Surface-Water-Quality Assessment of the Lower Kansas River Basin, Kansas And Nebraska: Dissolved Oxygen and *Escherichia Coli* Bacteria in Streams During Low Flow, July 1988 Through July 1989

By L.M. POPE

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
yard (yd)	0.9144	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
acre	4,047	square meter
acre-foot (acre-ft)	1,233	cubic meter
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
gallon per minute (gal/min)	0.06309	liter per second
million gallons per day (Mgal/d)	0.04381	cubic meter per second
pound per square inch (lb/in^2)	6.895	kilopascal
degree Fahrenheit (°F)	([1])	degree Celsius (°C)

[1] °C = 5/9 (°F - 32).
°F = 9/5 (°C) + 32.

Surface-Water-Quality Assessment of the Lower Kansas River Basin, Kansas and Nebraska: Dissolved Oxygen and *Escherichia Coli* Bacteria in Streams During Low Flow, July 1988 Through July 1989

By L.M. Pope

Abstract

The 15,300-square-mile lower Kansas River Basin in Kansas and Nebraska was investigated, as one of the pilot study units of the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program, to address a variety of water-quality issues. This report describes sanitary quality of streams as defined by concentrations of dissolved oxygen (DO) and densities of a fecal-indicator bacterium, *Escherichia coli* (*E. coli*).

Sixty-one surface-water sampling sites were chosen for this investigation. Synoptic surveys were conducted in July 1988, November 1988, March 1989, and May 1989 to define the concentrations and diel and seasonal variability in concentrations of DO. Synoptic surveys were conducted in July 1988 and July 1989 to define densities of *E. coli*. Ancillary data included measurements of specific conductance, pH, water temperature, barometric pressure, and concentrations of nutrients, total organic carbon, chlorophyll, and suspended sediment. Surveys were conducted during stable-flow, dry-weather conditions.

During the July 1988 synoptic survey for DO, emphasis was placed on the measurement of DO under maximum stress (high water temperature, low streamflow, and predawn conditions). Of 31 sites sampled just before dawn, 5 had DO concentrations less than the 5.0-milligrams-per-liter, 1-day minimum warmwater criterion for early life stages as established by the U.S. Environmental Protection Agency (USEPA), and 4 of these 5 sites had concentrations less than the 3.0-milligrams-per-liter criterion for all other life stages. For all four synoptic surveys, a total of 392 DO determinations were made, and 9 (2.3 percent) were less than water-quality criteria. Concentrations of DO less than water-quality criteria in the study unit are localized occurrences and do not reflect regional differences in DO. The most severe DO deficiencies are the result of discharges from wastewater-treatment plants into small tributary streams with inadequate assimilation capacity. Algal respiratory demand in combination with reduced physical reaeration associated with extreme low flow probably also contributes to temporary, localized deficiencies.

Densities of *E. coli* were determined at 57 surface-water sampling sites during the synoptic survey in July 1988. Results indicate large regional differences in *E. coli* densities within the study unit. Densities of *E. coli* in water at 19 sites in the Big Blue River subbasin, exclusive of the Little Blue River subbasin, ranged from 120 to 260,000 col/100 mL (colonies per 100 milliliters), with a median density of 2,400 col/100 mL. Densities at the 11 sites in the Little Blue River ranged from 100 to 30,000 col/100 mL, with a median density of 940 col/100 mL. Densities at the 27 sites in the Kansas River subbasin ranged from less than 1 to 1,000 col/100 mL, with a median density of 88 col/100 mL. Densities at

84 percent of the sites in the Big Blue River subbasin exceeded the USEPA *E. coli* criterion of 576 col/100 mL for infrequently used full-body contact recreation, and 53 percent exceeded the 2,000 col/100 mL fecal coliform criterion for uses other than full-body contact established by the Kansas Department of Health and Environment. Densities at 73 percent of the sites in the Little Blue River subbasin exceeded the 576 col/100 mL *E. coli* criterion, and 36 percent exceeded the 2,000 col/100 mL fecal coliform criterion. Densities at one of the sites in the Kansas River subbasin exceeded the 576 col/100 mL *E. coli* criterion, and none exceeded the 2,000 col/100 mL fecal-coliform criterion.

The largest densities of *E. coli* in the study unit were the result of discharges from municipal wastewater-treatment plants; however, densities in the Big Blue and Little Blue River subbasins were generally larger than those in the Kansas River subbasin. These larger densities in the Big Blue and Little Blue River subbasins may have been the result of irrigation return flow from fields where manure was used as a soil amendment or the result of livestock production, which may have increased *E. coli* densities in ground-water discharge to the streams.

INTRODUCTION

In 1986, Congress appropriated funds for the U.S. Geological Survey to test and refine concepts for a National Water-Quality Assessment (NAWQA) Program. The NAWQA Program is designed to provide information on a variety of water-quality issues that include chemical contamination, acidification, eutrophication, salinity, sedimentation, and sanitary quality. This information will provide water managers, policy makers, and the public with an improved scientific basis for evaluating the effectiveness of water-quality management programs and for projecting the likely effects of contemplated changes in land- and water-management practices.

The NAWQA Program is organized into study units on the basis of known hydrologic systems. The pilot phase of the assessment program included seven study units (see report cover) representing a diversity of hydrologic environments and water-quality conditions. The subject of this report is the lower Kansas River Basin in Kansas and Nebraska (one of the surface-water pilot studies), which includes the Kansas River and its drainage area downstream from the confluence of the Republican and Smoky Hill Rivers to the confluence with the Missouri River (fig. 1).

Dissolved-oxygen (DO) concentrations and sanitary quality, as defined by the occurrence of a fecal-indicator bacterium, are two surface-water-quality issues addressed by the NAWQA Program. Adequate concentrations of DO in surface water are essential for the survival and propagation of most forms of aquatic life. Factors that affect DO in surface water include stream characteristics, such as turbulence of flow, depth, slope, and water temperature; barometric pressure; extent and composition of the algal community and associated rates of photosynthesis and respiration; presence of reduced forms of inorganic constituents (ammonia, nitrites, sulfites, and sulfides); and the introduction of anthropogenic oxygen-demanding organic-carbon compounds (agricultural activities, feedlot operations, and wastewater discharges).

An evaluation of the sanitary quality of water is necessary to assess its use as a public-water supply and for recreational activities, such as swimming, wading, boating, and fishing. Surface water can carry many pathogenic organisms of fecal origin that cause diseases, such as cholera, typhoid fever, dysentery, and other related gastrointestinal disorders. The examination of water for specific pathogens can require elaborate, time-consuming procedures not suitable for readily assessing quality. Traditionally, assessments have relied on a simplier, membrane-filter procedure for the detection of a group of bacteria (fecal coliform or fecal *Streptococcus*) or bacterium (*Escherichia coli*) common to the intestinal tracts of humans and warm-blooded animals. The presence of the measured "fecal-indicator bacteria," denotes contamination by fecal material and the possible presence of pathogenic microorganisms. The indicator bacteria chosen for this study is *Escherichia coli* (*E. coli*).

This report (1) describes the areal distribution of dissolved-oxygen concentrations and *E. coli* bacteria in streams of the lower Kansas River Basin based on synoptic-sampling surveys conducted from July 1988 through July 1989 and (2) discusses the possible

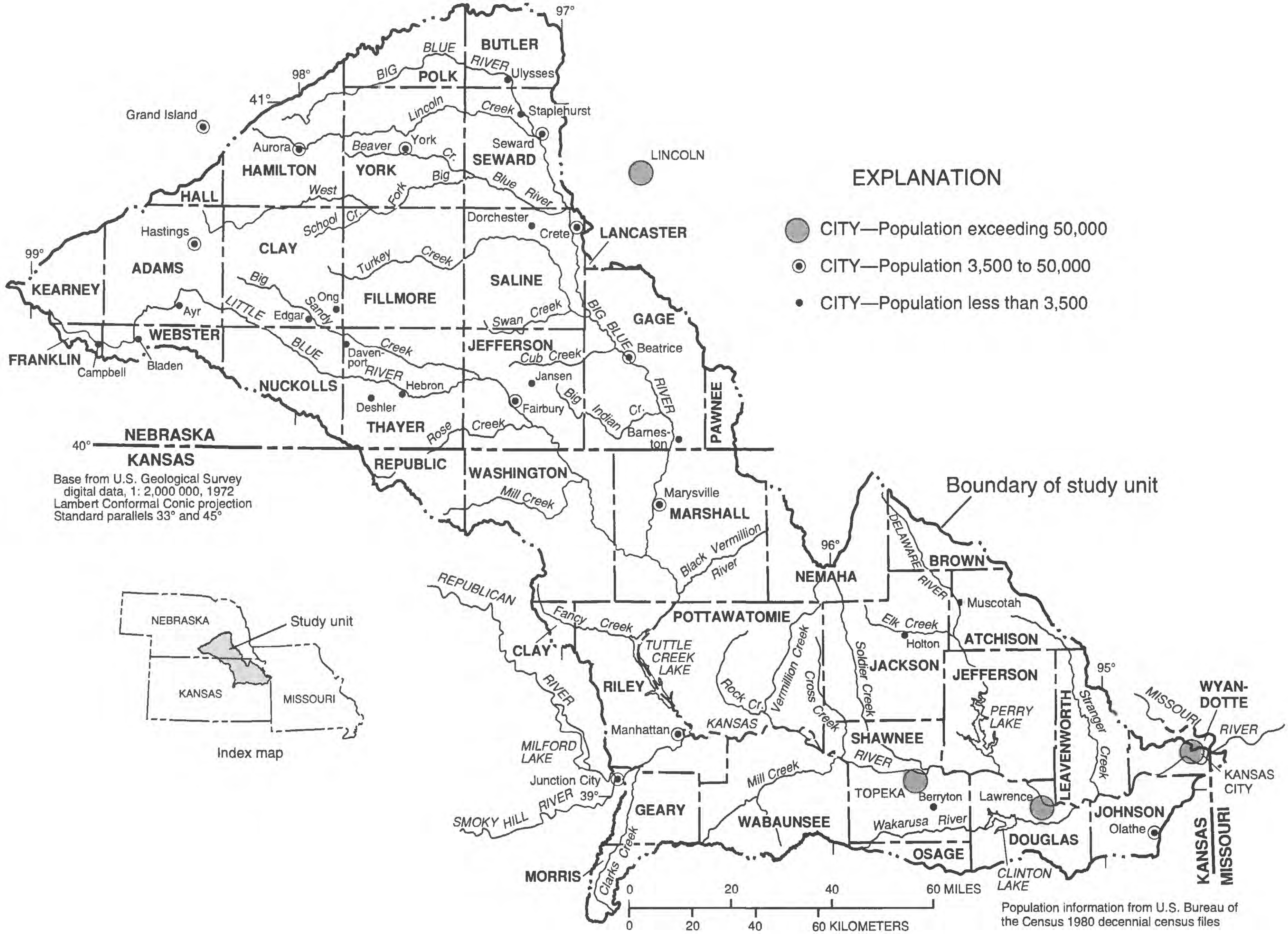

Figure 1. Major streams, surface-water impoundments, cities, and other geographic features in and near lower Kansas River Basin, Kansas and Nebraska.

causal factors related to the observed water-quality conditions. Synoptic-sampling provides a view of water-quality conditions as they exist simultaneously over a broad geographical area. Synoptic sampling is conducted by sampling many sites within a short period of time to minimize variation in water-quality conditions from either natural (rainfall) or anthropogenic causes (point-source discharges or irrigation return flow).

DESCRIPTION OF LOWER KANSAS RIVER BASIN

The lower Kansas River Basin drains about 15,300 mi^2 and coincides with the area defined by the U.S. Water Resources Council as hydrologic subregion 1027 (Seaber and others, 1984). Although 7.5 mi^2 of the subregion lies within Missouri, drainage from this small area near the confluence of the Kansas and Missouri Rivers does not affect the quality of water used within the study unit and is not included in the study. The study unit does include the Big Blue and Little Blue River subbasins in Nebraska and Kansas, as well as subbasins of smaller tributaries to the 170-mi reach of the Kansas River from Junction City to Kansas City, Kans. (fig. 1).

The Kansas River is formed by the confluence of the Smoky Hill and Republican Rivers at Junction City, Kans. Three large reservoirs, Tuttle Creek Lake on the Big Blue River, Perry Lake on the Delaware River, and Clinton Lake on the Wakarusa River, lie within the Kansas part of the study unit (fig. 1). The following discussion of physiography and topography, land use, climate, surface-water hydrology, water use, and stream classification is summarized from Jordan and Stamer (1991).

Physiography and Topography

Land forms in the lower Kansas River Basin are characterized by the four physiographic sections shown in figure 2 (Fenneman, 1946). The High Plains and Plains Border Sections are part of the Great Plains Province. Smooth plains with little local relief dominate the High Plains Section; fluvial and eolian deposits that consist of sand, gravel, silt, and clay underlie this part of the study unit. The generally flat topography of the High Plains provides gentle stream gradients that contribute to only limited stream dissection and rather broad, poorly defined valleys. The flat topography also contributes to a lack of external drainage in some areas.

The Plains Border physiographic section is more dissected than the High Plains and thus has greater local relief. It is underlain by shale, sandstone, and limestone, and minor fluvial and eolian deposits. The drainage pattern in the Plains Border Section is more defined than in the High Plains Section. Stream channels are characteristically narrow, well established, and bounded by a perceptible series of terraces.

The Dissected Till Plains and Osage Plains Sections are part of the Central Lowland Province. The Dissected Till Plains Section is characterized by dissected deposits of glacial till that consist of silt, clay, sand, gravel, and boulders that overlie bedrock of primarily shale and limestone with some sandstone. Maximum local relief is from 300 to 500 ft in the downstream part of the Big Blue River subbasin and generally less than 300 ft elsewhere. Drainage channels are well entrenched by tributaries flowing south to the Kansas River. The Kansas River generally separates the Osage Plains from the Dissected Till Plains in a broad, flat alluvial valley bounded by rolling hills.

Land Use

Land use in the lower Kansas River Basin (fig. 3) is typical of the agricultural region of the midwestern United States. Types of agricultural uses are affected by the physiographic and topographic characteristics of the different parts of the study unit. Agriculture accounts for about 95 percent of the land use in the High Plains and Plains Border physiographic sections. More than 75 percent of the agricultural land in this part of the study unit is used for cultivated crops, and the balance is used principally as pasture. The principal crops in this part of the study unit, ordered by decreasing acreage, are corn, grain sorghum, wheat, and soybeans. The most intensely cultivated part of the study unit is the High Plains Section, in which about 85 percent of the agricultural land is cultivated. In this area, soil, topography, and ground-water availability are well suited for cultivated and irrigated crops. Although the area has long been used for cultivated crops, the amount of irrigation has increased severalfold since 1950, as shown in figure 4 for three representative counties. In the Plains Border Section of the study unit, about 70 percent of the agricultural land is

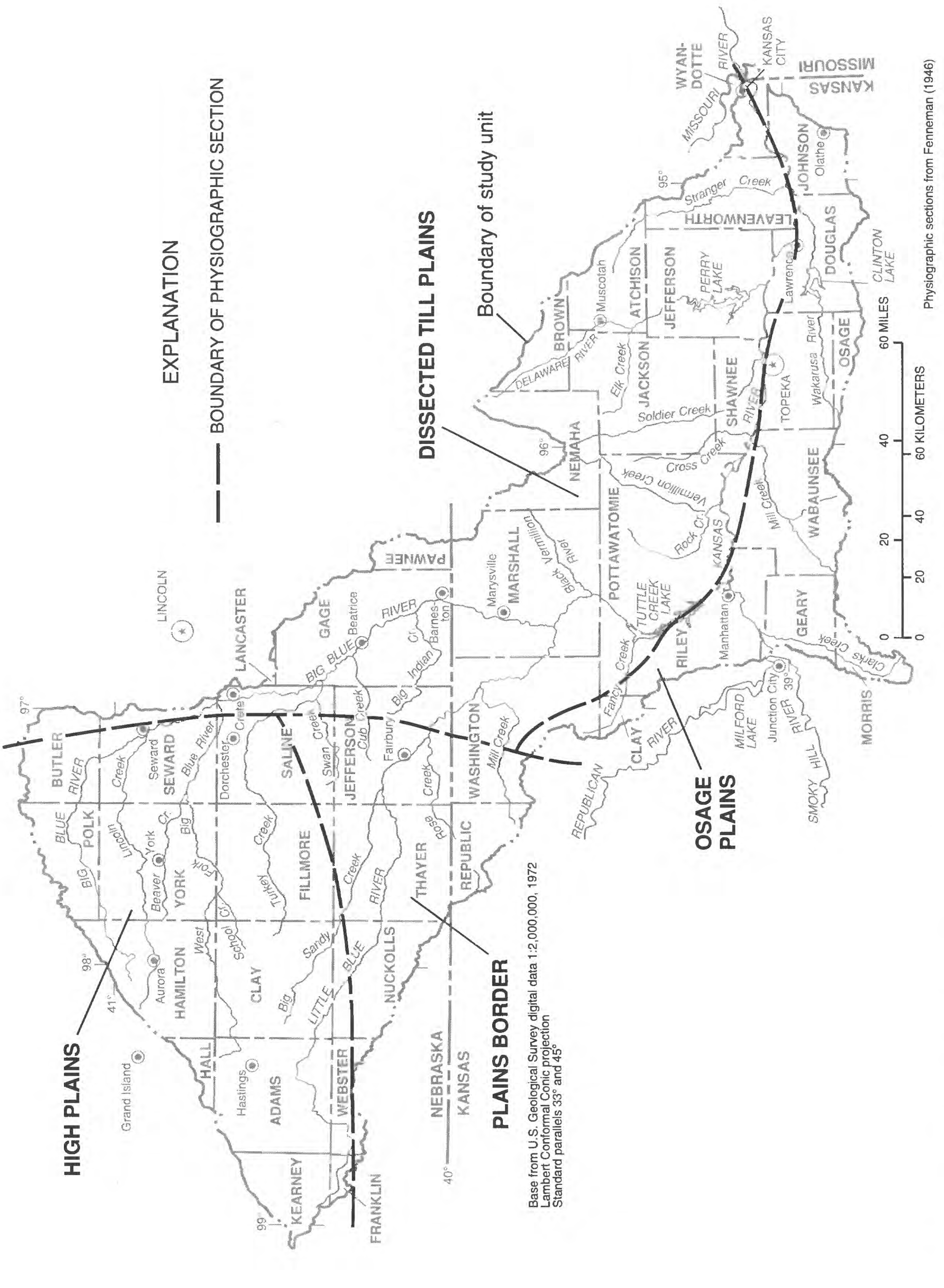

Figure 2. Physiographic sections in lower Kansas River Basin.

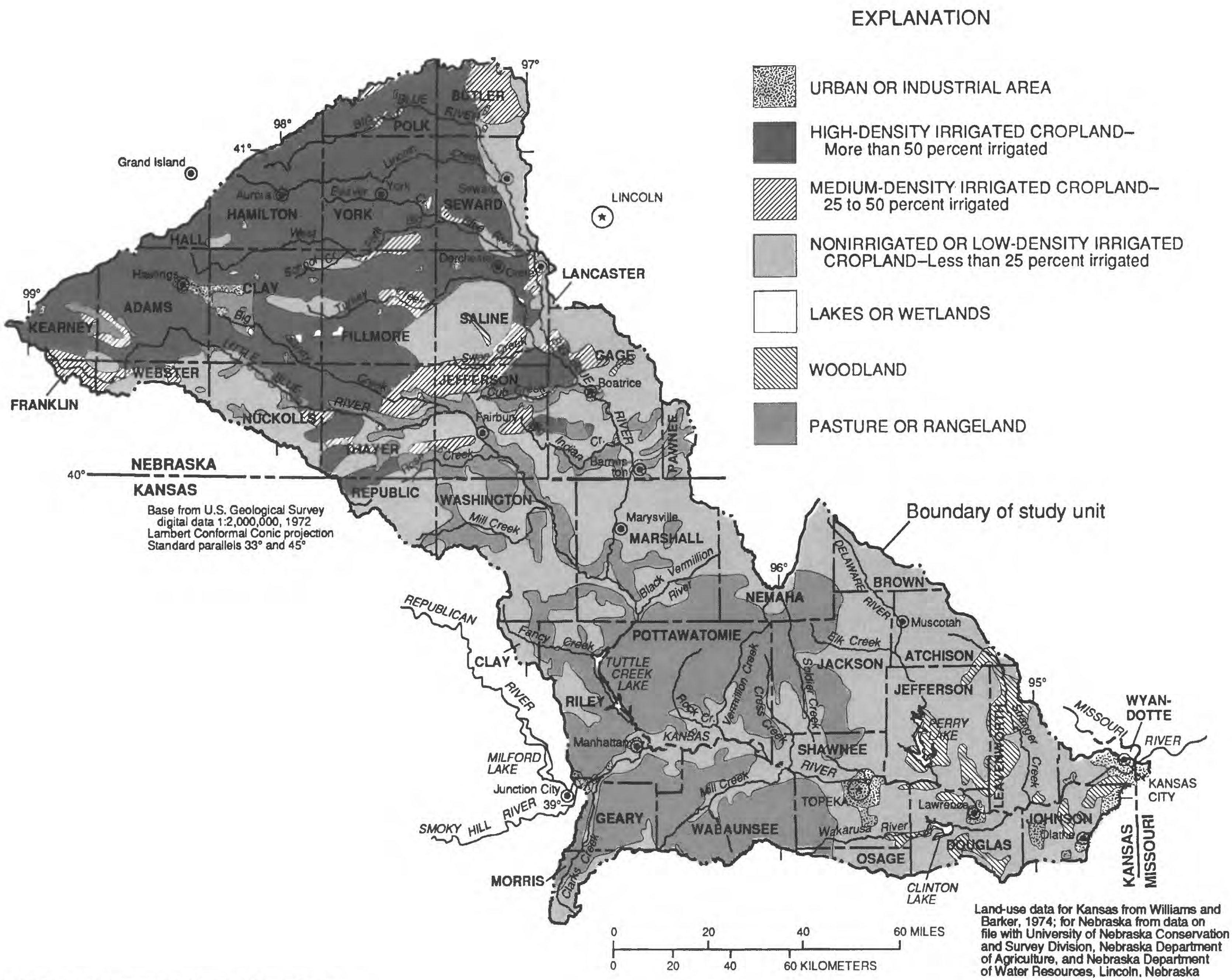

Figure 3. Land use in lower Kansas River Basin.

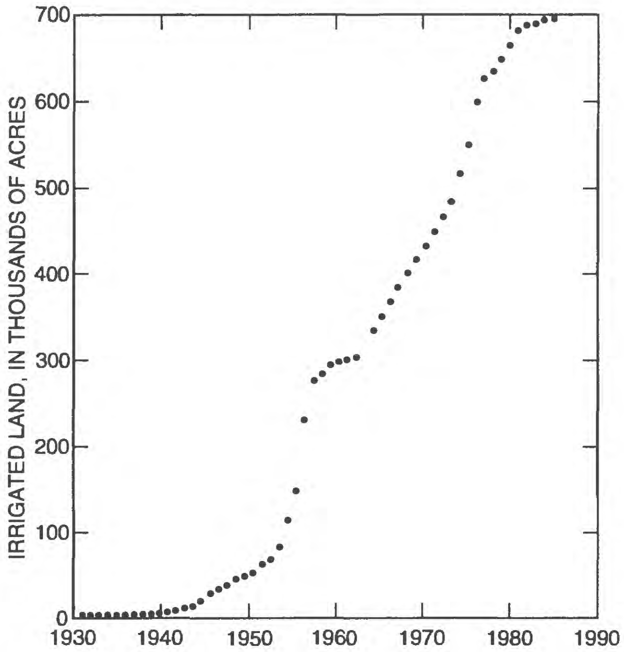

Figure 4. Total irrigated acreage in Adams, Butler, and Hamilton Counties, Nebr., 1930–85 (from data on file with the Nebraska Department of Water Resources, Lincoln).

used for nonirrigated, cultivated crops, and the remainder is used for pasture.

Land use in the Dissected Till Plains and the Osage Plains also is predominantly agricultural. These sections are characterized by more topographic relief and less ground-water availability than the area of the basin that lies in the High Plains and Plains Border Sections; thus, the area is less suited for cultivated and irrigated crops. The exception is the Kansas River flood plain and terrace area, which has low relief and substantial availability of ground water. Irrigation is practiced along much of the Kansas River in areas too small to be shown in figure 3. Principal crops in the Dissected Till Plains and Osage Plains are grain sorghum, wheat, corn, soybeans, and hay. The Flint Hills area in Riley, Geary, and Wabaunsee Counties, Kans., is mostly rangeland, and the remaining area in the Dissected Till Plains and Osage Plains is mixed cropland (30-60 percent) and pasture.

Agricultural land use in the principal subbasins of the study unit is shown in figure 5. Most of the irrigated area in the study unit occurs in the Big Blue River and Little Blue River subbasins. Little irrigated land (too little to show) occurs in the Kansas River subbasin. Pasture and rangeland are the predominant land uses in the Kansas River subbasin. The 51.8 percent of the subbasin in pasture and rangeland is more than twice the percentage of any of the other three subbasins.

