Changes in High-Flow Frequency and Channel Geometry of the Neosho River Downstream From John Redmond Dam, Southeastern Kansas

By SETH E. STUDLEY

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
foot per year (ft/yr)	0.3048	meter per year
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Water year: A water year is a 12-month period, from October 1 through September 30, designated by the calendar year in which it ends. Years are water years in this report unless otherwise stated.

Changes in High-Flow Frequency and Channel Geometry of the Neosho River Downstream From John Redmond Dam, Southeastern Kansas

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Abstract

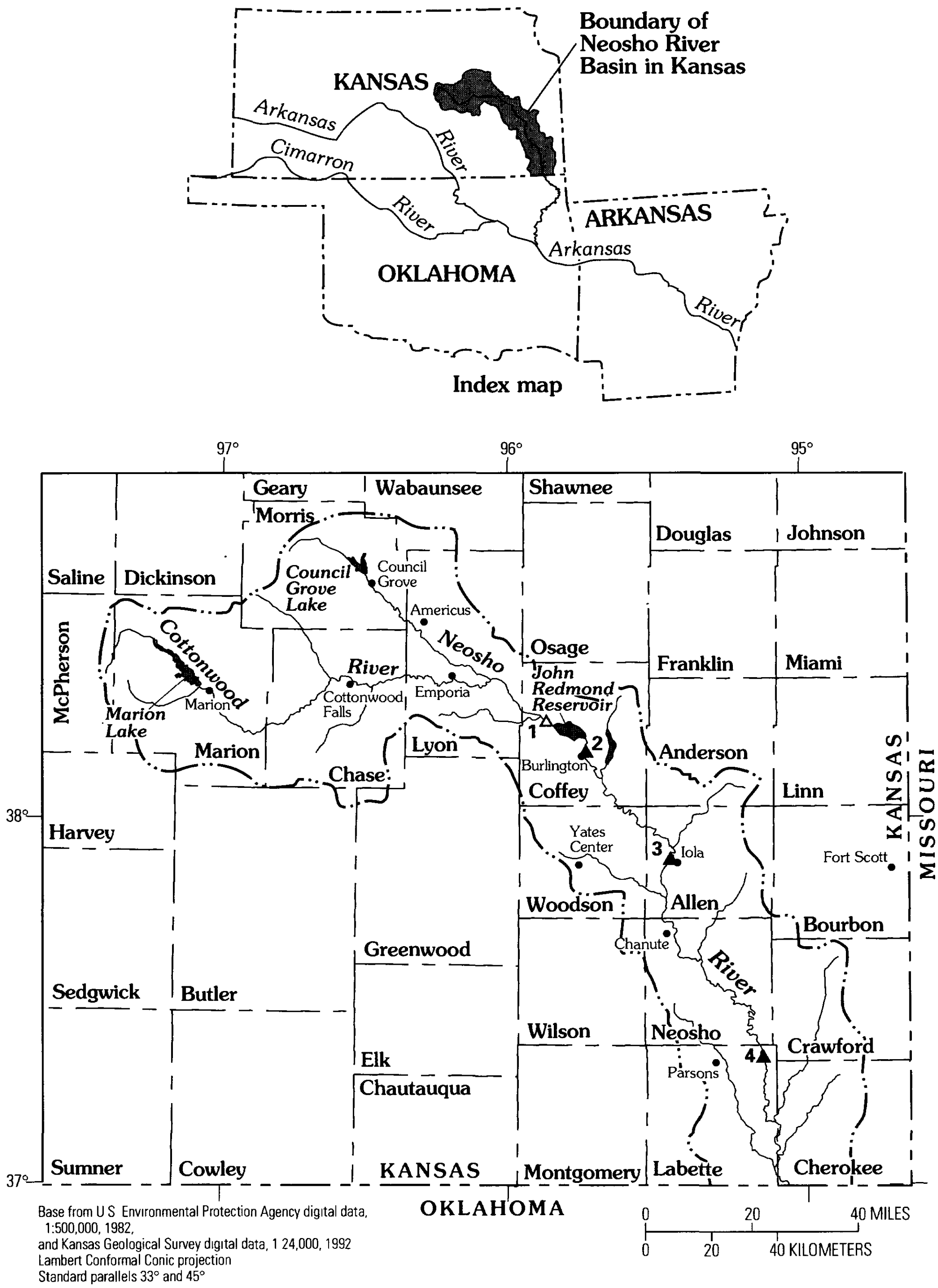
The streamflow regimen of the Neosho River downstream from John Redmond Dam in southeastern Kansas has changed significantly since the dam's completion in 1964. The controlled releases from the dam have decreased the magnitudes of peak discharges and increased the magnitudes of low discharges. The trends in river stage for selected discharges also have changed at two of the streamflow-gaging stations—those closest to the dam. There is a significant downward trend in the stages associated with the median annual peak discharges, but no significant trend in the stages associated with the annual mean discharges, which indicates that the river channel is increasing in width but not depth or that the flow velocity has increased at the streamflow-gaging stations. Because there were no significant trends present in precipitation, mean annual discharge, or annual peak discharge, the changes are attributed to John Redmond Dam.

INTRODUCTION

The Neosho River in southeastern Kansas flooded 57 times in the 34-year period prior to 1964 (Department of the Army, Tulsa District Corps of Engineers, 1984), which resulted in numerous requests from the public to the U.S. Army Corps of Engineers for flood protection. The response to these requests was to build three flood-control dams in the Neosho River Basin (fig. 1). The effect of one of the dams, John Redmond Dam (completed September 1964), on high-flow frequency and channel geometry of the Neosho River was the focus of a 1-year study (1995) conducted by the U.S. Geological Survey (USGS) in cooperation with the Kansas Water Office (KWO) and supported in part by the Kansas State Water Plan Fund. Results will contribute to improve understanding of the effects of dams on streams.

The purpose of this report is to describe changes in high-flow frequency and channel geometry of the Neosho River after the construction of John Redmond Dam. The scope of this report includes the analysis of high-flow frequency and stage-discharge relation changes at USGS streamflow-gaging stations downstream from John Redmond Dam and a comparison of the results of analyses based on data collected before and after completion of the dam.

The data used to determine high-flow frequencies and channel geometry were obtained from three currently operating USGS streamflow-gaging stations downstream from John Redmond Dam. In addition to these three stations, a discontinued station, which was located at Strawn, Kansas (07182400), was included to further analyze the high-flow frequency close to the dam. The discharge at the Strawn gage (operated from 1949 to 1963) should be comparable to what would have been recorded at the Burlington gage site if there would have been a gaging station at that site during that time period. The most current data were used whenever possible. The most current data are available for high-flow frequencies through the 1993 water year and for channel-geometry changes through the 1994 water year. Table 1 lists the four stations, their distance downstream from John Redmond Dam, drainage area, and period of record. The location of the streamflow-gaging stations is shown in figure 1.



EXPLANATION

—·—·— Boundary of Neosho River Basin

2▲ Current U.S. Geological Survey streamflow-gaging station—Map number used in table 1

1△ Discontinued U.S. Geological Survey streamflow-gaging station—Map number used in table 1

Figure 1. Location of Neosho River Basin in Kansas and streamflow-gaging stations used for analysis in this study.

