Surface-Water-Quality Assessment of the Lower Kansas River Basin, Kansas and Nebraska: Suspended-Sediment Conditions, May 1987 Through April 1990, and Trends, 1963 Through April 1990

By P.R. JORDAN

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CONVERSION FACTORS

Multiply	By	To obtain
inch	2.54	centimeter
foot	0.3048	meter
mile	1.609	kilometer
square mile	2.590	square kilometer
cubic foot per second	0.02832	cubic meter per second
acre-foot	1,233	cubic meter
ton	0.9072	megagram
ton per square mile	0.3503	megagram per square kilometer

Water Year: Water year is the 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends. Thus, the year ending September 30, 1990, is called the "1990 water year."

Surface-Water-Quality Assessment of the Lower Kansas River Basin, Kansas and Nebraska: Suspended-Sediment Conditions, May 1987 Through April 1990, and Trends, 1963 Through April 1990

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Abstract

Suspended-sediment samples were collected monthly or more frequently during May 1987 through April 1990 at 13 stations in the lower Kansas River Basin of Kansas and Nebraska. The samples were collected to help provide a description of the spatial distribution of suspended-sediment concentrations and transport, seasonal distribution of concentrations, trends from the earliest data available, and interpretation, where possible, of the relations of current (1990) conditions and trends to natural and human factors. Median (50th percentile; 50 percent of the sample values at the station were smaller) suspended-sediment concentrations ranged from 100 to 110 milligrams per liter for 3 stations on the Kansas River and from 4 to 110 milligrams per liter for 10 stations on tributary streams. Suspended-sediment concentrations at the 90th percentile (90 percent of the sample values at the station were smaller) for tributary stream stations ranged from 240 to 3,200 milligrams per liter, except at sampling stations immediately downstream from large reservoirs, which ranged from 58 to 170 milligrams per liter. The larger median and 90th-percentile concentrations were associated with high-density irrigated cropland in areas of little local relief and medium-density irrigated cropland in more dissected areas. Smaller median and 90th-percentile concentrations upstream from reservoirs were from areas of little or no row-crop cultivation or areas of substantially less-than-normal precipitation and streamflow.

The median proportion of suspended sediment finer than 0.062 millimeter varied from 84 to 99 percent. Differences in particle size among stations were relatively small and could have resulted as much from differences in the fraction of stream depth sampled as from other causes. Suspended-sediment concentrations in relation to streamflow rate followed a consistent seasonal pattern; after accounting for the effect of flow, concentrations were typically smallest during January–February and largest during July–August.

Mean annual suspended-sediment transport rates in the Kansas River from May 1987 through April 1990 increased substantially in the downstream direction from 1,700,000 tons per year at Fort Riley, Kans., to 4,100,000 tons per year at DeSoto, Kans. Suspended-sediment yields for tributary stream stations ranged from 17 to 260 tons per square mile per year. Because of abnormally dry climatic conditions and large uncertainty factors for the results of some computations, no conclusions could be reached concerning the relations of suspended-sediment transport rate or yield to natural and human factors.

Tests for trends in flow-adjusted suspended-sediment concentrations at five sampling stations resulted in one statistically significant downward trend for 1963–90 and one statistically significant

upward trend for 1977–90. The trend-test results could not be explained by data on cropland removed from production or the effect of detention structures.

INTRODUCTION

During the past two decades, public awareness of the importance of water-quality issues has increased substantially. Along with this increased awareness have come commitments by Federal, State, and local governments and industries for the assessment and protection of water quality. Progress in water-quality improvement will require increased knowledge of the nature and extent of potential problems, as well as knowledge of the physical, chemical, and biological processes that affect water quality in streams and aquifers. In 1986, the Congress appropriated funds for the U.S. Geological Survey to test and refine a National Water-Quality Assessment (NAWQA) Program (Hirsch and others, 1988). The long-term goals of the NAWQA program are: (1) To provide a nationally consistent description of current water-quality conditions for a large part of the Nation's water resources; (2) to define long-term trends (or lack of trends) in water quality; and (3) to identify, describe, and explain the major factors that affect observed water-quality conditions and trends. This information will be useful for examining the likely consequences of future management actions (Stamer and others, 1987).

The NAWQA program began with a pilot phase to test and modify assessment concepts and approaches. Seven pilot projects (four surface-water projects and three ground-water projects) were initiated in 1986. The lower Kansas River Basin in Kansas and Nebraska was one of the four surface-water pilot projects, which also included the Kentucky River Basin in Kentucky, the Yakima River Basin in Washington, and the upper Illinois River Basin in Illinois, Indiana, and Wisconsin. The lower Kansas River Basin was selected as a pilot project because it is typical of the Midwestern grain belt, which includes irrigated and nonirrigated cropland and nonirrigated pasture and rangeland. Specific objectives of the pilot study in the lower Kansas River Basin were to: (1) define existing surface-water-quality conditions; (2) define trends in surface-water quality; (3) calculate average annual constituent transport rates; (4) evaluate the effects of surface-water impoundments on downstream water quality; and (5) identify stream segments where water quality may be affected adversely by natural processes or human activities (Stamer and others, 1987).

Available suspended-sediment data through 1986 for the lower Kansas River Basin were analyzed in a previous report (Jordan and Stamer, 1991) that included summaries and interpretation of available data for numerous physical, chemical, and biological properties and constituents of the water. That analysis showed an overall basin median suspended-sediment concentration of 280 mg/L (milligrams per liter), the largest suspended-sediment yields occurring in the Dissected Till Plains physiographic division (fig. 1), and time trends of decreasing concentrations. The report also indicated inadequacies in the data through 1986 for defining the areal variations, trends, and relations to natural and human factors.

Problem

Sediment in streams and reservoirs commonly poses water-quality problems at and downstream of specific locations and also may indicate problems upstream. For example, suspended sediment may need to be removed from public water supplies, and large yields of sediment in streams and reservoirs may indicate excessive erosion of land in the upstream watershed. When suspended sediment becomes deposited in large quantities in a stream channel or an inlet of a lake or reservoir, it can result in raised water levels of floods. Deposits of sediment in surface-water impoundments can decrease the storage capacity for water supply or flood control and can impair propagation of fish and other aquatic life. In addition to the effects of its physical presence, suspended sediment can transport certain nutrients, trace elements, pesticides, and other synthetic organic compounds that have very slight solubility but that attach themselves to sediment particles.

Information on sediment is needed for planning of water projects and wise use of water, whether or not the sediment poses a special problem. The different applications of sediment information in the lower Kansas River Basin, classified by mode of sediment transport, are listed in table 1. No measurements of the "bedload" mode of transport were made for the pilot phase of the lower Kansas River Basin project, and discussion in this report will be limited to suspended sediment.

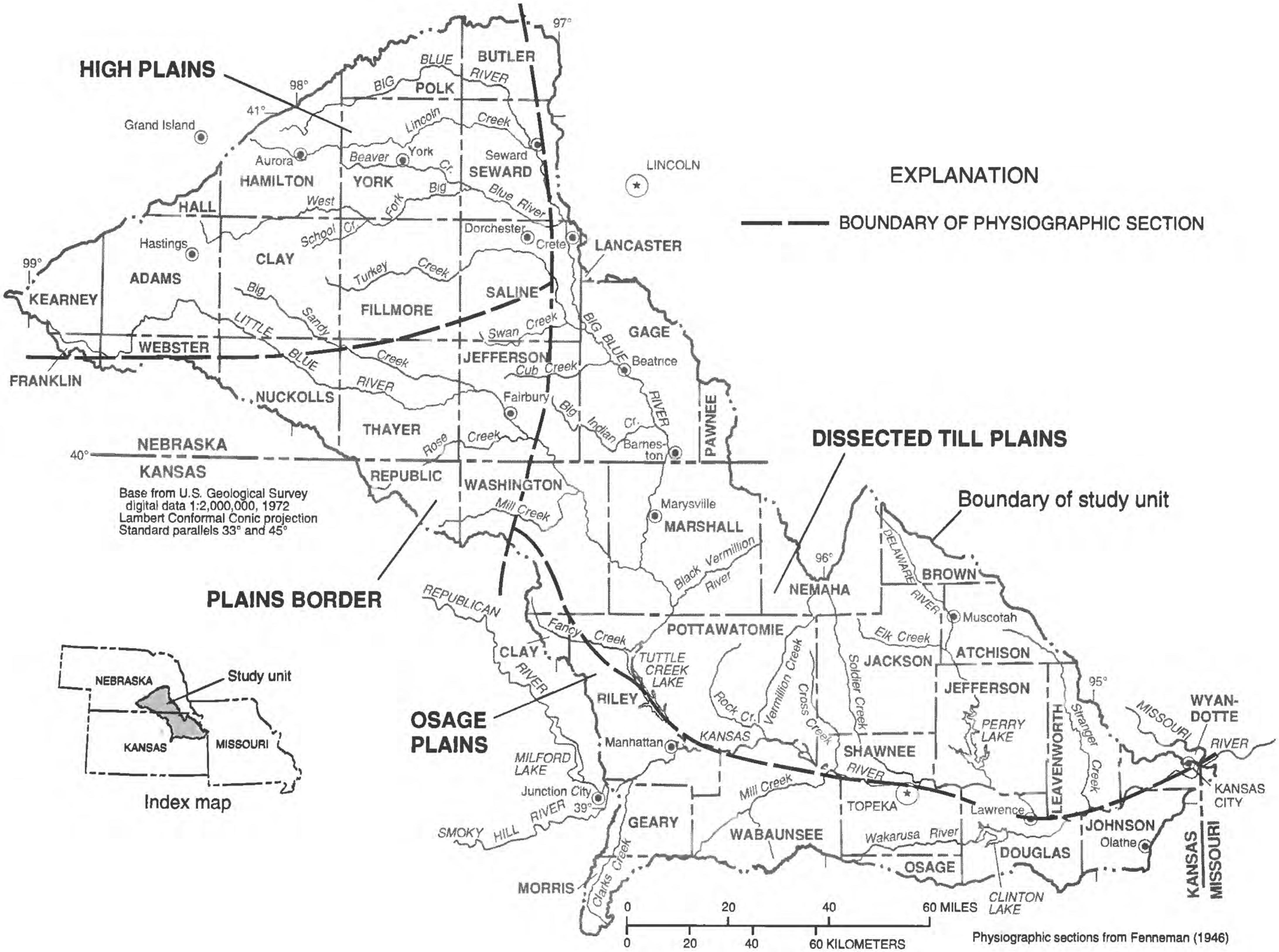

Figure 1. Physiographic divisions in lower Kansas River Basin.

Table 1. Sediment information that may be pertinent in the lower Kansas River Basin

[Modified from Mundorff, 1961, p. 22; X, pertinent; --, not pertinent]

Application or problem	Sediment information needed, classified by mode of transport					
	Suspended		Bedload[1]		Combined suspended and bedload	
	Concentration or transport rate	Particle size	Transport rate	Particle size	Transport rate	Particle size
Watershed development and flood control:						
Factors that affect erosion	X	X	X	X	X	X
Evaluation of conservation program	X	X	X	X	X	X
Trap efficiency of detention reservoirs	--	--	--	--	X	X
Aggradation or degradation of channels	X	X	X	X	X	X
Design and operation of storage reservoirs:						
Volume of sediment accumulation	--	--	--	--	X	X
Trap efficiency	X	X	X	X	X	X
Areal distribution of sediment deposits	--	--	--	--	X	X
Aggradation or degradation downstream	X	X	X	X	X	X
Irrigation diversion and distribution:						
Separation weirs	X	X	X	X	--	--
Stable distribution channels	X	X	X	X	X	X
Channel stabilization:						
Prediction of channel changes	X	X	X	X	X	X
Design of stable channels	X	X	X	X	X	X
Domestic and industrial water supply:						
Design of intake systems	X	X	X	X	--	--
Design of settling basins and filters	X	X	--	--	--	--
Recreation development:						
Location and design of swimming beaches	X	X	X	X	--	--
Location and design of boat-launching facilities	X	X	X	X	--	--
Fish and wildlife conservation:						
Effect of sediment on feeding and propagation	X	X	X	X	X	X

[1]The bedload mode of transport is the movement of sediment by rolling or sliding on the streambed or by short jumps near the streambed.