Urban development represents a very small fraction of the total basin land use. The major urban and industrial areas in the basin are the Kansas part of the Kansas City metropolitan area, Topeka, and Lawrence, Kans. The industrial area near Hastings, Nebr. (fig. 3), is larger than the city itself, but development in the area is very low density. Although the Kansas City metropolitan area is at the downstream end of the basin and has little effect on the Kansas River, some of its water supplies are affected by activities in the basin. Other land uses, such as woodland and lakes or wetlands, also occupy a very small part of the total area of the basin. The population of the study unit was about 500,000 in 1980 (U.S. Bureau of the Census 1980 decennial census files).

Climate

Climate in the lower Kansas River Basin is characterized by hot, humid summers and cold winters with no particular dry season. July is normally the warmest month in the basin with a mean temperature of about 25 °C, and January is normally the coldest month with a mean temperature of about -4 °C. Mean annual temperatures range from about 11 °C in the northwestern part of the basin to about 12 °C in the southeast. (Except as noted, climatic data in this report are from the National Oceanic and Atmospheric Administration, 1951–80.)

Precipitation in the basin is the most significant climatic factor affecting agriculture and surface-water availability because of both temporal and spatial variability. The 1951–80 mean annual precipitation ranged from about 24 in. in the northwestern part of the basin to about 36 in. in the southeast. Extreme variability, however, characterizes annual precipitation patterns. For example, during 1951 to 1980, annual precipitation on large parts of the basin ranged from less than 15 in. to more than 50 in. The potential for drought,

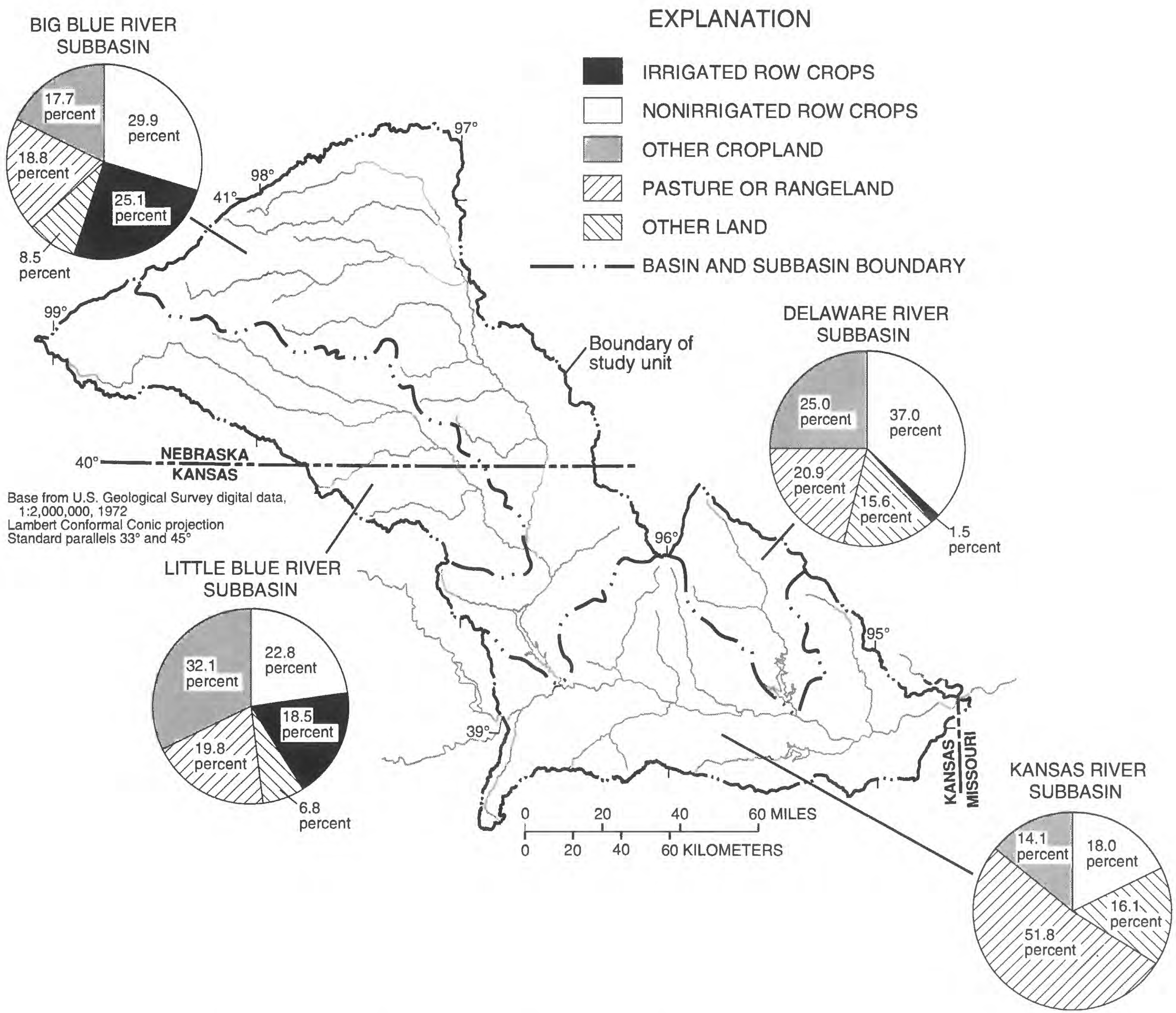

Figure 5. Comparison of various land-use percentages in the Big Blue River, Little Blue River, Kansas River, and Delaware River subbasins (data from U.S. Soil Conservation Service Natural Resources Inventory, 1987).

both short and long term, is always great within the basin. The potential for periodic flooding caused by excessive precipitation and runoff is equally great.

About 75 percent of the precipitation in the basin normally occurs during the warm season, April through September, which coincides for the most part with the growing season. Precipitation during the growing season, however, is not always sufficient to provide optimal soil-moisture conditions for most crops grown in the study unit. Thus, where water supplies are adequate, irrigation is a common practice.

Surface-Water Hydrology

The Republican and Smoky Hill Rivers, which join to form the Kansas River at Junction City, Kans., both begin in the plains of eastern Colorado and flow about 500 mi eastward to their confluence (fig. 1). Thus, the Kansas River at its beginning receives streamflow from a drainage area of about 45,000 mi^2. The Republican River, although it drains more than one-half of the area, provides about one-third of the mean flow (about 2,600 ft^3/s) entering the lower Kansas River study unit, and the Smoky Hill River provides the other two-thirds of the flow.

The largest tributary downstream from Junction City is the Big Blue River, which originates in Nebraska as does its principal tributary, the Little Blue River. The Big Blue River enters the Kansas River at Manhattan, Kans. Other principal tributaries that drain from the north to the Kansas River are Vermillion Creek, Soldier Creek, the Delaware River, and Stranger Creek. The drainage to the Kansas River from the south is much smaller than that from the north and includes Clarks and Mill Creeks and the Wakarusa River.

Runoff in the study unit varies areally as determined by precipitation, vegetation, topography, soil, and geology, and seasonally in response to precipitation and evapotranspiration. The 50-percent increase in mean annual precipitation from about 24 in. in the northwest to about 36 in. in the southeast is accompanied by a 350-percent increase in mean annual runoff from less than 2 in. in the northwestern part of the study unit to almost 9 in. in the southeast. Mean monthly runoff is large in the spring and summer and smallest in the late fall and early winter.

The mean flow rate of the Kansas River at its confluence with the Missouri River during 1971–86 was about 8,600 ft^3/s, of which the Big Blue River contributed about 27 percent; the Smoky Hill River, 19 percent; the Republican River, 12 percent; the Delaware River, 9 percent; and smaller tributaries, the remaining 33 percent.

Flow in the Big and Little Blue Rivers generally is well sustained during dry weather by ground-water contributions (Ellis, 1981, p. 44). Thus, surface-water quality during low flow is affected by ground-water quality although the effect is not quantitatively known. Although wells completed in sandstone, which underlies parts of the Plains Border, western Dissected Till Plains, and western Osage Plains physiographic sections, yield as much as 100 gal/min (Bayne, 1975), little is known about the quantity of ground water contributed to streams in these areas. Ground water is scarce in the uplands of the central and eastern parts of the Dissected Till Plains and Osage Plains where bedrock is primarily shale with thin layers of limestone and sandstone. Wells in buried-valley aquifers north of the Kansas River yield as much as 500 gal/min (Bayne, 1975). The extent of hydraulic connection of these aquifers to streams varies considerably within the area; thus, the effect of buried-valley aquifers on the quantity and quality of water in the streams ranges from negligible to appreciable.

Considerable interchange of water occurs between the Kansas River and its 1- to 2.5-mi wide alluvial aquifer. During periods of high river stage, the river provides recharge to the aquifer. During lengthy dry-weather periods, the alluvial aquifer contributes an estimated 1 to 4 ft^3/s of flow per river mile to the Kansas River (Fader, 1974). The exchange of water probably has a significant effect on quantity and quality of water in both the river and the aquifer; however, quantitative studies of those effects have not been conducted.

Water Use

Water use in the lower Kansas River Basin in 1985 totaled about 2.6 million acre-ft (calculated from data on file with the U.S. Geological Survey, Lawrence, Kans., and Lincoln, Nebr.). Irrigation withdrawals account for about 1.2 million acre-ft of the total water use and are predominantly ground water from the High Plains aquifer and the alluvial aquifer along the Kansas River and partly surface water from the Big and Little Blue Rivers and the Kansas River (fig. 6).

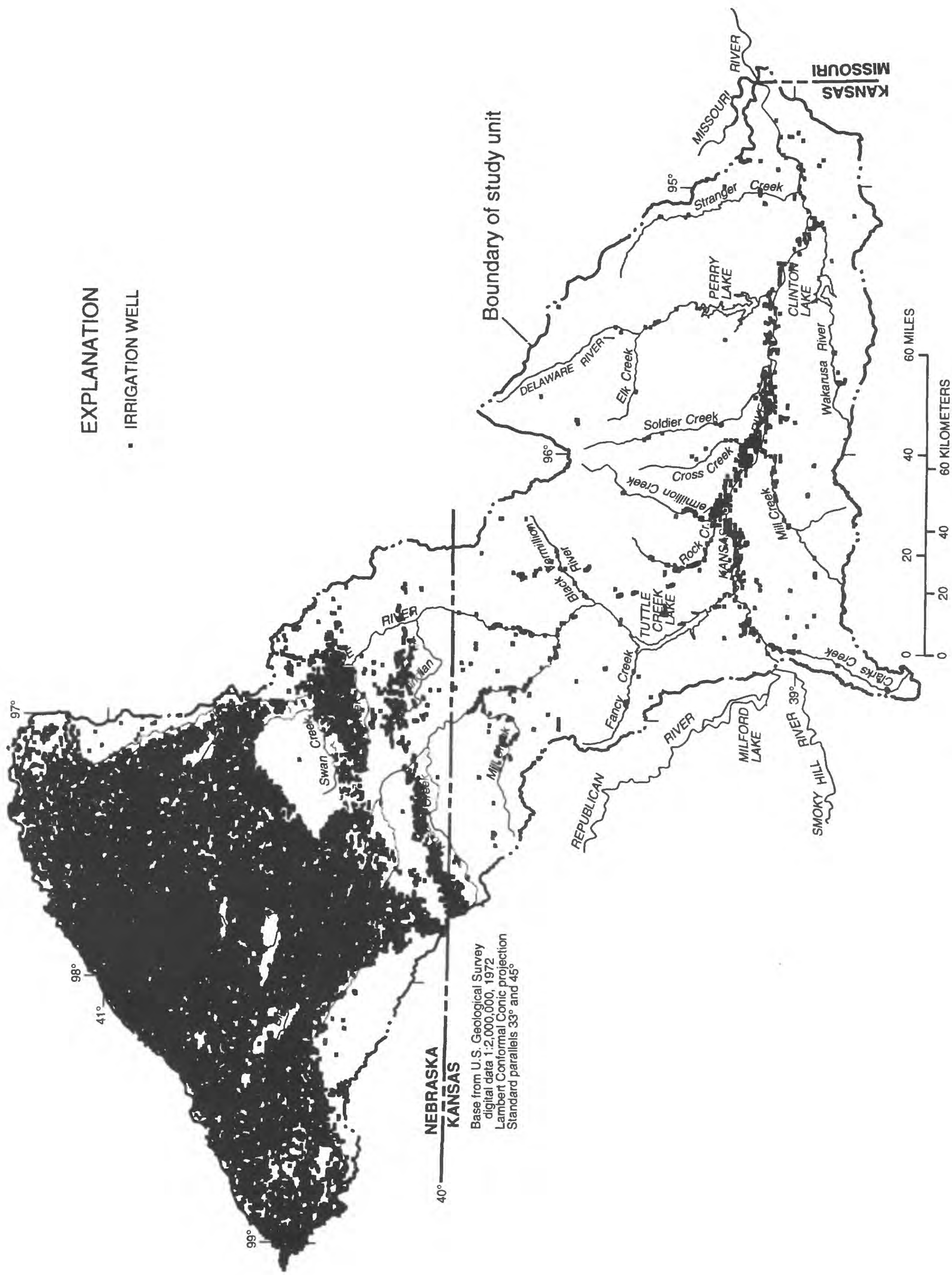

Figure 6. Location of wells permitted for irrigation withdrawal (from data on file with the Nebraska Department of Water Resources, Registered Wells File, 1991, and Kansas State Board of Agriculture, Division of Water Resources, 1991).

Irrigation accounts for about 90 percent (about 0.8 million acre-ft) of the consumptive use of water in the basin. Other major uses having significant (more than 25 percent) consumptive components are self-supplied industry and thermoelectric-power generation (115,000 acre-ft) and public supply (142,000 acre-ft).

Surface-water use in 1985 was about 1.3 million acre-ft/yr, which accounts for about 50 percent of the total water use. Surface water is used instream, non-consumptively, for hydroelectric power (1.0 million acre-ft/yr) and offstream for self-supplied industry and thermoelectric-power generation (91,000 acre-ft/yr), irrigation (82,000 acre-ft/yr), and public supplies (86,000 acre-ft/yr). Surface-water withdrawals for offstream use are mainly from the Kansas River, and the water is used within counties adjoining the river.

Stream Classification and Associated Water-Quality Criteria

Water-quality regulatory agencies of Kansas and Nebraska have taken slightly different approaches to stream classification. Although both States in 1986 had classified streams or stream segments for non-contact or secondary contact recreational use, Kansas also designated segments (defined as 200 yd long) for contact recreation, whereas Nebraska applied the criteria for contact recreation to the same stream segment (miles long) as for other uses. Kansas designated streams for drinking-water use if their quality was potentially suitable for such use after appropriate treatment, whether or not the stream was being used currently for that purpose. Nebraska designated stream segments for public drinking water only if that use was being made currently. In the following abbreviated summary, the only uses discussed will be recreation, aquatic life, and drinking-water supply. Other uses designated by the State classifications, such as livestock watering, will not be discussed here.

Kansas stream classifications and associated water-quality criteria are described in detail by the Kansas Department of Health and Environment (Fromm and Wilk, 1988). The quality criteria, in general, are based on the harmful effects of substances that originate from artificial sources, turbidity, nutrients, pH, temperature, dissolved oxygen, residual chlorine, toxic substances, and fecal coliform bacteria. The entire lengths of the Kansas and Big Blue Rivers are designated for noncontact recreation, aquatic life, and drinking-water supply. On other streams in the lower Kansas River Basin, 16 points are designated for contact recreation, and 37 streams are designated for noncontact recreation, aquatic life, and drinking-water supply.

Nebraska stream classifications in effect in 1986 and associated water-quality criteria are described by the Nebraska Department of Environmental Control (1986, p. 12, 29–33, and 55–59). The criteria considered chemical information, fecal indicator bacteria, toxic substances, suspended sediment, and biological information. Of the 415 stream mi in the lower Kansas River Basin within Nebraska that had been classified, 272 mi were assigned the designation "Recreation Class B (secondary contact)," and none were assigned "Recreation Class A (primary contact)." In addition, 360 stream mi were assigned the aquatic-life designation "Warmwater Class A," 55 mi were assigned "Warmwater Class B," and none were assigned a "Coldwater" designation. No stream miles were designated for "Public Drinking Water Supply."

Livestock Production

The production of livestock is a major industry in Kansas and Nebraska. Cash receipts from livestock production and associated products in 1988 exceeded $4.2 billion for Kansas and $5.3 billion for Nebraska, ranking nationally sixth and second, respectively (Kansas State Board of Agriculture and U.S. Department of Agriculture, 1988–89). The total value of livestock production in the two states is approximately twice the value of crop production. The magnitude of this fact is striking in that, in 1988, Kansas ranked first, nationally, in the production of grain sorghum and wheat and eighth in corn, while Nebraska ranked second, third, and ninth in the production of corn, grain sorghum, and wheat (Nebraska Department of Agriculture and U.S. Department of Agriculture, 1989).

The vast majority of the livestock industry in Kansas and Nebraska centers around the production of cattle and hogs. As inventoried on January 1, 1988, the cattle and calf count was 5.9 million in Kansas (ranked second nationally) and 5.4 million in Nebraska (ranked third nationally). Hogs and pigs numbered 1.5 million for Kansas (10th nationally) and 4.15 million for Nebraska (fifth nationally).

The extent and economic importance of the livestock industry in the lower Kansas River Basin mirror that delineated on a statewide basis. Estimates for the number of cattle and hogs, by county, in the study unit are provided in table 1. Estimates were calculated by multiplying the county inventory values provided in Kansas State Board of Agriculture and U.S. Department of Agriculture (1988–89) and Nebraska Department of Agriculture and U.S. Department of Agriculture (1989) by the percentage of the county within the study unit. Overall, there were approximately 1.07 million cattle (as of January 1, 1988) and about 1.15 million hogs (as of December 1, 1988) in the study unit. The number of cattle in the Nebraska part of the basin (563,200) was about 12 percent larger than the number in Kansas (503,100). However, a much wider disparity existed between the two states in the number of hogs. The Kansas hog inventory (323,000) was only 39 percent of the Nebraska inventory (822,400). A large part of this disparity can be attributed to the exceptionally large inventory in Clay (180,000), Fillmore (98,000), Gage (105,000), and York (84,000) Counties in Nebraska.

Although total livestock inventory is an important characteristic for assessing surface-water quality, the extent of confined feeding operations (feedlots) and livestock density (head per square mile) provide more useful information in assessing probable or potential effect. Feedlot operations vary from simple open lots that process tens of head per year to more elaborate, totally enclosed, and vastly larger operations capable of processing hundreds to thousands of head per year. Most large operations are required by regulations to control runoff by the installation of earthen retention impoundments. Smaller operations may be exempt from the construction of retention structures if the operators show that the facility does not constitute a water-quality hazard.

The extent and intensity of feedlot operations is shown in figure 7. The number of cattle on feed for the Nebraska counties for January 1, 1988 (table 1), although not directly provided in Nebraska Department of Agriculture and U.S. Department of Agriculture (1989), were estimated by multiplying the ratio of cattle on feed for the entire State on January 1, 1988 (2,000,000), to the State total placed on feed for the whole year (5,320,000) by the number placed on feed in each of the counties in the basin for the entire year (J.L. Aschwege, Nebraska Agricultural Statistics Service, oral commun., 1991). The computed statewide ratio of 0.376 was assumed to be valid for those Nebraska counties within the study unit.

By far, the largest percentage of the cattle inventory contained in feedlots, by county, occurs in the upstream part of the basin, generally north of the Kansas-Nebraska border. The percentage of cattle on feed in Nebraska counties ranged from 8.9 to 79.2 percent (table 1), with a county average of 43.0 percent. Those counties with the most intense feeding operations are in the headwaters and middlestream reaches of the Big Blue, West Fork Big Blue, and Little Blue Rivers. The smallest percentages of cattle confined to feedlots are in the downstream part of the basin, south of the Kansas-Nebraska border. Percentage of cattle on feed in those counties in Kansas ranged from 0.5 to 27.9 percent, with a county average of 4.6 percent. This disparity between the upstream and downstream parts of the basin can be attributed mainly to physiographic and land-use characteristics. As shown in figure 2, much of the upstream part of the basin occurs in the High Plains physiographic section, which is generally flat with gentle stream gradients and limited stream dissection. Soils in the High Plains tend to be deep and fertile and sustain intensive crop production as indicated in figure 3. Rangeland is scarce. The corn, grain sorghum, and silage produced in this area provide an excellent, locally available source of livestock feed. Farther downstream, the Dissected Till Plains and Osage Plains dominate. Local relief increases considerably, soils are thinner, irrigation water becomes scarce, and pasture and rangeland become abundant. Given the changes in local physiography and topography and the desire to utilize available resources, the majority of cattle in the downstream part of the basin are grass fed and not confined routinely to feedlots.

Livestock density, head per square mile, varies considerably throughout the basin (fig. 8). Generally, densities increase from the southeast (downstream) part of the basin to the northwest (upstream); this generalization is most pronounced in the distribution of hog densities. The largest densities for both cattle and hogs occur in or near the headwaters of the Big Blue, West Fork Big Blue, and Little Blue Rivers where densities of both cattle and hogs exceed 100 and 120 head per square mile, respectively, in five Nebraska counties.

Table 1. Reported cattle and hog inventory and estimated inventory for the lower Kansas River Basin, by county, 1988

[Data from Kansas State Board of Agriculture and U.S. Department of Agriculture (1988–89), and Nebraska Department of Agriculture and U.S. Department of Agriculture (1989)]

County	Area, in square miles	Percent of area in basin	Reported cattle and hog inventory			Estimated basin inventory					Density, head per square mile	
			Cattle, total[1]	Cattle on feed[1]	Hogs[2]	Cattle, total	Cattle on feed	Cattle on feed, percent of total	Hogs	Cattle and hogs, total	Cattle	Hogs
Kansas												
Atchison	431	67.0	31,000	1,300	19,600	20,800	870	4.2	13,100	33,900	72.0	45.4
Brown	572	29.7	43,500	5,300	40,600	12,900	1,600	12.4	12,100	25,000	76.0	71.2
Clay	632	8.3	41,600	700	41,500	3,500	60	1.7	3,400	6,900	66.7	64.8
Douglas	461	80.6	29,400	900	16,000	23,700	730	3.1	12,900	36,600	63.8	34.7
Geary	377	55.8	23,600	200	30,800	13,200	110	.8	17,200	30,400	62.7	81.8
Jackson	658	100	45,600	400	14,000	45,600	400	.9	14,000	59,600	69.3	21.3
Jefferson	535	100	34,500	1,000	12,000	34,500	1,000	2.9	12,000	46,500	64.5	22.4
Johnson	478	50.3	20,700	100	3,400	10,400	50	.5	1,700	12,100	43.3	7.1
Leavenworth	463	76.5	32,000	400	15,000	24,500	310	1.3	11,500	36,000	69.2	32.5
Marshall	878	96.4	52,600	1,300	41,000	50,700	1,300	2.6	39,500	90,200	59.9	46.7
Morris	693	16.0	58,000	6,600	10,000	9,400	1,100	11.7	1,600	11,000	84.8	14.4
Nemaha	719	52.7	61,400	1,200	75,000	32,400	630	1.9	39,500	71,900	85.5	104
Osage	695	13.5	39,500	1,200	10,000	5,300	160	3.0	1,400	6,700	56.5	14.9
Pottawatomie	828	100	59,500	1,100	33,000	59,500	1,100	1.8	33,000	92,500	71.9	39.9
Republic	719	27.9	61,500	17,200	19,000	17,200	4,800	27.9	5,300	22,500	85.7	26.4
Riley	593	89.4	33,000	2,000	30,500	29,500	1,800	6.1	27,300	56,800	55.6	51.5
Shawnee	549	100	20,900	500	5,600	20,900	500	2.4	5,600	26,500	38.1	10.2
Wabaunsee	797	75.3	51,900	2,300	13,000	39,100	1,700	4.3	9,800	48,900	65.2	16.3
Washington	898	76.9	61,200	700	80,000	47,100	540	1.1	61,500	108,600	68.2	89.1
Wyandotte	149	64.8	4,400	100	900	2,900	65	2.2	600	3,500	30.0	6.2
					Kansas totals	503,100	18,825	3.7	323,000	826,100		

Table 1. Reported cattle and hog inventory and estimated inventory for the lower Kansas River Basin, by county, 1988—Continued

County	Area, in square miles	Percent of area in basin	Reported cattle and hog inventory: Cattle, total[1]	Reported: Cattle on feed[1]	Reported: Hogs[2]	Estimated basin inventory: Cattle, total	Estimated: Cattle on feed	Estimated: Cattle on feed, percent of total	Estimated: Hogs	Estimated: Cattle and hogs, total	Density, head per square mile: Cattle	Density: Hogs
Nebraska												
Adams	564	97.3	83,000	66,000	29,000	80,800	64,000	79.2	28,200	109,000	147	51.4
Butler	584	48.2	34,000	11,000	51,000	16,400	5,300	32.3	24,600	41,000	58.3	87.4
Clay	574	100	68,000	47,000	180,000	68,000	47,000	69.1	180,000	248,000	118	314
Fillmore	576	100	35,000	14,000	98,000	35,000	14,000	40.0	98,000	133,000	60.8	170
Franklin	576	6.7	42,000	3,800	20,000	2,800	250	8.9	1,300	4,100	72.6	33.7
Gage	858	89.3	45,000	7,100	118,000	40,200	6,300	15.7	105,000	145,200	52.5	137
Hall	537	12.1	72,000	47,000	36,000	8,700	5,700	65.5	4,400	13,100	134	67.7
Hamilton	543	90.9	40,000	21,000	42,000	36,400	19,000	52.2	38,200	74,600	73.7	77.4
Jefferson	575	100	36,000	16,000	44,000	36,000	16,000	44.4	44,000	80,000	62.6	76.5
Kearney	519	44.4	59,000	39,000	36,000	26,200	17,000	64.9	16,000	42,200	114	69.4
Lancaster	839	1.1	31,000	3,400	43,000	300	40	13.3	500	800	32.5	54.2
Nuckolls	576	64.7	37,000	6,800	51,000	24,000	4,400	18.3	33,000	57,000	64.4	88.5
Pawnee	433	23.0	23,000	2,300	40,000	5,300	530	10.0	9,200	14,500	53.2	92.4
Polk	437	60.4	65,000	30,000	56,000	39,300	18,000	45.8	33,800	73,100	149	128
Saline	575	99.4	25,000	6,400	41,000	24,800	6,400	25.8	40,800	65,600	43.4	71.4
Seward	575	80.3	39,000	23,000	52,000	31,300	18,000	57.5	41,800	73,100	67.8	90.5
Thayer	575	99.6	38,000	28,000	35,000	37,800	28,000	74.1	34,900	72,700	66.0	60.9
Webster	575	24.6	40,000	17,000	19,000	9,900	4,200	42.4	4,700	14,600	70.0	33.2
York	576	100	40,000	23,000	84,000	40,000	23,000	57.5	84,000	124,000	69.4	146
				Nebraska totals		563,200	297,120	52.8	822,400	1,385,600		
				Basin totals		1,066,300	315,945	29.6	1,145,400	2,211,700		

[1]January 1, 1988.
[2]December 1, 1988.