Table 1. U.S. Geological Survey (USGS) streamflow-gaging stations used in this study
[mi, miles; mi^2, square miles; --, not applicable]

Map number (fig. 1)	USGS station number	USGS station name	Distance downstream from John Redmond Dam (mi)	Drainage area (mi^2)	Period of record (water years)
1	07182400	Neosho River at Strawn, KS	--	3,015	1949–63
2	07182510	Neosho River at Burlington, KS	5.3	3,042	1963–93
3	07183000	Neosho River near Iola, KS	56.3	3,818	1918–93
4	07183500	Neosho River near Parsons, KS	139.6	4,905	1922–93

A detailed description of the study area can be found in the Kansas Water Resource Board's Water Plan Study for the Neosho River Basin (Kansas Water Resources Board, 1961). The water plan study includes information on geology and soils as well as average annual precipitation and land use.

HIGH-FLOW FREQUENCY

High-flow frequency curves are used to estimate the exceedance probability of selected discharges. The median (50-percent exceedance-probability) discharge and the standard deviation of the fitted distribution curve help to describe the characteristics of the streamflow. In this study, comparisons of two curves, one using data prior to closure of John Redmond Dam and one using data after dam closure, are made using the discharge magnitudes of the 2-, 50-, and 95-percent exceedance probabilities as well as the standard deviation of each curve. Also, for this part of the report, the high-flow frequency curve for Strawn is illustrated and compared with data from the Burlington gaging station (map number 2, fig. 1) because of their close proximity and because the streamflow-gaging station at Burlington was not installed until 1963.

The high-flow frequency curves developed for the Neosho River downstream from John Redmond Dam illustrate how the discharge characteristics have changed since the dam was completed in September 1964. High-flow frequencies for 7-day and 30-day high-flow discharges at the stations downstream from the dam for the period up to and including 1963 and the period 1965 through 1993 are shown in figures 2-4. The differences for all the stations are summarized in tables 2-4. Since the closure of the dam, the discharge magnitudes associated with the upper end of the curves (lower exceedance probabilities) have been reduced, whereas those associated with the lower end of the curves (higher exceedance probabilities) have been increased. The magnitudes of the differences in the frequencies appear to be dependent upon the distance downstream from the dam. The differences are very large at Burlington, which is 5.3 mi downstream from the dam; they are much smaller at Parsons, which is about 140 mi downstream. This probably is due to a larger part of the drainage area being unregulated as the distance from the dam increases (approximately 27 mi^2 at Burlington and 1,863 mi^2 at Parsons). Also, the standard deviations of the logs of the 7-day and 30-day data are greatly reduced for the post-dam period. This is attributed to the regulation of releases through the dam.

Flow-duration curves for the periods before and after the construction of John Redmond Dam are shown in figure 5. For specified durations, the high-flow discharges have decreased subsequent to dam construction, and the medium- to low-flow discharges have increased. The discharges rarely, if ever, become as low as they did prior to completion of the dam because, although the primary purpose for the dam is flood control, it also is used to regulate low flow for the purpose of maintaining water quality in the Neosho River.

CHANNEL GEOMETRY

Reservoir release operations are known to produce channel changes downstream from a dam (Williams and Wolman, 1984). Other variables such as precipitation and streamflow also can cause changes in the river channel. These variables, known as driving or forcing variables, were tested for trend along with the response variable, stage. Changes with time in the stage-discharge relation can be used to infer channel changes in the immediate vicinity of the streamflow-

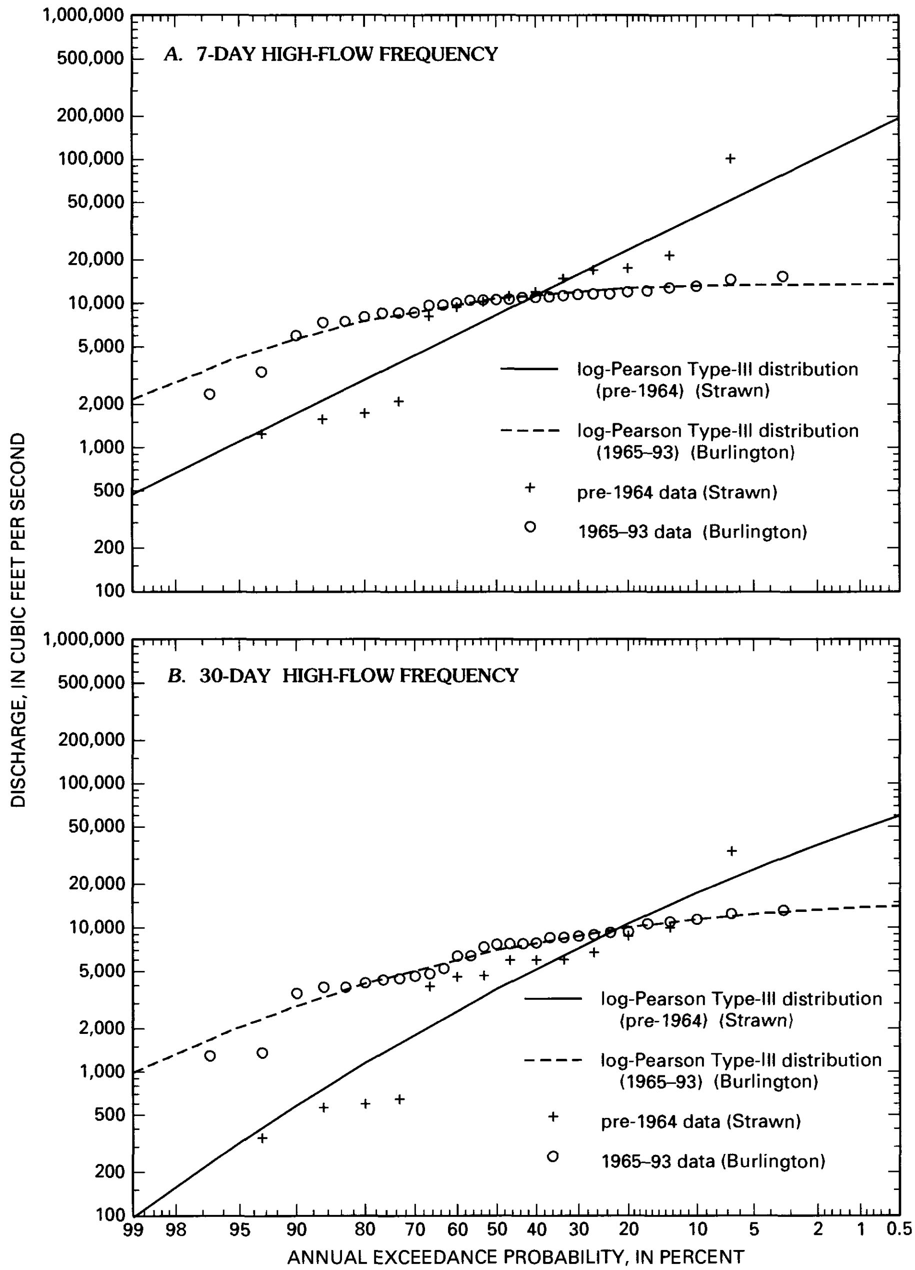


Figure 2. (*A*) 7-day and (*B*) 30-day high-flow frequency curves for the Neosho River at Strawn, Kansas (07182400), prior to completion of John Redmond Dam, and for Neosho River at Burlington, Kansas (07182510), after completion of John Redmond Dam.

gaging station (Wahl and Weiss, 1995). These variables were analyzed for the period up to the end of the 1963 water year and also for the period from 1965 through 1993, which coincide with the periods before and after completion of John Redmond Dam. The forcing variables considered in this study are described below:

Precipitation data are the annual averages and were obtained from the National Weather Service for Kansas climatic regions 6 and 9. These two regions cover most of the Neosho River Basin in southeast Kansas. The results of the trend test would indicate whether or not a climatic change occurred in the study area during the period of interest.

