration, 1986-95, and (B) streamflow and percent silt-clay, 1978-98, at St. Francis River at St. Francis, Arkansas. The solid line is the LOWESS smooth fit.

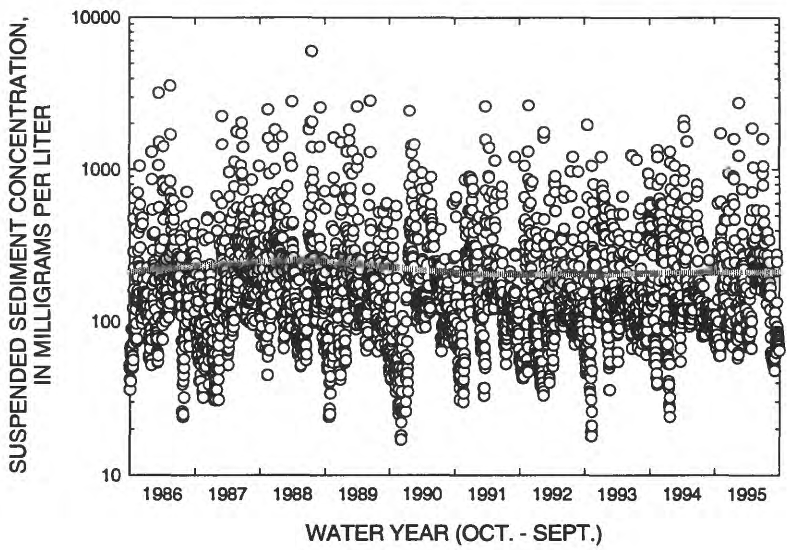

Figure 3. Suspended-sediment concentration time series at St. Francis River at St. Francis, Arkansas, 1986-95. The solid line is the LOWESS fit.

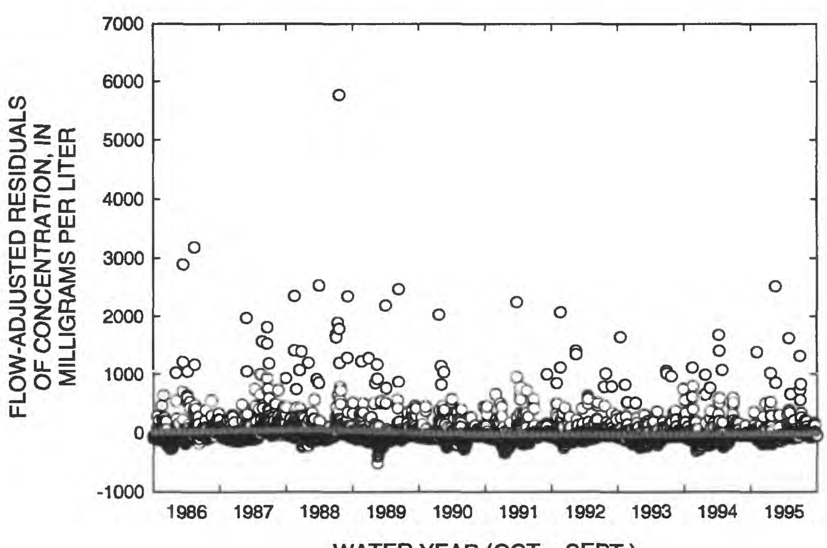

Figure 4. Flow-adjusted residuals of suspended-sediment concentration time series at St. Francis River at St. Francis, Arkansas, 1986-95. The solid line is the LOWESS fit.

