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KANSAS WATER OFFICE

Channel Stability of the Neosho River Downstream From John Redmond Dam, Kansas

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The stability of the Neosho River channel downstream from John Redmond Dam, in southeast Kansas, was investigated using multi-date aerial photographs and stream-gage information. Bankfull channel width was used as the primary indicator variable to assess pre- and post-dam channel change. Five 6-mile river reaches and four stream gages were used in the analysis. Results indicated that the overall channel response to the altered streamflow regime and sediment load introduced by the dam has been minor. Aside from some localized channel widening, there was little post-dam change in bankfull channel width. The lack of a pronounced post-dam channel response may be attributable to a substantial reduction in the magnitude of the post-dam annual peak flows in combination with the resistance to erosion of the bed and bank materials. Also, the channel may have been overwidened by a series of large floods that predated construction of the dam.

Introduction

The construction and operation of a reservoir can have a substantial effect on the stability of the river channel downstream from the dam. Since its completion in 1964, the downstream effect of John Redmond Dam on the Neosho River in southeast Kansas (fig. 1) has been much debated. Previous studies by the U.S. Army Corps of Engineers (COE) (1972) and the U.S. Geological Survey (USGS) (Studley, 1996) have indicated the possibility of channel widening. Also, anecdotal evidence of perceived channel widening has been provided by residents living along the Neosho River as far as 165 mi downstream from the dam. The available evidence, however, is not sufficient to conclude that John Redmond Dam has caused the Neosho River channel to change more than it otherwise would have changed without the dam.

To determine the effect of John Redmond Dam, a study of the Neosho River that compares the channel before, during, and after completion of the dam was undertaken by the USGS in cooperation with the Kansas Water Office. The objective of this study was to determine whether or not the Neosho River channel has widened in response to the changes in flow regime and sediment load introduced by the dam. Pre- and post-dam channel stability was assessed using multi-date aerial photographs and streamgage information.

Important issues related to the stability of the Neosho River channel include protection of riparian resources, protection of habitat for threatened and endangered species (for example, the Neosho Madtom, *Noturus placidus*), and bank stabilization as related to loss of property, general aesthetics, and recreation. The knowledge provided by this study will provide some of the information needed to best manage the Neosho River system.

Description of Study Area

The focus of this study was the middle 180-mile reach of the Neosho River between John Redmond Dam and the Kansas-Oklahoma State line (fig. 1). Throughout this reach the Neosho River is characterized by a meandering, gravel-bed channel. The channel slope averages about 1.2 feet per mile. Riverbank height varies from about 15 to 30 feet. The channel bed frequently is situated on bedrock. Alluvium in the Neosho River Valley averages about 25 feet in thickness and is typified by silt with a basal layer of sand and gravel that averages about 3 feet in thickness. The channel-bank materials consist mostly of cohesive silt and clay and are relatively resistant to erosion compared to sand banks. Also,

John Redmond Dam on the Neosho River near Burlington, southeast Kansas.