Annual mean discharge is the yearly average of the daily mean discharges for each station. The trend-test results are expected to show any systematic

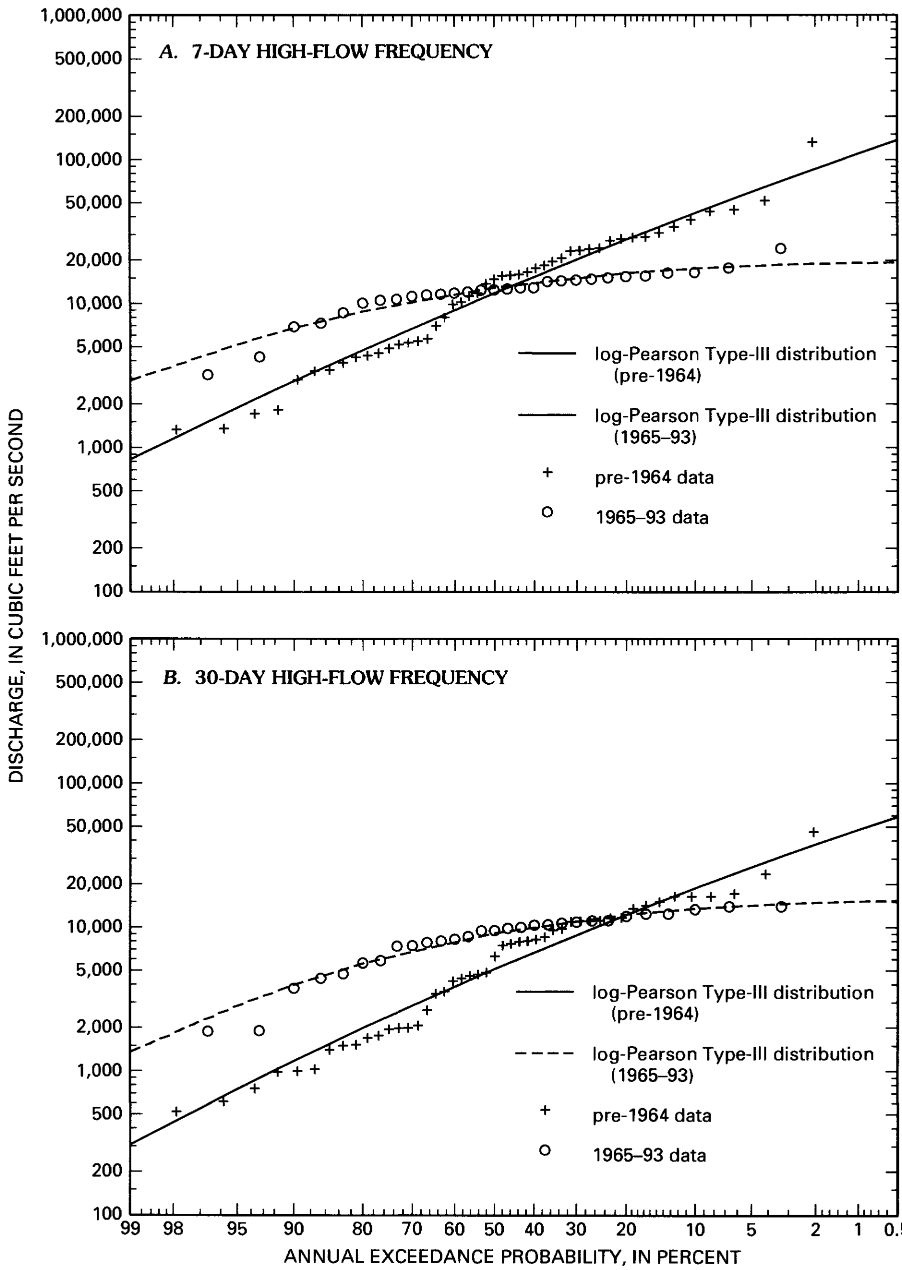


Figure 3. (*A*) 7-day and (*B*) 30-day high-flow frequency curves for Neosho River near Iola, Kansas (0718300).

departures from normal discharges, which could cause channel changes.

Annual peak discharge is the maximum instantaneous discharge for a given year. Changes in the magnitude of annual peaks can have an effect on the geometry and stability of the channel.

These forcing variables, except for precipitation, were only tested to determine if there are other systematic factors, in addition to the regulation effect of the dam, that may be affecting the response of the system. Precipitation was tested to determine any climatic trends.

The response variable tested for trend is the stream stage at selected discharge magnitudes. Two discharge magnitudes were selected. The annual mean discharge, or the average discharge for the period of record, was used because generally it reflects moderate to low discharges. The median annual peak discharge was used because it generally is about the same magni-

