Hydrologic Benchmark Network Stations in the West-Central U.S. 1963-95 (USGS Circular 1173-C)

Kings Creek near Manhattan, Kansas (06879650)

This report details one of the approximately 50 stations in the Hydrologic Benchmark Network (HBN) described in the four-volume U.S. Geological Survey Circular 1173. The suggested citation for the information on this page is:

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All of the tables and figures are numbered as they appear in each circular. Use the navigation bar above to view the abstract, introduction and methods for the entire circular, as well as a map and list of all of the HBN sites. Use the table of contents below to view the information on this particular station.

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Site Characteristics and Land Use

The Kings Creek HBN Basin is in the Central Lowland physiographic province (Fenneman, 1946) in eastern Kansas. The ecoregion of the basin is classified as the Prairie Parkland (Temperate) Province, with alternating prairie and deciduous forest (Bailey, 1995). Kings Creek drains 10.6 km^2 of grassy terrain in the Flint Hills (Figure 6. *Map showing study area of the Kings Creek Basin and photograph of the landscape of*

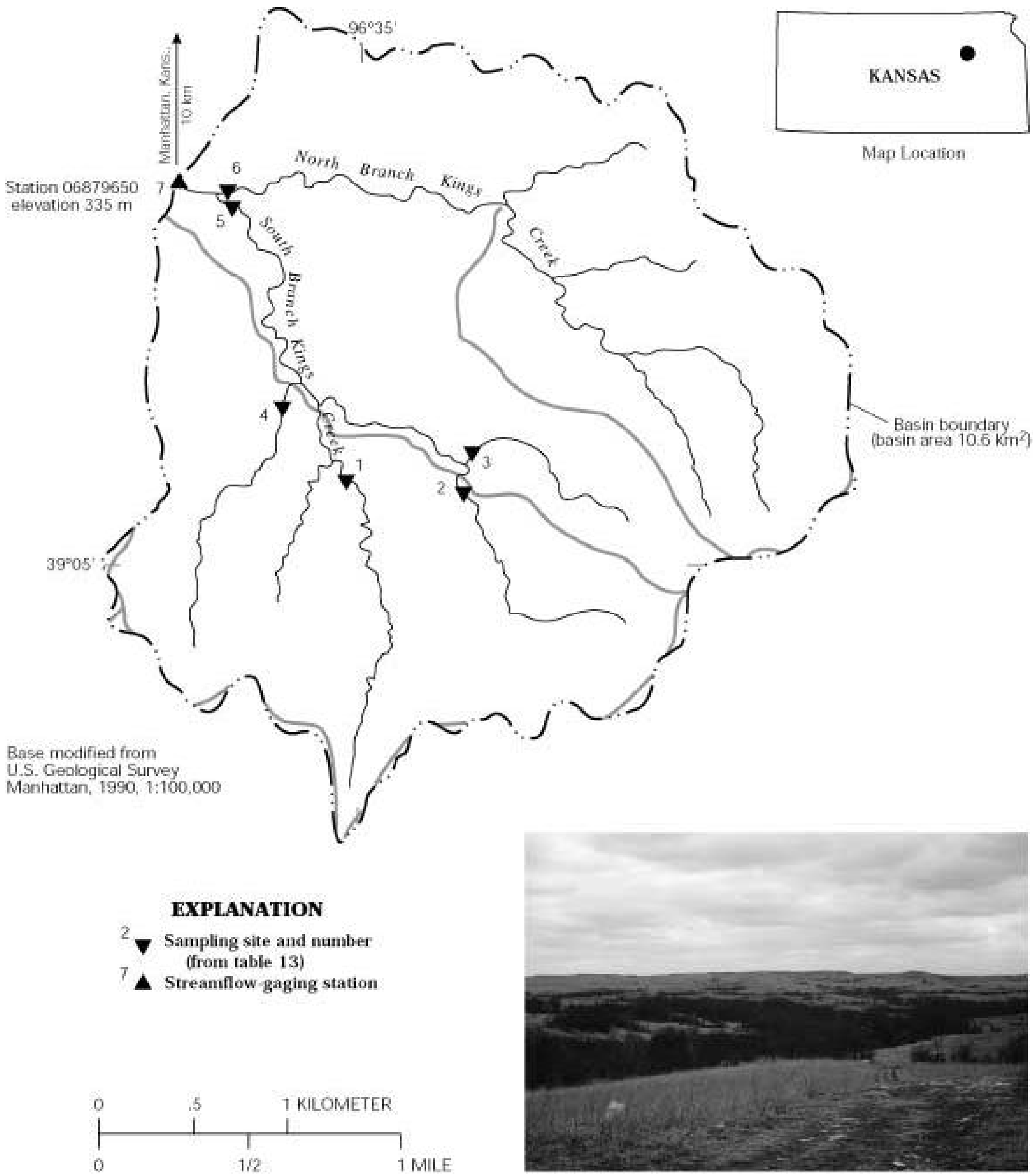

Figure 6. *Map showing study area of the Kings Creek Basin and photograph of the landscape of the basin*

the basin). The HBN station is 10 km south of Manhattan, Kans., at a latitude of 39×06'07" and a longitude of 96×35'42". The topography is gently rolling with basin elevations ranging from 335 to about 442 m. The slope of the main channel is 17m/km. Kings Creek is tributary to McDowell Creek, which drains into the Kansas River.

Kings Creek is an intermittent stream with sustained flows generally occurring in the spring. Average annual precipitation at the Manhattan, Kans., weather station is about 84 cm, which mostly falls in the form of rain during spring and early summer (National Climatic Data Center, 1996). Streamflow generally ceases during late summer, and the stream may remain dry during the fall. Flow in ephemeral headwater channels occurs only immediately following rainfall events. Mean monthly discharges range from less than 0.01 m^3/s in September to 0.23 m^3/s in May, and average annual runoff is about 20 cm (Putnam and others, 1996). The Kings Creek Basin is characterized by warm to hot summers and cold winters. Mean monthly temperature extremes at the weather station ranged from -1.8×C in January to 26.6×C in July during the period 1900–95 (National Climatic Data Center, 1996).