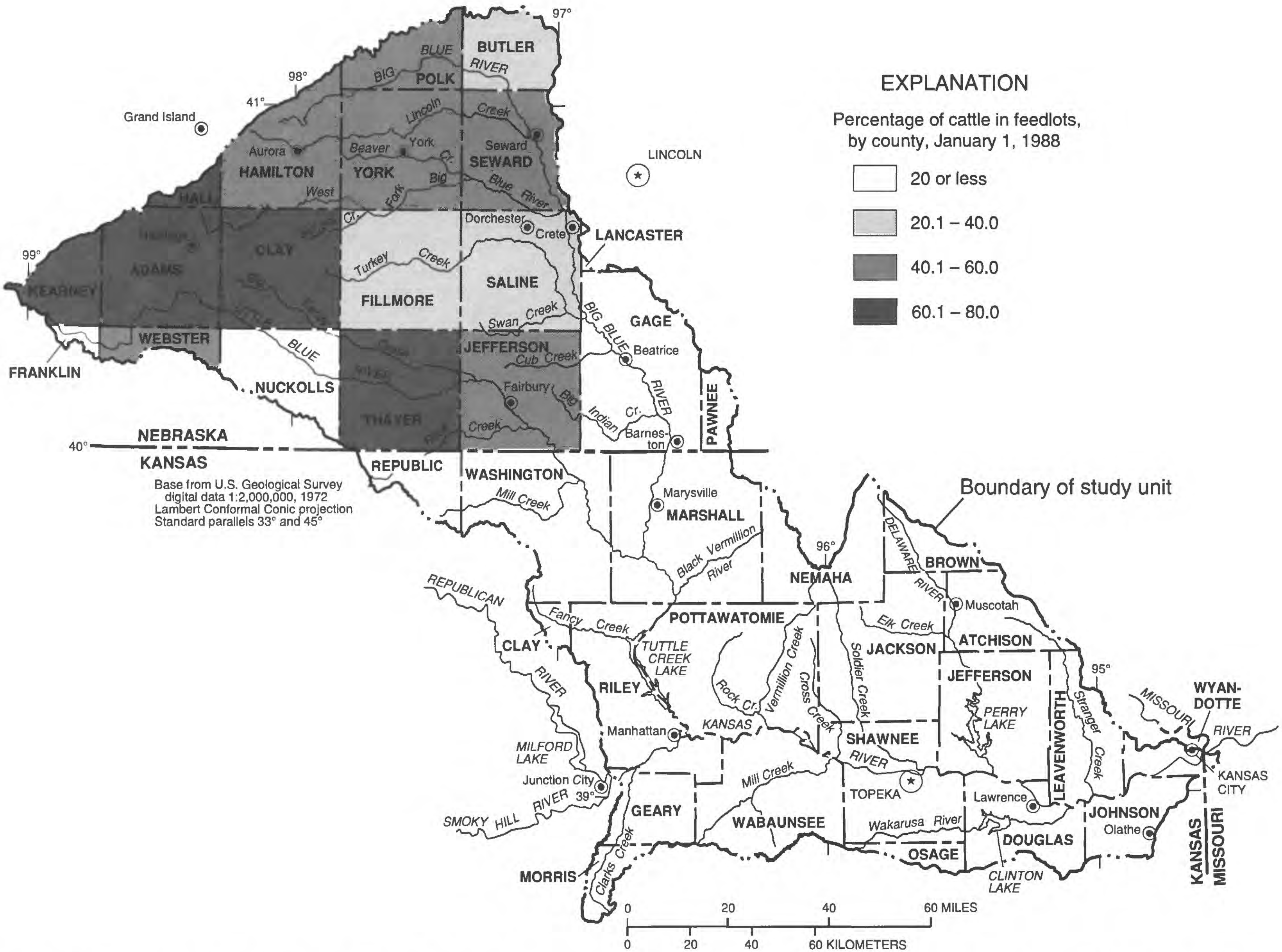

Figure 7. Estimated percentage of cattle in feedlots, by county, in lower Kansas River Basin, January 1, 1988 (data from Kansas State Board of Agriculture and U.S. Department of Agriculture, 1988–89, and Nebraska Department of Agriculture and U.S. Department of Agriculture, 1989).

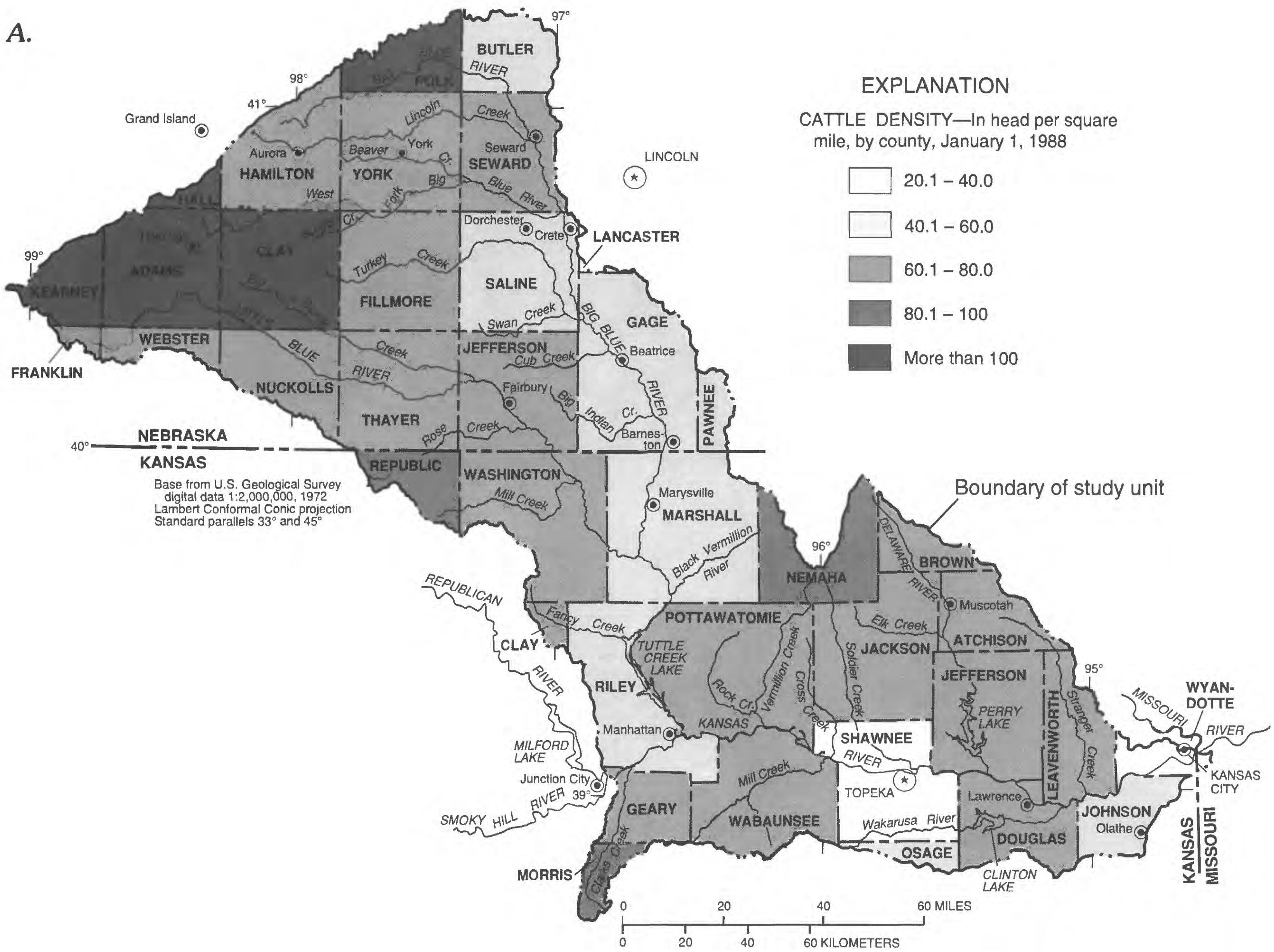

Figure 8. Estimated (*A*) cattle and (*B*) hog densities, by county, in lower Kansas River Basin, January 1 and December 1, 1988 (data from Kansas State Board of Agriculture and U.S. Department of Agriculture, 1988–89, and Nebraska Department of Agriculture and U.S. Department of Agriculture, 1989).

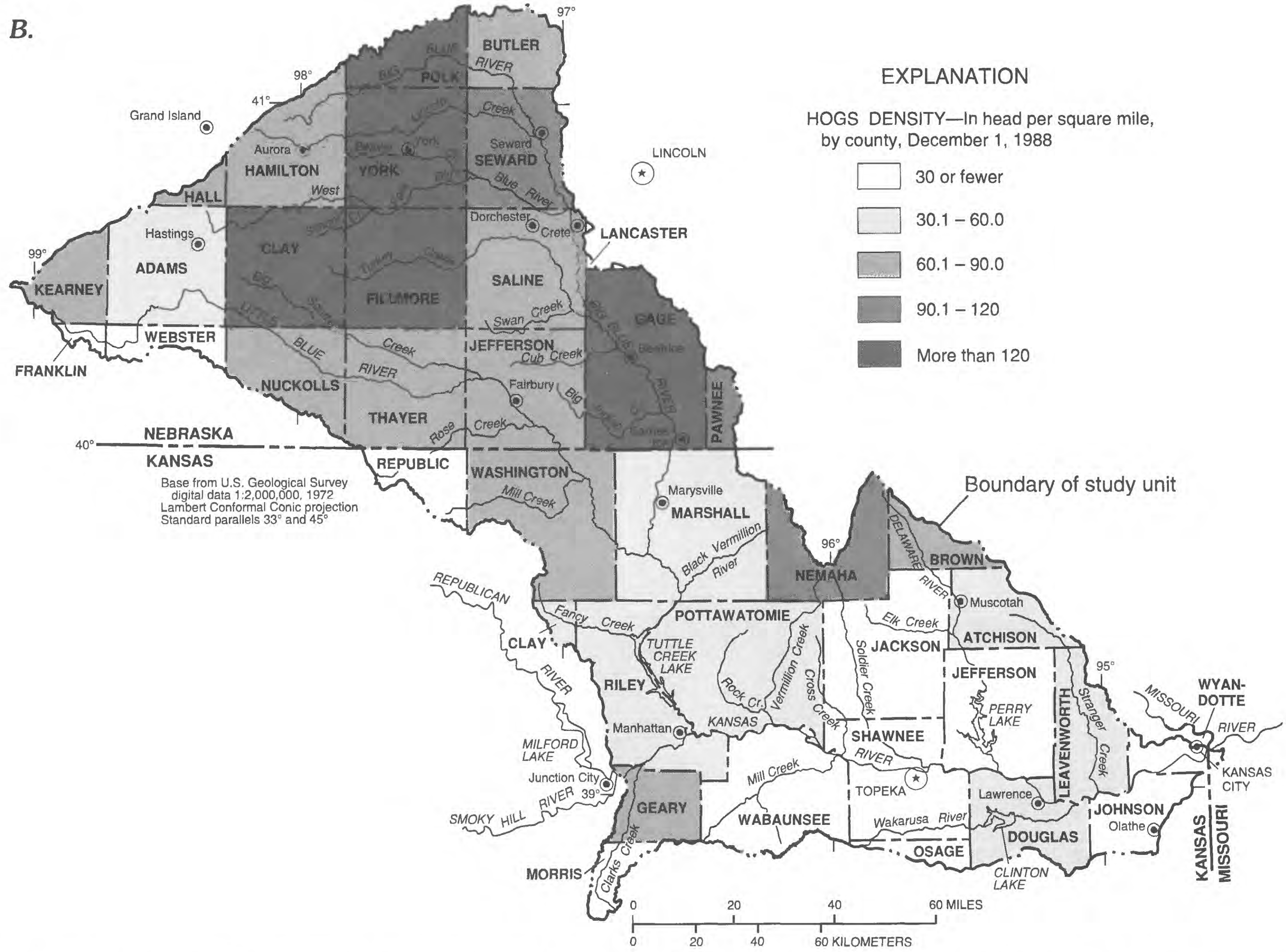

Figure 8. Estimated (*A*) cattle and (*B*) hog densities, by county, in lower Kansas River Basin, January 1 and December 1, 1988 (data from Kansas State Board of Agriculture and U.S. Department of Agriculture, 1988–89, and Nebraska Department of Agriculture and U.S. Department of Agriculture, 1989)—Continued.

Point Sources of Wastewater

Wastewater that enters a stream at a discrete point is referred to as a point source and, as such, is not necessarily a function of geology, soils, or land use of a watershed basin. The U.S. Environmental Protection Agency (USEPA) issues discharge permits under the National Pollutant Discharge Elimination System (NPDES). These permits specify the allowed limits for rate of discharge and chemical composition of the wastewater effluent.

There are 28 municipal and industrial facilities in the study unit that are permitted by the USEPA to discharge wastewater at a rate of 1.0 or more Mgal/d. Of these facilities, 16 are municipal wastewater-treatment plants and 12 are industrial wastewater-treatment plants. The location of these 28 facilities, 42 municipal wastewater-treatment plants with permitted discharges of 0.1 to 0.9 Mgal/d, and a municipal wastewater facility located outside the study unit on the Republican River is shown in figure 9. In addition to the facilities shown in figure 9, there are approximately 130 municipal wastewater-treatment facilities permitted to discharge less than 0.1 Mgal/d. About 64 percent of these facilities are located in the Big Blue River system, with all but one facility of the remaining 36 percent located in the Kansas River system downstream of Manhattan, Kans.

Most of the larger (5.0 Mgal/d or greater) wastewater-treatment facilities are located along the main stem of the Kansas River and coincide with the main population centers in the study unit. All but one of these large facilities discharge directly into the Kansas River. One facility in Johnson County discharges into Turkey Creek, a tributary of the Kansas River that discharges into the Kansas River about 2.2 mi upstream of its confluence with the Missouri River. One of the three largest (10 Mgal/d or more) municipal wastewater-treatment facilities, Kaw Point (28.0 Mgal/d) in Kansas City, Kansas, although physically located within the study unit, discharges into the Missouri River.

STUDY APPROACH

Design of Synoptic Surveys

The purpose of synoptic sampling is to provide information describing selected water-quality conditions throughout a large geographical area at many locations in as short a time as possible. In this study, each synoptic survey was completed within 6 days. Specifically, synoptic sampling provides (1) a means to increase the knowledge gained from an analysis of all available data; (2) a finer degree of resolution in describing water-quality conditions than provided by a small network of regularly sampled stations; (3) for an assessment of the spatial distribution of water-quality conditions in relation to such factors as physiography, topography, geology, land use, agricultural activities, and waste-management practices; and (4) a documentation of stream reaches where critical levels of DO and bacteria occur during hydrologic conditions most conducive to producing those levels (low flow and high water temperature).

This study was conducted to identify areas of the basin that may have DO deficiencies or degradation of sanitary quality (large *E. coli* densities) under conditions that would minimize the effects of runoff and maximize comparability of results throughout the basin. These requirements mandated that synoptic surveys be conducted under dry-weather, stable-flow conditions, or as nearly so as possible. Additionally, DO deficiencies are believed to be greatest during periods of maximum stress to the system—low streamflow (less dilution of waste), high water temperature (lower oxygen solubility), and maximum effect of algal respiration (usually just before sunrise). Also, nonpoint-source contamination during runoff can cause bacteria densities to fluctuate by several orders of magnitude; therefore, criteria for densities of *E. coli* have been established only for stable-flow, dry-weather conditions. In the lower Kansas River Basin, these conditions are most common in mid- to late-summer.

A synoptic survey to define the distribution and magnitude of DO and *E. coli* was conducted in July 1988. Approximately 50 percent of the 61 sites were sampled just prior to sunrise (predawn) to assess DO concentrations under maximum stress conditions. Additionally, studies of diel variation of DO were conducted at 11 sites. DO data also were collected as a supplemental constituent during synoptic surveys of nutrient concentration in November 1988 and March and May–June 1989. During these surveys, two sites were sampled to define diel variation and seasonal changes. A followup survey for *E. coli* was conducted in July 1989 to verify results from the July 1988 survey. Ancillary data for selected DO and *E. coli*

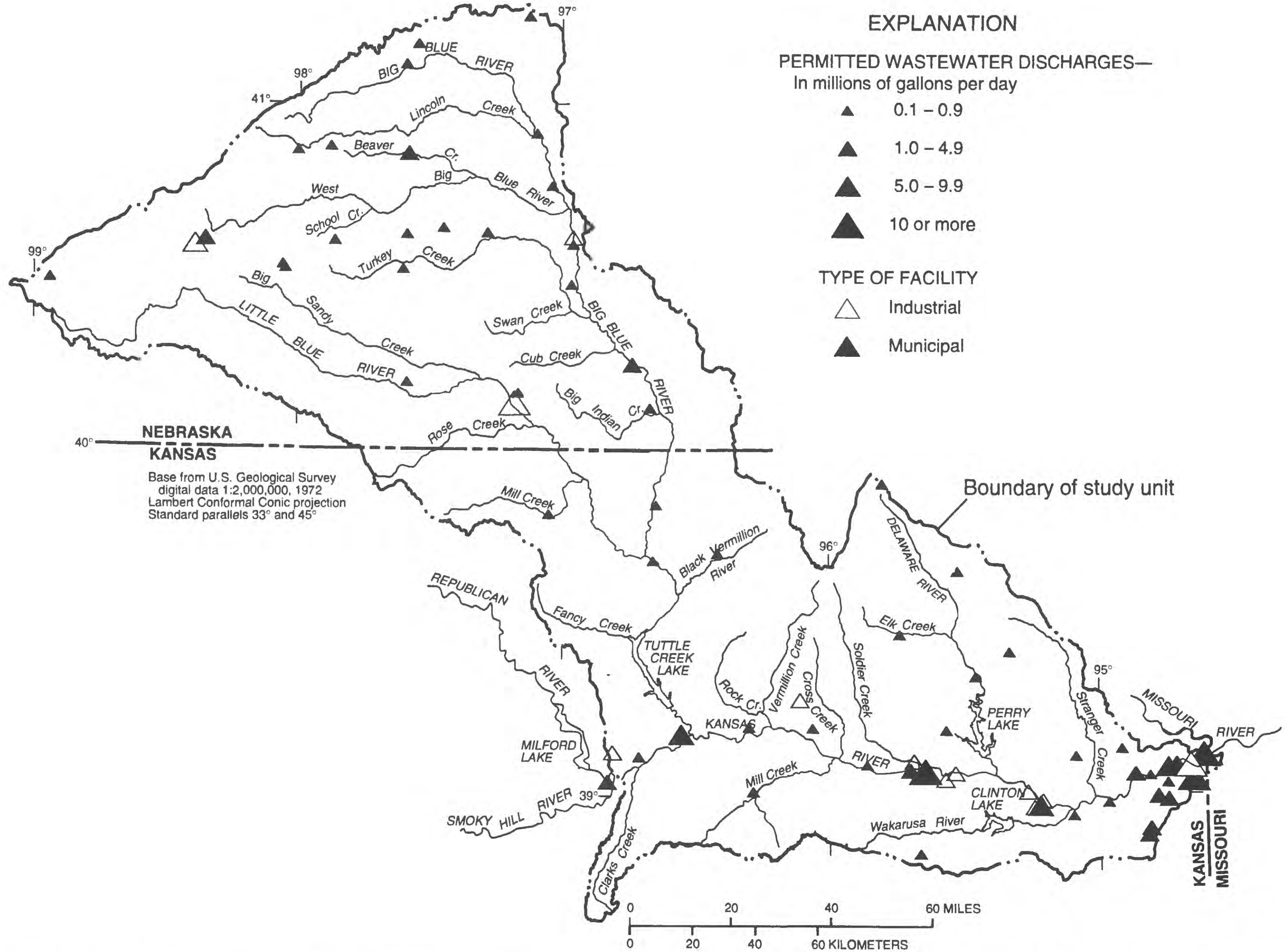

Figure 9. Location of municipal and industrial wastewater-treatment facilities with permitted discharges equal to or greater than 0.1 million gallons per day, 1990 (data from U.S. Environmental Protection Agency National Pollutant Discharge Elimination System).

surveys included onsite observations of streamflow, specific conductance, pH, water temperature, and barometric pressure, and laboratory analyses for concentrations of nutrients, total organic carbon, chlorophyll, and suspended sediment.

Sampling-Site Selection

Synoptic-sampling sites were selected based on existing data, location of wastewater discharges, land use, and physiographic sections. Sites were selected to satisfy one or more of the following criteria: (1) include all regularly sampled stations; (2) locations where DO depletion or bacteria densities might be significant; (3) locations on streams draining areas with reasonably homogeneous land use; (4) sites near the confluence of major tributaries; and (5) additional sites on the main stem Kansas River and major tributary streams to provide a resolution of no more than 50 river mi between sites. A description of the 61 synoptic-sampling sites used in this study is provided in table 2. Location of these sites is shown in figure 10. The sites chosen for this study and corresponding map-index numbers are a subset of all 91 downstream-ordered sampling sites for the lower Kansas River Basin NAWQA project as listed in Fallon and McChesney (1993); therefore, the map-index numbers for the 61 sites used in this study are not numbered consecutively but maintain consistency between individual reports for the lower Kansas River Basin NAWQA project.

DISSOLVED-OXYGEN CONCENTRATIONS

Sources, Consumption, and Water-Quality Criteria

Possible sources of DO in streams are: (1) ground water and surface runoff, (2) photosynthesis, and (3) physical aeration. Typically, ground water has very small concentrations of DO and, unless physically aerated prior to entering the stream, contributes little to the oxygen content of the receiving stream. Photosynthesis, the biochemical process of converting carbon dioxide and water into glucose and oxygen, is driven by light energy and carried on in the cells of all algae and plants containing chlorophyll. The oxygen produced in this process either becomes concentrated in cellular protoplasm or diffuses outward into the surrounding water. Factors that affect the contribution of photosynthesis to the DO concentration of a stream include light intensity, turbidity, algal population, nutrient concentration, and water temperature. Physical aeration, the process of securing oxygen directly from the atmosphere can be a major source of DO to streams, but its effect may have great variability from one stream to another depending upon such factors as streamflow velocity, turbulence, channel morphology, water temperature, and atmospheric pressure. The significance of water temperature and atmospheric pressure lies in the inverse relation of oxygen solubility to temperature and the direct relation to atmospheric pressure (Reid and Wood, 1976, p. 210–213).

Consumption of DO in streams is mainly the result of microbial decomposition of organic and nitrogenous organic compounds; oxidation of reduced compounds of sulfur, nitrogen, and iron; and cellular respiration. Respiration, in its simplest form, is the reverse of photosynthesis; glucose and oxygen are converted to carbon dioxide and water with a release of energy equivalent to that provided by sunlight in fueling the photosynthetic reaction (Robbins and others, 1964, p. 57). The introduction of large quantities of biochemical oxygen-demanding material, such as that discharged from a wastewater-treatment facility, can severely affect a stream with inadequate DO reserves and may produce a DO depression within a stream segment. These depressions often result in DO concentrations that are less than the acceptable water-quality criteria.

Water-quality criteria for DO have been established by the USEPA (U.S. Environmental Protection Agency, 1986). The 1-day minimum, warmwater criteria are 5.0 mg/L (milligrams per liter) for early life stages, which include all embryonic and larval stages and all juvenile forms to 30 days following hatching, and 3.0 mg/L for all other life stages. The daily minimums were established to prevent acute mortality of sensitive species resulting from a lack of oxygen. The criteria were designed to prevent significant episodes of continuous or regularly recurring exposures to DO concentrations at or near the lethal threshold.