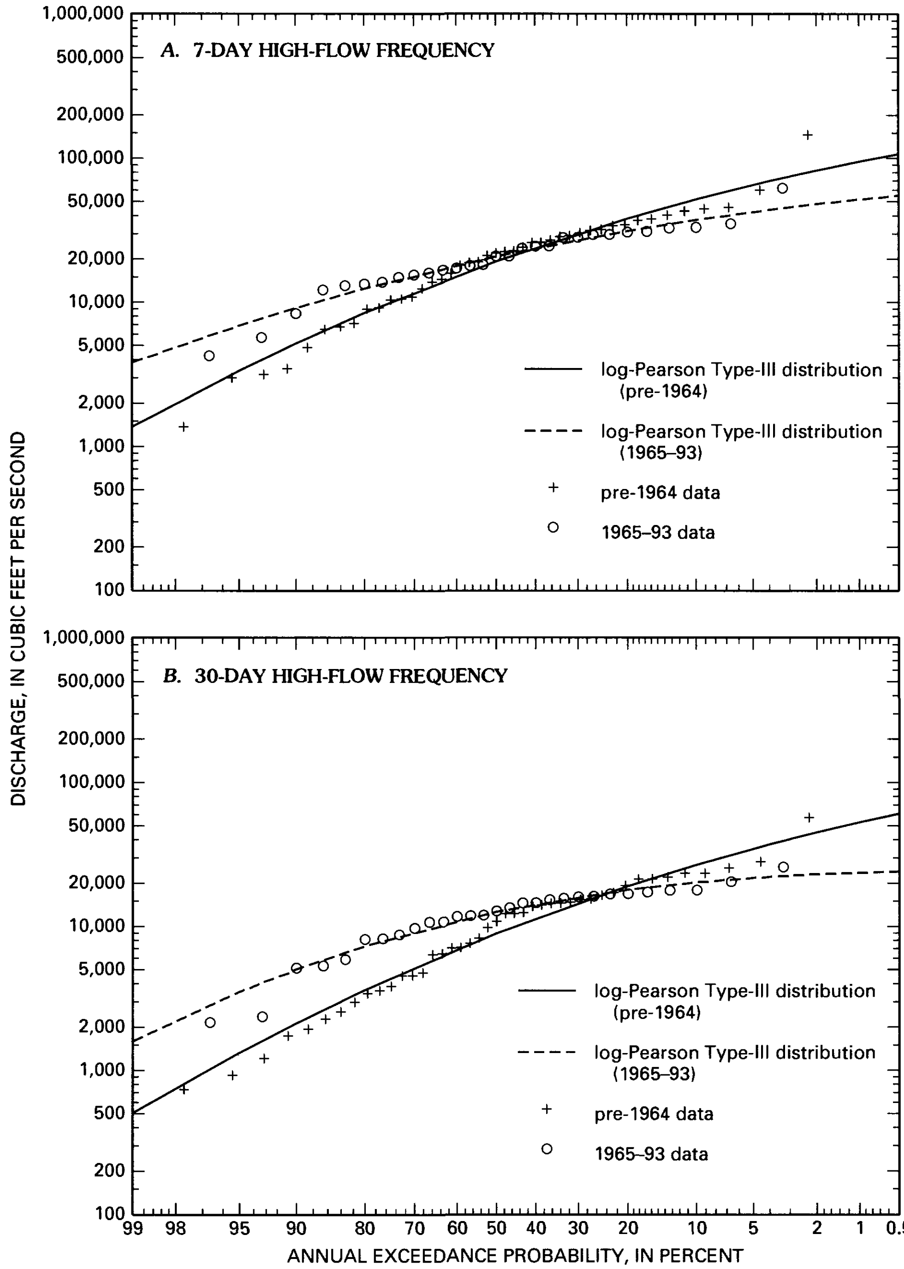


Figure 4. (*A*) 7-day and (*B*) 30-day high-flow frequency curves for Neosho River near Parsons, Kansas (07183500).

tude as the 2-year flood recurrence interval and because it generally reflects high to moderate discharges.

The stage-discharge relation tables throughout the period of record for each station were used to determine the stream stage (height of water surface above a datum) of each of the selected discharges. The time variable associated with each stage is the year, month, and day in which the stage-discharge relation was put into effect; therefore, there is not a separate stage associated with each year but only a stage associated with each stage-discharge relation.

The test used to determine the presence of trends commonly is referred to as Kendall's tau trend test (Kendall, 1938; 1975). It is a nonparametric test that, in application, tests the null hypothesis that the data are random observations that are identically distributed and not time dependent; no assumption is made about the identity or form of the underlying distribution.

Table 2. Pre- and post-dam comparisons of high-flow frequency estimates for the Neosho River at Strawn (07182400) and at Burlington, Kansas (07182510)

Exceedance probability (percent)	Discharge, in cubic feet per second					
	7-day high flow			30-day high flow		
	Pre-dam (Strawn)	Post-dam (Burlington)	Percentage differences	Pre-dam (Strawn)	Post-dam (Burlington)	Percentage differences
2.0	102,377	13,501	-87	37,491	13,266	-65
50.0	8,306	10,813	+30	3,768	7,005	+86
95.0	1,099	4,266	+288	321	2,064	+540
Standard deviation of logs	.533	.173	-68	.580	.249	-57

Table 3. Pre- and post-dam comparisons of high-flow frequency estimates for the Neosho River near Iola, Kansas (007183000)

Exceedance probability (percent)	Discharge, in cubic feet per second					
	7-day high flow			30-day high flow		
	Pre-dam	Post-dam	Percentage differences	Pre-dam	Post-dam	Percentage differences
2.0	86,400	18,700	-78	37,800	14,700	-61
50.0	11,800	13,000	+10	5,130	9,070	+77
95.0	1,890	5,290	+180	746	2,890	+287
Standard deviation of logs	.456	.176	-61	.472	.225	-52

Table 4. Pre- and post-dam comparisons of high-flow frequency estimates for the Neosho River near Parsons, Kansas (07183500)

Exceedance probability (percent)	Discharge, in cubic feet per second					
	7-day high flow			30-day high flow		
	Pre-dam	Post-dam	Percentage differences	Pre-dam	Post-dam	Percentage differences
2.0	82,441	47,531	-42	45,182	22,598	-50
50.0	19,201	20,635	+7	8,926	12,684	+42
95.0	3,351	6,988	+108	1,329	3,590	+170
Standard deviation of logs	.397	.241	-39	.436	.251	-42