The Kings Creek Basin is contained within the Konza Prairie Research Natural Area and is the only HBN Basin that exclusively drains pristine, native tallgrass prairie. The grass species are big bluestem, indian grass, switchgrass, little bluestem, Kentucky bluegrass, and Junegrass. The grasses have never been plowed because of the rocky soils and steep topography (Knapp and others, 1998). The prairie contains many species of herbaceous plants other than grasses, including heath aster, dotted gayfeather, ironweed, and several goldenrods. Annual burnings are set by land managers to control woody vegetation. The burning pattern varies in the basin; less frequently burned areas have a greater plant diversity, whereas burned areas tend to have a greater dominance of warm-season grasses. Woody vegetation in the unburned areas include sumac, dogwood, and eastern red cedar. Strips of forest along stream channels are composed of oak species, hackberry, and American elm.

The Kings Creek Basin lies within the Flint Hills Upland. The formation of prairie grass- lands probably is associated with the Miocene uplift of the Rocky Mountains (Knapp and others, 1998), which caused a rain shadow to develop to the east, favoring drought-tolerant grasses over trees. The basin is underlain by sedimentary rocks of Paleozoic age (Jewett, 1941). Shales and limestones of the upper Council Grove Group of Permian age are in the uplands, whereas shales and limestones of the lower Council Grove Group are exposed in the alluvial valleys (Jewett, 1941). Alternating layers of more resistant flint- and chert-bearing limestone and less resistant shales give the terrain a benched appearance. Limestone units are exposed on steep-sided hills above valleys (Knapp and others, 1998). Ridges are flat and have shallow, rocky soils. Upland soils are silty clay loams, which are well drained, moderately deep to shallow, and sloping to moderately steep (U.S. Department of Agriculture, 1975b). Near the channel, soils are deep and stratified with silty, clay loams with low slopes of 0–6 percent; limestone and chert fragments are present in the subsoils.