Purpose and Scope

The purpose of this report is to present an analysis of the suspended-sediment data and information collected from May 1987 through April 1990 in the lower Kansas River Basin, together with related data available prior to May 1987. The data and information collected are used to provide a description of the spatial distribution of suspended-sediment concentrations and transport, seasonal distribution of concentrations, trends from the earliest date of data available (1963 for one station) through April 1990, and interpretation, where possible, of the relations of current (1990) conditions and trends to natural and human factors.

To aid in the assessment of surface-water quality in the lower Kansas River Basin, suspended-sediment samples were collected monthly or more frequently at 13 selected stations during May 1987 through April 1990. The data and description of sampling methods are presented in a report by Fallon and McChesney (1993). Additional information on natural and human factors that affect suspended sediment also was obtained.

NATURAL AND HUMAN FACTORS THAT AFFECT SUSPENDED SEDIMENT

Many factors may affect the amount of suspended sediment found in surface water in the lower Kansas River Basin. These factors include physiography, surficial geology and soils, land use, surface-water impoundments, and precipitation and runoff.

Physiography

Land forms in the lower Kansas River Basin are characterized by the four physiographic divisions shown in figure 1. Smooth plains with little local relief dominate the High Plains division; fluvial and eolian deposits of sand, gravel, silt, and clay underlie this part of the study unit. The Plains Border physiographic division is more dissected than the High Plains and thus has more local relief. The Dissected Till Plains division is characterized by dissected deposits of glacial till, consisting of silt, clay, sand, gravel, and boulders, that overlie bedrock of primarily shale and limestone, with some sandstone. The Osage Plains are south of the limit of glaciation and are underlain primarily by shale and limestone, with some sandstone.

The principal physiographic factor affecting suspended sediment in the lower Kansas River Basin probably is the slight local relief in the upstream High Plains division. The slight local relief tends to decrease the rates of erosion to less than that which otherwise would occur from the surface materials and climatic setting found in the High Plains division.

Surficial Geology and Soils

Surficial geology in the northwestern part of the study unit consists primarily of Quaternary loess deposits, whereas the eastern part consists primarily of Quaternary glacial drift. A small area in the west-central part of the study unit is underlain by Cretaceous sandstone and limestone. The southern part of the study unit consists primarily of Permian and Pennsylvanian shale and limestone. Quaternary alluvium fills the major river valleys throughout the basin.

The predominant soil in the lower Kansas River Basin is the Mollisol order (fig. 2). Mollisols have a surface horizon that is thick, dark-colored, and granular in structure (Dugan, 1984, p. 6). Mollisols are prone to erosion, as indicated by conditions in Marshall County, Kansas, where Mollisols, particularly Udolls and Ustolls, predominate. "Soil erosion is the major problem on 75 percent of the cropland in Marshall County. Where the slope is more than 1 percent, erosion is a hazard" (Kutnink and others, 1980, p. 22). Entisols, Inceptisols, and Alfisols also are present in the study unit. Entisols, which are soils with no diagnostic horizon, occur on sandy parent material in the western part of the study unit (psamments) and on soil formed from alluvial deposits (fluvents). Inceptisols are considered to be immature soils resembling their parent material (Buol and others, 1980, p. 240), and Alfisols are characterized by an argillic or clay-rich horizon. Soil characteristics not only affect the rates of erosion under most conditions, but also have an effect on the success of measures taken to reduce erosion from cultivated land. "Terraces and diversions reduce the length of slopes and reduce runoff and erosion. They are most practical on deep, well drained soils..." (Kutnink and others, 1980, p. 22).

Nearly all the soils in the lower Kansas River Basin provide ample opportunities for erosion and

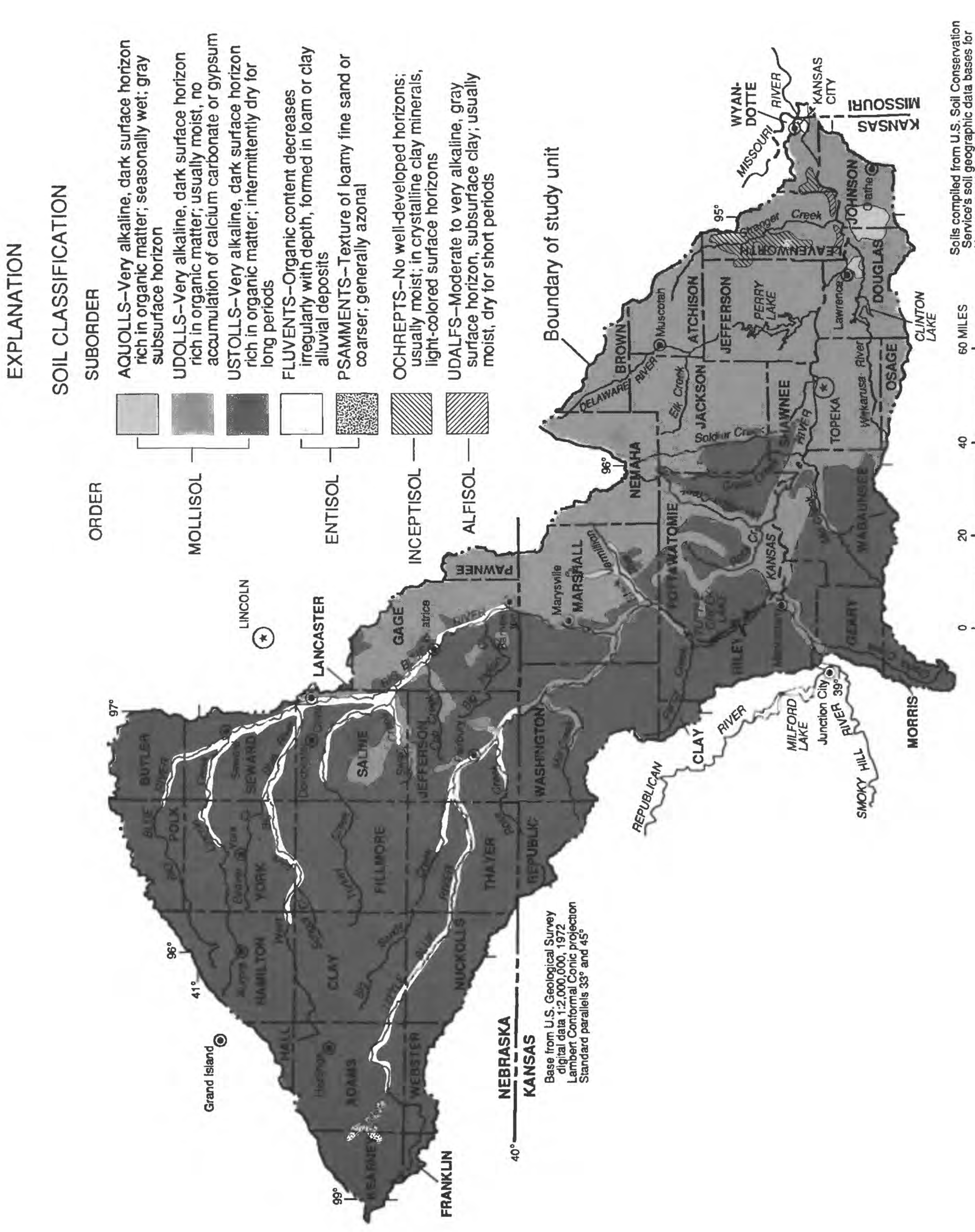

Figure 2. Classification of soils in lower Kansas River Basin.

contribution of suspended sediment to the streams when the other conditions for erosion, such as cultivated fields of exposed topsoil, moderate to steep slopes, and intense precipitation, are present.

Land Use

Land use is a major human factor that affects soil erosion and sediment yield. If other factors such as precipitation and land slope were equal, land used for row crops could be expected to have the largest rates of erosion; woodland, rangeland (assuming it was not overgrazed), and other land having continual vegetative cover would have much smaller rates of erosion (Wischmeier and Smith, 1965). Urban and industrial lands would have large erosion rates only where their vegetative or other cover was eliminated during construction activities.

Land use in the lower Kansas River Basin (fig. 3) is about 85 percent agricultural. Corn, grain sorghum, wheat, and soybeans are the principal crops. Much of the row cropland in the basin has had some erosion-control treatment, such as terraces and grassed waterways, although lands having such treatments are not differentiated in figure 3. The most intensively cultivated and irrigated lands are found in the northwestern part of the study unit. In a 1987 inventory of land use (U.S. Soil Conservation Service, written commun., data tables, 1990), estimates for drainage areas in the northwestern part of the basin indicate that more than 55 percent of the cropland is irrigated in those areas. Estimates from the same inventory indicate that, although only about 3 percent of the study unit is covered by woodland, nearly 10 percent of the southeastern part is wooded. Less than 3 percent of the study unit consists of urban or industrial areas. The principal urban developments include part of the Kansas City metropolitan area, Topeka, and Lawrence, Kansas. The large area of mostly rangeland in the southwestern part of the study unit, principally the area of Ustoll soils (fig. 2) in Morris, Geary, Wabaunsee, Pottawatomie, and Riley Counties, Kansas, accounts for most of the pasture and rangeland that together cover about 25 percent of the basin.

Surface-Water Impoundments

Large impoundments typically trap a very large part of their sediment inflow. An example is Kanopolis Lake (in Kansas outside the study unit) where the physical setting permitted accurate determination that the sediment trap efficiency was 96 percent (U.S. Army Corps of Engineers, 1972a, table 1). Within the study unit, three large reservoirs provide most of the surface-water storage and have large effects on sediment in the Kansas River. Tuttle Creek Lake on the Big Blue River (fig. 1) has a sedimentation pool of 211,500 acre-feet, a conservation pool of 177,100 acre-feet, and a flood-control pool of 1,937,000 acre-feet. Perry Lake on the Delaware River has a conservation and sedimentation pool of 225,000 acre-feet and a flood-control pool of 517,500 acre-feet. Clinton Lake on the Wakarusa River has a conservation pool of 129,100 acre-feet and a flood-control pool of 268,400 acre-feet (Geiger and others, 1991, p. 106, 117, 120, calculated from data provided by U.S. Army Corps of Engineers, Kansas City, Missouri).

Thousands of small farm ponds have been constructed within the study unit. In addition, numerous larger detention structures, also called grade-stabilization structures (see for example, Delaware Watershed Joint District No. 10, U.S. Department of Agriculture, and others, 1978) or floodwater-retarding structures (see Soil Conservation Districts, 1966), have been constructed as part of watershed-district activities. These detention structures typically receive runoff from 0.5 to 10 square miles of drainage area. Their sediment trap efficiencies probably range from 65 to 90 percent (estimated from relations developed by G.M. Brune and shown in Vanoni, 1975, p. 590–591). Between about 1955 and 1989, approximately 190 detention structures were completed in 12 organized watershed districts in the lower Kansas River Basin (estimate based on data supplied by the U.S. Soil Conservation Service, Salina, Kansas, and Lincoln, Nebraska).