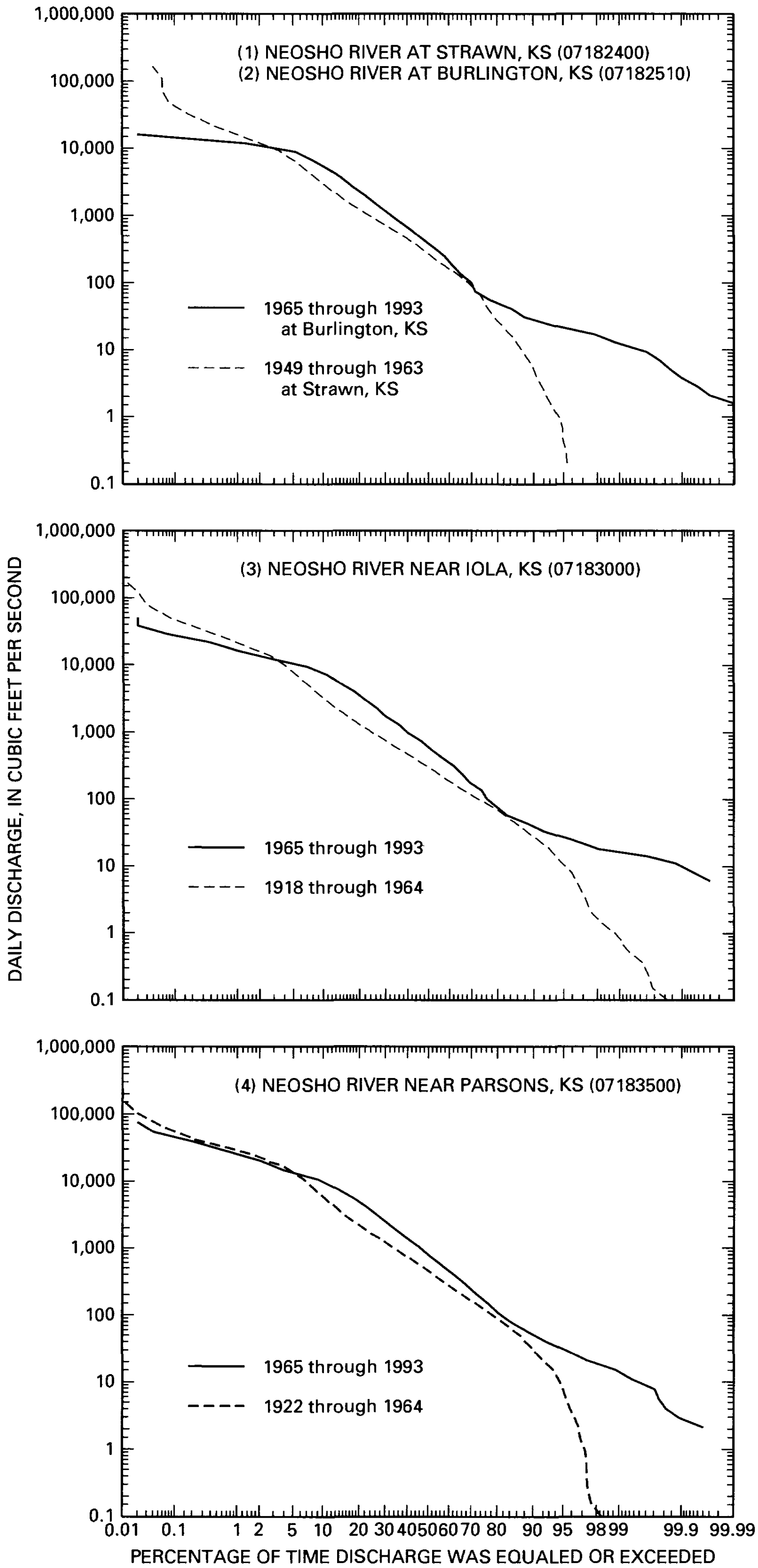
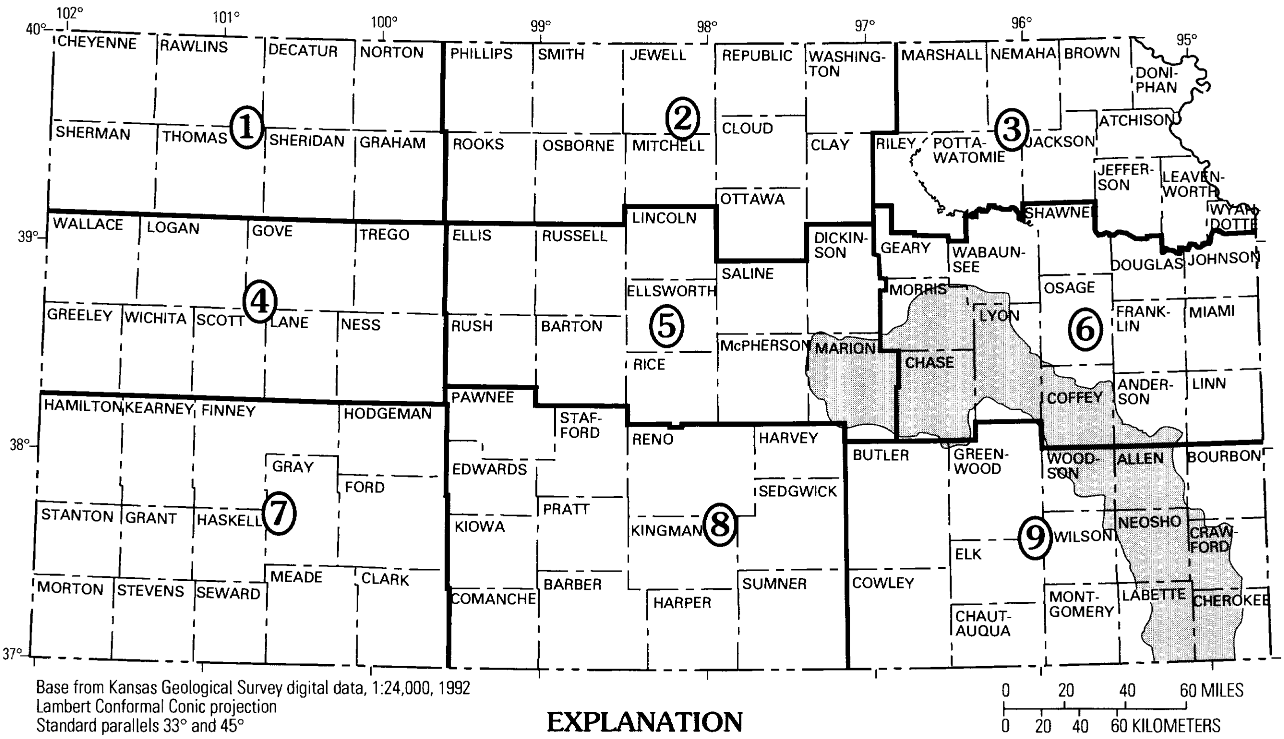


Figure 5. Flow-duration curves for U.S. Geological Survey streamflow-gaging stations downstream from John Redmond Dam. Location of stations shown in figure 1.



Base from Kansas Geological Survey digital data, 1:24,000, 1992
Lambert Conformal Conic projection
Standard parallels 33° and 45°

EXPLANATION

Neosho River Basin in Kansas

Boundary of climatic regions:

(1) Northwest	(6) East central
(2) North central	(7) Southwest
(3) Northeast	(8) South central
(4) West central	(9) Southeast
(5) Central	

Figure 6. National Weather Service climatic regions for Kansas.

Under the null hypothesis, tau values significantly different from zero are not expected, and their occurrence casts doubt on the truth of the null hypothesis. The test consists of comparing the observed value of tau for the sample with a critical value from the theoretical distribution for tau. If the absolute value of tau for the sample is greater than the critical value, the null hypothesis is rejected; that is, the observed value of tau is too great to have been obtained plausibly by random sampling from a single distribution without time trends. If the observed absolute value of tau does not exceed the critical value, the sample does not provide a basis for rejecting the null hypothesis.

The probability that tau will exceed the critical value when the null hypothesis is true is called the significance level (alpha) of the test; thus, the significance level is the probability of erroneously rejecting a true null hypothesis. High significance is associated with small values of alpha. In this study, an alpha value of 0.01 was used, representing a 1-percent probability of erroneously rejecting the null hypothesis. The attained significance level for a particular test, or p value, indicates the strength of the test result when compared with the alpha value.

Results from the trend tests on the forcing variables are summarized in table 5. Forcing-variable data are graphically illustrated in figures 7-9. No apparent trend was present in any of the variables tested. The tau values were below the critical value, and the p values were all larger than the alpha value, which indicates that there is no evidence to reject the null hypothesis. These results indicate no climatological change causing changes in the stage-discharge relations at the streamflow-gaging stations investigated in this report.