The Kings Creek Basin lies within Riley County and is entirely within the Konza Prairie Research Natural Area, which was established in 1972 as a research facility. The land was originally acquired by The Nature Conservancy and is leased to Kansas State University, Division of Biology, for research purposes (Knapp and others, 1998). The Konza Prairie was selected as a research site for the Long Term Ecological Research Program of the National

Science Foundation in 1981. Permission to access the site is obtained by contacting the Konza Prairie Office at Kansas State University in Manhattan. A light-duty service road provides access to some of the Kings Creek tributaries. Foot trails also provide access to the basin. Land-use activities are designed and controlled in the Kings Creek Basin. The land-management plan is designed to study the effect of fire and grazing on prairie plants and animals. The burn schedule is variable in the basin; sections are burned on a 1-, 2-, 4-, or 20-year cycle. Grazing divisions in the basin include grazed and ungrazed sections; both types of grazing divisions have burn schedules. Grazing in the South Branch Kings Creek drainage is by native bison, which were reintroduced to the prairie in 1987. Grazing by experimental cattle herds is allowed in other parts of the Konza research area, outside the Kings Creek Basin.

Historical Water-Quality Data and Time-Series Trends

The data set analyzed for the Kings Creek HBN station includes 72 water-quality samples that were collected from April 1980 to July 1995. Sampling frequency is described on the basis of water year, which begins on October 1 and ends on September 30. Annual sampling frequency was variable over the 15-year period. The median number of annual samples that were collected was three; only one sample was collected in 1994. The highest sampling frequencies were in 1989 and 1990 when 9 and 12 samples were collected, respectively. In 1989 and 1990, multiple sampling events were conducted during storm runoff as part of the USGS National Water-Quality Assessment Program, and those samples were used to supplement the HBN data set. All samples were analyzed at the NWQL in Arvada, Colo. The period of record for discharge is from water year 1979 to current year (2000).

Data quality was checked using ion balances and time-series plots. Calculated ion balances for samples with complete major-ion analyses are shown in Figures 7a and 7b. *Temporal variation of discharge, field pH, major dissolved constituents, and ion balance at Kings Creek, Kansas*. More than 90 percent of the samples had ion balances within the ±10 percent range, indicating that the major-ion analytical results generally were of good quality and that unmeasured constituents, such as organic anions, nutrients, and trace metals, generally do not contribute substantially to the ion composition of the stream water. Time-series plots of ion concentrations were inspected for data quality (fig. 7). The increase in scatter in the chemical data during 1989 and 1990 was the result of samples that were collected during storm runoff periods, which also is reflected in the scatter in the discharge data for that same period (fig. 7).

The median and range of major-ion concentrations in the stream water collected at the Kings Creek HBN station and VWM concentrations in wet precipitation measured at the Konza Prairie NADP station are presented in table 10. The NADP station is about 1.5 km west of the HBN station. Precipitation chemistry at the NADP station was dilute and slightly acidic with VWM pH of 5.0 during the period of record, 1982–95. The dominant cation in precipitation was ammonium, which contributed about 37 percent of the total cation concentration; calcium contributed 31 percent and hydrogen contributed 19 percent. The dominant anions in precipitation were sulfate and nitrate, which contributed 54 and 40 percent, respectively. This was the highest VWM sulfate concentration (27 meq/L) recorded for the NADP stations used in this study. Sulfate concentrations in precipitation tend to be higher in the Midwest and Ohio Valley, reflecting the sulfur emission source in these areas. Ammonium and nitrate tend to be higher in precipitation chemistry where livestock and fertilizer applications are common (National Atmospheric Deposition Program/National Trends Network, 1997). The dry deposition of nitrogen is not included in the wet deposition value but is important in tallgrass prairies and has been estimated to be 25 to 50 percent of the total atmospheric input (Gilliam, 1987).