Table 2. Description of synoptic-sampling sites in the lower Kansas River Basin

Map-index number (fig. 10)[1]	U.S. Geological Survey site identification number	Site name
1	06879100	Kansas River at Fort Riley, Kans.
2	390255096435000	Clarks Creek near Fort Riley, Kans.
5	06879820	Kansas River at Manhattan, Kans.
6	06879900	Big Blue River at Surprise, Nebr.
9	405221097582100	Lincoln Creek near Aurora, Nebr.
10	405438097354800	Lincoln Creek near York, Nebr.
11	06880000	Lincoln Creek near Seward, Nebr.
12	06880500	Big Blue River at Seward, Nebr.
16	403611098200600	West Fork Big Blue River near Hastings, Nebr.
17	404247097580600	West Fork Big Blue River near Stockham, Nebr.
18	403749097503400	School Creek near Sutton, Nebr.
19	404327097354600	West Fork Big Blue River near McCool Junction, Nebr.
21	405029097322100	Beaver Creek near York, Nebr.
23	06880800	West Fork Big Blue River near Dorchester, Nebr.
26	06881000	Big Blue River near Crete, Nebr.
27	403304097311400	Turkey Creek near Geneva, Nebr.
28	06881200	Turkey Creek near Wilber, Nebr.
29	402348096591100	Swan Creek near Dewitt, Nebr.
31	401730096500200	Cub Creek near Beatrice, Nebr.
32	06881500	Big Blue River at Beatrice, Nebr.
34	400632096401600	Big Indian Creek near Wymore, Nebr.
35	06882000	Big Blue River at Barneston, Nebr.
36	06882510	Big Blue River at Marysville, Kans.
37	402726098240500	Little Blue River near Hastings, Nebr.
38	06883000	Little Blue River near Deweese, Nebr.
39	401243097433500	Little Blue River near Deshler, Nebr.
40	06883570	Little Blue River near Alexandria (Gilead), Nebr.
41	401826097451100	Big Sandy Creek near Davenport, Nebr.
42	06883940	Big Sandy Creek at Alexandria, Nebr.
44	06884000	Little Blue River near Fairbury, Nebr.

Table 2. Description of synoptic-sampling sites in the lower Kansas River Basin—Continued

Map-index number (fig. 10)[1]	U.S. Geological Survey site identification number	Site name
46	400359097101400	Rose Creek near Fairbury, Nebr.
47	06884025	Little Blue River at Hollenberg, Kans.
48	395513096561100	Mill Creek near Hanover, Kans.
49	06884400	Little Blue River near Barnes, Kans.
50	06885500	Black Vermillion River near Frankfort, Kans.
51	06886500	Fancy Creek at Winkler, Kans.
52	06887000	Big Blue River near Manhattan, Kans.
55	392844096093500	Vermillion Creek near Onaga, Kans.
56	06888030	Vermillion Creek near Louisville, Kans.
57	06888300	Rock Creek near Louisville, Kans.
58	06888350	Kansas River near Belvue, Kans.
59	06888500	Mill Creek near Paxico, Kans.
60	390820095571500	Cross Creek at Rossville, Kans.
61	06888705	Kansas River at Willard, Kans.
62	06889000	Kansas River at Topeka, Kans.
63	06889160	Soldier Creek near Circleville, Kans.
64	06889500	Soldier Creek near Topeka, Kans.
71	394757095434300	Delaware River near Fairview, Kans.
72	06890100	Delaware River near Muscotah, Kans.
73	392823095362800	Elk Creek near Larkinburg, Kans.
74	06890900	Delaware River below Perry Dam, Kans.
76	06891000	Kansas River at Lecompton, Kans.
77	06891080	Kansas River at Lawrence, Kans.
78	06891100	Kansas River at Eudora, Kans.
79	385329095353400	Wakarusa River near Berryton, Kans.
83	06891500	Wakarusa River near Lawrence, Kans.
86	06891850	Stranger Creek at Easton, Kans.
87	06892000	Stranger Creek near Tonganoxie, Kans.
88	06892350	Kansas River at DeSoto, Kans.
90	06892940	Turkey Creek at Kansas City, Kans.
91	06892950	Kansas River at Kansas City, Kans.

[1]Map-index numbers from Fallon and McChesney (1993).

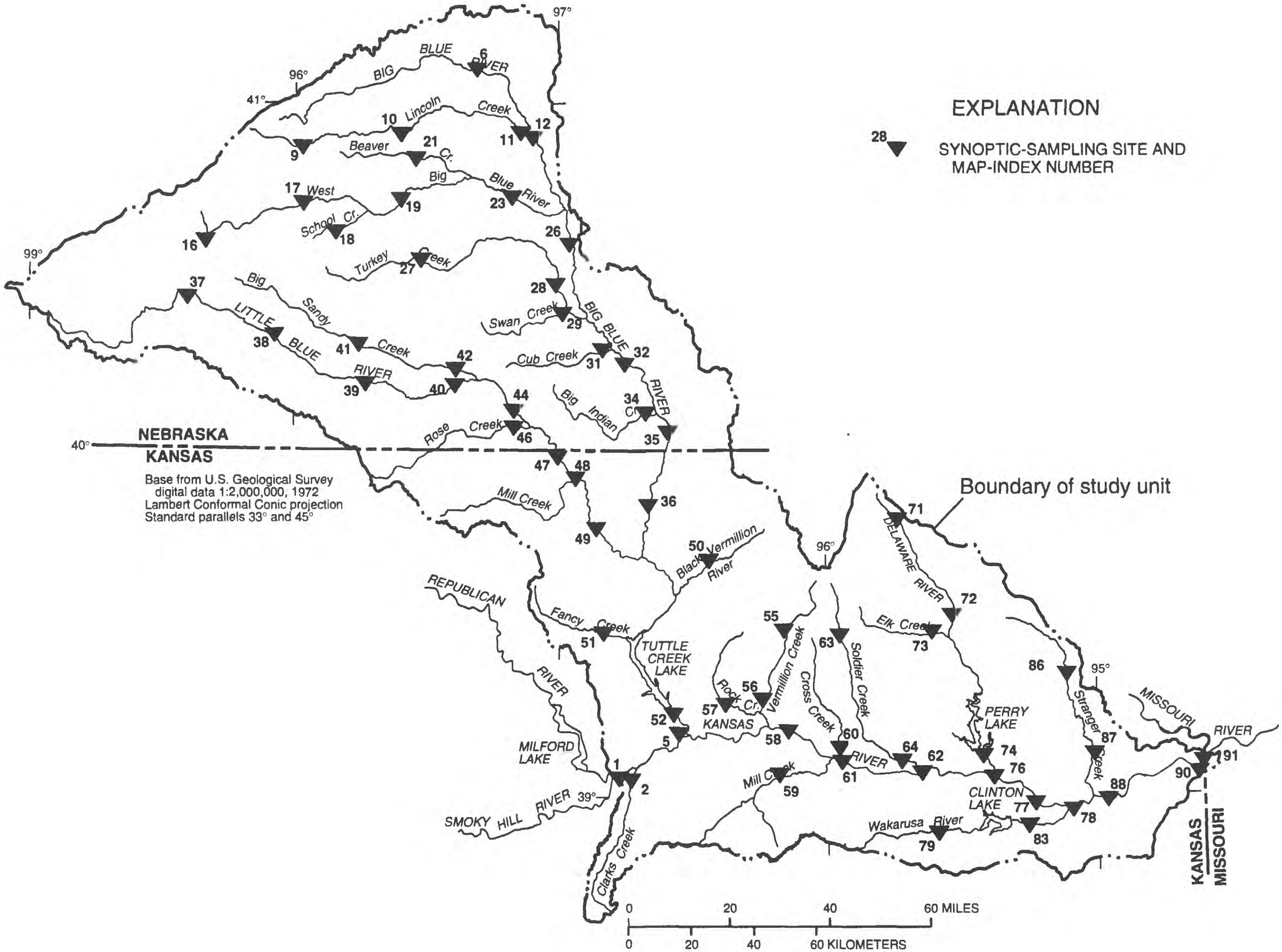

Figure 10. Location of synoptic-sampling sites.

Data Collection and Analysis

Because of the diel variability of DO and to assess the streams at a time of minimal DO concentration, efforts were made to sample sites before sunrise. During the 6 days of the July 1988 synoptic survey, 31 sites were sampled under predawn conditions (0415 to 0635 hours). The remaining 30 sites generally were sampled at times that fit most efficiently into the sampling schedules. To define diel variability, 11 sites were selected to represent a range in drainage area, land use, and physiographic characteristics. These 11 sites were sampled at 4- or 6-hour intervals during a 24-hour period.

All determinations of DO were made onsite with portable meters equipped with DO-specific probes. The meters used for this investigation were Yellow Springs Instrument[1] (YSI), model numbers 54 or 57, with a YSI 5739 DO probe. These meters have a measurement range of 0.1 to 20.0 mg/L. Before each measurement, the meters were calibrated using the air-calibration-in-water technique described in Hines and others (1977).

All samples for chemical analyses were collected in accordance with procedures described in Brown and others (1970). Generally, the equal-width-increment (EWI) method was used for all streams requiring depth-integrated sampling. A DH-81 suspended-sediment sampler was used for depth integration on wadeable streams. A D-77 cable-suspended sediment sampler was used from a bridge on streams where excessive depth or velocity prevented wading. On small streams where the use of a suspended-sediment sampler was impractical (shallow depth or small velocity), a dip sample at the centroid of flow was collected. Discrete dip or EWI samples collected during the horizontal transit of the stream were composited into a U.S. Geological Survey churn splitter. Representative subsamples for chemical analysis were withdrawn from the churn, bottled, and appropriately preserved.

Sample preservation and analysis of water samples for nutrients, organic carbon, and chlorophyll were made in accordance with procedures described in Fishman and Friedman (1989), Wershaw and others (1983), and Britton and Greeson (1987), respectively.

[1]The use of brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Chemical analysis of samples collected for this study was done by the U.S. Geological Survey laboratory in Arvada, Colo. Concentrations of dissolved chemical constituents presented in this report were determined for water samples that were filtered through a membrane filter with a pore size of 0.45 micrometer. Total concentrations of constituents were determined on unfiltered samples of the water-sediment mixture. Determinations made at the time of sample collection or at the U.S. Geological Survey laboratory, Lawrence, Kans., included streamflow discharge, specific conductance, pH, water temperature, barometric pressure, and concentrations of DO and suspended sediment.

Streamflow discharge for water samples collected at established U.S. Geological Survey gaging stations with a stable, well-defined stream stage-discharge relation was determined by referencing the observed stream stage to the stage-discharge relation. Streamflow discharge at gaging stations with a shifting or questionable stage-discharge relation and at ungaged sites was determined by measuring the streamflow at the time of sampling in accordance with procedures described in Buchanan and Somers (1976).

Onsite measurements of specific conductance and pH were made with portable electronic meters on an aliquot of the composite stream sample in accordance with procedures described in Fishman and Friedman (1989). All pH measurements were recorded to the nearest 0.1 standard unit. Water temperature was determined onsite with a mercury or alcohol thermometer and recorded to the nearest 0.5 °C. Barometric pressure was measured with a portable barometer calibrated to National Oceanic and Atmospheric Administration weather-station readings prior to start of the survey. Barometric pressure was recorded to the nearest 1.0 millimeter of mercury. Determinations of suspended-sediment concentrations were made in accordance with procedures described in Guy (1977).

Results of water-quality determinations and DO concentrations at all synoptic-sampling sites are shown in table 3. Results of analyses of water samples for concentrations of nutrients, total organic carbon, chlorophyll, and suspended sediment are shown in table 8 in the "Supplemental Information" section at the end of this report. Included in tables 3 and 8 are results from synoptic surveys of July 1988, November 1988, March 1989, and May–June 1989. Also included in tables 3 and 8 are quality-assurance measurements and analyses. These measurements and analyses consist of duplicate determinations at

Table 3. Results of water-quality determinations and dissolved-oxygen concentrations at synoptic-sampling sites in the lower Kansas River Basin, July 1988 through June 1989

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mm of Hg, millimeters of mercury; mg/L, milligrams per liter, E, estimated; --, no data; >, greater than]

Site map-index number (fig. 10)	Date	Time (24-hour)	Stream-flow, instan-taneous (cubic feet per second)	Specific conduct-ance (µS/cm)	pH (standard units)	Temper-ature, water (°C)	Baro-metric pressure (mm of Hg)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent satur-ation)
1	07-27-88	1300	353	1,830	8.4	28.0	739	9.3	123
	11-15-88	1205	327	2,600	8.3	15.0	718	10.2	108
	03-08-89	1000	395	1,730	8.5	3.0	745	15.3	117
	06-01-89	1010	500	1,250	8.0	21.0	740	8.6	100
2	07-27-88	1150	.65	571	8.3	27.5	740	8.1	106
	11-15-88	1050	2.1	613	8.3	15.0	720	8.8	93
	03-08-89	1140	3.7	543	8.4	5.5	745	14.1	115
	06-01-89	0830	1.3	586	8.2	22.0	738	6.0	71
5	07-24-88	1020	240	1,290	8.1	26.0	738	7.8	100
	11-16-88	0850	455	1,940	8.7	7.5	731	10.6	93
	03-09-89	0930	395	1,580	8.6	6.0	749	15.2	125
	06-02-89	0820	496	1,090	8.6	21.0	739	9.8	114
6	07-26-88	0730	6.2	583	8.2	24.0	741	7.0	86
	11-14-88	1200	1.4	656	8.0	6.0	718	11.0	94
	03-08-89	1015	24	334	7.8	.5	730	8.3	60
	05-31-89	1445	E1.5	657	8.2	19.5	726	11.2	128
9	07-26-88	0945	.34	458	7.6	20.5	725	1.6	19
	07-26-88	2150	E.30	--	--	26.0	722	2.9	38
	07-27-88	0550	E.30	--	--	21.5	721	1.2	14
	11-15-88	0815	1.4	1,130	7.8	6.5	705	4.4	39
	03-07-89	1015	E.01	452	5.9	.5	773	2.0	14
	05-31-89	0930	.40	964	7.5	16.0	718	1.0	11
10	07-26-88	0900	8.2	570	7.9	21.0	734	6.3	74
	07-26-88	1300	8.2	570	7.7	23.0	725	7.0	86
	07-26-88	1700	8.2	574	7.8	27.0	725	7.6	101
	07-26-88	2100	8.2	549	7.8	28.0	724	7.4	100
	07-27-88	0100	8.2	552	7.9	26.0	724	6.2	81

Table 3. Results of water-quality determinations and dissolved-oxygen concentrations at synoptic-sampling sites in the lower Kansas River Basin, July 1988 through June 1989—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Stream-flow, instan-taneous (cubic feet per second)	Specific conduct-ance (µS/cm)	pH (standard units)	Temper-ature, water (°C)	Baro-metric pressure (mm of Hg)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent satur-ation)
10	07-27-88	0500	8.2	561	7.7	23.0	724	5.5	68
	07-27-88	0900	8.2	566	7.9	22.0	725	6.0	72
	11-14-88	1345	--	513	8.0	7.0	715	10.4	91
	03-07-89	1000	.88	680	7.6	0	735	--	--
	05-31-89	1330	.19	586	7.6	16.5	724	6.1	66
11	07-26-88	0845	30	580	8.1	23.0	742	6.7	80
	11-14-88	1050	17	621	8.3	6.0	723	10.9	92
	03-08-89	1215	25	408	7.8	.5	739	11.5	82
	05-31-89	1600	E17	641	8.1	18.5	727	8.3	93
12	07-26-88	1000	55	555	8.0	23.0	741	5.8	70
	07-26-88	1005	55	555	8.0	23.0	741	5.8	70
	07-26-88	1400	55	548	8.0	25.0	741	7.4	92
	07-26-88	1800	55	549	8.2	26.0	741	8.4	107
	07-26-88	2200	55	585	7.6	26.0	740	7.4	94
	07-27-88	0200	55	577	8.0	24.0	740	6.7	82
	07-27-88	0600	55	595	8.0	23.0	741	5.5	66
	11-14-88	0845	29	689	8.2	5.5	724	11.4	95
	03-08-89	1130	114	476	7.6	.5	740	12.2	87
16	07-26-88	0630	6.7	--	7.6	21.0	719	2.1	25
	07-26-88	1800	E6.7	--	--	25.5	721	4.8	63
	07-27-88	1215	E6.7	--	--	20.5	720	2.1	25
	09-06-88	1145	5.8	946	7.7	20.0	714	2.5	29
	11-15-88	1015	3.0	1,030	7.5	14.5	702	.6	6
	03-07-89	1600	6.4	909	7.7	11.5	717	4.0	40
	05-30-89	1145	4.4	838	7.6	21.5	716	4.9	59
17	07-25-88	1230	14	--	8.0	26.5	726	6.8	92
	07-26-88	1300	E14	532	7.8	24.5	726	7.1	90
	07-26-88	1700	E14	356	8.0	27.0	725	8.1	107
	07-26-88	2100	E18	535	8.0	27.0	728	6.5	86
	07-27-88	0100	E18	644	8.0	25.5	723	5.6	72

Table 3. Results of water-quality determinations and dissolved-oxygen concentrations at synoptic-sampling sites in the lower Kansas River Basin, July 1988 through June 1989—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Stream-flow, instan-taneous (cubic feet per second)	Specific conduct-ance (µS/cm)	pH (standard units)	Temper-ature, water (°C)	Baro-metric pressure (mm of Hg)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent satur-ation)
17	07-27-88	0500	E18	662	8.0	23.5	722	5.9	74
	07-27-88	0900	E18	639	7.9	22.5	724	6.0	73
	07-27-88	1300	E16	626	7.8	24.5	725	7.1	90
	11-15-88	1130	3.5	970	7.7	6.5	708	8.4	74
	03-07-89	1300	2.6	920	7.6	.5	724	9.2	67
18	07-25-88	1130	3.8	427	7.8	23.5	727	5.1	63
	11-15-88	1230	.26	998	7.8	7.5	707	8.9	80
	03-07-89	1445	.55	828	7.7	0	724	12.4	90
	05-30-89	1445	.26	1,060	8.5	26.5	717	12.1	161
19	07-25-88	1200	27	533	8.3	27.0	734	7.6	99
	11-15-88	1300	14	713	8.3	7.5	709	11.2	101
	03-07-89	1245	15	630	7.6	0	732	14.7	105
	05-31-89	1100	15	604	7.8	19.0	723	6.2	71
21	07-26-88	1010	6.5	660	7.9	23.0	734	7.1	86
	09-06-88	1440	2.5	995	8.3	19.5	721	11.1	128
	11-14-88	1425	2.5	980	8.3	8.5	716	17.8	162
	03-07-89	1145	2.9	852	7.4	0	737	--	--
	05-31-89	1245	2.2	870	7.6	18.5	724	4.9	56
23	07-25-88	1245	75	518	8.2	25.5	743	7.6	95
	08-08-88	1115	81	556	8.1	26.0	726	7.6	99
	08-31-88	1400	48	590	8.5	21.0	730	11.3	133
	10-12-88	1230	55	467	7.8	11.5	733	10.6	101
	11-07-88	1200	57	--	8.3	8.0	730	11.3	--
	11-15-88	1420	58	610	8.0	8.0	711	9.9	90
	12-06-88	1000	53	--	8.2	3.5	735	10.7	--
	01-03-89	1130	59	684	7.8	0	732	13.8	99
	02-07-89	1000	49	668	7.8	0	731	10.8	77
	03-07-89	1400	76	539	8.0	0	731	13.1	94
	03-08-89	1345	98	484	7.9	1.0	741	13.6	99
	04-04-89	0955	70	632	8.1	7.0	726	12.7	110
	05-02-89	0830	64	609	8.3	9.5	726	9.7	89
	05-31-89	1430	E54	610	8.2	19.0	725	5.2	59

Table 3. Results of water-quality determinations and dissolved-oxygen concentrations at synoptic-sampling sites in the lower Kansas River Basin, July 1988 through June 1989—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Stream-flow, instan-taneous (cubic feet per second)	Specific conduct-ance (µS/cm)	pH (standard units)	Temper-ature, water (°C)	Baro-metric pressure (mm of Hg)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent satur-ation)
26	07-25-88	1030	184	526	8.6	25.5	744	8.8	110
	09-07-88	0840	83	644	8.4	16.0	720	8.2	88
	11-14-88	1530	112	715	8.2	8.5	722	13.5	122
	03-08-89	1500	192	515	7.9	4.0	741	11.6	91
	05-31-89	1300	E164	628	8.3	20.0	726	7.7	89
27	07-25-88	1325	2.1	362	8.0	28.5	734	6.8	91
	11-15-88	1110	.29	476	7.8	8.5	711	10.0	92
	03-07-89	1345	1.5	290	7.8	.5	730	--	--
	05-30-89	1445	E.50	860	8.6	29.5	715	17.5	246
28	07-25-88	0600	22	436	7.0	24.5	734	6.6	82
	11-14-88	1445	7.2	862	7.7	8.0	722	9.1	81
	03-07-89	0855	6.8	722	7.5	.5	736	10.3	74
	05-31-89	1215	E10	695	8.0	19.5	726	6.9	79
29	07-25-88	0630	13	847	7.5	24.0	734	6.3	78
	11-14-88	1200	11	1,000	7.8	8.5	725	12.6	114
	03-07-89	1240	30	739	7.8	1.0	736	13.4	98
	05-31-89	1100	8.0	913	8.0	19.0	725	9.2	105
31	07-25-88	1330	3.6	441	7.6	27.0	760	8.4	106
	07-25-88	1335	3.6	441	7.6	27.0	760	8.4	106
	07-25-88	1730	3.6	439	7.9	26.0	740	8.2	104
	07-25-88	2100	3.6	440	7.6	26.5	738	7.4	95
	07-26-88	0200	3.6	402	8.0	23.0	734	6.6	80
	07-26-88	0510	3.6	411	8.1	21.5	736	6.1	72
	07-26-88	0915	3.6	462	8.1	21.0	734	7.0	82
	11-14-88	1045	.75	601	7.2	7.0	728	8.4	73
	03-08-89	0900	2.9	518	7.6	.5	739	9.3	67
31	05-30-89	1630	0.51	582	8.0	24.0	722	5.1	64

Table 3. Results of water-quality determinations and dissolved-oxygen concentrations at synoptic-sampling sites in the lower Kansas River Basin, July 1988 through June 1989—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Stream-flow, instan-taneous (cubic feet per second)	Specific conduct-ance (μS/cm)	pH (standard units)	Temper-ature, water (°C)	Baro-metric pressure (mm of Hg)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent satur-ation)
32	07-25-88	1330	322	533	8.4	28.0	761	7.3	94
	07-25-88	1700	318	529	8.3	29.0	735	7.2	97
	07-25-88	2100	314	520	8.4	29.0	735	6.7	91
	07-26-88	0115	299	550	8.3	27.0	734	6.7	88
	07-26-88	0950	280	567	8.3	25.0	734	7.2	91
	07-27-88	0510	247	530	8.5	26.0	734	5.8	74
	11-14-88	0900	192	801	7.9	7.0	729	11.2	97
	11-14-88	0905	192	801	7.9	7.0	728	11.2	97
	11-14-88	1300	192	808	8.2	8.0	726	12.7	113
	11-14-88	1305	192	808	8.2	8.0	726	12.7	113
	11-14-88	1700	188	845	8.2	8.0	724	12.3	110
	11-14-88	1705	188	845	8.2	8.0	724	12.3	110
	11-14-88	2100	188	776	8.2	8.5	723	11.6	105
	11-14-88	2105	188	776	8.2	8.5	723	11.6	105
	11-15-88	0100	185	764	8.2	9.0	720	11.2	103
	11-15-88	0105	185	764	8.2	9.0	720	11.2	103
	11-15-88	0500	185	759	8.1	9.5	718	10.4	97
	11-15-88	0505	185	759	8.1	9.5	718	10.4	97
	11-15-88	0900	192	761	8.1	9.5	718	10.1	94
	11-15-88	0905	192	716	8.1	9.5	718	10.1	94
	03-07-89	1000	237	592	7.9	0	740	12.8	90
	03-07-89	1005	237	592	7.9	0	740	12.8	90
	03-07-89	1400	237	594	7.9	1.0	737	13.1	95
	03-07-89	1405	237	594	7.9	1.0	737	13.1	95
	03-07-89	1800	237	583	7.8	.5	736	12.7	91
	03-07-89	1805	237	583	7.8	.5	736	12.7	91
	03-07-89	2200	237	570	7.7	.5	737	14.0	101
	03-07-89	2205	237	570	7.7	.5	737	14.0	101
	03-08-89	0200	237	537	7.8	.5	738	13.0	93
	03-08-89	0205	237	537	7.8	.5	738	13.0	93