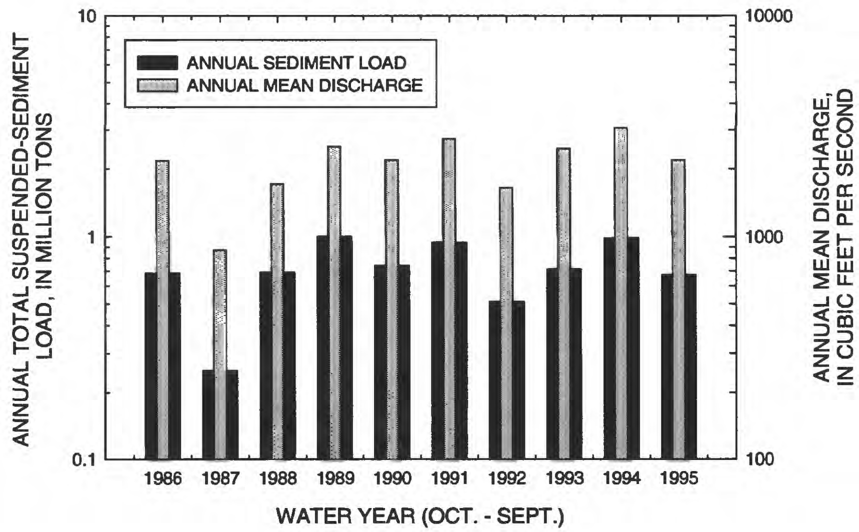

Figure 5. Annual suspended-sediment load and annual mean discharge at St. Francis River at St. Francis, Arkansas, 1986-95.

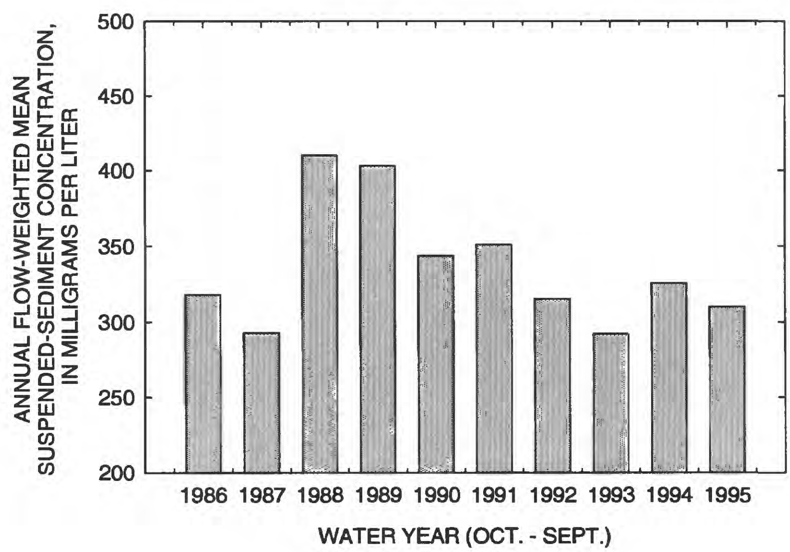

Figure 6. Annual flow weighted mean suspended-sediment concentration at St. Francis River at St. Francis, Arkansas, 1986-95.

Mass curves (accumulated mass plotted against time) and double-mass curves (accumulated mass plotted against another accumulated mass) are often used to help recognize changes in flow rates (mass accumulation). These methods can be problematic for sediment loads because disportionate amounts of sediment can be moved over a few days of very large discharge. Nonetheless, mass and double-mass curves can be useful if one ignores minor fluctuations and instead concentrates on overall rates of accumulation. Slight variations occurred in mass accumulation of suspended sediment as related to accumulated discharge (fig. 7).

Accumulation of suspended sediment appeared to fluctuate seasonally through the period of record (fig. 8). Little accumulation generally occurred during the late summer and early autumn months when both water discharge and sediment concentrations tend to be lower. More rapid accumulation occurred during winter and spring months. Results indicated that mass accumulation was less during water year 1987 than in other years. Low mass accumulation resulted from periods of low flow. The largest sediment discharges are known to be associated with large floods, and 1987 produced few flood days. Mass accumulation was greatest during water years 1989, 1994, and 1991.