Precipitation and Runoff

Precipitation and runoff are the most important climatic factors affecting erosion and transport of sediment to streams and reservoirs. The 1951–80 mean annual precipitation in the lower Kansas River Basin ranged from about 24 inches in the northwestern part of the study unit to about 36 inches in the southeast. Extreme variability, however, characterized annual precipitation patterns. For example, from 1951 to 1980, annual precipitation on large parts of the study unit ranged from less than 15 inches to more

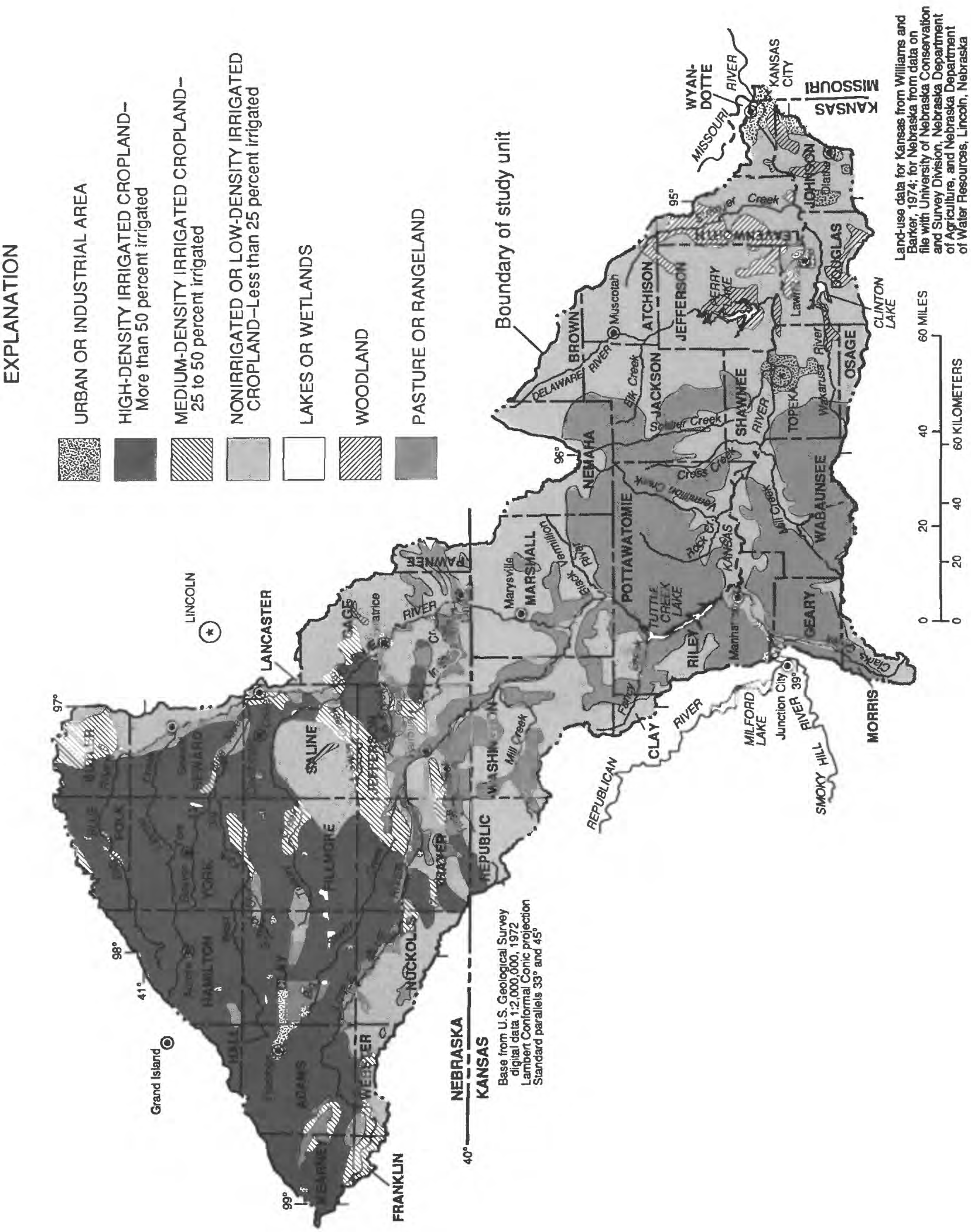

Figure 3. Land use in lower Kansas River Basin.

than 50 inches (data from National Oceanic and Atmospheric Administration, 1951–80). Because about 75 percent of the precipitation in the basin normally occurs during the growing season, April through September, suspended-sediment yields from row cropland are affected greatly by the seasonal patterns of plowing, early growth and later maturity of crops, time of harvest, and presence or absence of crop residues after harvest.

Runoff in the study unit varies areally in response to precipitation, topography, soil, geology, and vegetation, and seasonally in response to precipitation and evapotranspiration. The 50-percent variation in mean annual precipitation for 1951–80, from about 24 inches in the northwestern part of the lower Kansas River Basin to about 36 inches in the southeast, was accompanied by a 350-percent variation in mean annual runoff, from less than 2 inches to almost 9 inches (Jordan and Stamer, 1991). Monthly runoff is largest in the spring and summer and smallest in the late fall and early winter.

Selected streamflow characteristics are shown in table 2 for the 13 streamflow-gaging and sediment-sampling stations (fig. 4) for which suspended-sediment data are analyzed in this report. The first line of data for each station shows characteristics of daily flows for a period of at least 10 years to represent, as well as possible, long-term normal flow conditions. For the stations affected by large reservoirs, recent periods representing the effects of the reservoirs were chosen. The mean streamflow and the 10th, 50th, and 90th percentiles of flow are shown to represent the central tendency and the small and large flow rates frequently encountered. Also shown are the 95th- and 98th-percentile flow rates, which were not frequent but had a large effect on suspended-sediment transport. The second and third lines of data for each station contain information for the 1987–90 period of sampling and will be discussed under the next section of this report.

Mean streamflow in the Kansas River for 1968–90 more than doubled from station 1 at Fort Riley (fig. 4) to station 62 at Topeka, Kans. Most of that increase was flow contributed by the Big Blue River. From Topeka to DeSoto (station 88), the mean flow in the Kansas River increased by more than 35 percent. Slightly smaller percentage downstream increases occurred for 95th- and 98th-percentile flows, which are able to transport larger loads of sediment.

SAMPLING AND HYDROLOGIC CONDITIONS, MAY 1987 THROUGH APRIL 1990

Suspended-sediment samples were collected monthly or more frequently at 13 selected streamflow-gaging stations during May 1987 through April 1990. No samples were collected in some months from Kings Creek near Manhattan, Kans. (station 3), because the stream had no flow during some monthly visits. Stations were selected to provide information for a variety of water-quality constituents and properties and were not necessarily the optimum set for suspended-sediment sampling and analysis, particularly for study of trends, because some stations having long prior records of suspended sediment were omitted. Stations on the Kansas River represent the upstream end of the study unit, a location of large surface-water withdrawals (Topeka), and the farthest downstream station on the river. Three stations are immediately downstream from the three large reservoirs, Tuttle Creek, Perry, and Clinton Lakes, and reflect the sediment-trapping effect of the reservoirs. The other seven stations receive unregulated or only slightly regulated flow from representative parts of the study unit. These stations include Kings Creek near Manhattan, Kans., which drains a natural prairie research area operated by Kansas State University (Koelliker and others, 1985).

With the exception of a few samples collected by an automatic sampler at Kings Creek, samples were collected manually by using standard depth- and width-integrating methods of the U.S. Geological Survey (Guy and Norman, 1970). Laboratory analyses and quality assurance were as discussed by Fallon and McChesney (1993), who also compiled the sediment data for this study.

For many water-quality constituents and properties, and probably for suspended sediment in particular, hydrologic conditions during a period of sampling can have a substantial effect on the ability of the samples to represent typical concentrations. Precipitation and streamflow were substantially below normal during May 1987 through April 1990. Mean annual precipitation ranged from less than 21 inches in the northwestern part of the study unit to about 33 inches in the southeastern part (data from National Oceanic and Atmospheric Administration, 1987–90). Generalized lines of equal mean annual precipitation for the sampling period are shown in figure 5. Also shown in figure 5 are departures of the May 1987–April 1990

Table 2. Selected characteristics of streamflow at gaging stations used for suspended-sediment sampling

[Streamflow is in cubic feet per second. 98th-percentile values not shown for fewer than 40 instantaneous values. --, not applicable]

Map reference number (fig. 4)	Station number	Station name	Drainage area, in square miles	Streamflow data used[1]	Number of instantaneous values	Mean streamflow	Streamflow at indicated percentile				
							10	50 (median)	90	95	98
1	06879100	Kansas River at	44,870	D,1968–90	--	2,540	409	1,180	6,030	9,200	15,500
		Fort Riley, Kans.		D,1987–90	--	1,720	325	633	3,850	8,300	14,200
				I, 1987–90	43	1,950	323	625	6,890	9,580	16,900
3	06879650	Kings Creek near	4.09	D,1980–90	--	2.8	0	1.0	6.8	13	21
		Manhattan, Kans.		D,1987–90	--	.7	0	0	2.2	3.9	5.8
				I, 1987–90	19	17	.1	.8	67	124	--
23	06880800	West Fork Big	1,206	D,1959–90	--	178	44	78	295	617	1,290
		Blue River near		D,1987–90	--	138	52	75	198	393	985
		Dorchester, Nebr.		I, 1987–90	46	274	50	81	1,080	1,600	1,830
35	06882000	Big Blue River at	4,447	D,1933–90	--	816	95	252	1,650	3,300	6,990
		Barneston, Nebr.		D,1987–90	--	609	167	282	1,180	2,290	5,340
				I, 1987–90	43	970	168	347	3,730	6,110	7,500
47	06884025	Little Blue River at	2,752	D,1975–90	--	492	106	200	826	1,770	3,810
		Hollenberg, Kans.		D,1987–90	--	313	109	171	550	892	2,140
				I, 1987–90	44	530	98	169	1,700	3,930	4,690
50	06885500	Black Vermillion River	410	D,1954–90	--	152	3.5	24	213	577	1,640
		near Frankfort, Kans.		D,1987–90	--	72	5.0	16	91	202	630
				I, 1987–90	47	302	6.0	22	343	3,470	5,460
52	06887000	Big Blue River near	9,640	D,1965–90	--	2,330	162	937	5,960	10,100	17,400
		Manhattan, Kans.		D,1987–90	--	1,720	141	570	3,220	5,730	20,100
				I, 1987–90	41	2,120	79	915	4,330	19,100	22,600

Table 2. Selected characteristics of streamflow at gaging stations used for suspended-sediment sampling—Continued

Map reference number (fig. 4)	Station number	Station name	Drainage area, in square miles	Streamflow data used[1]	Number of instantaneous values	Mean streamflow	Streamflow at indicated percentile: 10	50 (median)	90	95	98
59	06888500	Mill Creek near Paxico, Kans.	316	D,1955–90	--	177	4.4	55	322	571	1,200
				D,1987–90	--	73	2.8	21	161	247	449
				I, 1987–90	42	175	2.7	19	184	413	5,120
62	06889000	Kansas River at Topeka, Kans.	56,720	D,1968–90	--	5,990	976	2,900	14,700	23,700	33,100
				D,1987–90	--	3,930	777	1,800	6,960	14,800	33,200
				I, 1987–90	41	4,050	810	1,780	7,040	26,800	38,600
72	06890100	Delaware River near Muscotah, Kans.	431	D,1970–90	--	266	5.6	46	427	1,010	2,630
				D,1987–90	--	96	2.0	17	137	339	785
				I, 1987–90	41	119	2.1	17	220	502	3,090
74	06890900	Delaware River below Perry Dam, Kans.	1,117	D,1971–90	--	689	25	102	2,030	3,020	5,100
				D,1987–90	--	248	22	30	707	1,000	1,500
				I, 1987–90	38	175	22	25	730	1,500	--
83	06891500	Wakarusa River near Lawrence, Kans.	425	D,1981–90	--	261	7.9	35	882	1,380	1,970
				D,1987–90	--	107	4.3	21	300	607	946
				I, 1987–90	39	256	3.5	20	600	960	--
88	06892350	Kansas River at DeSoto, Kans.	59,756	D,1971–90	--	8,210	1,180	3,980	21,200	31,600	42,200
				D,1987–90	--	4,740	898	2,330	8,260	16,600	39,200
				I, 1987–90	43	5,170	892	2,230	14,000	26,600	39,200

[1]Streamflow data used in this report: D, daily streamflow data used are for water years through 1986 and May 1987–April 1990. I, instantaneous streamflow at times of suspended-sediment samples used in concentration summaries from May 1987 through April 1990 (sampling was not random, thus the statistics differ from those of the daily data for the same time period).