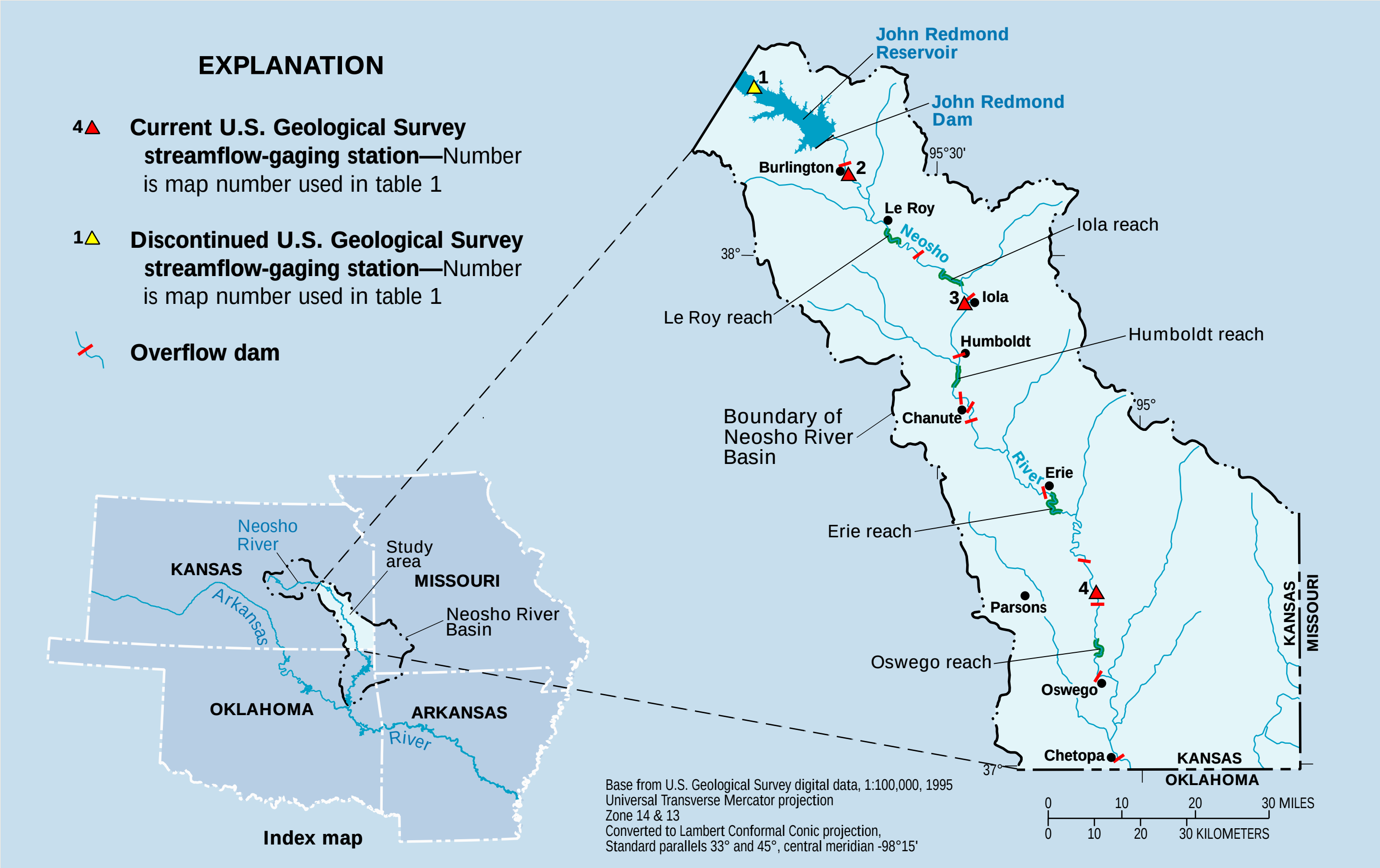

Figure 1. Location of Neosho River Basin, study area, river reaches, and streamflow-gaging stations.

the channel banks are typically covered by partial to complete mature tree cover which may enhance bank stability at some locations.

Several tributaries contribute unregulated flow to the Neosho River downstream from John Redmond Dam. Also noteworthy are 12 overflow dams (fig. 1) that were constructed within the main-stem channel mostly in the 1930's or 1950's. Changes in the streamflow regime attributable to the operation of John Redmond Dam have included a decrease in the magnitudes of peak discharges (flows) and an increase in the magnitudes of low discharges (fig. 2) (Studley, 1996). Post-dam suspended-sediment concentrations are substantially reduced immediately downstream from the dam.

Methods

A stable river channel naturally meanders across its river valley over time while maintaining approximately the same cross-sectional shape. Therefore, changes in channel geometry may be used to infer channel instability. In this study, bankfull channel width was used as the primary indicator variable to assess channel change after the completion of the dam.