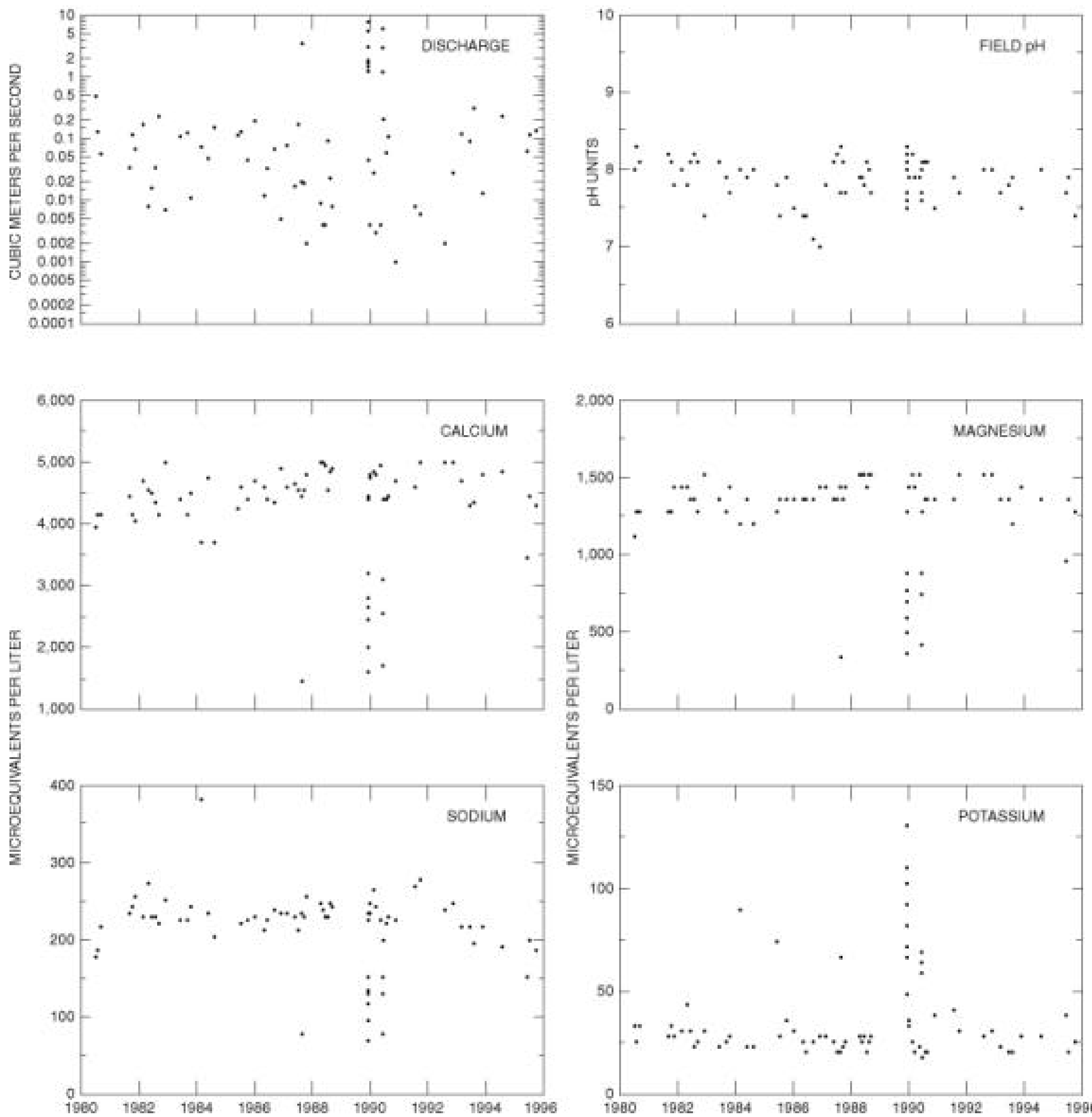

Figure 7a. *Temporal variation of discharge, field pH, major dissolved constituents, and ion balance at Kings Creek, Kansas*