Figure 4. Location of sampling stations having suspended-sediment data analyzed in this report.

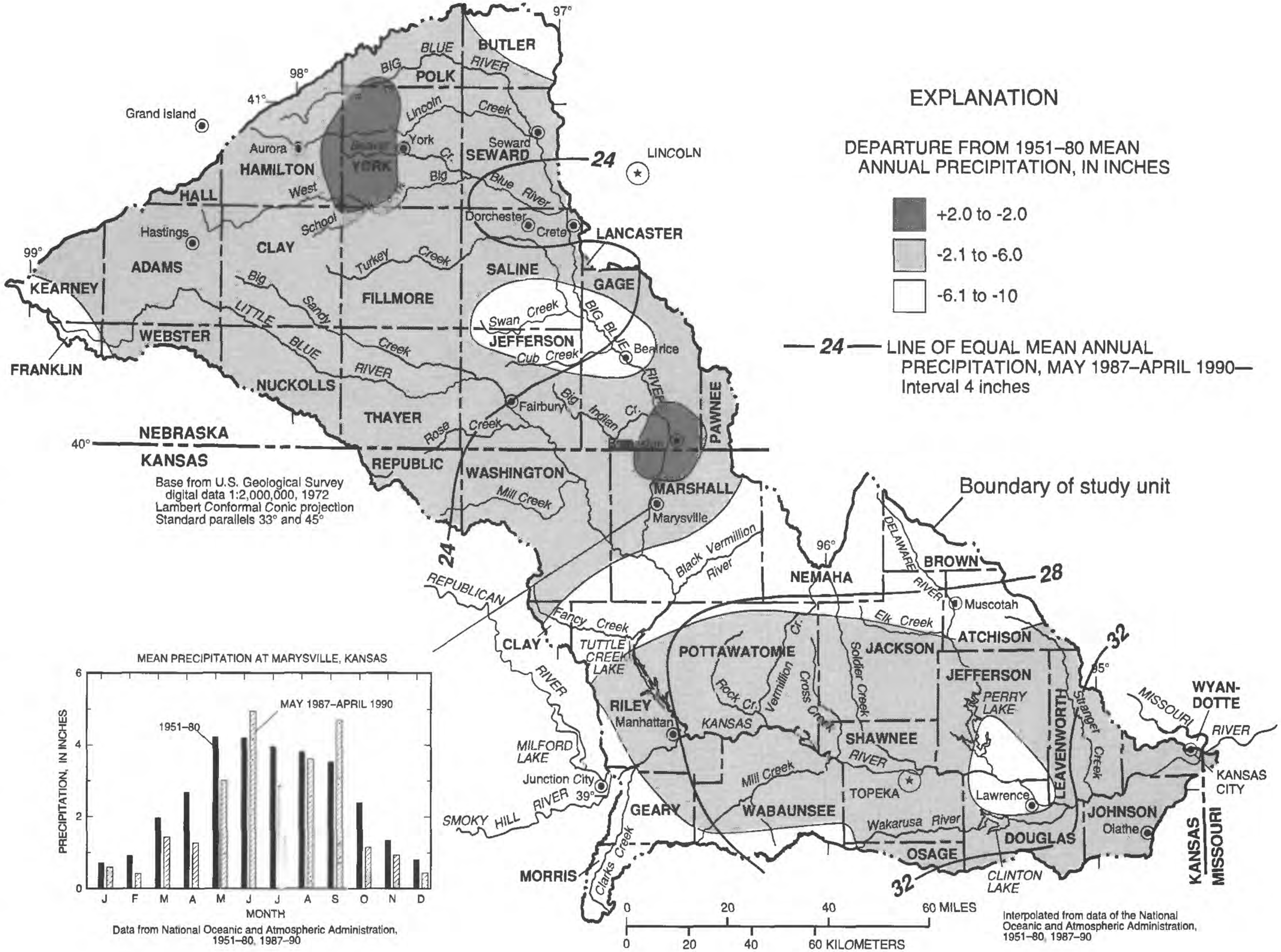

Figure 5. Areal distribution of mean annual precipitation, May 1987 through April 1990, and departures from 1951–80 mean; and mean monthly precipitation at Marysville, Kans.

mean values from the 1951–80 mean values. Departures of -2.1 to -6.0 inches (deficits of 2.1 to 6.0 inches compared to 1951–80 mean values) were prevalent over large parts of the study unit. Two small areas had smaller deficits, and some areas, including much of the drainage areas of the Black Vermillion and Delaware Rivers in Kansas, had larger deficits (6.1 to 10 inches). Monthly mean precipitation during May 1987–April 1990 at Marysville, Kans., was less than for 1951–80 in every month except June and September (fig. 5).

The precipitation during May 1987–April 1990 combined with other factors, such as evapotranspiration, intensity and timing of precipitation, and groundwater contributions, to produce runoff averaging about 1 inch per year in the northwestern part of the study unit to about 5 inches per year in the southeast (fig. 6). These runoff rates were closest to the 1951–80 mean values in the northwestern part of the study unit but were as much as 5 inches less than the 1951–80 mean values in the southeast.

The sampling period of May 1987–April 1990 began with a few months of high streamflows but then subsided to generally low flows. For example, the Kansas River at Topeka had very high flows during May and June 1987, and flows were above the 1968–90 average for the remainder of the water year (through September). The subsequent 31 months of the sampling period included 28 months of below-average streamflow and only 3 months above average. For the 3-year period, mean streamflows at all the sampling stations were substantially less than the long-term mean flows. Monthly mean runoff during May 1987–April 1990 for the Big Blue River at Barneston, Nebr., was less than for 1951–80 or only slightly exceeded 1951–80 for every month except September (fig. 6).

Representing outflow from the study area, mean streamflow in the Kansas River at DeSoto, Kans., for May 1987–April 1990, was 4,740 cubic feet per second or 58 percent of the 1971–90 mean of 8,210 cubic feet per second (table 2). For other stations at which suspended-sediment samples were collected monthly, except for Kings Creek, mean streamflows for May 1987–April 1990 as a percentage of long-term mean ranged from 36 percent for both stations on the Delaware River to 78 percent for the West Fork Big Blue River near Dorchester, Nebr. (table 2).

In addition to the monthly scheduled samples, additional sampling of high flow was done in an attempt to sample the full range of hydrologic conditions. The mean and various percentiles of instantaneous streamflow at the times of the samples used in the concentration summaries, shown in table 2 on the third line of data for each station, generally were larger than those for all the daily flows of May 1987 through April 1990. Sampling on Kings Creek included use of an automatic sampler to collect samples of any high flows that occurred. The automatic sampler was used because cross-section samples could not be obtained during the short duration of high flows; however, those samples may not accurately represent the suspended sediment in the stream cross section.

SUSPENDED-SEDIMENT CONCENTRATION AND PARTICLE SIZE, MAY 1987 THROUGH APRIL 1990

Suspended-sediment concentrations and particle-size distribution in samples collected during May 1987 through April 1990 are summarized in table 3. Aside from duplicate samples for quality-assurance purposes, the 12 stations other than Kings Creek each had 38 to 47 samples that were analyzed for suspended-sediment concentration. Kings Creek had fewer samples because of no flow during some monthly visits, even though the monthly sampling was augmented by automatic samples of high flow and one sample from each period of high flow was used in the concentration summary. For all stations, fewer samples were analyzed for particle size than for concentration.

Median suspended-sediment concentrations at the 13 stations ranged from 4 to 110 mg/L, and 90th-percentile concentrations ranged from 58 to 3,200 mg/L (table 3). Some indications of the relations of suspended-sediment concentration to natural and human factors are suggested by the summary data together with other information, although the variations of precipitation and runoff from their long-term averages tend to reduce confidence in those indications.

Median concentrations at the three Kansas River stations (stations 1, 62, and 88) were consistent at 100 to 110 mg/L (fig. 7), despite the inflow of tributaries with smaller concentrations of suspended sediment, such as the Big Blue River (station 52) and the Delaware River (station 74). Streambed and bank erosion in the Kansas River could account for the