The results of the trend tests on the stage data are summarized in table 6, and plots of the stage data are presented in figure 10. There was little or no trend in the stages associated with the mean annual discharges

Table 5. Trend analysis of forcing variables tested in the Neosho River Basin downstream from John Redmond Dam
[precipitation data from the National Weather Service]

Variable tested	Period (water years)	Number of years in test	tau	p value
Annual precipitation				
Climatic region 6, east-central Kansas	1895–1994	100	+0.04	0.51
Climatic region 9, southeast Kansas	1895–1994	100	+.11	.10
Annual mean discharge				
at Burlington, Kansas (07182510)				
Post-dam	1965–93	28	-.08	.55
near Iola, Kansas (07183000)				
Pre-dam	1918–64	54	+.07	.42
Post dam	1965–93	29	+.05	.68
near Parsons, Kansas (07183500)				
Pre-dam	1922–64	43	0	.99
Post-dam	1965–93	29	+.11	.39
Annual peak discharge				
at Burlington, Kansas (07182510)				
Post-dam	1965–93	29	-.05	.68
near Iola, Kansas (07183000)				
Pre-dam	1918–64	58	-.10	.27
Post-dam	1965–93	29	+.18	.16
near Parsons, Kansas (07183500)				
Pre-dam	1922–64	43	-.01	.92
Post-dam	1965–93	28	+.24	.07

at all three stations downstream from John Redmond Dam. This probably is because the preferred location for gaging stations is where there will be stable control for low to medium discharges, which means that there is little chance that the channel will scour or degrade at medium to low stages. The median annual peak-discharge stages did show trends at Burlington and Iola. There is a relatively large negative trend just downstream from the dam at Burlington (-0.104 ft/yr). Farther downstream, at the Iola gaging station, the trend is not as large (-0.046 ft/yr), and at the Parsons gaging station, there was no evidence of a trend in the median annual peak stages.

Because the stages are declining at the higher discharges and not at the lower discharges, it can be assumed that the channel is either widening rather than deepening or the flow velocity has increased. Also, the results of the trend tests show that there is a decrease in the magnitudes of the trends as the distance downstream from the dam increases and less proportion of the drainage area is regulated by the dam.

Factors that could be affecting the scouring of the upper part of the channel cross section are the procedures used for reservoir releases, increased construction of levees downstream from the dam, channelization of sections of the river, and changes in land use along the flood plain. All of these factors can change the average velocity of the streamflow and(or) change the duration of higher streamflows, which generally will change the amount of scour or deposition.

Although these data indicate that some scouring is occurring at two of the streamflow-gaging stations, it is only a starting point in determining the amount of channel change in the Neosho River channel. A more definitive analysis of channel-geometry changes could be accomplished with surveys of channel cross sections.

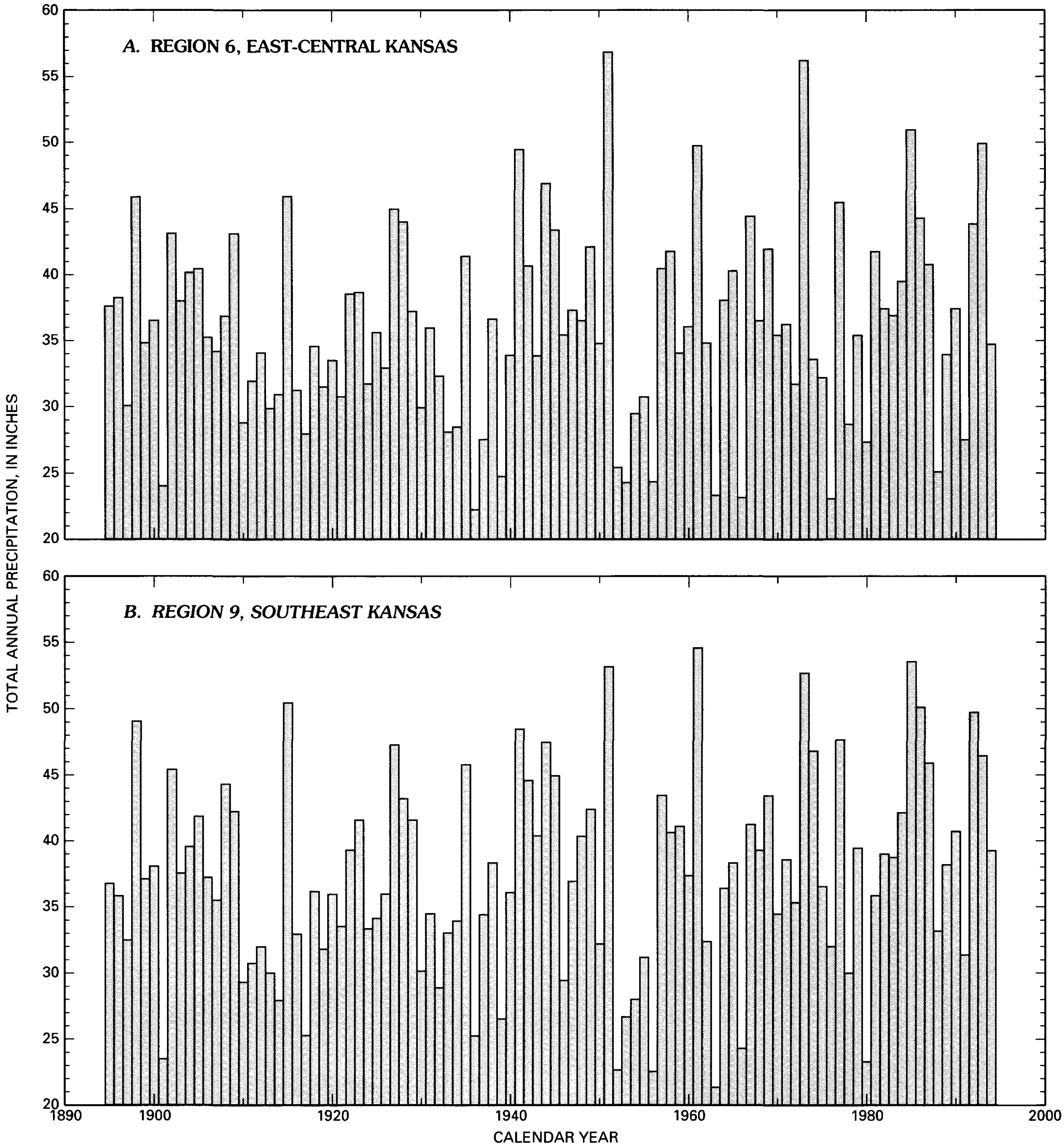


Figure 7. Total annual precipitation for climatic regions (*A*) 6 and (*B*) 9 in Kansas (data from National Weather Service).