Five 6-mile river reaches were selected for use in this study (fig. 1) with the objective being to obtain a spatially representative sample while avoiding, to the extent possible, localized human-caused or natural conditions that might obscure channel adjustment. Human-caused conditions include overflow dams (fig. 1), bridges, and channel modifications (for example, riprap). Natural conditions include split-channel locations and hard points (that is, locations where the channel is situated along the valley wall). Additional factors considered in the selection of the reaches included proximity to John Redmond Dam and the availability and usability of aerial photographs.

For each reach, aerial photographs were obtained for three time periods—pre-dam (late 1930's), construction (early 1960's), and post-dam (early 1990's). The bankfull channel area was interpreted from the aerial photographs for each time period and traced on a scale-stable mylar overlay. Primary indicators used in the delineation of the bankfull channel included breaks in slope, the tops of point bars, and changes in vegetation. The channel centerline was added, and all information was digitized. Mean bankfull channel width then was estimated for all reaches and dates as channel area divided by channel centerline length.

To compare pre- and post-dam channel stability, the mean bankfull channel widths for all reaches and dates were tabulated, and pre- and post-dam differences were evaluated. For each reach, pre-dam change was computed as the percentage difference in mean bankfull channel width between the pre-dam and construction time periods. Similarly, post-dam change was computed for each reach as the percentage difference in mean bankfull channel width between the construction and post-dam time periods. The magnitude and direction of the changes were used to assess pre- and post-dam channel stability for the individual reaches as well as the entire system. Due to various potential sources of error in the use of aerial photographs to measure bankfull channel widths, only a change in bankfull width of 10 percent or more was considered significant.

Information from USGS streamflow-gaging stations (fig. 1, table 1) was also analyzed to assess pre- and post-dam channel stability downstream from the dam. A comparison of pre- and post-dam conditions included an assessment of stage-discharge, discharge-width, discharge-area, and discharge-velocity relations. The Parsons gaging station was excluded from all analyses due to back-water effects from an overflow dam located 2.7 miles downstream from the gage (fig. 1, map number 4). The gaging stations provide site-specific information at locations separate from the river reaches analyzed in this study.

Results and Discussion

The aerial-photograph analyses indicate that the construction and operation of John Redmond Dam has not resulted in a substantial and pervasive downstream widening of the Neosho River channel. The mean bankfull channel widths (table 2) show that, with the exception of the Iola reach (10-percent increase in width), post-dam changes have been minor (and may be attributable in part to measurement error). In comparison, relatively large pre-dam channel-width changes had occurred at the Le Roy, Humboldt, and Oswego reaches with respective increases of 15, 14, and 10 percent. The fact that three of the four largest increases in mean bankfull channel width predate the dam may be indicative of a predam period of channel widening possibly associated with one or more large floods.

In many river systems 90 to 99 percent of significant bank erosion occurs during large floods. A large flood occurred in July 1951 when the Neosho River had a flow with an estimated 500-year recurrence interval. The peak discharge during this flood at Strawn (fig. 1) was 400,000 cubic feet per second (The mean annual peak discharge for the period of record at Strawn is about 43,000 cubic feet per second). Interestingly, the three reaches that had the largest pre-dam increases in bankfull channel width also had the smallest post-dam changes in bankfull

Downstream Effects of Dams on River Channels

Primary changes introduced by a dam include a reduction in the river's sediment load as well as an alteration of the flow regime. Typical changes in the flow regime include a reduction in the magnitude of peak flows and a possible increase in the magnitude of low flows. Such artificially introduced changes may trigger an adjustment by the river as it attempts to re-establish an approximate equilibrium between the channel and the discharge and sediment load being transported.

