COMPARISON OF ESTIMATED SEDIMENT LOADS USING CONTINUOUS TURBIDITY MEASUREMENTS AND REGRESSION ANALYSIS

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ABSTRACT

Suspended-sediment loads commonly are estimated with a streamflow regression model. However, turbidity, which is the reduction in the transparency of water due to suspended and dissolved particles, may be a better surrogate than streamflow in estimating suspended-sediment loads. To test this hypothesis, regression equations that relate suspended-sediment concentrations to discrete turbidity measurements were developed for eight U.S. Geological Survey stream-gaging stations in Kansas. For comparison, estimates also were calculated using simple regression equations with streamflow and multiple regression equations with streamflow and turbidity.

Turbidity Measurements and Regression Analysis: Between 1998 and 2001, about 20 discrete water samples were collected at each of the eight stream-gaging stations and analyzed for suspended sediment. Samples were collected throughout a range of streamflow conditions and sediment concentrations. In addition, samples collected for suspended-sediment analysis represented the range of recorded turbidity values, with a nearly equal representation of high and low values at most stations. The eight stations are equipped with water-quality monitors that provide relatively inexpensive, continuous (hourly) measurements of turbidity. The water-quality monitors are serviced at least monthly to check calibration and to verify that the continuous monitor is representing the stream cross section. Site-specific regression equations were developed relating laboratory analyzed suspended-sediment concentrations in the discrete samples to turbidity measurements recorded by the water-quality monitors. Suspended-sediment loads were estimated using the continuous turbidity measurements and were compared to suspended-sediment loads estimated with streamflow measurements. Examples from two of the eight gaging stations are shown in figure 1.

Results: Suspended-sediment concentrations in the Kansas River at DeSoto were strongly related to turbidity with a coefficient of determination (R^2) of 0.987, compared to an R^2 of 0.792 for streamflow. The suspended-sediment concentrations in the Little Arkansas River at Sedgwick were strongly related to both streamflow and turbidity, and the estimated average daily load did not differ substantially between the streamflow and the turbidity equations.

The results showed that, in general, suspended-sediment loads at stream-gaging stations where flows are affected by human-related factors (for example, reservoir releases) were more strongly related to turbidity than to streamflow. The Kansas River is affected by a series of reservoirs that act as sediment traps. During large reservoir releases, the streamflow at DeSoto increased, whereas turbidity increases were relatively small. On the other hand, during periods of substantial storm runoff, large increases were seen in both streamflow volume and turbidity values. The difference in sediment loads estimated using streamflow and turbidity regression equations (fig. 1) is about 8 million tons per year for the Kansas River at DeSoto, which demonstrates the need to determine whether streamflow or turbidity is a better surrogate. There are no large reservoirs on the Little Arkansas River to affect the flow, which may be why suspended-sediment concentration is more strongly related to streamflow at this gaging station (compared to the DeSoto station).