SUMMARY

A description of the effects of John Redmond Dam on the high-flow frequency and channel geometry of the Neosho River downstream from the dam is presented in this report. Long-term data from four U.S. Geological Survey streamflow-gaging stations were used to calculate 7-day and 30-day high-flow frequencies and to determine the river stages for the annual mean discharges and the median annual peak

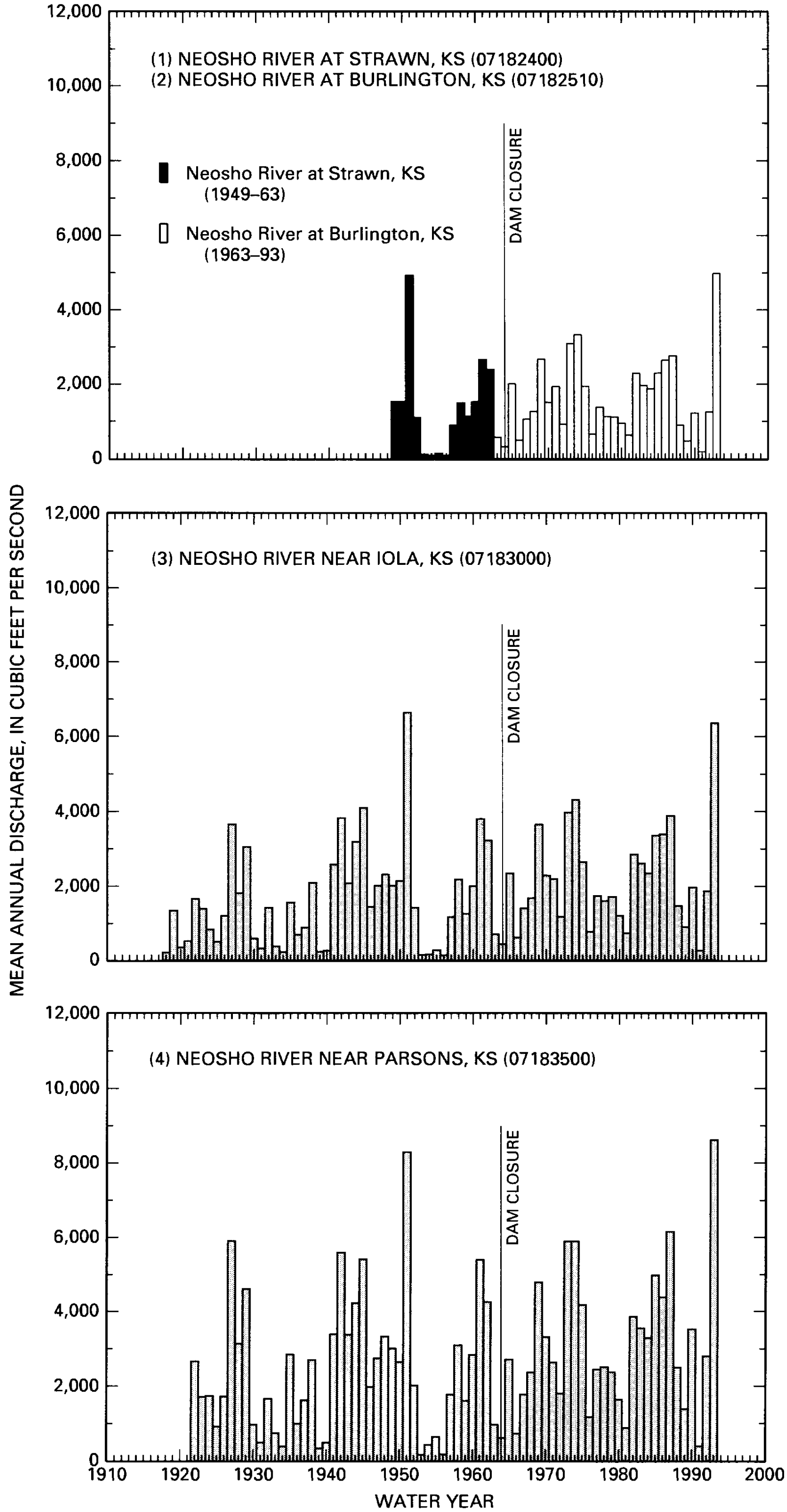


Figure 8. Mean annual discharges at U.S. Geological Survey streamflow-gaging stations downstream from John Redmond Dam. Location of gaging stations shown in figure 1.

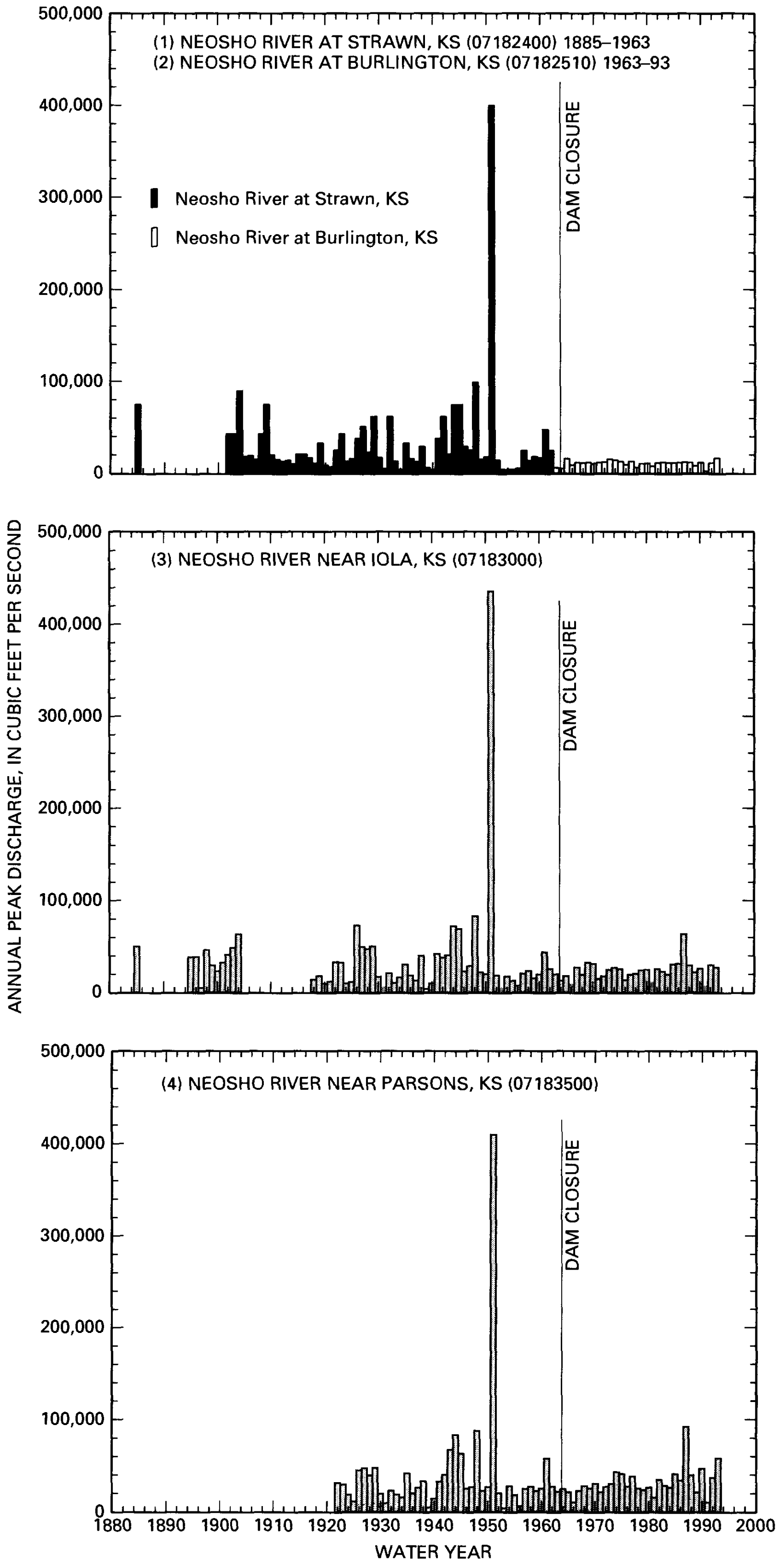


Figure 9. Annual peak discharges for U.S. Geological Survey streamflow-gaging stations downstream from John Redmond Dam. Location of gaging stations shown in figure 1.