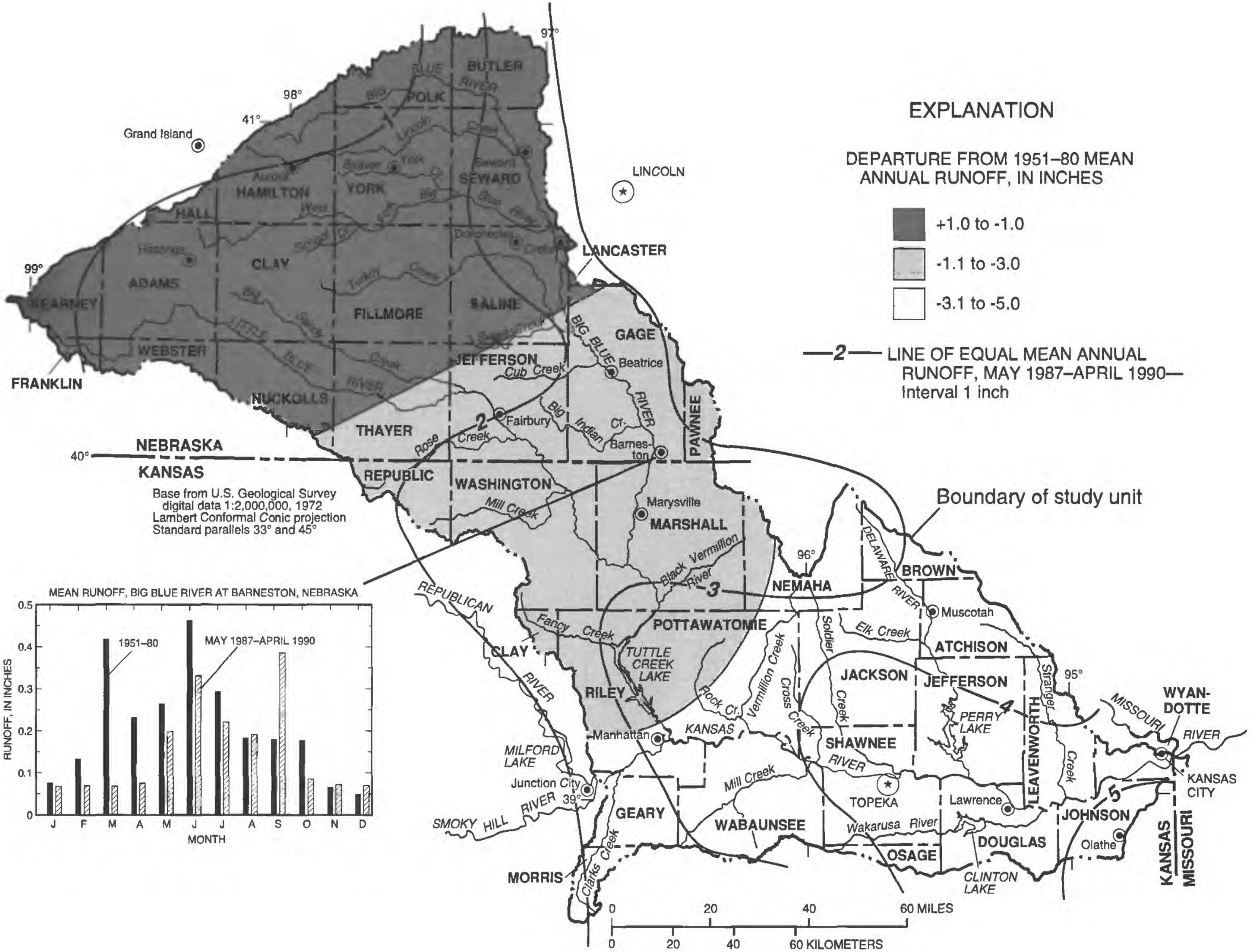

Figure 6. Areal distribution of mean annual runoff, May 1987 through April 1990, and departures from 1951–80 mean; and mean monthly runoff of Big Blue River at Barneston, Nebr.

Table 3. *Statistical summary of data for suspended-sediment concentration and particle size, May 1987 through April 1990*

[This table includes only those stations having 10 or more analyses; --, the 10- and 90-percentile values are not shown for sampling stations having fewer than 30 analyses]

Map reference number (fig. 4)	Station name	Number of analyses	Value at indicated percentile 10	25	50 (median)	75	90
	Suspended-sediment concentration, in milligrams per liter						
1	Kansas River at Fort Riley, Kans.	43	18	49	100	350	930
3	Kings Creek near Manhattan, Kans.	19	--	2	4	20	--
23	West Fork Big Blue River near Dorchester, Nebr.	46	11	41	110	320	1,700
35	Big Blue River at Barneston, Nebr.	43	15	30	51	160	2,200
47	Little Blue River at Hollenberg, Kans.	44	17	39	88	400	3,200
50	Black Vermillion River near Frankfort, Kans.	47	18	40	100	150	1,600
52	Big Blue River near Manhattan, Kans.	41	7	13	22	35	110
59	Mill Creek near Paxico, Kans.	42	11	19	28	49	280
62	Kansas River at Topeka, Kans.	41	35	49	100	200	550
72	Delaware River near Muscotah, Kans.	41	10	16	34	62	240
74	Delaware River below Perry Dam, Kans.	38	5	7	13	31	58
83	Wakarusa River near Lawrence, Kans.	39	9	30	52	90	170
88	Kansas River at DeSoto, Kans.	43	16	47	110	280	950
	Suspended-sediment particle size, percent finer than 0.004 millimeter						
23	West Fork Big Blue River near Dorchester, Nebr.	16	--	67	71	76	--
35	Big Blue River at Barneston, Nebr.	10	--	63	86	94	--
47	Little Blue River at Hollenberg, Kans.	12	--	56	61	65	--
88	Kansas River at DeSoto, Kans.	10	--	42	53	64	--
	Suspended-sediment particle size, percent finer than 0.062 millimeter						
1	Kansas River at Fort Riley, Kans.	38	53	82	93	96	99
3	Kings Creek near Manhattan, Kans.	21	--	72	84	94	--
23	West Fork Big Blue River near Dorchester, Nebr.	42	85	93	98	99	100
35	Big Blue River at Barneston, Nebr.	36	89	96	99	100	100
47	Little Blue River at Hollenberg, Kans.	39	52	84	92	96	99

Table 3. Statistical summary of data for suspended-sediment concentration and particle size, May 1987 through April 1990—Continued

Map reference number (fig. 4)	Station name	Number of analyses	Value at indicated percentile: 10	25	50 (median)	75	90
	Suspended-sediment particle size, percent finer than 0.062 millimeter—Continued						
50	Black Vermillion River near Frankfort, Kans.	42	74	89	97	98	100
52	Big Blue River near Manhattan, Kans.	36	75	90	96	99	100
59	Mill Creek near Paxico, Kans.	36	41	80	95	98	100
62	Kansas River at Topeka, Kans.	35	71	87	94	97	99
72	Delaware River near Muscotah, Kans.	36	61	78	97	99	100
74	Delaware River below Perry Dam, Kans.	32	84	89	97	99	100
83	Wakarusa River near Lawrence, Kans.	35	86	93	98	100	100
88	Kansas River at DeSoto, Kans.	38	52	74	87	95	98
	Suspended-sediment particle size, percent finer than 0.125 millimeter						
23	West Fork Big Blue River near Dorchester, Nebr.	11	--	95	100	100	--
35	Big Blue River at Barneston, Nebr.	12	--	100	100	100	--
47	Little Blue River at Hollenberg, Kans.	13	--	73	94	99	--
83	Wakarusa River near Lawrence, Kans.	10	--	100	100	100	--
88	Kansas River at DeSoto, Kans.	12	--	57	79	97	--
	Suspended-sediment particle size, percent finer than 0.250 millimeter						
23	West Fork Big Blue River near Dorchester, Nebr.	11	--	98	100	100	--
35	Big Blue River at Barneston, Nebr.	12	--	100	100	100	--
47	Little Blue River at Hollenberg, Kans.	13	--	78	99	100	--
83	Wakarusa River near Lawrence, Kans.	10	--	100	100	100	--
88	Kansas River at DeSoto, Kans.	12	--	67	82	99	--
	Suspended-sediment particle size, percent finer than 0.500 millimeter						
23	West Fork Big Blue River near Dorchester, Nebr.	11	--	100	100	100	--
35	Big Blue River at Barneston, Nebr.	12	--	100	100	100	--
47	Little Blue River at Hollenberg, Kans.	13	--	99	100	100	--
83	Wakarusa River near Lawrence, Kans.	10	--	100	100	100	--
88	Kansas River at DeSoto, Kans.	12	--	91	99	100	--

Table 3. Statistical summary of data for suspended-sediment concentration and particle size, May 1987 through April 1990—Continued

Map reference number (fig. 4)	Station name	Number of analyses	Value at indicated percentile: 10	25	50 (median)	75	90
	Suspended-sediment particle size, percent finer than 1.00 millimeter						
23	West Fork Big Blue River near Dorchester, Nebr.	11	--	100	100	100	--
35	Big Blue River at Barneston, Nebr.	12	--	100	100	100	--
47	Little Blue River at Hollenberg, Kans.	13	--	100	100	100	--
83	Wakarusa River near Lawrence, Kans.	10	--	100	100	100	--
88	Kansas River at DeSoto, Kans.	12	--	100	100	100	--

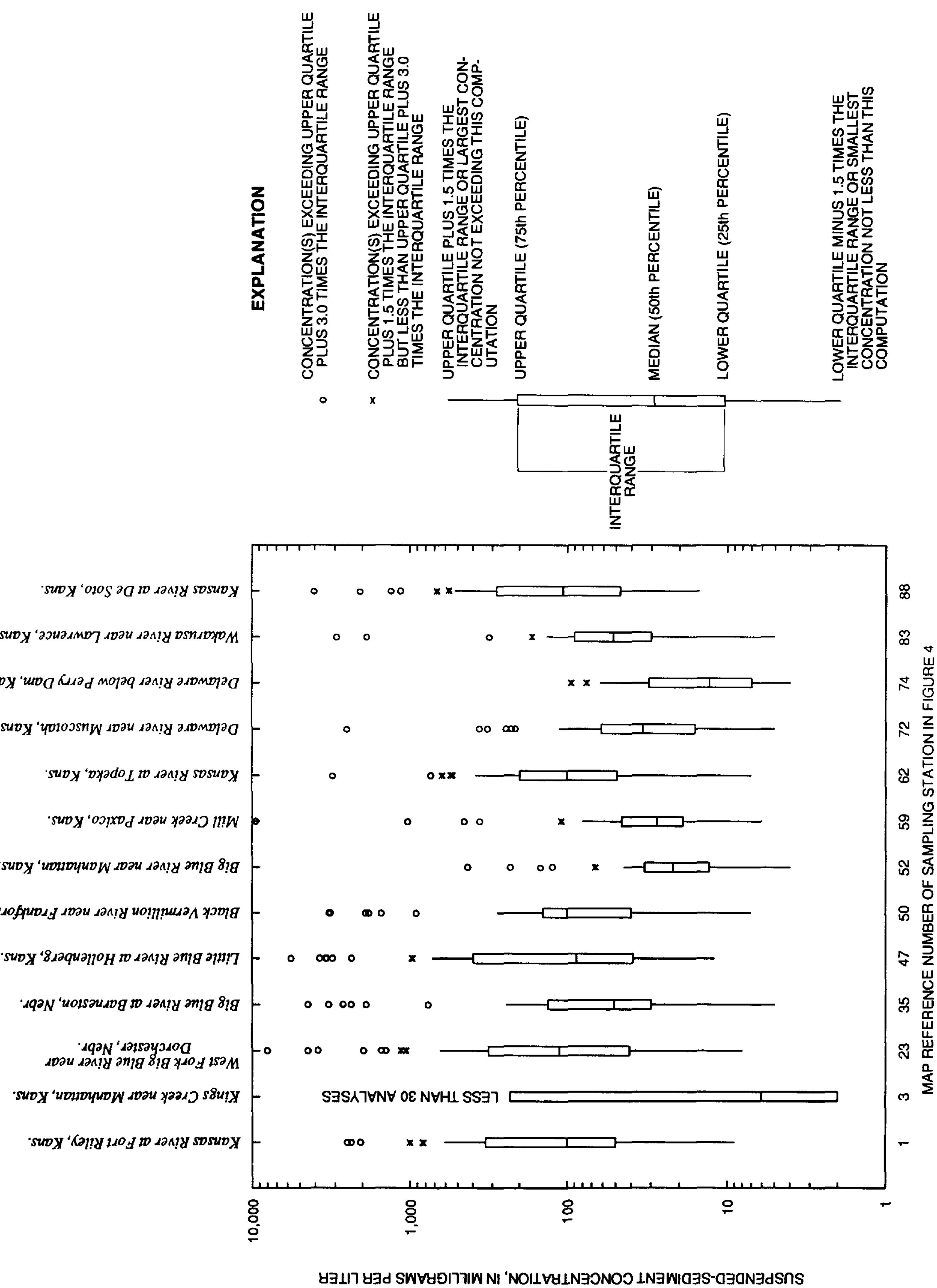

Figure 7. Distribution of suspended-sediment concentrations, May 1987 through April 1990.

consistent concentrations; however, streambed and bank measurements have not been made to substantiate that possibility.

Large reservoirs immediately upstream from stations 52, 74, and 83 undoubtedly accounted for small median concentrations (13 to 52 mg/L) at those stations and the smallest 90th-percentile concentrations (58 to 170 mg/L) of all the stations. Other stations having small concentrations included Kings Creek (station 3) and Mill Creek (station 59); the drainage area upstream of the Kings Creek station has no row crops, and the drainage area upstream of the Mill Creek station includes only small areas of row crops.