Table 3. Results of water-quality determinations and dissolved-oxygen concentrations at synoptic-sampling sites in the lower Kansas River Basin, July 1988 through June 1989—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Stream-flow, instan-taneous (cubic feet per second)	Specific conduct-ance (µS/cm)	pH (standard units)	Temper-ature, water (°C)	Baro-metric pressure (mm of Hg)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent satur-ation)
32	03-08-89	0600	237	548	7.9	0	739	12.0	85
	03-08-89	0605	237	548	7.9	0	739	12.0	85
	03-08-89	1000	237	574	7.9	.5	739	13.2	95
	03-08-89	1005	237	574	7.9	.5	739	13.2	95
	05-30-89	1000	163	740	8.6	23.0	722	7.7	95
	05-30-89	1005	163	740	8.6	23.0	722	7.7	95
	05-30-89	1500	163	735	8.9	25.0	722	13.9	178
	05-30-89	1505	163	735	8.9	25.0	722	13.9	178
	05-30-89	1800	163	708	8.9	25.0	723	13.5	173
	05-30-89	1810	163	708	8.9	25.0	723	13.5	173
	05-30-89	2200	163	720	8.8	25.0	725	10.2	130
	05-30-89	2205	163	720	8.8	25.0	725	10.2	130
	05-31-89	0200	163	725	8.3	24.5	726	8.1	102
	05-31-89	0210	163	725	8.3	24.5	726	8.1	102
	05-31-89	0600	163	731	8.8	22.5	727	6.0	73
	05-31-89	0610	163	731	8.8	22.5	727	6.0	73
	05-31-89	1000	163	735	8.8	21.5	725	7.1	85
	05-31-89	1005	163	735	8.8	21.5	725	7.1	85
34	07-25-88	0650	12	--	8.0	25.0	740	6.2	78
	07-26-88	0915	19	448	8.1	24.0	738	6.4	79
	07-26-88	1045	19	475	7.8	24.5	738	7.2	89
	07-26-88	1445	19	476	8.0	28.0	735	8.9	118
	07-26-88	1450	19	476	8.0	28.0	735	8.9	118
	07-26-88	1845	19	490	8.1	28.0	733	9.3	124
	07-26-88	2230	19	546	8.1	25.0	734	7.5	95
	07-27-88	0230	19	517	7.9	24.5	732	7.5	94
	07-27-88	0635	19	500	8.0	23.0	730	7.3	89
	11-14-88	1020	5.2	1,060	7.8	6.0	727	10.1	85
	03-07-89	1520	4.5	811	8.3	2.5	738	18.9	143
	05-30-89	1345	3.1	930	8.3	27.0	723	8.1	108

Table 3. Results of water-quality determinations and dissolved-oxygen concentrations at synoptic-sampling sites in the lower Kansas River Basin, July 1988 through June 1989—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Streamflow, instantaneous (cubic feet per second)	Specific conductance (µS/cm)	pH (standard units)	Temperature, water (°C)	Barometric pressure (mm of Hg)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)
35	07-25-88	0540	376	524	8.2	25.0	740	7.4	93
	08-09-88	0915	138	654	8.6	28.0	734	6.6	88
	08-30-88	1400	136	552	8.6	23.5	739	8.3	101
	10-18-88	1000	171	554	7.8	15.0	741	9.3	95
	11-08-88	1200	166	738	8.8	9.0	740	12.3	110
	11-14-88	1145	193	755	8.2	6.5	726	13.0	111
	12-06-88	0900	229	750	8.7	3.5	734	15.6	122
	01-04-89	1100	200	809	8.8	1.5	734	17.5	130
	01-31-89	1100	329	779	7.4	1.0	718	15.9	119
	03-07-89	1435	303	593	8.2	1.0	739	14.4	105
	03-28-89	1130	270	689	8.3	12.5	726	11.0	109
	04-19-89	1130	223	699	8.9	13.0	738	10.0	98
	05-24-89	0940	220	628	8.6	23.0	715	7.8	97
	05-30-89	1245	187	665	8.4	23.0	723	8.6	106
36	07-25-88	1230	393	557	7.8	28.0	737	--	--
	11-16-88	1050	270	792	7.6	7.5	741	12.1	104
	03-09-89	0940	316	585	8.4	.5	741	14.7	105
	05-31-89	1240	161	661	9.0	25.0	730	10.8	137
37	07-26-88	0515	18	349	7.8	22.5	727	7.8	95
	11-15-88	1100	8.0	380	7.6	7.5	703	10.9	99
	03-08-89	0800	11	461	7.6	4.0	722	11.9	96
	05-30-89	1200	8.3	476	8.5	20.0	714	11.7	138
38	07-26-88	0810	31	412	8.0	20.0	738	7.9	90
	11-15-88	0940	55	370	7.5	7.5	706	10.9	98
	03-08-89	0920	67	444	8.1	1.5	726	13.7	103
	05-30-89	1320	52	477	8.3	24.0	714	8.6	109
39	07-26-88	0630	32	375	8.3	21.0	738	7.3	85
	11-15-88	0815	52	370	8.0	7.5	709	10.2	92
	03-08-89	1100	79	444	8.1	0	730	12.5	89
	05-31-89	1030	45	495	8.7	19.0	722	7.8	89

Table 3. Results of water-quality determinations and dissolved-oxygen concentrations at synoptic-sampling sites in the lower Kansas River Basin, July 1988 through June 1989—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Stream-flow, instan-taneous (cubic feet per second)	Specific conduct-ance (µS/cm)	pH (standard units)	Temper-ature, water (°C)	Baro-metric pressure (mm of Hg)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent satur-ation)
40	07-26-88	0630	55	397	8.0	22.0	734	6.0	71
	11-14-88	1655	69	430	8.2	9.0	718	12.2	112
	03-08-89	1345	118	448	8.2	0	734	16.4	117
	05-31-89	1200	61	500	8.3	20.0	730	8.5	98
41	07-26-88	0600	1.5	378	7.8	18.0	738	8.1	89
42	07-26-88	0545	37	370	7.5	17.5	734	6.6	72
	11-14-88	1730	20	337	7.4	11.0	716	7.9	76
	03-08-89	1250	26	354	7.7	12.5	734	11.3	110
	05-31-89	1130	25	385	7.8	15.0	725	9.8	102
44	07-25-88	0845	133	396	7.4	28.0	734	6.8	91
	07-26-88	1320	119	374	--	27.0	732	9.4	123
	07-26-88	1710	127	423	--	27.0	733	10.6	139
	07-26-88	2150	116	435	--	27.0	734	6.5	85
	07-27-88	0120	127	375	--	27.5	732	5.7	75
	07-27-88	0545	112	393	8.3	25.0	734	5.3	67
	11-14-88	1555	118	455	8.0	7.0	720	13.1	114
	03-08-89	1225	133	488	8.2	2.5	738	15.0	114
	05-31-89	1300	91	520	8.2	21.0	730	8.3	97
46	07-25-88	0615	18	398	7.8	26.0	734	6.4	82
	07-26-88	1355	9.0	411	8.1	26.5	732	7.0	91
	07-26-88	1750	E8.5	460	7.9	27.0	732	7.2	94
	07-26-88	2110	8.0	498	7.7	26.5	734	5.6	73
	07-27-88	0100	E7.5	440	8.2	25.5	732	7.0	89
	07-27-88	0510	E7.0	448	7.2	23.5	734	5.6	69
	11-14-88	1515	8.0	560	8.1	6.5	723	12.9	111
	03-08-89	1200	13	599	8.1	1.0	738	15.5	113
	05-31-89	1330	6.8	604	8.0	21.0	730	6.9	81
47	07-25-88	1150	163	501	8.7	29.0	740	7.2	97
	07-27-88	0920	119	512	9.0	27.0	740	15.0	195
	08-09-88	1135	78	578	8.4	26.5	733	10.9	141

Table 3. Results of water-quality determinations and dissolved-oxygen concentrations at synoptic-sampling sites in the lower Kansas River Basin, July 1988 through June 1989—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Stream-flow, instan-taneous (cubic feet per second)	Specific conduct-ance (µS/cm)	pH (standard units)	Temper-ature, water (°C)	Baro-metric pressure (mm of Hg)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent satur-ation)
47	08-30-88	1100	75	610	8.6	21.0	739	10.3	119
	10-18-88	1300	113	518	8.0	14.0	739	9.5	95
	11-09-88	1200	118	520	8.3	8.0	737	10.4	91
	11-14-88	1350	133	523	8.1	9.0	722	12.6	115
	12-06-88	1300	135	564	8.3	3.0	733	14.5	112
	01-10-89	1050	86	696	8.2	0	733	13.1	93
	02-07-89	1115	109	643	7.4	0	747	--	--
	03-07-89	1100	179	537	8.1	0	737	13.4	95
	03-08-89	1040	200	524	8.1	.5	740	14.1	101
	04-05-89	0955	138	566	8.3	9.5	736	13.3	121
	05-01-89	1200	142	593	8.4	12.5	738	10.7	104
	05-31-89	1420	110	600	8.4	21.0	730	8.7	102
48	07-26-88	1215	12	763	8.3	24.0	734	7.0	87
	11-16-88	1400	12	855	8.1	7.0	732	8.5	73
	03-09-89	0830	13	652	8.2	1.0	738	13.7	100
	05-31-89	1415	5.9	734	8.3	23.0	730	7.3	89
49	07-25-88	1400	206	454	7.9	31.0	737	10.6	148
	11-16-88	1130	166	580	8.5	5.0	735	12.4	101
	11-16-88	1135	166	580	8.5	5.0	735	12.4	101
	03-08-89	1630	150	715	8.3	4.5	738	12.0	96
	03-08-89	1635	150	715	8.3	4.5	738	12.0	96
	03-08-89	1715	150	715	8.3	4.5	738	12.0	96
	03-08-89	1720	150	715	8.3	4.5	738	12.0	96
	05-31-89	1540	110	640	8.8	24.0	730	11.8	147
	05-31-89	1545	110	640	8.8	24.0	730	11.8	147
	05-31-89	1550	110	639	8.8	24.0	730	11.8	147
	05-31-89	1555	110	639	8.8	24.0	730	11.8	147
50	07-24-88	1320	7.0	--	8.1	26.0	736	7.9	101
	11-16-88	1340	16	572	7.9	8.0	740	10.8	94
	11-16-88	1350	16	572	7.9	8.0	740	10.8	94
	11-16-88	1355	16	572	7.9	8.0	740	10.8	94

Table 3. Results of water-quality determinations and dissolved-oxygen concentrations at synoptic-sampling sites in the lower Kansas River Basin, July 1988 through June 1989—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Stream-flow, instan-taneous (cubic feet per second)	Specific conduct-ance (µS/cm)	pH (standard units)	Temper-ature, water (°C)	Baro-metric pressure (mm of Hg)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent satur-ation)
50	03-09-89	1130	16	588	8.3	3.0	740	16.8	129
	05-31-89	1055	4.0	592	8.1	21.0	732	13.5	158
51	07-24-88	1445	5.7	655	8.2	29.0	738	8.6	116
	11-16-88	0940	15	857	8.9	8.0	737	8.6	75
	03-09-89	1115	6.0	1,350	8.3	6.0	740	15.4	128
	05-31-89	1730	1.0	1,110	8.1	25.0	730	6.3	80
52	07-24-88	1045	1,870	549	8.1	26.0	738	10.0	128
	11-15-88	1445	492	660	8.2	12.0	719	11.2	110
	03-08-89	1430	442	684	8.2	4.0	746	18.3	143
	06-02-89	1030	396	591	8.3	21.0	738	7.9	92
55	07-27-88	0930	1.4	504	6.6	23.0	740	5.4	65
	11-15-88	1330	1.6	865	7.8	12.0	720	8.4	83
	03-08-89	1345	4.3	526	8.4	1.0	743	17.2	124
	05-31-89	0900	.59	503	8.0	23.5	733	12.2	150
56	07-27-88	1120	4.2	550	7.1	27.0	742	9.0	116
	11-15-88	1115	3.6	--	7.7	10.0	725	8.6	--
	03-08-89	1100	6.2	629	8.3	3.0	746	16.8	128
	06-01-89	1450	1.6	468	8.3	22.5	742	10.4	124
57	07-29-88	0815	2.2	457	7.9	20.0	739	6.8	77
	03-08-89	1645	2.4	637	8.4	8.0	742	13.6	118
	06-01-89	1645	1.7	476	7.7	18.0	740	8.5	93
58	07-27-88	0910	2,550	701	8.4	25.0	730	7.7	98
	11-15-88	1445	1,190	1,040	8.4	17.0	715	8.4	93
	03-10-89	1110	897	1,080	8.5	8.0	742	11.0	96
	05-30-89	1845	1,040	845	8.3	28.0	730	7.0	94
59	07-27-88	1010	7.8	656	8.1	26.0	730	6.8	88
	11-15-88	1100	5.7	698	8.0	13.5	721	8.7	88
	03-08-89	1310	4.6	--	8.3	8.0	750	11.8	--
	06-01-89	1145	2.7	727	7.9	21.5	742	5.7	67

Table 3. Results of water-quality determinations and dissolved-oxygen concentrations at synoptic-sampling sites in the lower Kansas River Basin, July 1988 through June 1989—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Streamflow, instantaneous (cubic feet per second)	Specific conductance (µS/cm)	pH (standard units)	Temperature, water (°C)	Barometric pressure (mm of Hg)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)
60	07-29-88	0535	1.8	615	8.2	25.5	740	6.7	85
	11-15-88	1240	1.5	831	8.3	14.5	717	8.4	88
	03-09-89	1230	2.5	748	8.2	6.5	751	14.2	117
	06-01-89	1310	.98	815	7.9	21.0	742	4.7	54
61	07-28-88	1745	1,910	621	8.8	29.0	741	10.2	137
	07-29-88	0415	1,910	595	8.2	26.0	741	6.3	80
	11-15-88	1030	720	1,100	8.7	16.5	720	11.2	122
	03-08-89	1030	909	1,040	8.3	1.0	748	13.6	98
	05-31-89	1710	759	892	8.4	27.0	734	7.9	103
62	07-28-88	1815	2,280	633	8.3	30.0	744	9.7	132
	07-29-88	0530	2,250	642	7.5	26.0	742	6.0	76
	07-29-88	0535	2,250	642	7.5	26.0	742	6.0	76
	11-15-88	0755	809	983	8.5	15.0	723	11.6	122
	03-07-89	1510	1,020	1,130	8.6	3.5	748	14.4	111
	06-01-89	1815	876	864	8.4	22.5	740	8.8	105
63	07-29-88	0910	.50	834	7.2	25.0	737	5.5	69
	11-14-88	1000	.58	1,020	7.9	7.5	722	8.5	75
	03-07-89	1010	1.2	730	8.1	3.0	743	13.6	104
	06-01-89	1300	.36	698	7.6	19.5	732	6.7	76
64	07-28-88	1230	6.4	504	8.3	30.0	743	8.8	120
	07-28-88	1235	6.4	504	8.3	30.0	743	8.8	120
	07-28-88	1830	6.4	490	8.3	30.0	742	7.5	102
	07-29-88	0005	6.4	524	7.9	26.0	740	6.3	80
	07-29-88	0435	6.4	522	7.9	25.0	742	5.4	67
	11-14-88	1530	3.9	645	8.5	17.0	734	17.2	185
	03-07-89	1230	4.6	650	8.3	6.0	749	18.0	147
	03-07-89	1235	4.6	650	8.3	6.0	749	18.0	147
	03-07-89	1330	4.6	655	8.3	7.0	749	>20.0	>167
	03-07-89	1335	4.6	655	8.3	7.0	749	>20.0	>167

Table 3. Results of water-quality determinations and dissolved-oxygen concentrations at synoptic-sampling sites in the lower Kansas River Basin, July 1988 through June 1989—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Stream-flow, instantaneous (cubic feet per second)	Specific conductance (μS/cm)	pH (standard units)	Temperature, water (°C)	Barometric pressure (mm of Hg)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)
64	05-31-89	1430	3.0	543	7.9	28.0	734	10.8	144
	05-31-89	1435	3.0	543	7.9	28.0	734	10.8	144
71	07-27-88	0610	1.0	1,600	7.6	23.0	738	4.5	55
	11-17-88	1230	2.5	1,350	7.9	6.5	737	11.4	96
	03-09-89	1100	2.2	1,420	8.1	4.5	747	14.9	118
	06-01-89	1445	3.6	--	7.7	20.0	737	7.0	79
72	07-27-88	0745	2.4	677	7.8	20.5	739	6.2	71
	08-31-88	1025	1.5	694	8.3	20.5	--	10.0	--
	10-05-88	1000	1.5	636	8.7	10.5	--	9.7	--
	11-09-88	1020	2.5	860	8.3	8.5	--	8.7	--
	11-17-88	1020	22	816	8.4	5.5	743	12.1	99
	12-21-88	1010	9.6	--	8.5	0	--	10.5	--
	01-25-89	1220	12	736	8.6	4.0	--	11.2	--
	02-15-89	1035	E6.1	963	8.2	0	--	13.5	--
	03-09-89	1230	14	602	8.4	9.0	749	15.1	133
	03-15-89	1135	9.9	569	8.8	9.0	--	9.0	--
	04-19-89	0925	4.7	717	8.4	10.0	--	10.0	--
	05-17-89	1320	2.5	917	8.3	19.5	--	7.9	--
	06-02-89	0945	2.1	--	7.9	19.5	732	9.0	--
73	07-27-88	0810	.60	697	7.7	20.5	738	5.2	60
	11-17-88	1300	3.5	730	8.1	6.5	740	12.6	106
	11-17-88	1305	3.5	730	8.1	6.5	740	12.6	106
	11-17-88	1345	3.5	730	8.1	6.5	740	12.6	106
	11-17-88	1350	3.5	730	8.1	6.5	740	12.6	106
	03-09-89	1400	6.5	630	8.2	6.5	747	13.7	114
	03-09-89	1405	6.5	630	8.2	6.5	747	13.7	114
	03-09-89	1440	6.5	630	8.2	6.5	747	13.7	114
	03-09-89	1445	6.5	630	8.2	6.5	747	13.7	114
	06-02-89	1100	.79	753	7.9	22.0	735	8.3	99
	06-02-89	1105	.79	753	7.9	22.0	735	8.3	99

Table 3. Results of water-quality determinations and dissolved-oxygen concentrations at synoptic-sampling sites in the lower Kansas River Basin, July 1988 through June 1989—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Stream-flow, instan-taneous (cubic feet per second)	Specific conduct-ance (µS/cm)	pH (standard units)	Temper-ature, water (°C)	Baro-metric pressure (mm of Hg)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent satur-ation)
74	07-29-88	1020	25	401	7.6	20.5	742	8.4	96
	08-10-88	1300	25	431	8.0	23.5	--	7.9	--
	08-31-88	1320	100	384	8.2	26.0	--	8.2	--
	10-05-88	1300	200	360	8.6	18.0	--	9.6	--
	11-09-88	1310	50	396	8.6	12.0	--	10.7	--
	11-15-88	1430	50	378	8.4	11.5	724	9.0	87
	12-21-88	1315	25	--	8.8	5.0	--	13.2	--
	01-25-89	0845	22	354	8.8	2.5	--	11.3	--
	02-15-89	1335	22	394	8.1	1.5	--	10.7	--
	03-07-89	0800	22	389	7.8	2.5	758	12.9	95
	03-15-89	0845	22	390	8.3	8.0	--	10.9	--
	04-19-89	1235	22	385	8.5	15.5	--	13.1	--
	05-17-89	1045	22	419	8.1	16.0	--	8.9	--
	05-31-89	1630	22	399	7.8	18.5	735	8.1	90
76	07-27-88	1805	2,240	628	8.4	30.5	743	11.4	157
	07-28-88	0025	2,210	586	8.5	28.0	746	7.6	100
	07-28-88	0615	2,260	634	7.7	27.0	744	5.8	75
	07-28-88	1215	2,240	680	8.6	28.5	744	9.6	127
	07-28-88	1220	2,330	680	8.6	28.5	744	9.6	127
	11-14-88	0600	1,090	1,010	7.7	9.0	747	10.2	90
	11-14-88	0610	1,090	1,010	7.7	9.0	747	10.2	90
	11-14-88	1000	1,080	1,120	8.1	9.0	737	10.6	95
	11-14-88	1005	1,080	1,120	8.1	9.0	737	10.6	95
	11-14-88	1400	1,080	1,010	8.3	15.0	738	9.8	101
	11-14-88	1410	1,080	1,010	8.3	15.0	738	9.8	101
	11-14-88	1800	1,080	1,030	8.4	13.0	733	10.1	100
	11-14-88	1805	1,080	1,030	8.4	13.0	733	10.1	100
	11-14-88	2200	1,080	1,050	8.3	13.0	732	9.5	94
	11-14-88	2205	1,080	1,050	8.3	13.0	732	9.5	94

Table 3. Results of water-quality determinations and dissolved-oxygen concentrations at synoptic-sampling sites in the lower Kansas River Basin, July 1988 through June 1989—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Stream-flow, instan-taneous (cubic feet per second)	Specific conduct-ance (μS/cm)	pH (standard units)	Temper-ature, water (°C)	Baro-metric pressure (mm of Hg)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent satur-ation)
76	11-15-88	0200	1,080	1,070	8.3	13.0	732	9.1	90
	11-15-88	0205	1,080	1,070	8.3	13.0	732	9.1	90
	11-15-88	0605	1,060	1,060	8.5	14.5	724	9.9	103
	03-07-89	0615	1,010	1,180	8.2	.5	758	14.1	99
	03-07-89	1010	932	1,190	8.4	.5	755	13.8	97
	03-07-89	1015	932	1,190	8.4	.5	755	13.8	97
	03-07-89	1400	852	1,170	8.3	4.0	747	13.1	102
	03-07-89	1405	852	1,170	8.3	4.0	747	13.1	102
	03-07-89	1410	852	1,170	8.3	4.0	747	13.1	102
	03-07-89	1800	892	1,240	8.4	5.5	752	12.8	103
	03-07-89	1805	892	1,240	8.4	5.5	752	12.8	103
	03-07-89	2200	964	1,190	8.5	4.0	754	12.7	98
	03-07-89	2205	964	1,190	8.5	4.0	754	12.7	98
	03-08-89	0200	1,020	1,180	8.7	2.0	757	12.8	94
	03-08-89	0205	1,020	1,180	8.7	2.0	757	12.8	94
	03-08-89	0600	1,070	1,310	8.7	.5	748	13.0	92
	03-08-89	0605	1,070	1,310	8.7	.5	748	13.0	92
	05-31-89	1845	852	866	8.2	26.0	730	7.2	93
77	07-27-88	1825	2,940	625	7.9	29.0	745	10.7	143
	07-28-88	0605	E2,940	567	8.3	28.5	745	8.5	112
	11-14-88	1030	1,520	1,100	8.5	10.0	743	10.8	98
	03-07-89	1345	784	1,180	8.5	3.0	749	16.2	123
	06-03-89	0935	950	913	8.5	25.0	740	8.0	100
78	07-28-88	0515	2,580	570	8.3	26.0	740	6.6	84
	11-14-88	1440	980	966	8.6	12.0	733	11.4	110
	03-07-89	1030	767	1,170	8.3	1.0	751	15.8	113
	06-01-89	1800	860	810	8.4	23.5	730	9.0	111
79	07-29-88	0645	.36	409	7.6	24.5	740	5.0	62
	03-07-89	1600	.40	528	8.0	6.5	748	12.0	100
	05-31-89	0930	E.15	507	7.6	24.0	736	4.5	56

Table 3. Results of water-quality determinations and dissolved-oxygen concentrations at synoptic-sampling sites in the lower Kansas River Basin, July 1988 through June 1989—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Stream-flow, instan-taneous (cubic feet per second)	Specific conduct-ance (µS/cm)	pH (standard units)	Temper-ature, water (°C)	Baro-metric pressure (mm of Hg)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent satur-ation)
83	07-29-88	0530	24	320	7.8	26.0	741	6.7	85
	08-10-88	1500	23	339	8.3	29.0	--	8.5	--
	08-31-88	1500	240	313	8.4	25.5	--	8.0	--
	10-05-88	1500	28	291	8.3	16.5	--	9.4	--
	11-09-88	1555	9.2	--	8.1	10.0	--	8.3	--
	11-16-88	1520	11	476	7.4	10.5	--	2.7	--
	12-21-88	1515	4.9	375	8.3	4.0	--	11.8	--
	01-25-89	1605	8.6	300	7.9	6.0	--	9.6	--
	02-15-89	1535	E6.2	386	8.2	1.0	--	12.7	--
	03-07-89	1300	4.2	373	8.3	2.5	746	14.3	107
	03-15-89	1435	4.6	376	8.3	10.5	--	10.2	--
	04-19-89	1450	24	347	8.3	15.5	--	9.6	--
	05-17-89	0755	24	358	8.0	19.0	--	7.1	--
	05-31-89	1045	22	340	7.8	24.5	738	5.9	73
86	07-28-88	0615	E.05	529	7.5	22.5	743	2.7	32
	07-28-88	0620	E.05	529	7.5	22.5	743	2.7	32
	07-28-88	1200	E.40	515	7.8	25.5	745	7.0	88
	03-08-89	1200	4.5	534	8.2	3.5	757	15.5	118
	06-02-89	1250	E.30	557	7.8	23.5	736	8.1	99
87	07-28-88	0445	.06	481	7.7	25.5	745	5.4	68
	07-28-88	1500	.06	474	8.1	29.0	745	8.5	113
	11-14-88	1345	2.4	490	7.8	10.0	735	8.4	77
	11-14-88	1350	2.4	490	7.8	10.0	735	8.4	77
	03-08-89	1415	6.0	494	8.3	5.5	748	13.7	111
	06-02-89	1530	9.1	304	7.7	23.0	738	5.6	68
88	07-27-88	1815	2,500	525	8.2	30.0	730	7.0	97
	07-27-88	2400	2,320	628	7.7	29.0	746	6.8	91
	07-28-88	0610	2,290	656	8.4	27.0	740	5.8	75
	07-28-88	1220	2,280	709	8.2	28.0	740	8.2	108
	07-28-88	1225	2,280	709	8.2	28.0	740	8.2	108

Table 3. Results of water-quality determinations and dissolved-oxygen concentrations at synoptic-sampling sites in the lower Kansas River Basin, July 1988 through June 1989—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Streamflow, instantaneous (cubic feet per second)	Specific conductance (μS/cm)	pH (standard units)	Temperature, water (°C)	Barometric pressure (mm of Hg)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)
88	11-16-88	1510	1,060	1,080	8.5	9.5	739	10.0	91
	11-16-88	1515	1,060	1,080	8.5	9.5	739	10.0	91
	03-07-89	1550	608	1,380	8.8	8.0	750	11.6	100
	03-07-89	1555	608	1,380	8.8	8.0	750	11.6	100
	03-07-89	1630	608	1,380	8.8	8.0	750	11.6	100
	03-07-89	1635	608	1,380	8.8	8.0	750	11.6	100
	05-30-89	1905	1,180	927	8.6	28.0	735	10.4	138
	05-30-89	1910	1,180	927	8.6	28.0	735	10.4	138
90	07-29-88	0510	9.9	972	7.7	24.0	740	2.9	36
	07-29-88	0515	9.9	972	7.7	24.0	740	2.9	36
	11-14-88	1210	24	1,030	8.1	16.0	736	7.4	78
	11-14-88	1215	24	1,030	8.1	16.0	736	7.4	78
	11-14-88	1315	24	1,000	7.8	17.0	736	6.4	69
	11-14-88	1320	24	1,000	7.8	17.0	736	6.4	69
	03-07-89	0925	28	1,510	8.4	6.0	752	12.0	98
	06-02-89	1440	32	1,100	7.9	23.0	739	7.3	88
91	07-29-88	0615	E2,550	723	8.4	28.0	740	5.5	73
	11-14-88	1000	1,010	923	8.3	11.5	736	8.4	80
	03-07-89	1320	1,090	--	9.0	6.0	752	11.8	--
	06-02-89	1145	1,180	1,170	8.0	26.0	744	5.0	63

selected sites and times and are denoted by a time 5 minutes later than the primary determination. Duplicate analyses reported in table 8 were performed on splits of single water samples.