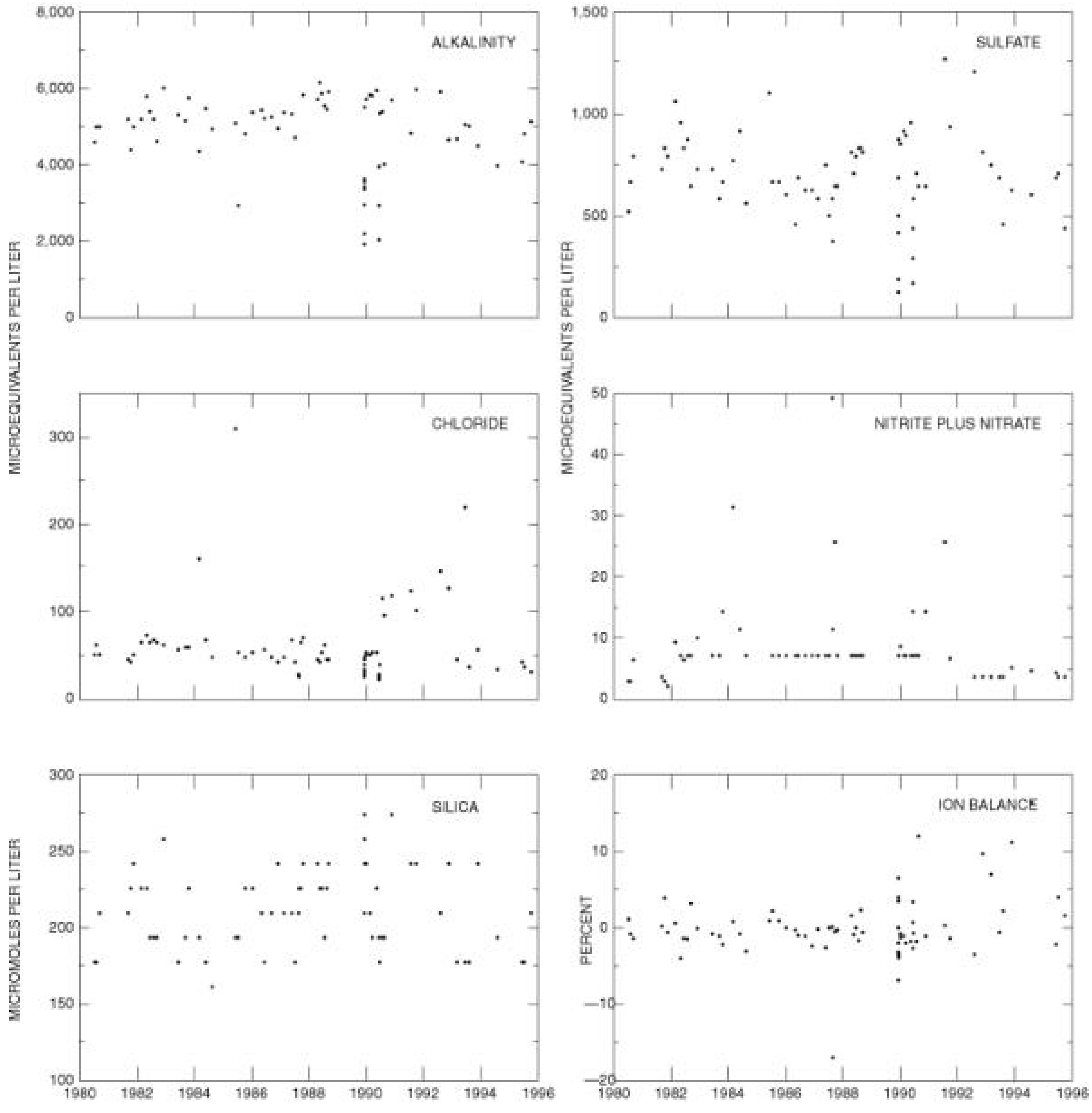

Figure 7b. *Temporal variation of discharge, field pH, major dissolved constituents, and ion balance at Kings Creek, Kansas - Continued*