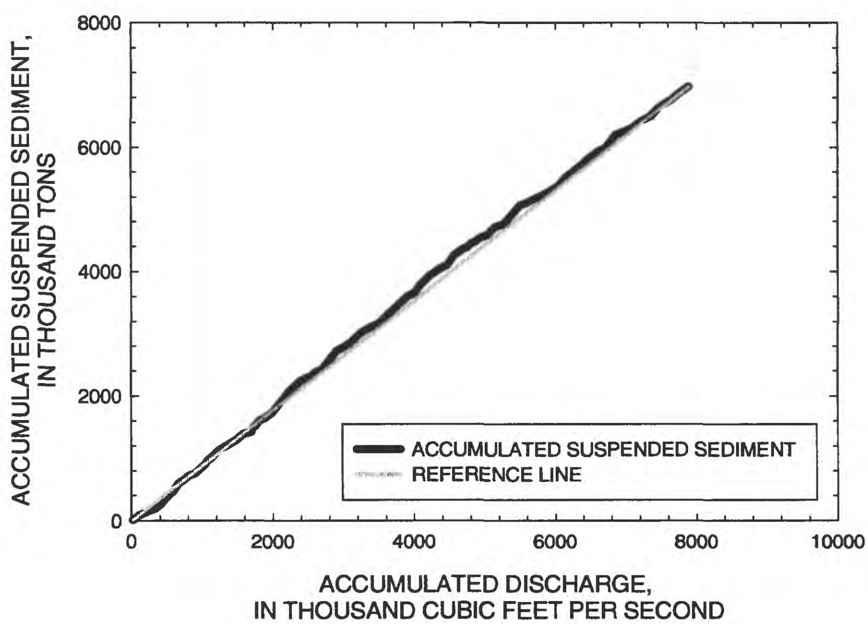

Figure 7. Double-mass curve of daily suspended-sediment and discharge at St. Francis River at St. Francis, Arkansas, 1986-95.

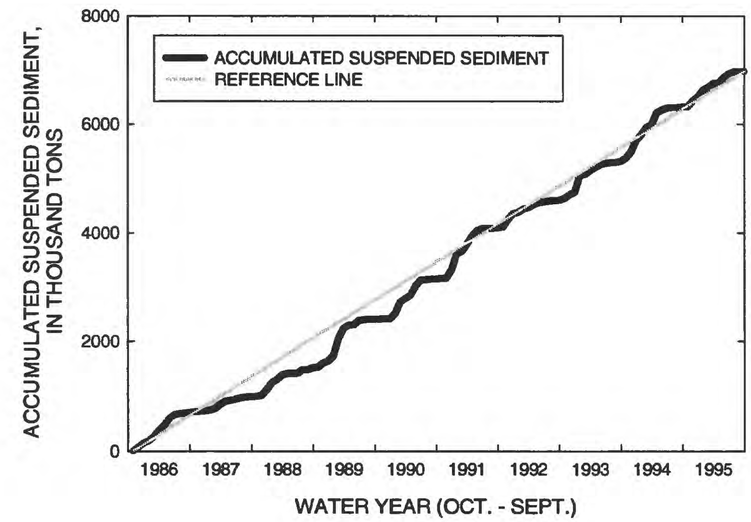

Figure 8. Mass curve of suspended sediment at St. Francis River at St. Francis, Arkansas, 1986-95.

SUMMARY AND CONCLUSIONS

Suspended-sediment concentrations at St. Francis River at St. Francis, Arkansas, 1986-95 were influenced by discharge; lowest concentrations typically occurred during late summer and early autumn months when discharge was lowest, highest during early spring when discharge was greatest. Nonparametric trend analysis identified a slight decrease through time in suspended-sediment concentration. Flow-adjusted residuals of suspended-sediment concentration also decreased slightly over the period of record. Annual suspended-sediment load varied year to year. No trends were identified for annual suspended-sediment load or annual flow-weighted suspended-sediment concentration.

Continued monitoring of daily suspended-sediment concentration and load and particle size distribution will allow verification or rejection of forecasted suspended-sediment concentrations and loads. Water year 1996 was an extremely dry year. Data are not available for daily suspended-sediment concentration or load during this year. If daily data were available for the 1996 water year, it would be expected that the annual load would be much less than in previous years. Changes in landscape within the St. Francis River Basin also might influence sediment concentrations and percent silt-clay affecting the overall variability in these parameters. These data are important to provide a more complete evaluation of suspended-sediment concentration and particle size distribution in the St. Francis River at St. Francis, Arkansas.

The suspended-sediment analyses provided in this report apply only to St. Francis River at St. Francis, Arkansas, and results are not transferable to other sites. Differences in geomorphology, basin characteristics, and regulated and nonregulated flow obstructions all affect sediment size concentration, load, and transport. Further analyses conducted independently at other daily sediment monitoring sites will yield results specific to the respective sites. Analysis of all sites where daily sediment data are available will provide a better understanding of sediment transport within the St. Francis River Basin.

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