Areal Variations

Areal variations in predawn DO concentrations for the July 1988 synoptic survey are shown in figure 11. Of the 31 sites shown in figure 11, 5 had concentrations smaller than the 5.0-mg/L, 1-day minimum, warmwater criterion for early life stages. Concentrations at 4 of these 5 sites were less than the 3.0-mg/L criterion for all other life stages. These 5 sites were: Lincoln Creek near Aurora, Nebr. (site 9), West Fork Big Blue River near Hastings, Nebr. (site 16), Delaware River near Fairview, Kans. (site 71), Stranger Creek at Easton, Kans. (site 86), and Turkey Creek at Kansas City, Kans. (site 90). DO concentrations for these sites are listed in table 3.

The DO deficiencies at sites 9, 16, and 90 appear to be the result of discharge of oxygen-demanding material from a municipal wastewater-treatment facility in excess of the assimilation capacity of the stream. Site 9 is approximately 1.25 stream mi downstream from the Aurora, Nebr., municipal-wastewater discharge point. The USEPA permitted discharge for this facility is 0.37 Mgal/d or an average discharge of 0.57 ft^3/s. Measured streamflow at site 9 on July 26, 1988, was 0.34 ft^3/s (table 3); therefore, a substantial part of this streamflow probably originated as wastewater discharge. Measurement of DO on subsequent synoptic surveys showed similar concentrations to those observed on July 26, with the exception of the November 15, 1988, measurement of 4.4 mg/L. Although a DO concentration of 4.4 mg/L appears large in relation to other DO data and nutrient concentrations, it may be the result of larger streamflow (1.4 ft^3/s) that probably produced greater surface turbulence, greater reaeration, and cooler water temperature (6.5 °C), which contributed to greater oxygen solubility. However, 4.4 mg/L was only 39 percent of saturation, similar to the July 26, 1988 (2150 hours), observation.

Site 16 is about 2 mi downstream from the Hastings, Nebr., wastewater-treatment facility. The permitted discharge for this facility is 2.75 Mgal/d (4.26 ft^3/s) and, thus, conceivably accounts for a substantial part of the 6.7 ft^3/s streamflow measured at site 16 on July 26, 1988 (table 3). The 2.1-mg/L, predawn (0630 hours) DO concentration measured on July 26, 1988, was considerably less than the 3.0-mg/L, 1-day minimum criteria for adult organisms. Additionally, a DO measurement was made at 1800 hours on July 26 to estimate maximum diel variability and the result of photosynthesis. This second measurement (4.8 mg/L) was less than the 5.0-mg/L criterion. In fact, no DO measurements at site 16 for any of the synoptic surveys were greater than the 5.0-mg/L criterion, and furthermore, the smallest DO concentration observed in water at any site during any synoptic survey was at site 16 on November 15, 1988 (0.6 mg/L). The exact length of the West Fork Big Blue River adversely affected by wastewater discharge is not known; however, the predawn DO concentration at the next downstream sampling site (site 17) was 5.9 mg/L at 0500 hours on July 27, 1988, and nutrient concentrations were considerably smaller. Site 17 is 43 stream mi from site 16.

Site 90 is approximately 2 mi downstream from a major wastewater-treatment facility, which has a permitted discharge rate of 15 Mgal/d. The effect of this discharge during the July 1988 synoptic survey is evident at site 90. The predawn (0510 hours) DO concentration was 2.9 mg/L on July 29, 1988. Concentrations of nutrients and organic carbon were exceptionally large at this site and were some of the largest observed at any site during any synoptic survey. However, DO concentrations less than the 5.0-mg/L criteria were not observed at site 90 during any of the other surveys. This can be attributed to a combination of larger flow rates, cooler water temperatures, and the fact that predawn sampling (when DO concentrations would be minimal) was not conducted at this site during subsequent synoptic surveys.

The predawn DO concentration at site 71 was 4.5 mg/L on July 27, 1988. The flow at this site includes discharge from the Sabetha, Kans., wastewater-treatment facility, which is located about 12 mi upstream from site 71, but the effect of this discharge on DO concentrations at site 71 appears to be minimal. An examination of nutrient concentrations from this site indicates no unusually large concentrations that may indicate wastewater discharges; therefore, it appears that the reach of stream upstream of site 71 is adequate for the assimilation of the 0.13 Mgal/d permitted discharge from this facility. The small DO concentration observed on July 27 is pro-

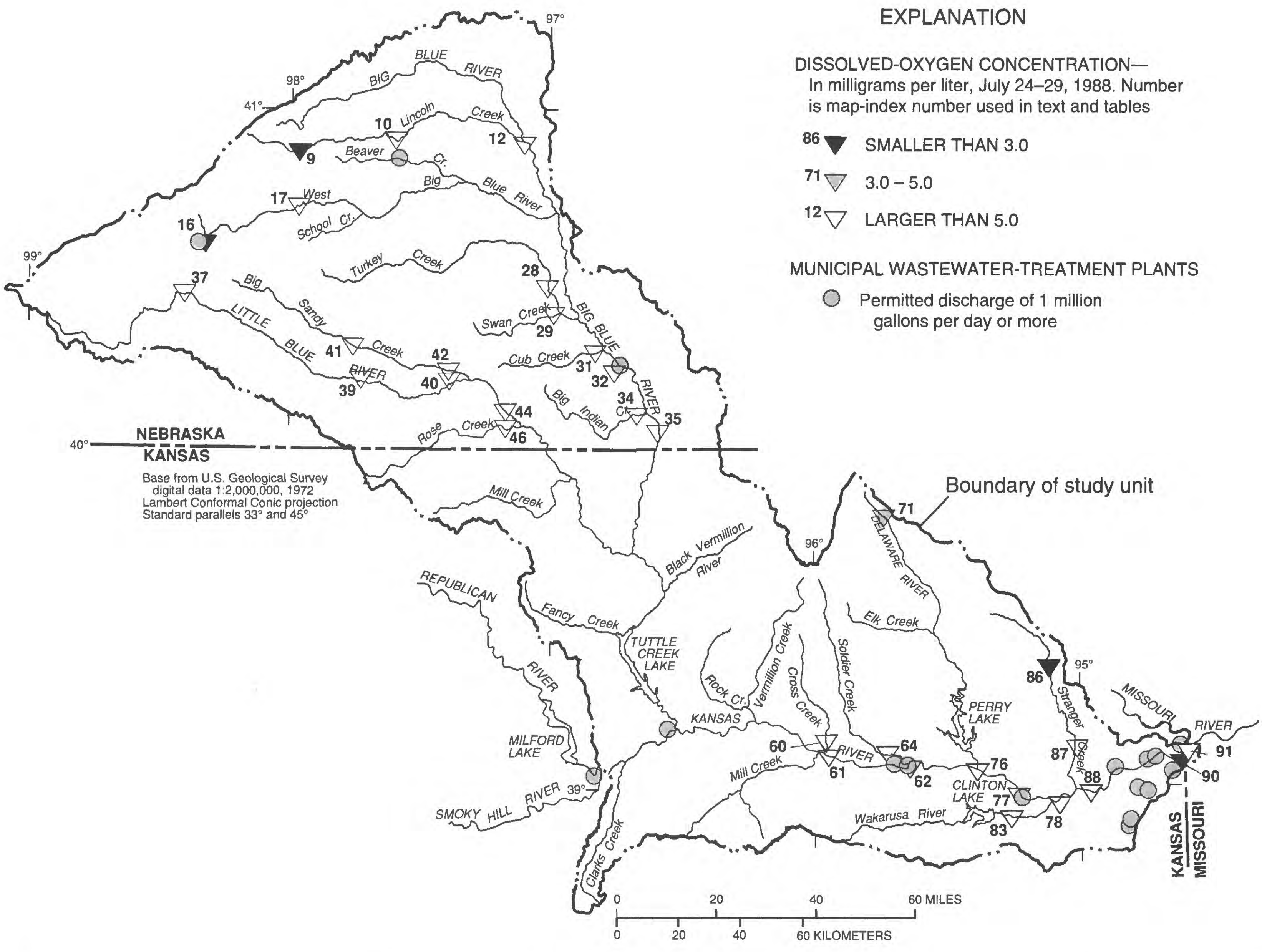

Figure 11. Areal distribution of predawn dissolved-oxygen concentrations, July 24–29, 1988, and location of municipal wastewater-treatment plants with permitted discharges of 1.0 million gallons per day or more.

bably the result of reduced reaeration during low flow and of algal respiration. Although the algal biomass, as indicated by a chlorophyll-*a* concentration of 15 μg/L (micrograms per liter) (table 8), was not exceptionally large compared to other sites, it probably was sufficient to create an oxygen depression during the night. In addition to the free-floating algae, large accumulations of periphyton have been observed at this site. Periphyton respiration also would place an oxygen demand on the stream. No other DO concentrations less than the criteria were observed at this site during subsequent surveys.

The predawn DO concentration at site 86 was 2.7 mg/L on July 28, 1988. Upstream of site 86 there are two wastewater-treatment facilities with a combined permitted discharge of 0.07 Mgal/d. However, these facilities are about 20 mi upstream of site 86 and are believed to have little effect at this site. The small predawn DO concentration observed on July 28 probably was the result of inadequate physical reaeration associated with extremely small streamflow (0.05 ft^3/s) and of algal respiration. When the site was revisited at 1200 hours on July 28, streamflow had increased to 0.40 ft^3/s, and the DO concentration to 7.0 mg/L. The unusual increase in streamflow might have been the result of beaver activity upstream from site 86. Beavers have built dams on the upstream reaches of Stranger Creek, including site 86, for many years. Their nocturnal construction activities can substantially reduce streamflow for short periods of time. The increase in streamflow observed on July 28 may be attributed to a breach in one of these upstream dams or may represent a reestablishment of normal base flow following dam construction. Another possible explanation may be the withdrawal of upstream water for irrigation purposes, ceasing sometime after 0615 hours, and subsequent resumption of normal flow. The 7.0-mg/L DO concentration observed at 1200 hours probably is the result of reaeration and photosynthesis. No other DO concentrations measured at site 86 during subsequent surveys were less than established criteria.

DO concentrations were measured as part of the ancillary data collected with synoptic surveys for nutrients in November 1988 and March and May–June 1989. Four of those measurements were less than established criteria: 4.9 mg/L, Beaver Creek near York, Nebr. (site 21), May 31, 1989; 4.7 mg/L, Cross Creek at Rossville, Kans. (site 60), June 1, 1989; 4.5 mg/L, Wakarusa River near Berryton, Kans. (site 79), May 31, 1989; and 2.7 mg/L, Wakarusa River near Lawrence, Kans. (site 83), November 16, 1988.

Site 21 is located approximately 5 mi downstream from the 1.28-Mgal/d (permitted) municipal wastewater-treatment facility at York, Nebr. Although discharge from this facility did not seem to have an adverse effect on DO concentrations during the July 1988 synoptic survey, subsequent surveys identified large concentrations of nutrients, particularly nitrite plus nitrate-nitrogen and phosphorus. Discharge from the facility may have caused the 4.9-mg/L DO concentration measured on May 31, 1989.

The DO concentrations measured at sites 60 and 79 during the May–June 1989 synoptic survey were slightly less than the 5.0-mg/L criterion. This probably resulted from a combination of reduced physical reaeration associated with low flow (0.98 ft^3/s at site 60 and 0.15 ft^3/s at site 79) and decomposition of organic material accelerated by warmer water. Upstream from site 60 are two municipal wastewater-treatment facilities with a combined permitted-discharge rate of 0.8 Mgal/d; however, the nearest of these facilities is more than 10 stream mi from site 60. An examination of nutrient concentrations for site 60 shows small concentrations, which seems to indicate that the effects of wastewater discharge are not evident at this sampling site. No wastewater-treatment facilities are upstream from site 79; however, a beaver dam was located immediately upstream of the sampling site. Decomposition of bottom material in the placid water behind the dam, a reduction in physical reaeration associated with extremely low streamflow, and the relatively early-morning (0930 hours) observation, all may contribute to the 4.5-mg/L DO concentration measured on May 31, 1989.

The 2.7-mg/L DO concentration measured at site 83 on November 16, 1988, probably was the result of oxygen-demanding material transported into the stream by an isolated, short-duration rain the day of sampling. Observer notes for November 16 indicated that the stream was turbid with a very fine suspended material resulting from localized runoff from adjacent farmland. Site 83 is downstream of Clinton Lake and does not receive discharge from wastewater-treatment facilities.

Concentrations of DO in violation of water-quality criteria in the lower Kansas River Basin are localized occurrences and do not reflect regional variation in DO. Generally, the most severe DO deficiencies are the result of discharges from municipal wastewater-treatment facilities into small tributary streams with inadequate dilution or assimilation capacity. Algal respiration in combination with reduced physical reaeration associated with low streamflow also may cause temporary, localized deficiencies in DO concentrations. Oxygen demand from the decomposition of benthic material in pooled or placid streams may serve to compound the effect of reduced physical reaeration.

Concentrations of DO less than water-quality criteria were not observed on major tributaries or the main stem of the Kansas River. DO concentrations appear to be relatively similar throughout the basin. When mean predawn concentrations are compared between sites on the Big Blue River (sites 12, 32, 35), Little Blue River (sites 37, 39, 40, 44), and Kansas River (sites 61, 62, 76, 77, 78, 88, 91), there is little appreciable difference (6.23 mg/L, 6.60 mg/L, and 6.36 mg/L, respectively). Of the 31 sites where predawn DO measurements were made, 5 sites (16 percent) had concentrations less than water-quality criteria. Of all DO concentrations measured (392) in conjunction with synoptic surveys (table 3), only 9 measurements (2.3 percent) were less than water-quality criteria.

Diel Variability

Daily DO fluctuations and diel variability are largely dependent on temperature fluctuations and photosynthesis-respiration relations. In slow, shallow streams (typical of the lower Kansas River Basin) that contain an abundance of phytoplankton, periphyton, and rooted aquatic plants, daytime photosynthetic production exceeds physical reaeration as a source of oxygen and exceeds consumption from respiration. The result frequently is supersaturation during the day, followed by a decrease to less than saturation at night. Depending upon oxygen demand, daily minimum DO concentrations usually occur prior to early-morning water-temperature lows (Reid and Wood, 1976, p. 215). DO concentrations may be acutely affected by sunlight intensity. The considerable diel variability in DO indicates the importance of more than a single DO measurement to adequately define the oxygen regime in a stream.

To describe DO diel variability in the lower Kansas River Basin, 11 sites were sampled during July 1988, at 4- or 6-hour intervals for approximately 24 hours. Results of DO measurements for these sites are shown in figure 12. Results of ancillary onsite measurements are listed in table 3. Results of chemical analysis of water samples for nutrients, organic carbon, chlorophyll, and suspended sediment collected during these diel studies are listed in table 8 in the "Supplemental Information" section of this report. At site 32, Big Blue River at Beatrice, Nebr., the DO measurement at 0500 hours on July 26, 1988, was inadvertently omitted during the survey. The DO concentration for 0500 hours shown in figure 12 for site 32 was assumed to be equal to the 5.8-mg/L concentration measured at 0510 hours on July 27.

At nearly every site, minimum DO concentrations occurred just before dawn (about 0600 hours), and maximum concentrations occurred in late afternoon-early evening (about 1800 hours). Concentrations of DO less than the 5.0-mg/L criterion were not measured at any of the diel-study sites. The largest DO concentrations measured were at site 44, Little Blue River near Fairbury, Nebr. (10.6 mg/L) and site 76, Kansas River at Lecompton, Kans. (11.4 mg/L). The largest ranges in DO concentration also occurred at these two sites (5.3 and 5.6 mg/L, respectively). Two of the three largest chlorophyll concentrations (chlorophyll-*a* plus chlorophyll-*b*) occurred at site 44 and site 76 (113 and 85 μg/L, respectively, table 8).

As a result of diel variability, DO shown in figure 12 and table 3 was supersaturated during the day and less than saturation during the night except at sites 32 and 46. Maximum DO at all sites ranged from 94-percent saturation at site 46 to 157 percent at site 76, with a mean maximum of 115 percent. Minimum DO at all sites ranged from 66-percent saturation at site 12 to 79 percent at site 34, with a mean minimum of 72 percent. Mean DO using all measurements at all sites was 92-percent saturation. It appears that diel variability in streams not affected by localized problems is basically a function of the photosynthesis-respiration relation and, to a lesser extent, a function of the temperature-atmospheric, pressure-solubility relation.

Seasonal effects on diel variability were examined at site 32, Big Blue River at Beatrice, Nebr., and site 76, Kansas River at Lecompton, Kans. Diel studies were conducted at both sites in July and November 1988 and March 1989; and at site 32 in May 1989. Results of these diel studies are shown in figure 13. The effect of water temperature on oxygen solubility is evident in figure 13. Water temperatures at both sites

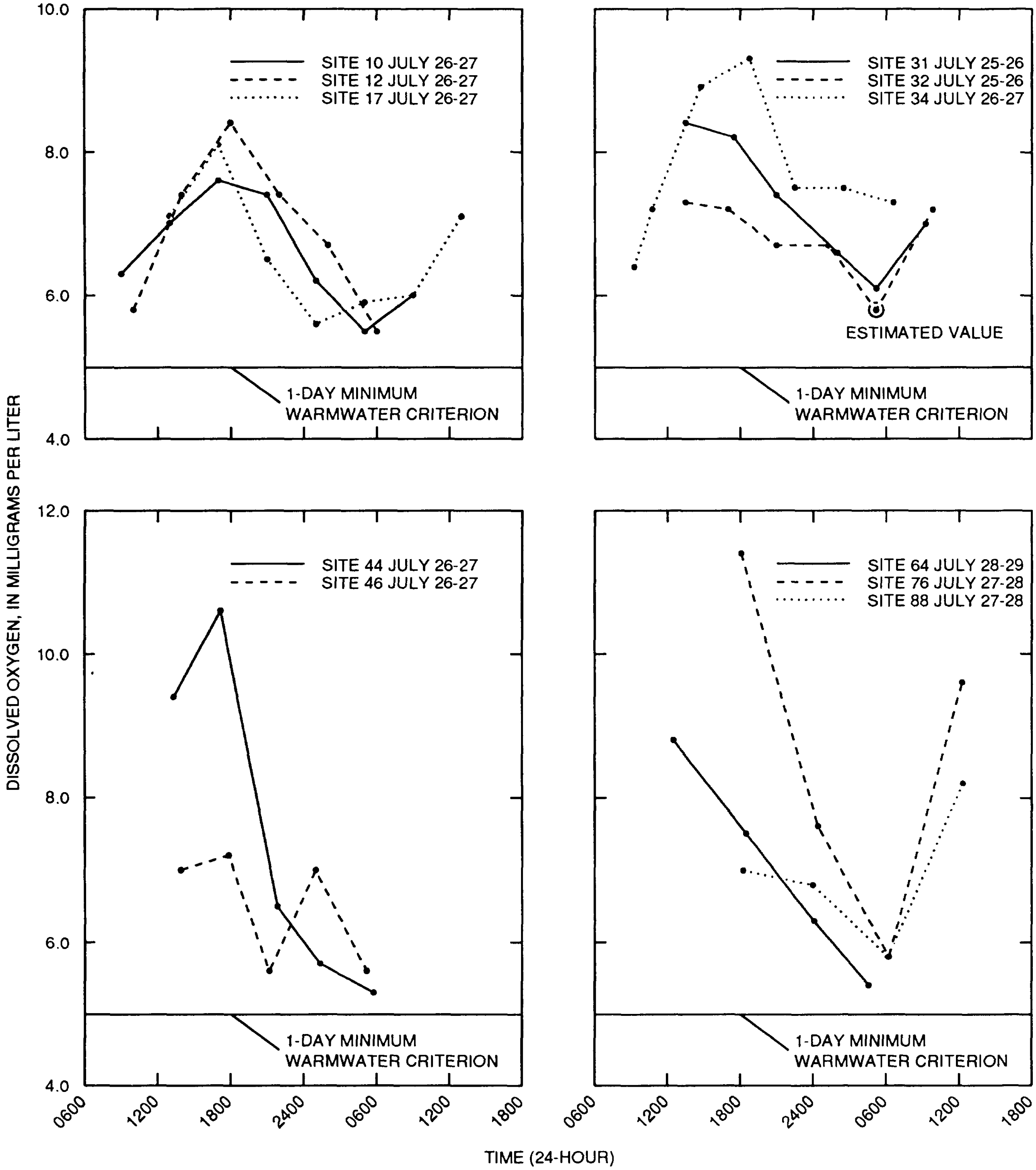

Figure 12. Diel variability of dissolved-oxygen concentrations at selected synoptic-sampling sites in the lower Kansas River Basin for survey of July 1988 (criterion established by U.S. Environmental Protection Agency, 1986).

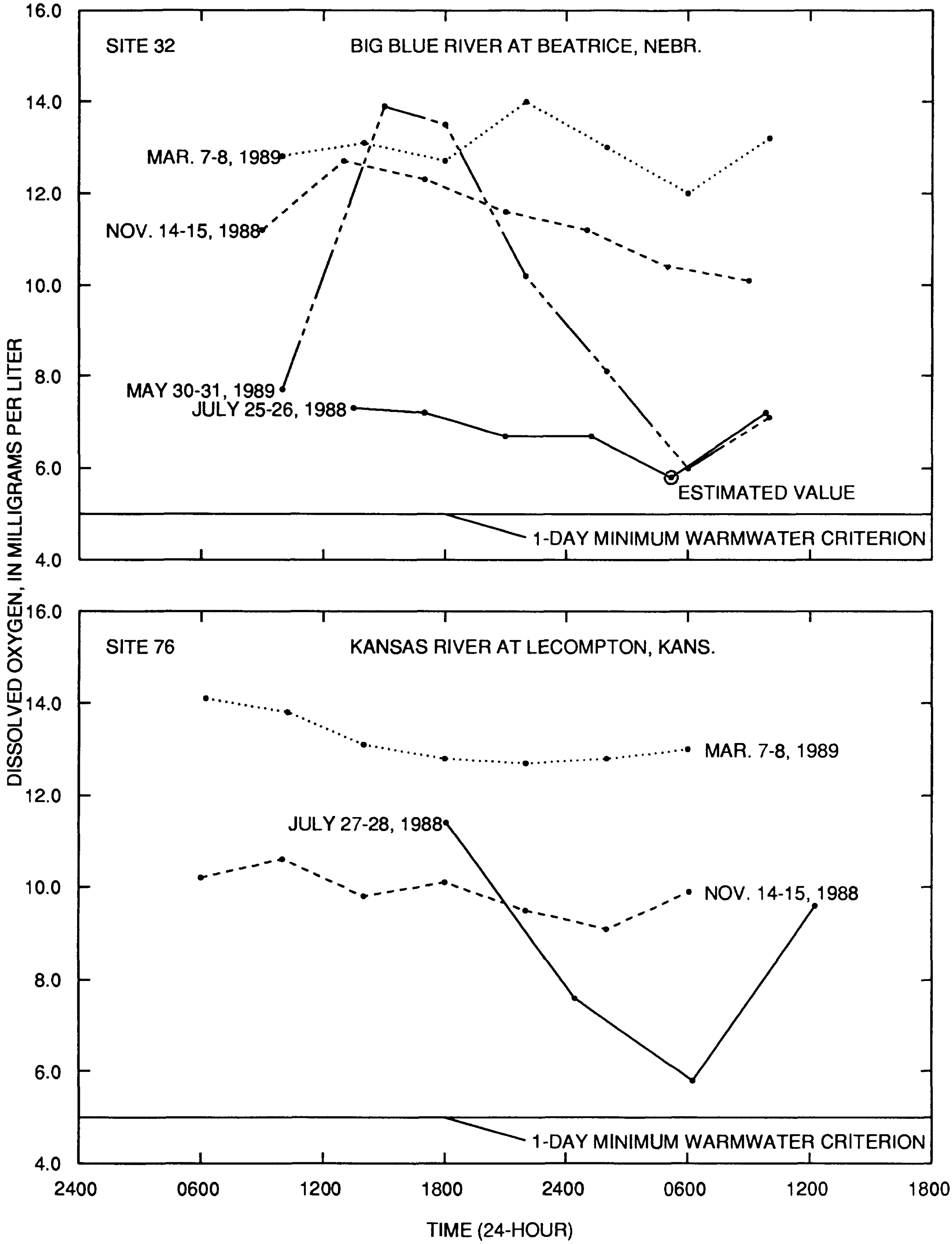

Figure 13. Seasonal effect on the diel variability of dissolved-oxygen concentrations in the Big Blue River at Beatrice, Nebr., and the Kansas River at Lecompton, Kans. (criterion established by U.S. Environmental Protection Agency, 1986).

ranged from 25.0 to 30.5 °C in July 1988, 7.0 to 15.0 °C in November 1988, 0 to 5.5 °C in March 1989, and 21.5 to 25.0 °C in May 1989. As water temperature decreased, DO concentrations increased, and generally, diel variability decreased. The decreased diel variability was most pronounced at site 76.