Table 10. Minimum, first quartile, median, third quartile, and maximum values of physical properties and major ions measured in water-quality samples from Kings Creek, Kansas, 1980—95, and volume-weighted mean concentrations in wet precipitation collected at the Konza Prairie Station, Kansas, 1982—95

[Parameters in units of microequivalents per liter, except for discharge in cubic meters per second, specific conductance in microsiemens per centimeter at 25 degrees Celsius, pH in standard units, and silica in micromoles per liter; n, number of stream samples; VWM, volume-weighted mean; spec. cond., specific conductance; --, not reported; <, less than]

Parameter	Stream Water						Precipitation VWM
	Minimum	First quartile	Median	Third quartile	Maximum	n	
Discharge	<0.001	0.01	0.07	0.17	7.9	72	--
Spec. cond., field	180	481	540	576	618	67	--
pH, field	7.0	7.7	7.9	8.1	8.3	72	5.0[a]
Calcium	1,400	4,200	4,400	4,800	5,000	72	16
Magnesium	340	1,300	1,400	1,400	1,500	72	2.5
Sodium	70	200	230	240	380	72	3.5
Potassium	18	23	28	38	130	72	.8
Ammonium	<.7	<.7	2.1	2.9	7.1	60	19
Alkalinity, laboratory	1,900	4,600	5,200	5,500	6,200	70	--
Sulfate	120	580	690	830	1,300	72	27
Chloride	22	41	51	65	310	72	3.4
Nitrite plus nitrate	2.1	6.4	7.1	7.1	49	65	20[b]
Silica	160	190	210	240	270	72	--

[a] Laboratory pH.

[b] Nitrate only.

Stream water in Kings Creek is a calcium bicarbonate type. The sum of ion concentrations ranged from about 4,300 to about 14,000 meq/L. Alkalinity ranged from 1,900 to 6,200 meq/L, and bicarbonate was the primary contributor to alkalinity at this station. The major cation, calcium, contributed 73 percent of median cation concentration in stream water. The major anion, bicarbonate, contributed 87 percent of the median anion concentration. The ion composition of the stream water reflects the weathering of the underlying limestone bedrock. Median concentrations of ammonium and nitrate were lower in the stream water than in the precipitation, indicating that nitrogen generally is retained by the prairie biomass. Nitrogen generally is a limiting nutrient in tallgrass prairies (Gilliam, 1987). Mean annual transport of nutrients from Kings Creek was very low compared to other streams in the lower Kansas River Basin (Helgesen, 1996); nitrate concentrations were low enough to limit algal growth during the summer (McArthur and others, 1985).

Correlations among dissolved constituents and discharge were determined for Kings Creek (table 11). The base cations and anions, except dissolved potassium, showed inverse relations with discharge. These results are consistent with a hydrologic system where base-flow chemistry that is dominated by ground water is diluted during periods of increased discharge, particularly rainfall events. Ion concentrations in ground water tend to be greater than in surficial sources because the contact time with rocks and minerals is longer. The time-series plots for base cations, except potassium, and base anions (fig. 7) show the inverse relation when compared to the discharge time-series plot during the 1989 and 1990 storm-event sampling. The behavior of potassium is more similar to plant nutrients and sediment. Exportation of nitrogen from the basin was reported to increase during storm events (McArthur and others, 1985), and sediment also shows a flow- driven relation during storm events (Knapp and others, 1998). The strongest ion correlation was between calcium and magnesium (rho value = 0.907), which is typical of a carbonate-dominated geologic environment.