In general, rivers downstream from dams initially adjust by channel degradation. Typically, a river will scour, and thus lower, its channel bed as the sediment-depleted water emerging from the dam attempts to replenish its sediment load. Concurrently, the reduced magnitude of peak flows emerging from the dam eventually may result in channel narrowing as vegetation encroaches. An exception is the case where the channel bed is armored or situated on bedrock. Unable to effectively scour the resistent channel bed, the river may instead erode laterally and thus widen its channel. Typically, channel degradation initiates near the dam following closure and eventually may migrate a considerable distance downstream (Williams and Wolman, 1984).

The type, rate, duration, and downstream extent of channel degradation downstream from dams are controlled by a number of factors, including discharge, sediment load, bed and bank material composition, local bed-elevation control (for example, bedrock, armoring), channel geometry, climate, tributary inflow, and vegetation. Considerable variation in the type and rate of channel degradation may occur even between sites located close together due to the variability of the controlling factors.

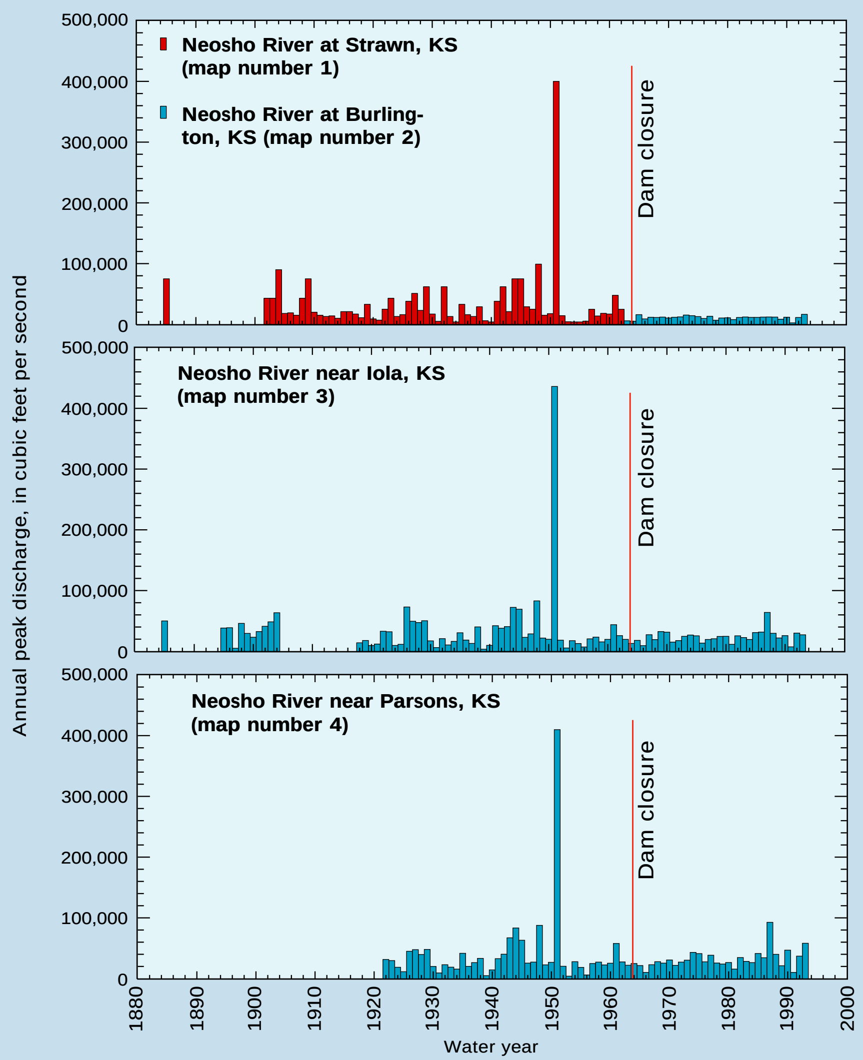

Figure 2. Annual peak discharges for U.S. Geological Survey streamflow-gaging stations downstream from John Redmond Dam. Location of stations shown in figure 1.