During the July 1988 survey at site 76, the diel variability of DO concentrations was 5.6 mg/L. Variabilities for the November 1988 and March 1989 surveys were 1.5 and 1.4 mg/L, respectively. This reduced diel variability can be attributed to smaller algal biomass and cooler water, which reduces the rate of biochemical reactions including photosynthesis and respiration. Reduction in algal biomass is shown by chlorophyll concentrations of March 7, 1989, which averaged 5.9 µg/L for three replicate samples (table 8). This contrasts with the 85-µg/L concentration on July 28, 1988, when the water was considerably warmer.

Generally, DO concentrations during the cold-weather months are a function of the water temperature. This can be seen in the gradual reduction in DO concentrations during the daylight hours as the water warms. Maximum DO concentrations occur before noon when water temperature is coolest, the reverse of the warm-weather response. This was most evident during the November 1988 survey at sites 32 and 76 and the March 1989 survey at site 76.

ESCHERICHIA COLI DENSITIES

Sources and Water-Quality Criteria

The bacterium *Escherichia coli* (*E. coli*) is indigenous solely to the intestinal tract of warm-blooded animals. It is a member of the family *Enterobacteriaceae* and the predominate bacterium in the fecal coliform group (McKinney, 1962). Therefore, the presence of *E. coli* in the aquatic environment is an indication of fecal contamination. This contamination may come from municipal wastewater discharges; leachate from domestic septic systems, runoff or ground-water seepage from livestock-producing areas (pasture and confined feedlots), or wildlife populations.

Seyfried and others (1984) state that municipal wastewater discharges can have a detrimental effect on the water quality of receiving streams not only in regard to fecal bacteria but also to the introduction of pathogenic organisms, such as reo-, adeno-, and enterovirus; coxsackievirus; and poliovirus. The studies of Stephenson and Street (1978), Doran and others (1981), and Gary and others (1983) have demonstrated the effect of cattle production on fecal coliform densities in runoff from grazed and pastured land and in streams adjacent to these areas. Kress and Gifford (1984) attempted to quantify release of fecal coliforms from cattle fecal deposits of various ages and under varying rainfall intensities. Hagedorn and others (1978) have shown that *E. coli* can survive lateral movement through soil at sites with as little as 2-percent slope.

The survival characteristics of *E. coli* in aquatic environments of various chemical compositions were studied by Lim and Flint (1989). They found that in filtered, autoclaved lake water, *E. coli* survived for 12 days without a decline in viable counts. The addition of synthetic sewage to unfiltered water led to an increase in viable counts and also to an increase in survival time relative to unfiltered water without synthetic sewage. The addition of a nitrogen source, likewise, increased survival times and was proportional to the concentration of the nitrogen source.

For many years prior to 1986, densities of fecal coliform and total coliform bacteria were traditional measures of sanitary quality. In 1986, the USEPA revised the ambient water-quality criteria for marine and freshwater (U.S. Environmental Protection Agency, 1986) and recommended that criteria for *E. coli* and the *Enterococci* organisms replace criteria for fecal coliform and total coliform bacteria in State water-quality regulations for the protection of primary-contact recreation. The USEPA has established several levels of human-health protection with regard to the single-sample maximum allowable density of *E. coli* based on frequency of use of the water body. The least stringent of these levels, infrequently used full-body contact recreation, has been set at 576 col/100 mL (colonies per 100 milliliters of water). Additionally, the Kansas Department of Health and Environment has established a criterion for fecal coliform of 2,000 col/100 mL for those streams available for all beneficial uses other than primary (full-body) contact recreation (Fromm and Wilk, 1988). Because the fecal coliform group may contain bacteria other than *E. coli*, the 2,000-col/100 mL criterion, if applied to *E. coli*, may result in a less-stringent criterion than that currently established (that is, 2,000 *E.-coli* col/100 mL probably equates to more than 2,000 fecal coliform col/100 mL). However, because few streams or segments of streams in the study unit are classified by the Kansas Department of Health and Environment or the Nebraska Department of Environmental Control for full-body contact, it is appropriate that some criterion for other than primary contact be used for evaluating *E. coli* densities observed during this study. Therefore, both the 2,000-col/100 mL criterion and the 576-col/100 mL criterion will be used in this report. These criteria are applicable only during stable-flow, dry-weather conditions.

Data Collection and Analysis

Water samples for determination of *E. coli* densities were collected July 24–29, 1988, in conjunction with a synoptic survey for determination of DO concentrations. A followup synoptic survey of *E. coli* was conducted July 16–21, 1989, to verify results obtained the previous year. The location of synoptic-sampling sites are described in table 2 and shown in figure 10.

Samples at 57 sites were collected during stable, low-streamflow, conditions. Samples representative of the stream cross section were collected using the equal-width-increment (EWI) method and a sterile DH-81 depth-integrating suspended-sediment sampler on wadeable streams or a sterile D-77 suspended-sediment sampler where depth necessitated collection from a bridge (Guy and Norman, 1970). The EWI method has been described previously in the "Study Approach" section of this report; however, samples for *E. coli* analysis were not composited in a churn splitter. On small, shallow streams where depth-integrating samplers were inappropriate, a sample was collected by hand dipping a sterilized sample-collection bottle into the centroid of flow. Sampler nozzles, gaskets, and collection bottles were cleaned and autoclaved for 20 minutes at 121 °C and 15 lb/in^2 prior to use. These parts were replaced between sampling sites to prevent cross contamination of samples.

Samples were chilled after collection and transported to a centrally located site for analysis. Samples collected in the upper Big Blue River and Little Blue River subbasins were analyzed in Beatrice, Nebr. Samples collected along the main stem Kansas River and tributaries were analyzed at the U.S. Geological Survey laboratory in Lawrence, Kans.

The membrane filter (MF) method was used for the detection and enumeration of *E. coli* densities (U.S. Environmental Protection Agency, 1985). The MF method provides a direct count of bacteria based on the development of colonies on the membrane filter after a water sample has been filtered through it. Subsequently, the membrane containing the bacteria cells is placed on a selective and differential medium, mTEC, incubated at 35 °C for 2 hours to resuscitate injured or stressed bacteria, and then incubated at 44.5 °C for 22 hours to promote colony growth. Following incubation, the filter is transferred to a filter pad saturated with urea substrate. After 15 minutes, *E. coli* will become yellow or yellow brown and are counted under a lamp and magnifying lens.

Samples were filtered and the incubation process started as soon as possible after collection. Samples were chilled until processed, but no sample was held longer than 6 hours. Sterile, disposable, polystyrene filter units with 0.45-micrometer-porosity membrane filters were used to filter samples. One filter unit was used per water sample. Different membrane filters were used for each filtered sample volume. Sample volumes ranged from 0.1 to 100 mL (milliliters) in a series of five or six volumes. Sample volumes were filtered in ascending order. Plate counts were converted to densities in colonies per 100 mL of sample. Because of the potential for slight variations in analytical procedure between analysts, a single analyst processed, filtered, and counted all samples collected for both synoptic surveys. This was done to limit fluctuation in analytical precision and maintain comparability among sites. Results for determination of *E. coli* densities for synoptic surveys of July 1988 and July 1989 are listed in table 4.

Associated Rainfall and Streamflow Characteristics

The objectives of conducting a synoptic survey for *E. coli* densities were to define the spatial occurrence of fecal contamination, document the effect of major point-source discharges, and describe the relation between fecal contamination and factors such as land use, agricultural practices, and waste-management practices. For determinations of *E. coli* densities to be comparable between sampling sites, it was necessary to sample all sites under similar hydrologic conditions. Sampling to meet these objectives is most appro-

Table 4. *Escherichia coli* densities and streamflow for synoptic surveys of July 1988 and July 1989

[Densities are in colonies per 100 milliliters of water; streamflow is in cubic feet per second; a, estimated concentration based on non-ideal colony count; <, less than; --, no data]

Site map-index number (fig. 10)	Site name	July 1988				July 1989			
		Day	Time (24-hour)	*Escherichia coli* density	Streamflow	Day	Time	*Escherichia coli* density	Streamflow
1	Kansas River at Fort Riley, Kans.	27	1300	a210	353	19	1150	330	520
2	Clarks Creek near Fort Riley, Kans.	27	1150	a9	.65	--	--	--	--
5	Kansas River at Manhattan, Kans.	24	1020	[1]96	240	--	--	--	--
6	Big Blue River at Surprise, Nebr.	26	0730	160	6.2	18	1300	800	[2]3.7
9	Lincoln Creek near Aurora, Nebr.	26	0945	2,600	.34	--	--	--	--
10	Lincoln Creek near York, Nebr.	26	0900	1,900	8.2	--	--	--	--
11	Lincoln Creek near Seward, Nebr.	26	0845	5,500	30	17	1440	2,600	[2]35
12	Big Blue River at Seward, Nebr.	26	1000	10,000	55	17	1505	2,600	[2]49
16	West Fork Big Blue River near Hastings, Nebr.	26	0630	a260,000	6.7	18	1630	a790,000	[2]16
18	School Creek near Sutton, Nebr.	25	1130	6,000	3.8	18	1135	a880	[2]17
21	Beaver Creek near York, Nebr.	26	1010	2,500	6.5	18	1025	4,700	[2]57
23	West Fork Big Blue River near Dorchester, Nebr.	25	1245	2,400	75	18	1450	5,200	[2]352
26	Big Blue River near Crete, Nebr.	25	1030	1,500	184	17	1145	13,000	[2]416
28	Turkey Creek near Wilber, Nebr.	25	0600	[1]3,200	15	17	1120	3,400	[2]168
29	Swan Creek Dewitt, Nebr.	25	0630	4,100	13	--	--	--	--
31	Cub Creek near Beatrice, Nebr.	26	0510	[1]10,000	3.6	18	0755	95,000	[2]26
32	Big Blue River at Beatrice, Nebr.	27	0510	2,000	163	--	--	--	--
34	Big Indian Creek near Wymore, Nebr.	25	0650	[1]1,800	12	16	1355	640	4.0
35	Big Blue River at Barneston, Nebr.	25	0540	a380	402	18	1330	[1]5,200	[2]627
36	Big Blue River at Marysville, Kans.	25	1230	770	393	18	0800	4,900	[2]700

Table 4. *Escherichia coli* densities and streamflow for synoptic surveys of July 1988 and July 1989—Continued

Site map-index number (fig. 10)	Site name	July 1988 Day	July 1988 Time (24-hour)	July 1988 *Escherichia coli* density	July 1988 Streamflow	July 1989 Day	July 1989 Time	July 1989 *Escherichia coli* density	July 1989 Streamflow
37	Little Blue River near Hastings, Nebr.	26	0515	a3,800	18	--	--	--	--
38	Little Blue River near Deweese, Nebr.	26	0810	940	31	17	1020	50,000	[2]3,240
39	Little Blue River near Deshler, Nebr.	26	0630	3,000	32	--	--	--	--
40	Little Blue River near Alexandria, Nebr.	26	0630	100	55	--	--	--	--
41	Big Sandy Creek near Davenport, Nebr.	26	0600	30,000	1.5	--	--	--	--
42	Big Sandy Creek near Alexandria, Nebr.	26	0545	530	37	17	0850	8,500	[2]190
44	Little Blue River near Fairbury, Nebr.	25	0845	1,200	133	17	1545	[1]24,000	[2]1,890
46	Rose Creek near Fairbury, Nebr.	25	0615	5,500	18	17	1445	9,200	[2]114
47	Little Blue River at Hollenberg, Kans.	25	1150	620	163	18	1040	10,000	[2]2,260
48	Mill Creek near Hanover, Kans.	26	1215	770	12	--	--	--	--
49	Little Blue River near Barnes, Kans.	25	1400	470	206	18	1145	10,000	2,490
50	Black Vermillion River near Frankfort, Kans.	24	1320	[1]710	7.0	19	0925	[1]990	[2]8.0
51	Fancy Creek at Winkler, Kans.	24	1445	120	5.7	--	--	--	--
52	Big Blue River near Manhattan, Kans.	24	1045	a[1]7	1,870	19	1100	a16	2,570
55	Vermillion Creek near Onaga, Kans.	27	0930	120	1.4	--	--	--	--
56	Vermillion Creek near Louisville, Kans.	27	1120	a32	4.2	19	1330	590	3.2
57	Rock Creek near Louisville, Kans.	29	0815	a64	2.2	--	--	--	--
58	Kansas River near Belvue, Kans.	27	0910	a48	2,550	19	1430	360	[2]3,250
59	Mill Creek near Paxico, Kans.	27	1010	[1]21	9.5	19	1525	45	5.1
60	Cross Creek at Rossville, Kans.	29	0535	140	1.8	--	--	--	--
61	Kansas River at Willard, Kans.	29	0415	a9	1,910	--	--	--	--
62	Kansas River at Topeka, Kans.	29	0535	a24	2,250	20	1320	530	[2]2,760
63	Solider Creek near Circleville, Kans.	29	0910	a88	.50	--	--	--	--
64	Soldier Creek near Topeka, Kans.	28	1230	a42	4.6	20	1440	[1]390	1.6
71	Delaware River near Fairview, Kans.	27	0610	190	1.0	--	--	--	--

Table 4. *Escherichia coli* densities and streamflow for synoptic surveys of July 1988 and July 1989—Continued

Site map-index number (fig. 10)	Site name	July 1988				July 1989			
		Day	Time (24-hour)	*Escherichia coli* density	Streamflow	Day	Time	*Escherichia coli* density	Streamflow
72	Delaware River near Muscotah, Kans.	27	0745	[1]160	2.4	21	0955	480	.88
73	Elk Creek near Larkinburg, Kans.	27	0810	1,000	.60	--	--	--	--
74	Delaware River below Perry Dam, Kans.	29	1020	<1	25	21	1000	[1]5	24
76	Kansas River at Lecompton, Kans.	28	0615	560	2,260	21	0930	a10,000	[2]2,460
77	Kansas River at Lawrence, Kans.	28	0605	a27	2,940	--	--	--	--
78	Kansas River at Eudora, Kans.	28	0515	250	2,580	20	1010	1,200	2,400
79	Wakarusa River near Berryton, Kans.	29	0645	210	.36	--	--	--	--
83	Wakarusa River near Lawrence, Kans.	29	0530	280	24	20	0915	100	23
87	Stranger Creek near Tonganoxie, Kans.	28	0445	a62	.06	19	1630	a1,500	23
88	Kansas River at De Soto, Kans.	28	0610	a[1]54	2,290	20	1520	a2,500	2,420
90	Turkey Creek, at Kansas City, Kans.	29	0510	[1]187	9.9	20	1400	1,000	2.7
91	Kansas River at Kansas City, Kans.	29	0615	390	2,550	20	1140	330	2,240

[1]Average of duplicate plate counts.
[2]Affected by storm runoff and (or) reservoir release.

priately conducted during stable low-flow conditions when effects of overland runoff would be less likely to cause large fluctuations in *E. coli* densities. Therefore, an evaluation of rainfall before and during sampling periods was needed to define the potential for or occurrences of overland runoff. An evaluation of streamflow was necessary to determine whether baseflow conditions prevailed.

Antecedent and concurrent rainfall characteristics for the July 1988 and July 1989 synoptic surveys are listed in table 5. No rainfall was recorded at any of the six locations listed in table 5 for at least 4 days before the start of the July 1988 survey. Total rainfall during the 2 weeks before the July 1988 survey ranged from 0.53 in. at Topeka, Kans., to 3.53 in. at Manhattan, Kans. During the 6 days of the survey, rainfall ranged from zero at Hastings, Nebr., and Manhattan, Kans., to 0.22 in. at Marysville, Kans. Based on these rainfall characteristics plus an examination of hydrographic records and field observations, it was concluded that none of the sites sampled during the July 1988 synoptic survey were affected by nonpoint-source contributions from overland runoff as a result of rainfall. However, irrigation-water return flow was observed at one site in the upper Big Blue River subbasin. The effect of irrigation-water return flow on streamflow at base-flow conditions, both from a hydrologic and water-quality aspect, may be substantial in the upper Big Blue River and Little Blue River subbasins. As previously indicated in figure 4, the amount of irrigated acreage in a representative area of these subbasins has increased substantially since the 1930's. With this increase in irrigation has come an increase in return flow to area streams probably affecting both streamflow and water quality. Figure 6 shows that the majority of irrigation wells in the study unit are located in the upper Big Blue River and Little Blue River subbasins.

Rainfall characteristics before and during the July 1989 synoptic survey were considerably wetter than those of the July 1988 survey. No dry days immediately preceded the start of the July 1989 survey at any of the six locations listed in table 5 (some rainfall was recorded at every location on July 15, 1989). Rainfall recorded during the 3 days prior to July 16, 1989, ranged from 0.02 in. at Manhattan, Kans., to 2.50 in. at Topeka, Kans. However, the largest rainfall amounts recorded during the survey were at those locations in the Big Blue River subbasin and ranged from 0.58 in. at Beatrice, Nebr., to 1.06 in. at Hastings, Nebr. Because of the wet antecedent conditions and substantial rainfall during the survey, streamflows at most sites in the Big Blue River and Little Blue River subbasins were affected by overland runoff.

Occurrence of base-flow conditions during synoptic surveys in July 1988 and July 1989 can be evaluated by an examination of flow-duration data for the observed streamflows. Table 6 lists selected sampling sites, date and time of sampling, streamflow, and percentage of time streamflow is equalled or exceeded. Based on long-term records, the mean percentage of time that streamflow during the July 1988 synoptic survey is equalled or exceeded at main-stem sites on the Big Blue River (sites 6, 12, 32, 36), Little Blue River (sites 38, 47), and Kansas River (sites 1, 58, 62, 76, 88) were 42 percent, 81 percent, and 70 percent, respectively. Streamflow on the upper Big Blue River during the July 1988 survey was not at extreme low flow; however, it was at stable conditions based on hydrographic record and observations made at the time of sampling. The relatively large flows at the Big Blue River sites were probably the result of groundwater discharge resulting from rainfall during the previous 2 weeks and, possibly as important, from irrigation-water return flow. Streamflow in the Kansas River downstream of Manhattan was stable but somewhat increased because of a reservoir release from Tuttle Creek Lake. The Big Blue River near Manhattan, Kans. (site 52), downstream of Tuttle Creek Lake, was at a flow rate equalled or exceeded only 29 percent of the time. The release from Tuttle Creek Lake kept the Kansas River downstream of Manhattan, Kans., at a flow rate equalled or exceeded an average of 63 percent (sites 58, 62, 76, 88) of the time compared to the upstream most Kansas River site at Fort Riley, Kans. (site 1), which had a flow rate equalled or exceeded 95 percent of the time.

Generally, streamflows in the Big Blue River and Little Blue River subbasins for the July 1989 synoptic survey were either larger than streamflows during the July 1988 survey or were affected by overland runoff from recent rains. The Big Blue River at Surprise, Nebr. (site 6), and near Seward, Nebr. (site 12), had flow rates similar to those sampled in July 1988 but were affected by overland runoff as determined by an examination of hydrographic records and field observations. Streamflows in the Big Blue River subbasin downstream of Seward, Nebr., and in the Little Blue River subbasin were affected substantially by overland runoff (sites 23, 28, 36, 38, 42, 47). The largest

Table 5. Rainfall characteristics at selected locations for synoptic surveys of July 1988 and July 1989

[Data from National Oceanic and Atmospheric Administration, 1988–89a, b; rainfall values are in inches]

Location (fig. 1)	July 24–29, 1994				July 16–21, 1989			
	Number of antecedent dry days	Antecedent rainfall		Total rainfall during sampling period	Number of antecedent dry days	Antecedent rainfall		Total rainfall during sampling period
		Prior 3 days	Prior 14 days			Prior 3 days	Prior 14 days	
York, Nebr.	4	0	1.65	0.09	0	0.88	0.92	0.63
Hastings, Nebr.	4	0	1.57	0	0	1.98	2.21	1.06
Beatrice, Nebr.	4	0	2.28	.03	0	1.47	1.54	.58
Marysville, Kans.	4	0	2.23	.22	0	.80	2.79	.25
Manhattan, Kans.	4	0	3.53	0	0	.02	.58	.38
Topeka, Kans.	7	0	.53	.08	0	2.50	2.88	.40

streamflows were in the upper Little Blue River subbasin. The Little Blue River near Deweese, Nebr. (site 38), had a flow rate equalled or exceeded only 0.4 percent of the time. Streamflow along the main stem Kansas River and tributary streams during the July 1989 survey were similar to those observed during the July 1988 survey. However, because of fluctuations in releases from Tuttle Creek Lake, several Kansas River sites (sites 58, 62, 76) were not under stable-flow conditions. No sites on the main stem Kansas River or tributary streams appeared to be affected by recent overland runoff.

Quality Assurance

Within-site variations in *E. coli* counts may be the result of variability in (1) analytical procedures, (2) sample-collection procedures, (3) natural microbial distribution, and (4) differences in techniques of multiple analysts. Procedures were developed to evaluate or control these sources of variation to the extent possible. Other quality-assurance procedures included verification of the sterility of the buffered-dilution water and equipment used in the filtration process.

Variation in *E. coli* counts caused by analytical procedures was evaluated by filtering duplicate volumes of samples collected at 10 randomly selected sites during the July 1988 synoptic survey. Two to four duplicate volumes were filtered for each site, producing a total of 28 duplicate pairs. Counts of *E. coli* colonies were made for the duplicate pairs (table 7), and variation was evaluated with a technique used by Dufour and others (1981) to quantify the precision of the mTEC procedures. They calculated variation as a percentage of the mean with the equation:

$$\text{variation} = \frac{s/\sqrt{n}}{\bar{x}} \cdot 100, \quad (1)$$

where

s is the standard deviation,
n is the number of duplicates, and
$\bar{x}$ is the mean count of the duplicate pairs.