Table 11. Spearman rank correlation coefficients (rho values) showing the relation among discharge, pH, and major ions, Kings Creek, Kansas, 1980 through 1995

[Q, discharge; Ca, calcium; Mg, magnesium; Na, sodium; K, potassium; Alk, alkalinity; SO_4, sulfate; Cl, chloride; SiO_2, silica; --, not applicable]

	Q	pH	Ca	Mg	Na	K	Alk	SO_4	Cl
pH	0.176	--	--	--	--	--	--	--	--
Ca	-.782	-0.164	--	--	--	--	--	--	--
Mg	-.804	-.187	0.907	--	--	--	--	--	--
Na	-.758	-.050	.682	0.774	--	--	--	--	--
K	.238	-.041	-.346	-.402	-0.164	--	--	--	--
Alk	-.784	-.051	.711	.742	.661	-0.362	--	--	--
SO4	-.638	.159	.570	.610	.726	-.102	0.590	--	--
Cl	-.551	.047	.439	.480	.588	-.228	.441	0.626	--
SiO_2	-.274	-.085	.206	.205	.255	.566	.125	.053	-0.072

Results of the seasonal Kendall test for trends in discharge and major dissolved constituents for Kings Creek from 1982 through 1995 are presented in table 12. The only statistically significant trend (a = 0.01) was decreasing sodium for flow-adjusted concentrations. Except for the 1989 and 1990 storm-event sampling, sodium concentrations were generally constant until about 1992, after which they begin to decline. The time-series plot indicates that most discharge measurements made during 1993–95 were higher than the median discharge, and sodium did show an inverse correlation with discharge. However, the flow-adjustment should remove the bias introduced by discharge. The downward sodium trend is consistent with the decrease in sodium detected in precipitation by Lynch and others (1995). For the period 1980–92, decreasing sodium concentrations were detected at 53 of 58 NADP stations throughout the country. Statistically significant downward trends (a = 0.05) were reported at 28 of the 53 stations with decreasing sodium concentrations; many of these were in the regional area that includes Kansas.

Table 12. Results of the seasonal Kendall test for trends in discharge and unadjusted and flow-adjusted pH and major-ion concentrations, Kings Creek, Kansas, 1982 through 1995

[Trends in units of microequivalents per liter per year, except for discharge in cubic meters per second per year, pH in standard units per year, and silica in micromoles per liter per year; p-value, attained significance level; --, not calculated; <, less than]

Parameter	Unadjusted		Flow adjusted	
	Trend	p-value	Trend	p-value
Discharge	0.01	0.701	--	--
pH	-.02	.055	-0.02	0.124
Calcium	8	.728	7	.698
Magnesium	<.01	.670	-2	.635
Sodium	-2	.056	-2	.007
Potassium	<.01	.824	.08	.698
Alkalinity	-50	.016	-70	.016
Sulfate	-7	.318	-5	.211
Chloride	-.4	.897	([b])	--
Nitrite plus nitrate	-.2[a]	.086	--	--
Silica	<.01	.999	.4	.635

[a] Trend test for highly censored data was used.

[b] Concentration-flow model not significant at a = 0.10.

Synoptic Water-Quality Data

Results of a surface-water synoptic sampling conducted April 5, 1993, in the Kings Creek Basin are presented in table 13, and locations of the sampling sites are shown in figure 6. Discharge at the HBN station (site 7) was 0.48 m^3/s, which is higher than the mean monthly discharge of 0.16 m^3/s for the month of April (Putnam and others, 1996). Concentrations of dissolved constituents of tributaries generally were near or less than the median concentrations at the HBN station for the period 1980–95 (table 10). The sum of ions in the basin varied little, ranging from about 11,000 meq/L on South Branch Kings Creek (site 1) to about 12,000 meq/L on North Branch Kings Creek (site 6). The water chemistry in all the tributaries was similar to that at the HBN station and was a calcium bicarbonate type. The percent difference of cations and anions ranged from 0.2 to 1.2 percent, which indicates that unmeasured constituents, such as organic ions, nutrients, and trace metals, do not substantially contribute to the ionic composition of the basin waters.