Stations representing areas of high-density irrigated cropland in areas of little local relief in the High Plains (station 23) and medium-density irrigated cropland in more dissected areas (stations 35, 47, and 50) had the largest 90th-percentile concentrations (1,600 to 3,200 mg/L) and relatively large median concentrations (51 to 110 mg/L). Station 72 was an exception, having relatively small 90th-percentile and median concentrations although the cropland and slope characteristics are similar to those of station 50. The small concentrations at station 72 probably resulted from substantially less-than-normal streamflows at the times of sampling.

Most suspended-sediment samples were analyzed for the percentage finer than the 0.062-millimeter particle size, representing the relative abundance of fine particles derived from silt and clay, whereas fewer samples were analyzed for other particle sizes. The median percentage finer than 0.062 millimeter (table 3) varied only from 84 to 99 percent within the study unit. The smallest value, 84 percent, for Kings Creek near Manhattan, Kans., may reflect less abundance of very fine particles derived from clay in the thin soils in the drainage basin or may have been affected by the automatic sampler. Sediment particles finer than 0.062 millimeter usually have nearly uniform concentration throughout the depth of a stream at any one time, whereas coarser particles increase in concentration from the surface to the streambed. Suspended-sediment samplers leave the bottom 0.3 to 0.5 foot of depth unsampled. Thus, differences among any of the stations could result as much from differences in the fraction of depth sampled as from any other cause. The fact that most of the suspended sediment in the study unit is silt and clay means that detention basins designed to remove sediment should have detention times long enough to remove material that does not settle rapidly.

Seasonal variations of suspended-sediment concentration are expected because of seasonal variations of precipitation and streamflow and because of seasonal patterns of land cover resulting from row-crop cultivation. Snow cover and frozen soil also probably have some effects. The seasonal variation of suspended-sediment concentrations may be important considerations for operation of facilities that treat surface water for municipal or industrial use, for modification of agricultural practices to reduce sediment, and for efficient monitoring. In addition, computation of transport rate or trend uses the relation between concentration and streamflow rate; the computations can be made more reliable by also accounting for seasonal departures from the relation.

As shown in figure 8, the seasonal departures from the relation between suspended-sediment concentrations and streamflow rate were consistent throughout the lower Kansas River Basin. For the Kansas River stations and tributary stations alike, the largest median negative departures were for January–February samples, and the largest median positive departures were for July–August samples. These departures indicate that, after accounting for the effect of flow, suspended-sediment concentrations typically were smallest during January–February and largest during July–August. The seven tributary stations used in the calculations omitted the three stations immediately downstream from the large reservoirs. For the seven tributary stations, the January–February median departure was -0.38 log-10 units, representing suspended-sediment concentrations 58 percent smaller than for the year as a whole for any given streamflow rate. The July–August median departure was 0.32 log-10 units, representing 109 percent larger concentrations.

SUSPENDED-SEDIMENT TRANSPORT RATE AND YIELD, MAY 1987 THROUGH APRIL 1990

"Transport rate" as used in this report is the rate at which a constituent passes a section of a stream, in units of dry weight per unit time. "Yield" is the transport rate per unit of drainage area. Suspended-sediment transport for each station was calculated by applying the relation among measured transport rate, streamflow rate, and seasonal factor to each daily mean streamflow rate as described in Jordan and Stamer (1991). Results of the calculations are shown in table 4. The first uncertainty factor, root-mean-

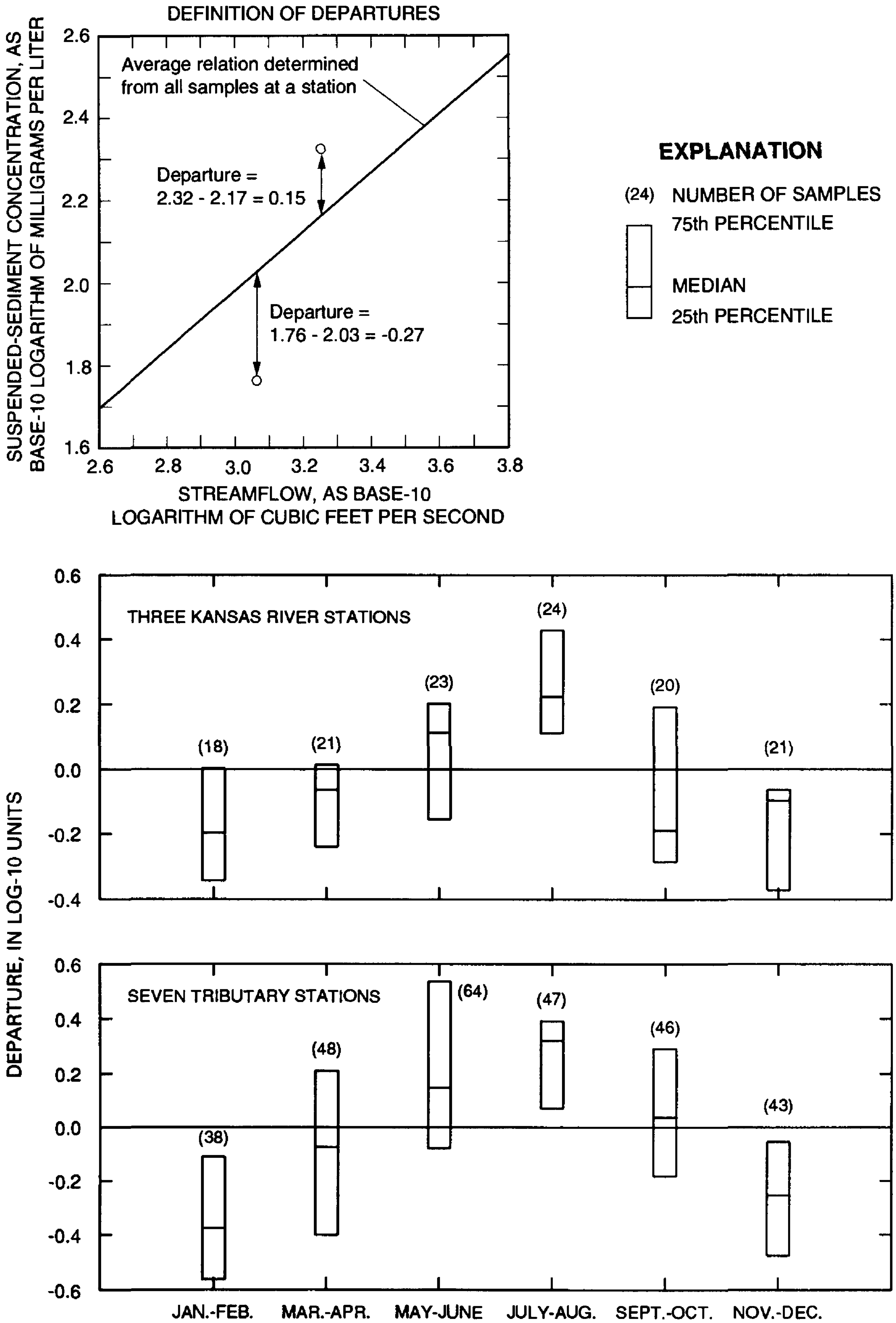

Figure 8. Seasonal departures from relations between suspended-sediment concentration and streamflow rate.

Table 4. Transport rate and yield of suspended sediment at selected sampling stations within lower Kansas River Basin, May 1987 through April 1990

[--, yield is not calculated for stations with one or more large impoundments upstream]

Map reference number (fig. 4)	Station name	Mean annual transport rate (tons per year)	Mean annual yield (tons per square mile of drainage area per year)	Root mean-square error of transport rate and yield (percent)	Percentage of transport rate and yield based on extrapolation[1]
1	Kansas River at Fort Riley, Kans.	1,700,000	--	21	12
3	Kings Creek near Manhattan, Kans.	71	17	54	0
23	West Fork Big Blue River near Dorchester, Nebr.	130,000	110	24	20
35	Big Blue River at Barneston, Nebr.	680,000	150	33	20
47	Little Blue River at Hollenberg, Kans.	710,000	260	32	31
50	Black Vermillion River near Frankfort, Kans.	91,000	220	36	0
52	Big Blue River near Manhattan, Kans.	110,000	--	25	10
59	Mill Creek near Paxico, Kans.	23,000	73	53	28
62	Kansas River at Topeka, Kans.	2,900,000	--	30	17
72	Delaware River near Muscotah, Kans.	35,000	81	58	52

Table 4. Transport rate and yield of suspended sediment at selected sampling stations within lower Kansas River Basin, May 1987 through April 1990—Continued

Map reference number (fig. 4)	Station name	Mean annual transport rate (tons per year)	Mean annual yield (tons per square mile of drainage area per year)	Root mean-square error of transport rate and yield (percent)	Percentage of transport rate and yield based on extrapolation[1]
74	Delaware River below Perry Dam, Kans.	7,700	--	30	56
83	Wakarusa River near Lawrence, Kans.	61,000	--	50	0
88	Kansas River at DeSoto, Kans.	4,100,000	--	14	0

[1] Percentage of transport rate calculated from streamflow values larger than those used to establish the relation between transport rate and streamflow.

square error of the mean annual transport rate and yield, may be an underestimate of the true root-mean-square error if a large proportion of the calculated transport and yield was for streamflows larger than the sampled streamflows. The second uncertainty factor shows the percentage that was based on extrapolation of the relation between transport rate and streamflow.

Mean annual suspended-sediment transport rate in the Kansas River increased from 1,700,000 tons per year at station 1 to 2,900,000 tons per year at station 62 and about 4,100,000 tons per year at station 88 (table 4 and fig. 9). Of the calculated increase from station 1 to 62, only 9 percent was contributed by the Big Blue River (110,000 tons per year at station 52), and the remaining 91 percent was contributed by smaller tributaries and by erosion of the Kansas River channel. Of the calculated increase from station 62 to 88, only 6 percent was contributed by the Delaware and Wakarusa Rivers (both controlled by reservoirs), and the remaining 94 percent was contributed by other tributaries (Stranger Creek is the largest, equal in size to the Wakarusa River) and erosion of the Kansas River channel. No computations of the relative contributions of tributaries and channel erosion were possible.

For the 3-year sampling period, the largest mean annual suspended-sediment yield was 260 tons per square mile per year for the Little Blue River (station 47 in table 4 and fig. 10). Under the more normal climatic conditions of 1978–86, the Black Vermillion River (station 50) and the Delaware River at station 72 had yields much larger than 260 tons per square mile per year (Jordan and Stamer, 1991). Because of the abnormal climatic conditions during 1987–90 and the uncertainty of some results, no conclusions can be developed concerning the relations of suspended-sediment transport rate or yield to natural and human factors during this period.

To provide additional insight to variation in suspended-sediment transport rates in the Kansas River, additional computations were made for the three Kansas River stations to estimate suspended-sediment transport rates for selected low-, medium-, and high-flow years during 1978–90 (table 5). The strong influence of high streamflows on the sediment transport rate is shown clearly; for example, at the DeSoto station (station 88) the high streamflow of 16,900 cubic feet per second was 530 percent larger than the low streamflow of 2,700 cubic feet per second, but the suspended-sediment transport rate was 900 percent larger during the high-flow year.