Table 6. Trend analysis of stages related to the mean annual discharge and median annual peak discharge at selected streamflow-gaging stations in the study area

[--, not determined]

Map number (fig. 1)	Station number	Station name	Variable tested	tau	p value	Trend slope (feet per year)	Number of years in test
2	07182510	Neosho River at Burlington, KS	Stage for mean annual discharge (feet)	-0.04	0.77	--	29
			Stage for median annual peak discharge (feet)	-.89	<.01	-0.104	29
3	07183000	Neosho River near Iola, KS					
		Pre-dam	Stage for mean annual discharge (feet)	-.24	.06	--	47
			Stage for median annual peak discharge (feet)	+.57	<.01	+.017	47
		Post-dam	Stage for mean annual discharge (feet)	-.54	<.01	-.005	29
			Stage for median annual peak discharge (feet)	-.58	<.01	-.046	29
4	07183500	Neosho River near Parsons, KS					
		Pre-dam	Stage for mean annual discharge (feet)	+.14	<.01	+.003	43
			Stage for median annual peak discharge (feet)	-.62	.02	--	43
		Post-dam	Stage for 10-percent exceedance discharge (feet)	+.10	.64	--	29
			Stage for mean annual discharge (feet)	+.46	.85	--	29

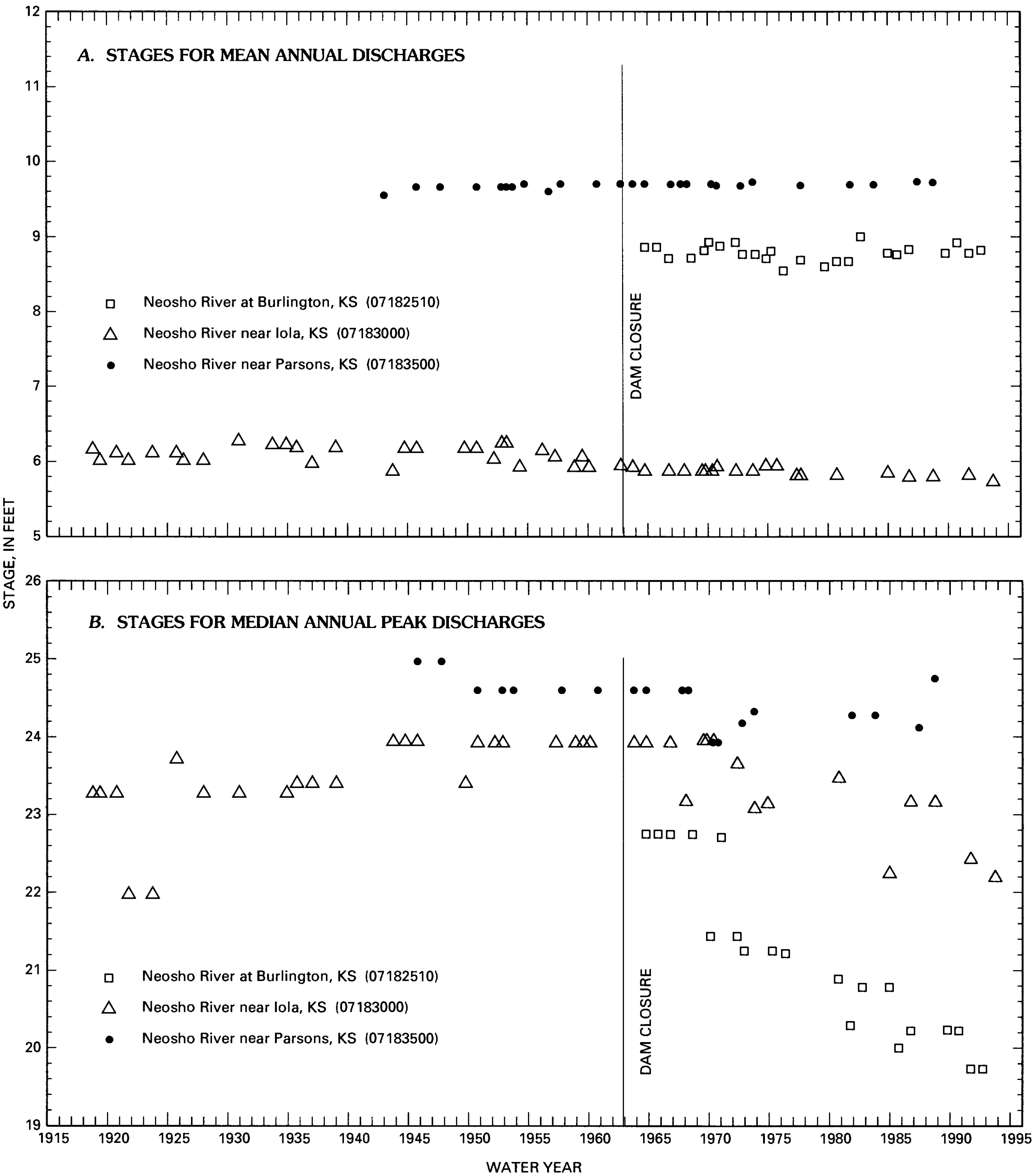


Figure 10. Stages for (*A*) mean annual discharges and (*B*) median annual peak discharges at U.S. Geological Survey streamflow-gaging stations downstream from John Redmond Dam. Location of gaging stations shown in figure 1.

discharges for each streamflow-gaging station for the periods before and after completion of the dam.

High-flow frequency and flow-duration results show that there has been a change in high-flow frequencies since completion of John Redmond Dam. Discharge magnitudes during periods of low flow have increased, and both the magnitude and frequency of high flows have decreased.

A Kendall's tau test for trend was applied to the forcing variables (precipitation, annual mean streamflow, and annual peak discharge) at each of the streamflow-gaging stations. These forcing variables, except for precipitation, were only tested to determine if there were trends within the pre- and post-dam periods. Precipitation was tested to determine any climatic trends. The results of the trend test indicate that there is no significant trend in the data and, therefore, there is no evidence of climatic effects on the changes found in the high-flow frequencies. Kendall's tau trend test also was used to test for trends in the river stages for the annual mean discharges and the median annual peak discharges at each of the streamflow-gaging stations. The results of the test indicate that there is a downward trend at the two streamflow-gaging stations closest to the dam and that the magnitudes of the trends decrease as the distance downstream from the dam increases.

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