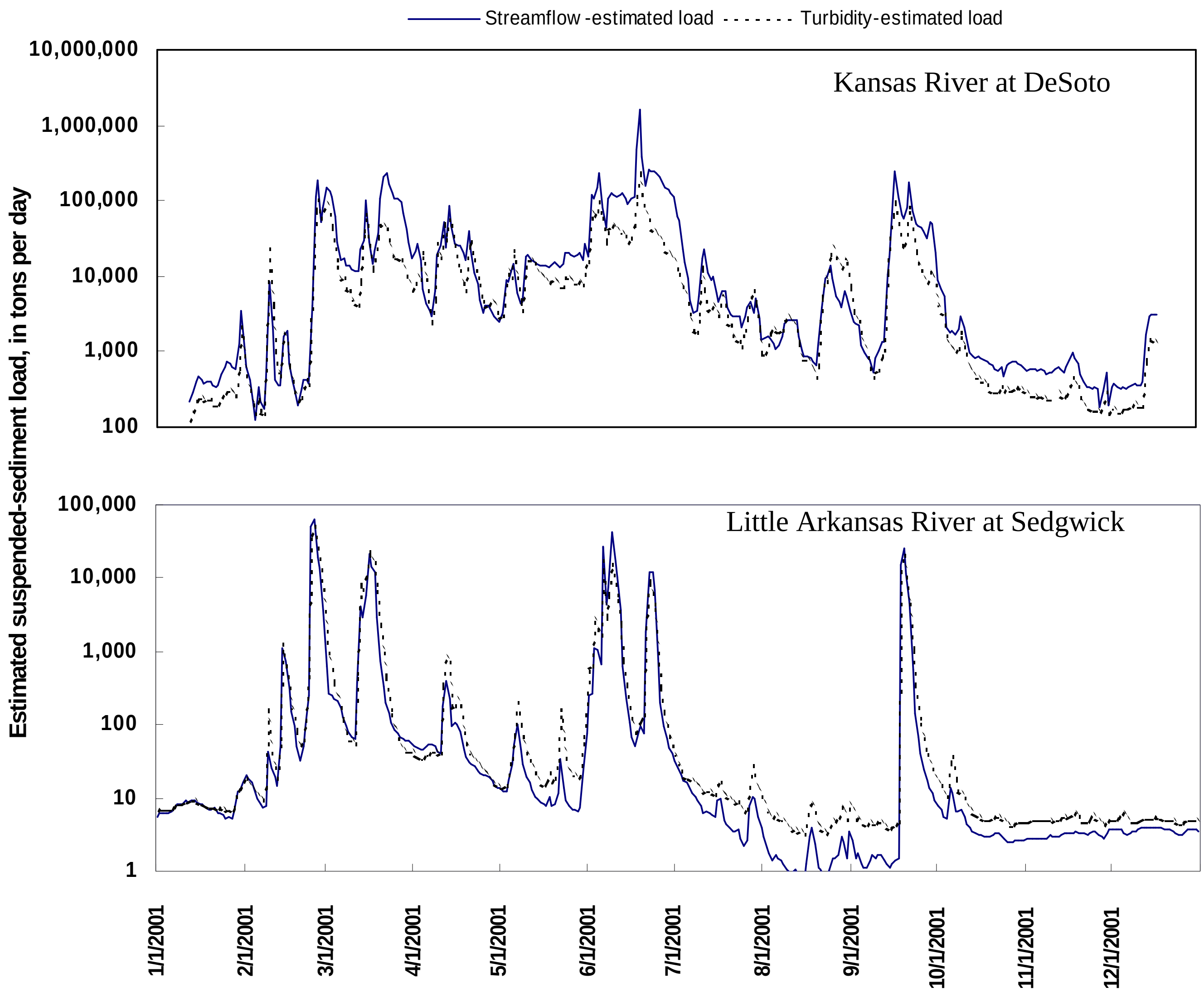

Figure 1. Estimated suspended-sediment loads for the Kansas River at DeSoto and the Little Arkansas River at Sedgiwck, Kansas, 2001.

The suspended-sediment concentrations for all eight gaging stations were significantly correlated to turbidity. The suspended-sediment concentrations at four of the eight gaging stations were also correlated to streamflow. The relation between suspended-sediment concentration and turbidity is affected by particle-size distribution (samples with the same sediment concentration but different particle sizes may have different turbidity measurements). However, the median particle size for all samples used in the regression analyses was 95-percent fines (particles smaller than 0.065 millimeters). This may indicate that suspended particle sizes in Kansas streams are generally small and have a relatively consistent relation to turbidity.

To determine whether streamflow or turbidity is a better surrogate for suspended sediment, a comparison was made between instantaneously measured suspended sediment loads and streamflow- and turbidity-estimated loads (table 1), using all the manually collected suspended-sediment samples used in the regression analyses (1998-2001). For the Kansas River at DeSoto, the difference between the measured and the streamflow-estimated suspended load is more than 100 percent, whereas the difference between the measured and turbidity-estimated load is about 4 percent. For the Little Arkansas River at Sedgwick, the difference between the measured and the streamflow-estimated suspended load is about 50 percent, whereas the difference between the measured and turbidity-estimated load is 6 percent.

Based on the results for these two Kansas stations, turbidity is a more reliable surrogate for determining suspended-sediment loads.

Table 1. Comparison of measured instantaneous suspended-sediment loads to streamflow- and turbidity-estimated suspended-sediment loads in the Kansas River at DeSoto and the Little Arkansas River at Sedgwick, Kansas, 1998-2001.

	Kansas River at DeSoto	**Little Arkansas River at Sedgwick**
Number of samples	24	33
Mean measured suspended-sediment concentration (milligrams per liter)	679	434
Mean measured streamflow (cubic feet per second)	8,520	1,530
Mean measured instantaneous suspended-sediment load (tons/day)	49,500	3,010
Mean streamflow-estimated instantaneous suspended-sediment load (tons/day)	106,000	4,610
Percentage difference from measured load	**-110**	**-53**
Mean turbidity-estimated instantaneous suspended-sediment load (tons/day)	47,200	2,830
Percentage difference from measured load	**4.6**	**6.0**

Limitations: Turbidity meters may have an upper limit that should be considered before using continuous turbidity measurements to calculate suspended-sediment load. Typically, limits vary for each meter and range from about 1,200 to 1,800 nephelometric turbidity units (NTU). The limit for the meter in the Little Arkansas River at Sedgwick is approximately 1,750 NTU. This limit was not reached in 2001. However, the limit for the meter in the Kansas River at DeSoto is about 1,200 NTU. The turbidity measurements reached this limit for parts of 7 days during 2001. The turbidity record was truncated during these periods. If the turbidity measurements are not adjusted, the estimated suspended-sediment load could be underestimated. In addition, there are 12 days of missing measurements in January 2001 due to ice at the Kansas River gaging station.

For more information on the real-time, continuous monitoring and regression analysis to estimate constituent concentrations and loads refer to http://ks.water.usgs.gov/Kansas/rtqw/

REFERENCES

Christensen, V.G., 2001, Characterization of Surface-Water Quality Based on Real-Time Monitoring and Regression Analysis, Quivira National Wildlife Refuge, South-Central Kansas, December 1998 through June 2001. U.S. Geological Survey Water-Resources Investigations Report 01-4248, 28 p.

Christensen, V.G., Jian, Xiaodong, Ziegler, A.C., 2000, Regression Analysis and Real-Time Water-Quality Monitoring to Estimate Constituent Concentrations, Loads, and Yields in the Little Arkansas River, South-Central Kansas, 1995-99. U. S. Geological Survey Water-Resources Investigations Report 00-4126, 36 p.

Wagner, R.J., Mattraw, H.C., Ritz, G.F., Smith, B.A., 2000, Guidelines and Standard Procedures for Continuous Water-Quality Monitors--Site Selection, Field Operation, Calibration, Record Computation, and Reporting. U.S. Geological Survey Water-Resources Investigations Report 00-4252, 53 p.