In the downstream direction, the increase of suspended-sediment transport rate in the Kansas River was limited by trapping of sediment in Tuttle Creek, Perry, and Clinton Lakes located on tributaries, whereas the increase of streamflow was subject only to the relatively minor effect of evaporation from the lake surfaces. For the medium-flow year, the streamflow increased from Fort Riley to Topeka by 130 percent from 2,200 to 5,020 cubic feet per second, but the suspended-sediment transport rate increased only 60 percent. In the same year, streamflow increased from Fort Riley to DeSoto by 250 percent from 2,200 to 7,650 cubic feet per second, whereas suspended-sediment transport rate increased 210 percent.

TRENDS IN SUSPENDED-SEDIMENT CONCENTRATION, 1963 THROUGH APRIL 1990

Although suspended-sediment data were collected from May 1987 through April 1990 at 13 sampling stations, adequate data for trend tests for at least 10 years through 1990 were available for only 5 stations. Statistical tests for trend were performed as described in Jordan and Stamer (1991), using programs developed by Schertz and others (1991). Multi-year trends in suspended-sediment concentration at a site can be obscured by the large variability of concentration that is related to streamflow, season, and other (usually unknown) factors. In addition to contributing to the variability of concentration, the rates of streamflow at the times of sampling may have trends of their own that could produce the appearance of trends in concentration. Trends in streamflow also could, in the statistical test, counteract trends in concentration and prevent their detection. For these reasons, suspended-sediment concentrations were flow adjusted for the trend tests, and the tests used seasonal adjustment in their method of calculating Kendall's tau statistic from which the probability level was determined.

The results of trend tests for the longest period available through 1990 for each of the five sampling stations are shown in table 6. The period 1977–90 for the Kansas River at station 88 also is shown for comparison with three other stations for the same period. A trend test could not be done for 1977–90 for the West Fork Big Blue River at station 23 because of a lack of data for 1977–79. Results of trend tests for 1977–90 at four stations and for 1963–90 at one station are shown in figure 11.

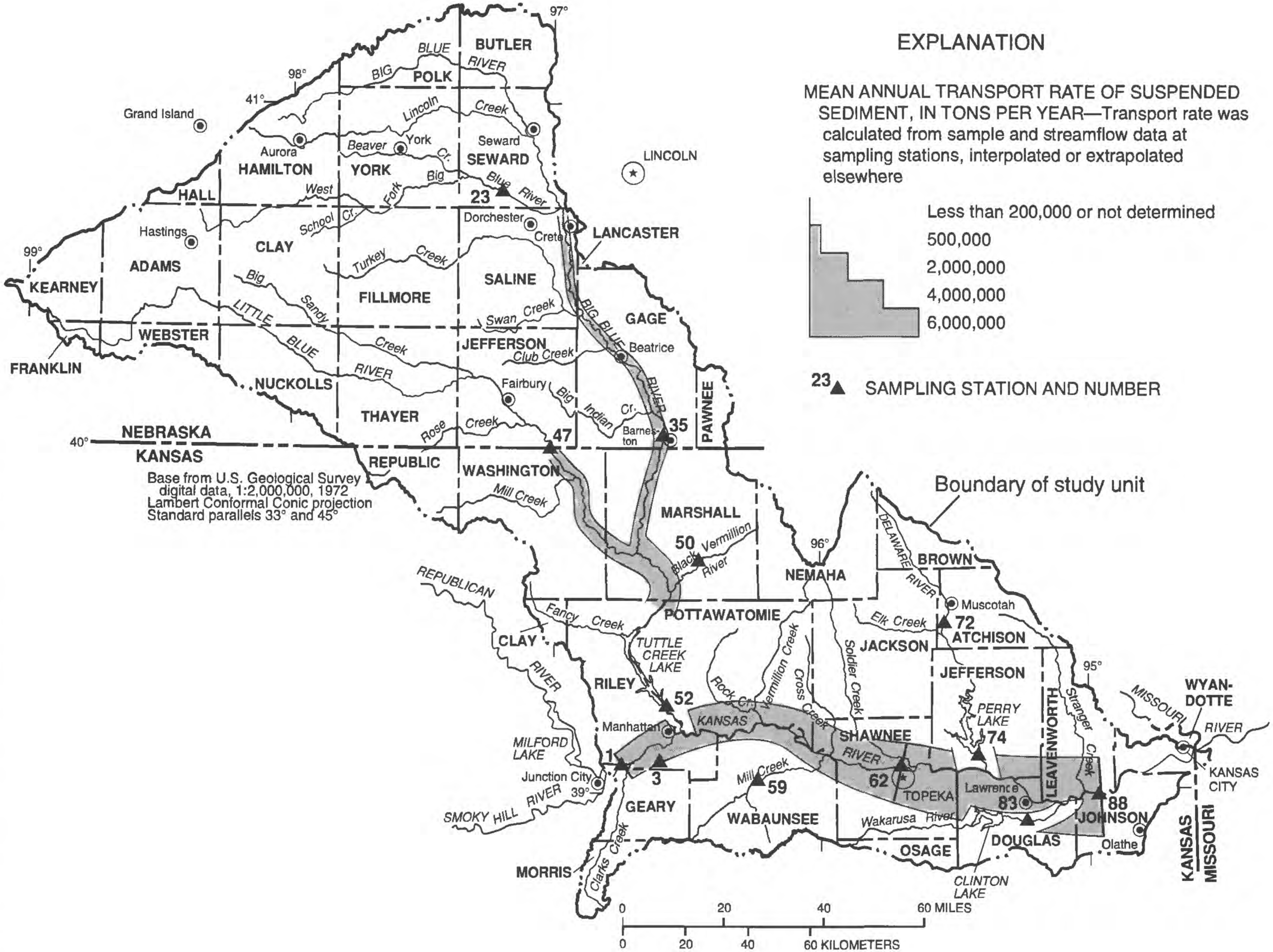

Figure 9. Geographic distribution of mean annual transport rate of suspended sediment, May 1987 through April 1990.

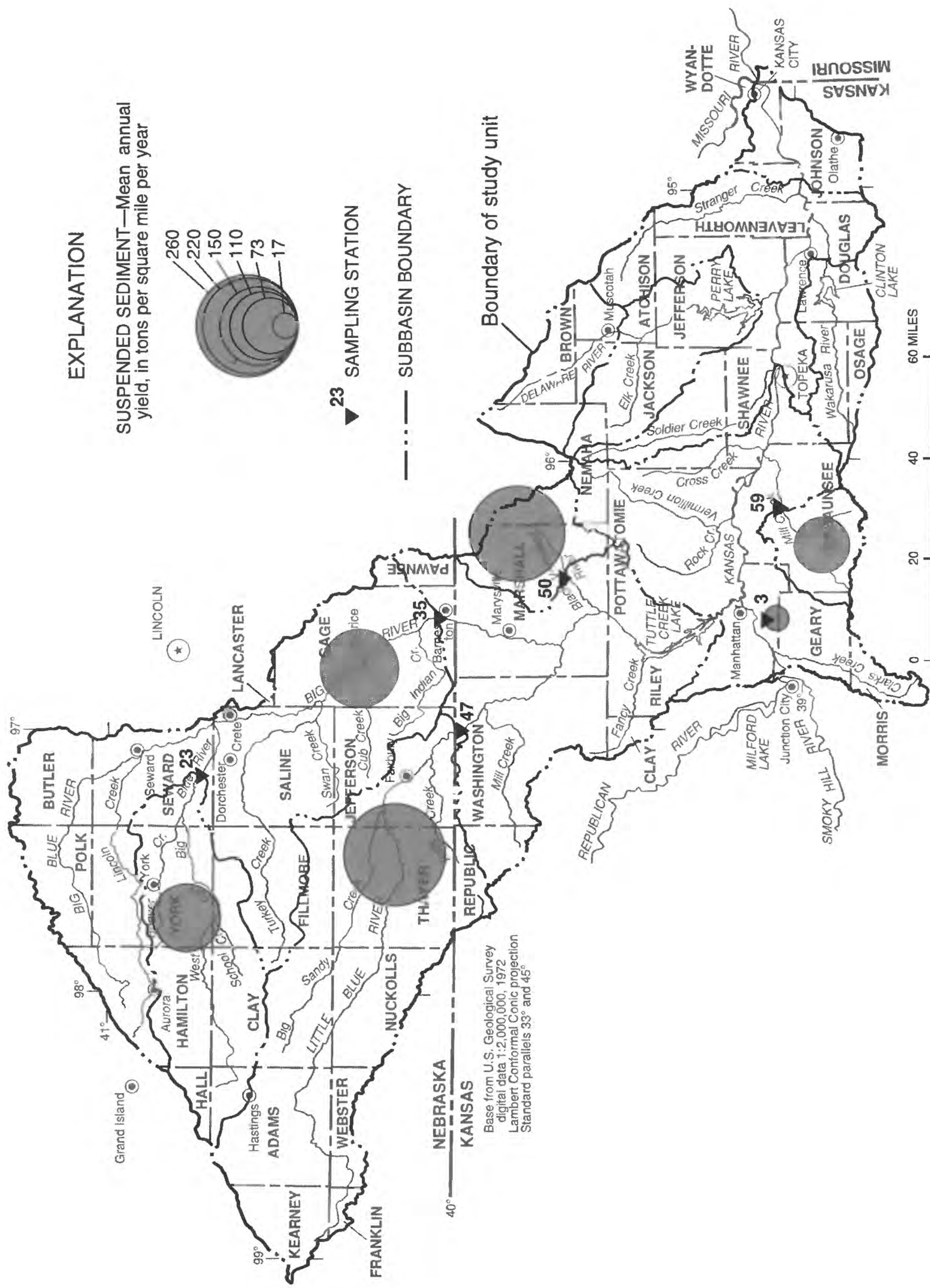

Figure 10. Geographic distribution of mean annual suspended-sediment yield, May 1987 through April 1990.

Table 5. Annual transport rate of suspended sediment at Kansas River stations for selected years of low, medium, and high streamflows from the 1978 through the1990 water years

Map reference number (fig. 4)	Station name	Yearly mean streamflow (cubic feet per second)	Transport rate (tons per year)	Root mean-square error (percent)	Percentage of transport rate based on extrapolation[1]
		Low streamflow (1989)			
1	Kansas River at Fort Riley, Kans.	870	450,000	31	0
62	Kansas River at Topeka, Kans.	2,410	1,600,000	37	29
88	Kansas River at DeSoto, Kans.	2,700	2,100,000	29	0
		Medium streamflow (1985)			
1	Kansas River at Fort Riley, Kans.	2,200	1,600,000	22	0
62	Kansas River at Topeka, Kans.	5,020	2,600,000	28	0
88	Kansas River at DeSoto, Kans.	7,650	5,000,000	14	0
		High streamflow (1987)			
1	Kansas River at Fort Riley, Kans.	6,230	7,500,000	28	30
62	Kansas River at Topeka, Kans.	13,400	13,000,000	41	18
88	Kansas River at DeSoto, Kans.	16,900	21,000,000	17	0

[1]Percentage of transport rate calculated from streamflow values larger than those used to establish the relation between transport rate and streamflow.