Table 13. Physical properties and major-ion concentrations in surface-water samples collected at sites in the Kings Creek Basin, April 5, 1993

[Site locations shown in fig. 6; Q, discharge in cubic meters per second; SC, specific conductance in microsiemens per centimeter at 25 degrees Celsius; pH in standard units; Ca, calcium; Mg, magnesium; Na, sodium; K, potassium; Alk, alkalinity; SO_4, sulfate; Cl, chloride; NO_3, nitrate; SiO_2, silica; concentrations in microequivalents per liter, except silica is in micromoles per liter; --, not measured; <, less than; criteria used in selection of sampling sites: LU = land use]

Site	Identification number	Q	SC	pH	Ca	Mg	Na	K	Alk	SO_4	Cl	NO_3	SiO_2	Criteria
1	390515096350300	0.08	489	8.2	4,200	1,200	160	18	5,200	290	25	<0.4	170	LU
2	390513096343700	.04	538	8.1	4,300	1,100	160	21	5,400	290	23	1.6	170	LU
3	390519096343500	.01	493	8.2	4,000	1,000	170	24	5,000	290	28	1.8	170	LU
4	390529096351700	--	521	8.1	4,600	1,200	160	18	5,400	330	31	<.4	170	LU
5	390604096352900	.22	539	8.2	4,200	1,200	170	20	5,300	350	31	<.4	170	LU
6	390606096352900	.16	543	8.2	4,400	1,300	210	23	5,300	500	45	.7	180	LU
7	06879650	.48	543	8.1	4,400	1,300	190	21	5,300	460	37	1.2	180	--

The low variability of the water quality at the sampling sites is due to the small size of the Kings Creek Basin and the homogeneity of the geology and soils. The subbasins do have different burn and grazing practices. The North Branch Kings Creek (site 6) drains an area that is ungrazed, whereas the other tributaries drain areas grazed by bison. Samples from the ungrazed area have slightly higher concentrations of some of the base cations and anions, including sodium, sulfate, and chloride. The naming of the tributary (Appendix A) represents the burn schedule—for example, N20B is burned on a 20-year cycle. The effects of burning practices are difficult to assess with only one synoptic sample in each cycle. Some slight variation in nitrate exists—1.8 meq/L for the 20-year cycle subbasin and less than 0.4 meq/L in the 2- and 4-year cycle subbasins. However, all the nitrate concentrations were low. A study of soil-water chemistry found that burning does not appear to substantially alter soil-water nitrogen (Knapp and others, 1998).

Researchers have reported on other factors that affected nitrogen concentrations in prairie stream waters of the Konza Prairie Research Natural Area. Seasonal fluctuations were studied by McArthur and others (1985). They reported less nitrogen is exported from the basin during the summer growing season compared to fall or spring. Nitrate concentrations also responded to diurnal variations; the lowest concentrations tended to occur during daylight hours, corresponding to photosynthetic activity (McArthur and others, 1985). Tate (1990) reported that changes in flow characteristics influenced nitrate concentrations in the basin; nitrate concentrations were higher when the intermittent channels began to flow, then decreased as flow continued.

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Appendix A. List of Map References

a. U.S. Geological Survey topographic maps:

- Manhattan, Kansas (1:100,000), 1990
- Swede Creek, Kansas (1:24,000), 1982, streamflow- gaging station

b. Geologic maps:

- Jewett, J.M., 1941, The geology of Riley and Geary Counties, Kansas: State Geological Survey of Kansas Bulletin 39.

c. Soil surveys:

- U.S. Department of Agriculture, 1975, Soil survey of Riley County and part of Geary County, Kansas: U.S. Department of Agriculture, Soil Conservation Service, 71 p.

Appendix B. NWIS Site-Identification Numbers

Table B–1. NWIS site-identification numbers and site names for water-quality sampling sites.

Site	Identification Number	Site Name
1	390515096350300	WATERSHED N4D
2	390513096343700	WATERSHED N1B
3	390519096343500	WATERSHED N20B
4	390529096351700	WATERSHED N2B
5	390604096352900	SOUTH BRANCH KINGS CREEK
6	390606096352900	NORTH BRANCH KINGS CREEK
7	06879650	KINGS CREEK NEAR MANHATTAN, KS