Table 1. U.S. Geological Survey (USGS) streamflow-gaging stations used in this study

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

Table 2. River-reach locations and mean bankfull channel widths

River reach (fig. 1)	Distance downstream from dam (miles)	Mean bankfull channel width (feet) (percent change from previous time period)		
		Pre-dam	Construction	Post-dam
Le Roy	23–29	197	226 (+15)	233 (+3)
Iola	42–49	240	236 (-2)	259 (+10)
Humboldt	63–69	243	276 (+14)	266 (-4)
Erie	102–108	246	253 (+3)	269 (+6)
Oswego	146–152	233	256 (+10)	256 (0)

channel width. This may be due to the overwidened condition of the channel at these locations in response to the 1951 and other pre-dam floods.

The gaging-station analyses provided some indication of channel widening at Burlington in the years immediately following completion of John Redmond Dam in 1964. Results indicated an initial increase in channel width of about 10 to 20 feet, followed by apparent stabilization at this location. At Iola, channel width has not changed. However, an increase in flow velocity was indicated. The increase in velocity may be due to an increase in channel slope and (or) a decrease in channel roughness.

Together, the aerial-photograph and gaging-station analyses indicate that the overall downstream response of the Neosho River channel to John Redmond Dam has been minor. With one exception, the five river reaches indicated little if any post-dam change in channel width. However, the apparent initial widening of the channel at the Burlington gage shows that localized widening has occurred. Such localized widening is also evident in a series of six COE cross sections located successively at intervals of about 1 mile immediately downstream from the dam. The cross sections, surveyed in 1963, 1974, and 1983, indicate minor widening at one site (10 to 20 feet), moderate widening at one site (30 to 40 feet), and little if any change at the remaining four sites (Harry Hartwell, U.S. Army Corps of Engineers, written commun., 1995). Localized widening may or may not be directly related to the operation of John Redmond Dam.

The overall lack of a pronounced post-dam channel response may be attributable to several factors. First, there has been a substantial post-dam reduction in the magnitude of the annual peak discharges. A second factor is the strength of the bed and bank materials. Degradation of the channel bed has been limited due to the presence of bedrock and (or) coarse gravel, the latter of which would require large flows to transport. The channel banks consist mostly of cohesive silt and clay and are relatively resistant to erosion. Moreover, bank stability may be enhanced at some locations by partial to complete mature tree cover. Therefore, significant bank erosion (beyond site-specific occurrences) may only occur during large flows which have mostly been eliminated by the dam.

A third factor is the pre-dam condition of the channel. As indicated by the five river reaches, there is some indication of a pre-dam widening of the channel, possibly due in part to the 1951 flood. Thus, it is possible that the channel, at least in places, may have been in an overwidened condition at the time of dam construction. Thus, additional widening at such locations may be unlikely. In fact, there is some field evidence to indicate that a new lower flood plain may be forming within the confines of the original channel. Eventually, this may result in a narrowing of the channel.

The findings of this study suggest two possibilities. First, the Neosho River is a relatively stable system that may only change significantly in response to extreme events. Second, it may be that insufficient time has transpired for pronounced channel changes to become manifest. Local residents' perception of channel widening may be correct at specific locations. However, also likely are instances where normal channel migration has been mistaken for channel widening, especially where property (for example, cropland and structures) has been lost or is threatened.

Acknowledgments

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References

Studley, S.E., 1996, Changes in high-flow frequency and channel geometry of the Neosho River downstream from John Redmond Dam, Southeastern Kansas: U.S. Geological Survey Water-Resources Investigations Report 96–4243, 16 p.

Williams, G.P., and Wolman, M.G., 1984, Downstream effects of dams on alluvial rivers: U.S. Geological Survey Professional Paper 1286, 83 p.

U.S. Army Corps of Engineers, 1972, Memorandum of findings, riverbank stabilization study, Grand (Neosho) River, Kansas & Oklahoma, John Redmond Dam & Reservoir to Kansas-Oklahoma State line: U.S. Army Corps of Engineers, September 1972, Tulsa, Oklahoma, 24 p.

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