Table 6. Trend-test results for flow-adjusted, suspended-sediment concentrations at selected sampling stations within lower Kansas River Basin

[Underlined, significant at 0.1 probability level; <, less than]

Map reference number (fig. 4)	Station name	Inclusive years	Number of years	Results of seasonal Kendall tests for time trend of flow-adjusted, suspended-sediment concentration	
				Probability level	Average rate of of change (percent per year)
1	Kansas River at Fort Riley, Kans.	1977–90	14	0.30	3.5
23	West Fork Big Blue River near Dorchester, Nebr.	1963–90	28	≤.005	-3.9
50	Black Vermillion River near Frankfort, Kans.	1977–90	14	.74	-.4
72	Delaware River near Muscotah, Kans.	1977–90	14	.71	-.6
88	Kansas River	1975–90	16	.72	.6
	at DeSoto, Kans.	1977–90	14	.05	2.8

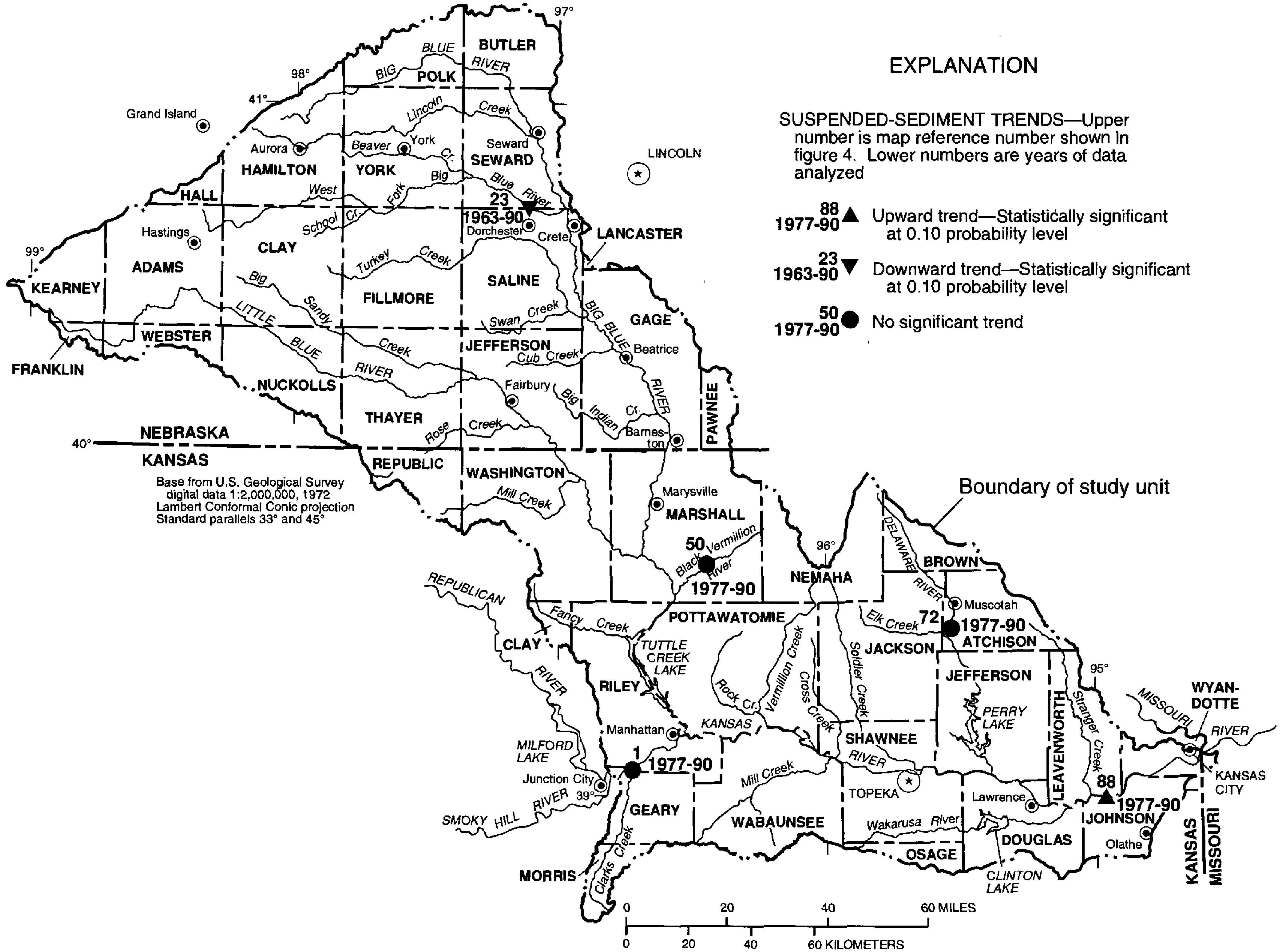

Figure 11. Trends in flow-adjusted, suspended-sediment concentration at selected sampling stations, 1963–90 and 1977–90.

Flow adjustment of suspended-sediment concentrations was done by using the relation between the logarithms of concentration and streamflow. The resulting average rate of change, therefore, represents the average percentage change from year to year.

Trends in suspended-sediment concentration could be affected by many factors for which relevant data are not readily available. One factor for which data are available is the percentage of cropland removed from production during 1986 through January 1990 as part of the U.S. Department of Agriculture's Conservation Reserve Program (table 7). The downward trend of flow-adjusted, suspended-sediment concentration at station 23 on the West Fork Big Blue River may not be closely related to the small percentage of cropland removed from production. However, the drainage area is in the Upper Big Blue Natural Resources District, established in 1972, which has been promoting conservation of soil and water by such measures as terraces and grade stabilization structures (newsletters of Upper Big Blue Natural Resources District, York, Nebr.). The upward trend for 1977–90 and apparent absence of trend for 1975–90 at station 88 on the Kansas River cannot be readily explained. Erosion of the riverbanks was known to occur during the period (Simons, Li, and Associates, Inc., 1984) but probably was more intense in the early part of the period, so this could not explain the upward trend.

Downward trends in flow-adjusted, suspended-sediment concentration for station 50 on the Black Vermillion River and station 72 on the Delaware River were not statistically significant despite 6.6 and 6.4 percent of the cropland in the drainage areas being removed from production during 1986–90 (table 7) and having numerous reservoir detention structures being completed during 1977–90. Perhaps more time is needed before the effects of these conservation measures will be evident. The amount of drainage area upstream from detention structures in the two basins from the end of 1976 through the end of April 1990 is shown in table 8. About 65 to 90 percent of the sediment entering detention reservoirs from upstream would have been trapped in the reservoirs (estimates from relations developed by G.M. Brune and shown in Vanoni, 1975, p. 590–591). In addition to the detention structures affecting part of the drainage area, organized watershed-district efforts include land-treatment measures, such as terraces and grassed waterways, intended to decrease runoff rates, erosion damages, and sediment yield (see U.S. Soil Conservation Service, 1979, p. 4–6). These measures have been accomplished at different rates than completion of detention structures; thus, data on detention structures are only a partial measure of the effect of watershed-district activities on sediment concentrations at a downstream sampling station. For the drainage of station 50 on the Black Vermillion River, the area upstream from detention structures increased from 7.5 to 15.1 percent of the total drainage area during the period analyzed for trend, and for the drainage of station 72 on the Delaware River, the area increased only from 6.7 to 8.1 percent. Because of the small changes in those areas relative to the total drainage areas and because of natural large short-term variations in suspended-sediment concentrations from land downstream from structures, the effects of increases in detention structures could not be discerned clearly in data collected at the sampling sites downstream.

Although some of the cropland having above-average susceptibility to erosion was removed from production upstream from near Frankfort and Muscotah, Kans. (stations 50 and 72), under the Conservation Reserve Program, data on exact location of that land were not readily available. Cropland removed from production upstream from detention structures would have much less effect on suspended sediment at a sampling station than would cropland downstream from detention structures. Although the average rates of change were downward for the two stations, the changes were not statistically significant. A future program of suspended-sediment data collection for the Delaware River at Muscotah, Kans. (station 72), would provide for more accurate assessment of the effects of the Conservation Reserve Program. Future data, showing the full effect of the program, could be compared with data for 1977–85 before the program began and could be interpreted with reference to detailed information on location of cropland removed from production.

CONCLUSIONS

Monthly or more frequent suspended-sediment sampling during May 1987 through April 1990 at 13 stations in the lower Kansas River Basin of Kansas and Nebraska showed median concentrations of 100 to 110 mg/L for 3 stations on the Kansas River and 4 to 110 mg/L for 10 stations on tributary streams.

Table 7. Land removed from crop production in selected drainage areas as part of the U.S. Department of Agriculture's Conservation Reserve Program

[Data are cumulative totals for 1986 through January 1990. Calculated from data provided by the U.S. Agricultural Stabilization and Conservation Service, Lincoln, Nebr., U.S. Soil Conservation Service, Salina, Kans., Nebraska Natural Resources Data Bank of the Nebraska Natural Resources Commission, Lincoln, Nebr., and U.S. Bureau of the Census (1989, p. 210–223)]

Map reference number (fig. 4)	Station name	Land removed from production, as a percentage of total cropland in drainage area
23	West Fork Big Blue River near Dorchester, Nebr.	0.7
35	Big Blue River at Barneston, Nebr.	2.9
47	Little Blue River at Hollenberg, Kans.	2.4
50	Black Vermillion River near Frankfort, Kans.	6.6
59	Mill Creek near Paxico, Kans.	18.4
72	Delaware River near Muscotah, Kans.	6.4

Table 8. Drainage areas upstream from detention structures in the Black Vermillion and Delaware River Basins, 1976–90

[Calculated from data provided by U.S. Soil Conservation Service, Salina, Kans.]

Year	Drainage area upstream from detention structures completed by end of year or month indicated			
	Black Vermillion River (station 50 fig. 4) (square miles)	Percentage of total drainage area	Delaware River (station 72, fig. 4) (square miles)	Percentage of total drainage area
1976	30.6	7.5	28.9	6.7
1977	37.8	9.2	28.9	6.7
1978	44.8	10.9	28.9	6.7
1979	47.7	11.6	28.9	6.7
1980	53.1	13.0	28.9	6.7
1981	57.7	14.1	28.9	6.7
1982	57.7	14.1	28.9	6.7
1983	59.2	14.4	28.9	6.7
1984	59.2	14.4	28.9	6.7
1985	59.2	14.4	29.7	6.9
1986	59.2	14.4	29.7	6.9
1987	62.1	15.1	31.1	7.2
1988	62.1	15.1	34.7	8.1
1989	62.1	15.1	34.7	8.1
1990 (April)	62.1	15.1	34.7	8.1

Concentrations in the 90th percentile for tributary stream stations ranged from 240 to 3,200 mg/L, except at stations immediately downstream from large reservoirs, which ranged from 58 to 170 mg/L. The larger median and 90-percentile concentrations were associated with high-density irrigated cropland in areas of little local relief and medium-density irrigated cropland in more dissected areas. Smaller median and 90th-percentile concentrations upstream from reservoirs were from areas of little or no row-crop cultivation or areas of substantially less-than-normal precipitation and streamflow.

The median percentage of suspended sediment finer than 0.062 millimeter varied from 84 to 99 percent. Differences among stations were relatively small and could have resulted as much from differences in the fraction of stream depth sampled as from any other cause. Suspended-sediment concentrations in relation to streamflow rate followed a consistent seasonal pattern; after accounting for the effect of flow, concentrations were typically smallest during January–February and largest during July–August.

Mean annual suspended-sediment transport rate in the Kansas River from May 1987 through April 1990 increased substantially in the downstream direction from 1,700,000 tons per year at the Fort Riley station to 4,100,000 tons per year at the DeSoto station. Suspended-sediment yields for tributary stream stations ranged from 17 to 260 tons per square mile per year. Because of abnormally dry climatic conditions and large uncertainty factors for the results of some computations, no conclusions could be reached concerning the relations of suspended-sediment transport rate or yield to natural and human factors.

Tests for trends in flow-adjusted, suspended-sediment concentrations at five sampling stations resulted in one statistically significant downward trend for 1963–90 and one statistically significant upward trend for 1977–90. The trend-test results could not be explained by data on cropland removed from production or the effect of detention structures.

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