For a sample size of two, variation can be shown to be expressed as:

$$\text{variation} = \frac{(x_1 - x_2)/2}{\bar{x}} \cdot 100. \quad (2)$$

The variations computed by equation 2 for the duplicate-pair counts are listed in table 7. Average variation for the mTEC analytical procedure as determined from all data in table 7 is 22 percent of the mean. Average variation for duplicate pairs with both counts within the ideal counting range of 20–80 col/100 mL is 10 percent of the mean. Average variation for duplicate pairs with one or both counts within the ideal counting range is 13 percent of the mean. Average variation for duplicate pairs where

Table 6. Streamflow-duration data at selected locations and sampling times

[Streamflow is in cubic feet per second; >, greater than; --, no data]

Map-index number (fig. 10)	Site name	July 1988				July 1989			
		Day	Time (24-hour)	Streamflow	Percentage of time flow equalled or exceeded[1]	Day	Time (24-hour)	Streamflow	Percentage of time flow equalled or exceeded[1]
1	Kansas River at Fort Riley, Kans.	27	1300	353	95	19	1150	520	79
6	Big Blue River at Surprise, Nebr.	26	0730	6.2	25	18	1300	3.7	33
11	Lincoln Creek near Seward, Nebr.	26	0845	30	31	17	1440	35	25
12	Big Blue River at Seward, Nebr.	26	1000	55	31	17	1505	49	34
23	West Fork Big Blue River near Dorchester, Nebr.	25	1245	75	55	18	1450	352	9.1
28	Turkey Creek near Wilber, Nebr.	25	0600	15	56	17	1120	168	8.7
32	Big Blue River at Beatrice, Nebr.	27	0510	247	52	--	--	--	--
36	Big Blue River at Marysville, Kans.	25	1230	393	58	18	0800	700	32
38	Little Blue River near Deweese, Nebr.	26	0810	31	94	17	1020	3,240	.4
42	Big Sandy Creek at Alexandria, Nebr.	26	0545	37	39	17	0850	190	7.4
47	Little Blue River at Hollenberg, Kans.	25	1150	163	68	18	1040	2,260	4.8
50	Black Vermillion River near Frankfort, Kans.	25	1320	7.0	80	19	0925	8.0	77
52	Big Blue River near Manhattan, Kans.	24	1045	1,870	29	19	1100	2,570	23
59	Mill Creek near Paxico, Kans.	27	1010	9.5	83	19	1525	5.1	89
58	Kansas River near Belvue, Kans.	27	0910	2,550	51	19	1430	3,250	44
62	Kansas River at Topeka, Kans.	29	0535	2,250	60	20	1320	2,760	51
64	Soldier Creek near Topeka, Kans.	28	1230	4.6	80	20	1440	1.6	90
72	Delaware River near Muscotah, Kans.	27	0745	2.4	98	21	0955	.88	>99
74	Delaware River below Perry Dam, Kans.	29	1020	25	80	21	1000	24	84
76	Kansas River at Lecompton, Kans.	28	0615	2,260	66	21	0930	2,460	63
83	Wakarusa River near Lawrence, Kans.	29	0530	24	62	20	0915	23	64
87	Stranger Creek near Tonganoxie, Kans.	28	0445	.06	>99	19	1630	23	70
88	Kansas River at De Soto, Kans.	28	0610	2,290	76	20	1520	2,420	74

[1]Based on at least 7 years of data at each site.

Table 7. Variation of *Escherichia coli* counts in two-plate duplicate-volume filtrations from samples collected during synoptic survey of July 1988

[Variation is computed by equation 2; *Escherichia coli* counts are actual plate counts]

Site map-index number (fig. 10)	*Escherichia coli* counts Plate 1 (x_1)	Plate 2 (x_2)	Variation, in percent of mean
5	2	1	33
	8	10	11
	19	29	21
28	1	5	67
	24	17	17
	54	50	4
31	8	11	16
	41	41	0
	115	95	10
34	6	9	20
	30	26	7
	83	55	20
50	1	3	50
	14	8	27
	53	38	16
52	3	2	20
	7	6	8
59	2	1	33
	20	22	5
72	7	4	27
	13	12	4
	49	32	21
87	3	1	50
	6	8	14
	10	12	9
	44	31	17
88	4	11	47
	6	11	29

neither count was within the ideal counting range is 26 percent. Therefore, as counts deviate from the ideal counting range, variation increases considerably.

Variations in *E. coli* counts caused by sample-collection procedures (the ability to collect a representative sample of the bacterial population) and natural bacterial distribution were not examined in this study because micro-organisms are rarely distributed randomly and because bacteria within any habitat will have a clumped or patchy distribution (Britton and Greeson, 1987, p. 4) and will produce uncertainty in computed variation when viewed from a temporal perspective. Under these conditions, the ability to distinguish between variation caused by sample-collection procedures and that caused by distributional patterns may be questionable without devoting substantial effort to collect and process a sufficient number of samples to define the contribution of both potential sources of variability. Additionally, within-site variation may be site specific, and assumptions made based on computed variation at a particular site may not be true for other sites in the synoptic survey. A detailed examination of sample-collection variability and natural variability in distribution at individual synoptic sites was beyond the scope of this study.

Variations in *E. coli* counts caused by variability in analytical technique among multiple analysts were not of concern in this study. As previously described, a single analyst filtered, plated, and counted all *E. coli* samples. This same analyst performed these functions for both the July 1988 and July 1989 synoptic surveys.

Four equipment-blank samples using sterile, buffered dilution water were filtered and plated on mTEC medium. After incubation, none of the plates showed development of *E. coli* colonies. This lack of development verified the sterility of the buffered water used for sample dilutions and equipment used during the filtration process. Also, it indicated that the filtration equipment and procedure were not a source of contamination.

Areal Variations

The areal variations of *E. coli* densities for the July 1988 survey are shown in figure 14. Densities of *E. coli* in water at the 19 sites in the Big Blue River subbasin, exclusive of the Little Blue River subbasin, upstream of Tuttle Creek Lake (sites 6–36, 50, and 51, table 7) ranged from 120 col/100 mL in Fancy Creek at Winkler, Kans. (site 51), to 260,000 col/100 mL in the West Fork Big Blue River near Hastings, Nebr. (site 16). Densities at the 11 sites in the Little Blue River subbasin (sites 37–49, table 7) ranged from 100 col/100 mL in the Little Blue River near Alexandria, Nebr. (site 40), to 30,000 col/100 mL at

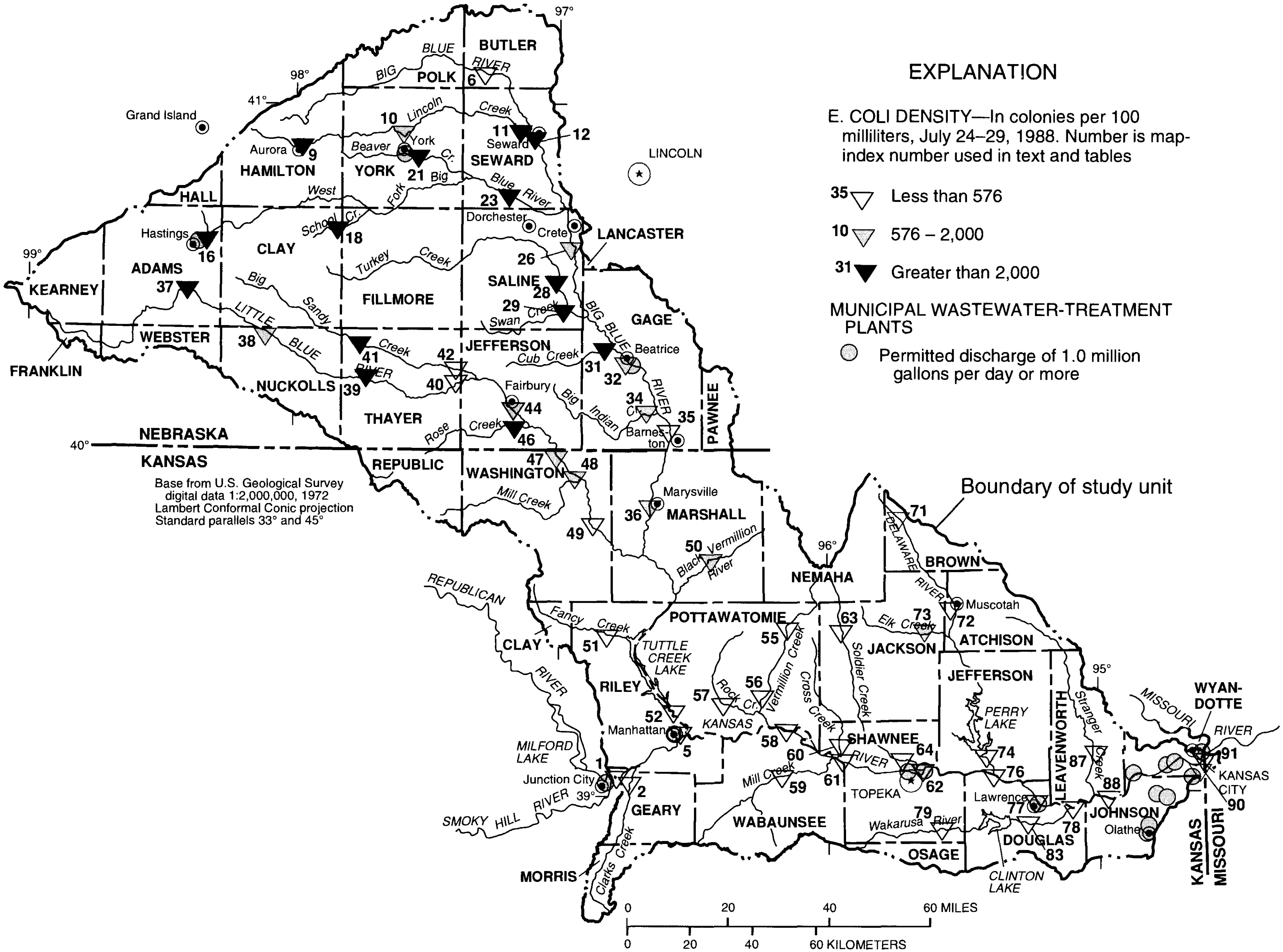

Figure 14. Areal distribution of *Escherichia coli* densities for synoptic survey of July 24–29, 1988, and location of municipal wastewater-treatment plants with permitted discharges of 1.0 gallons per day or more.

Big Sandy Creek near Davenport, Nebr. (site 41). Densities of *E. coli* at the 27 sites located in the Kansas River subbasin (sites 1, 2, 5, and 52–91, table 7) ranged from less than 1 col/100 mL in the Delaware River below Perry Dam, Kans. (site 74), to 1,000 col/100 mL in Elk Creek near Larkinburg, Kans. (site 73).

Of the 19 sites sampled in the Big Blue River subbasin upstream of Tuttle Creek Lake, stream water at 16 of those sites (84 percent) exceeded the USEPA criterion for *E. coli* densities (576 col/100 mL) for infrequently used full-body contact recreation, and 10 sites (53 percent) exceeded the 2,000-col/100 mL fecal coliform criterion for uses other than full-body contact established by the Kansas Department of Health and Environment (Fromm and Wilk, 1988). A downstream-ordered distribution of *E. coli* densities for the Big Blue River subbasin is shown in figure 15. For tributary streams only the downstream-most sampling site is shown. Generally, downstream from the Big Blue River at Seward, Nebr. (site 12), densities of *E. coli* decreased on both the main stem and tributary streams probably because of a combination of dilution and bacterial die off.

The *E. coli* density (10,000 col/100 mL) at site 12 apparently reflects not only the contribution (5,500 col/100 mL) from Lincoln Creek (site 11) but also a significant nonpoint-source contribution. Site 12 is upstream of the Seward municipal wastewater-treatment plant and, thus, is not affected by its discharge. Upstream of site 12, there are only two small wastewater-treatment plants—the municipal wastewater-treatment plant at Staplehurst, 12 stream mi upstream, with a permitted discharge of 0.01 Mgal/d and Ulysses, 28 stream mi upstream, with a permitted discharge of 0.04 Mgal/d. Because of the distances upstream of these two wastewater-treatment plants and their small permitted discharge rates, it is believed that these two point sources would have little effect on *E. coli* densities at site 12. Therefore, it appears that a large part of the *E. coli* density determined at site 12 was from nonpoint-source contributions. These contributions probably originated as irrigation return flow or ground-water discharge and were related to livestock production upstream of site 12. As previously indicated in table 1 and figures 7 and 8, production of cattle and hogs in this area are at some of the highest levels in the study unit.

The relatively large *E. coli* density (10,000 col/100 mL) in Cub Creek (site 31) was probably of nonpoint-source origin. The only known point-source discharge of *E. coli* is the Jensen municipal wastewater-treatment plant, which has a permitted discharge rate of 0.02 Mgal/day. This plant is located on a tributary to Cub Creek many miles upstream of site 31. Therefore, its effect on *E. coli* densities at site 31 is believed to be minimal. As is common in much of the northern part of the study unit, livestock production in the Cub Creek Basin is substantial (table 1, figs. 7 and 8) and probably contributes to the occurrence of *E. coli* in local streams.

Of the 11 sites sampled for *E. coli* in the Little Blue River subbasin, 8 (73 percent) exceeded the 576 col/100 mL primary-contact criterion, and 4 (36 percent) exceeded the 2,000-col/100 mL criterion for other than primary contact. Figure 16 shows a downstream-ordered distribution of *E. coli* densities in the Little Blue River subbasin as determined during the July 1988 synoptic survey. The density of *E. coli* in the Little Blue River near Hastings (site 37) was the largest (3,800 col/100 mL) determined at any main-stem site and may have come in large part from nonpoint sources. Upstream from site 37 are three small wastewater-treatment plants; however, their location (4.6 to 41 stream mi upstream) and combined total permitted discharge (0.08 Mgal/d) are believed to have minimal effect on *E. coli* density at site 37. The much smaller density (940 col/100 mL) determined at Little Blue River near Deweese, Nebr. (site 38), may indicate that the 26-mi stream reach between sites 37 and 38 is an area of *E. coli* die off, with no exceptionally large nonpoint-source contribution. There are no known point sources between sites 37 and 38.

The increase in *E. coli* density (3,000 col/100 mL) in the Little Blue River near Deshler, Nebr. (site 39), may have been the result of discharge from the Deshler wastewater-treatment plant 3 stream mi upstream from site 39. Permitted discharge for the wastewater-treatment plant is 0.10 Mgal/d. The 100-col/100 mL *E. coli* density determined at the Little Blue River near Alexandria, Nebr. (site 40), represents the smallest *E. coli* density determined in the Little Blue River subbasin, in spite of the fact that it is downstream of the Hebron, Nebr., wastewater-treatment plant, which has a permitted discharge of 0.16 Mgal/d. However, the 18 stream mi between the Hebron wastewater-treatment plant and site 40 may provide enough distance for self purification, may give some insight into *E. coli* die-off rates, and may indi-

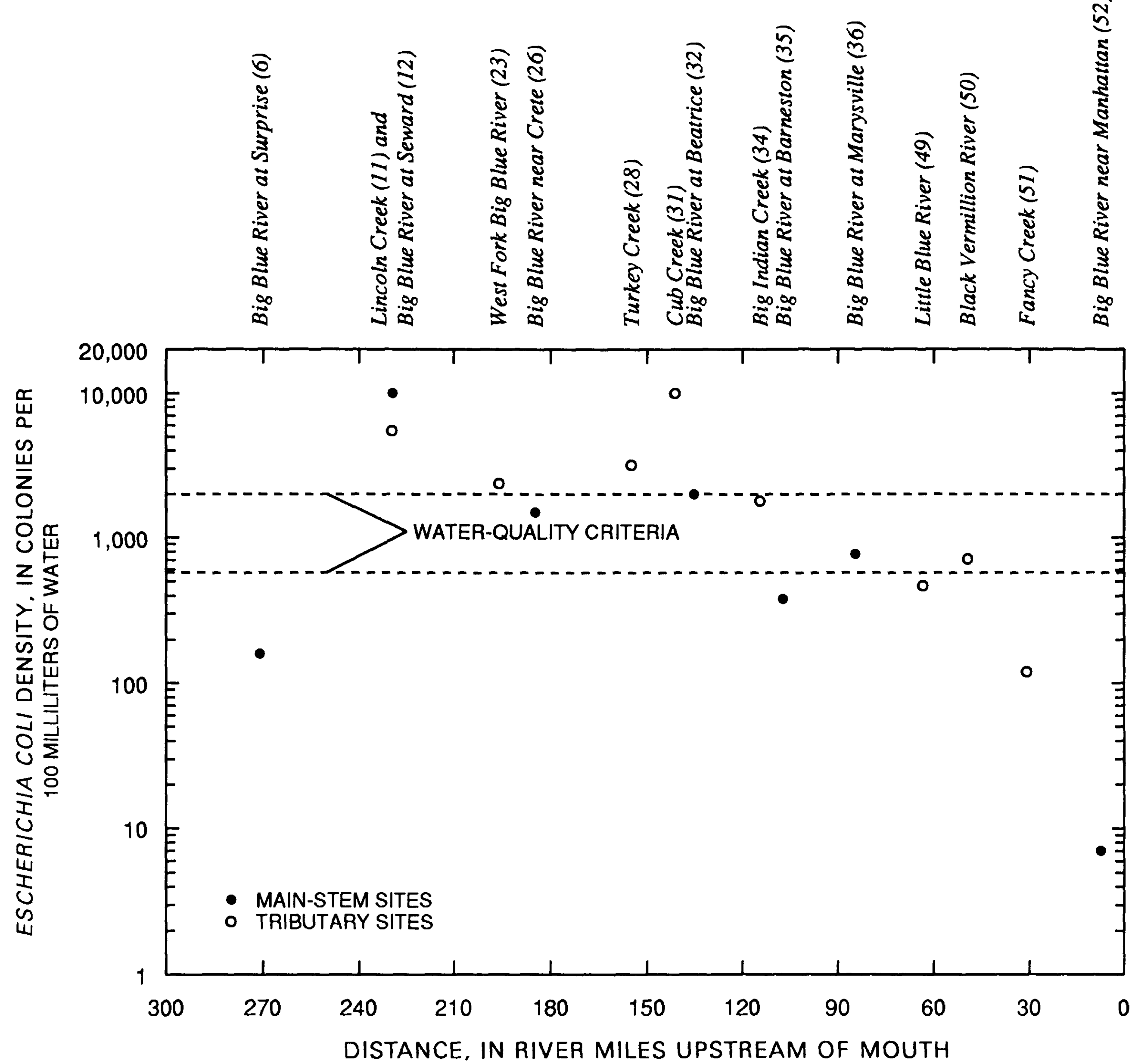

Figure 15. Distribution of *Escherichia coli* densities in water from the Big Blue River and its major tributaries for synoptic survey of July 24–29, 1988. [Number in parentheses is synoptic-sampling site number. Water-quality criteria established by U.S. Environmental Protection Agency (1986) and Kansas Department of Health and Environment (Fromm and Wilk, 1988).]

cate that nonpoint-source contamination is minimal in this part of the subbasin. The Little Blue River near Fairbury, Nebr. (site 44), is approximately 2 mi downstream of the Fairbury municipal wastewater-treatment plant. This plant has a permitted discharge of 0.65 Mgal/d and is probably responsible for the increase in *E. coli* density (1,200 col/100 mL) over that determined at site 40. Nonpoint-source contamination may be responsible for the relatively large *E. coli* density (5,500 col/100 mL) in Rose Creek near

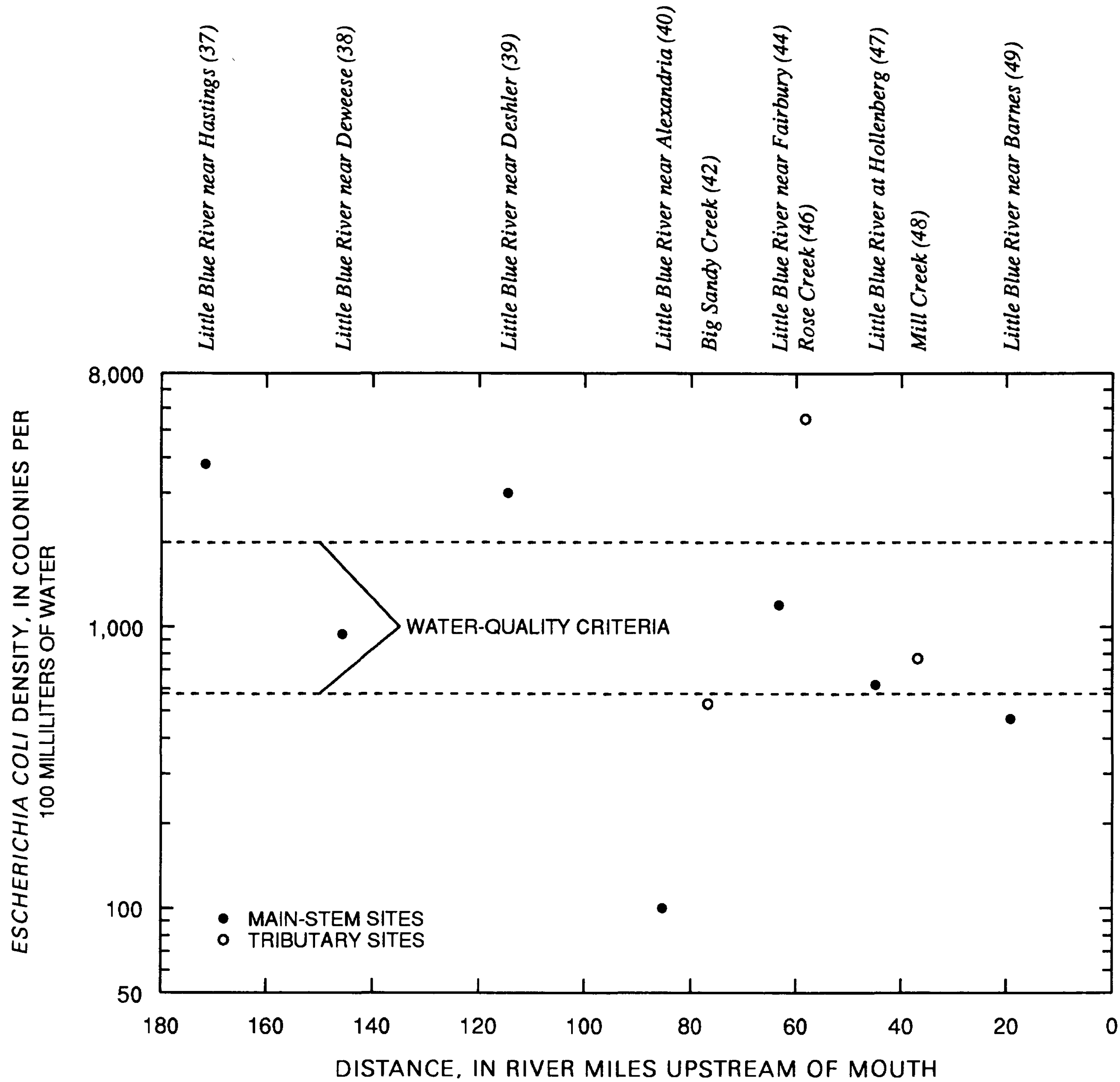

Figure 16. Distribution of *Escherichia coli* densities in water from the Little Blue River and its major tributaries for synoptic survey of July 24–29, 1988. [Number in parentheses is synoptic-sampling site number. Water-quality criteria established by U.S. Environmental Protection Agency (1986) and Kansas Department of Health and Environment (Fromm and Wilk, 1988).]

Fairbury (site 46). Although there are two wastewater-treatment plants upstream from site 46, the closest is more than 20 stream mi upstream and has a permitted discharge of only 0.01 Mgal/d. Therefore, the contribution of these wastewater-treatment plants to the *E. coli* density determined at site 46 is thought to be minimal.

Downstream of Fairbury, Nebr., *E. coli* densities gradually decline on both main-stem and tributary streams. Although not shown in figure 16, the largest

E. coli density (30,000 col/100 mL) in the Little Blue River subbasin was determined in Big Sandy Creek near Davenport, Nebr. (site 41). This density may be point-source dominated. Although three small wastewater-treatment plants are located upstream of site 41 (3 to 20 stream mi), their proximity and combined permitted discharge (0.13 Mgal/d) are probably insuffucent to produce the density determined at site 41.

Of the 27 sites sampled for *E. coli* in the Kansas River subbasin, only Elk Creek near Larkinburg, Kans. (site 73), a tributary to the Delaware River, exceeded the 576-col/100 mL criterion for primary contact. That 1,000-col/100 mL density did not exceed the 2,000-col/100 mL criterion for other than primary contact. This relatively large density may result from the 0.49-Mgal/d permitted discharge from the Holton, Kans., wastewater-treatment plant, located approximately 8 stream mi upstream from site 73.

A downstream-ordered distribution of *E. coli* densities for the main stem of the Kansas River and major tributaries as determined during the July 1988 synoptic survey is shown in figure 17. Densities of *E. coli* in the Kansas River generally appear to be point-source dominated during stable base-flow conditions. The most upstream site, Kansas River at Fort Riley, Kans. (site 1), likely is affected by the Junction City, Kans., wastewater-treatment plant about 2 stream mi upstream. The Junction City wastewater-treatment plant has permitted discharge exceeding 1.0 Mgal/d. *E. coli* density at site 1 was 210 col/100 mL. At Manhattan (site 5), *E. coli* density was 96 col/100 mL, which may indicate that the distance between sites 1 and 5 is a reach of *E. coli* die off; however, because of differences in sampling times and flow rates (table 4), this is difficult to confirm. Near Belvue, Kans. (site 58), approximately 35 stream mi downstream of site 5, density of *E. coli* had decreased to 48 col/100 mL despite the 2.74-Mgal/d permitted discharge from the Manhattan wastewater-treatment plant. The smaller density at site 58 was probably the result of dilution by a large release (1,870 ft^3/s) from Tuttle Creek Lake via the Big Blue River. Downstream of the confluence of the Big Blue and Kansas Rivers, Tuttle Creek Lake water comprised 89 percent of the flow in the Kansas River. Density of *E. coli* in the release water from Tuttle Creek Lake was 7 col/100 mL (site 52), which provided a substantial dilution effect in the Kansas River.

The largest densities of *E. coli* in the Kansas River occur downstream of large municipal wastewater treatment-plant discharge points. Site 76 and site 78 are downstream of the 14.3 Mgal/d permitted discharge at Topeka, Kans., and the 5.3 Mgal/d permitted discharge at Lawrence, Kans., respectively. The 390-col/100 mL density determined at the downstream-most site, Kansas River at Kansas City, Kans. (site 91), probably can be attributed to wastewater discharges from several large and small treatment plants in Johnson County, Kans.

Point-source discharges from municipal wastewater-treatment plants have a substantial effect on *E. coli* densities at several of the sites in the Big Blue River and Little Blue River subbasins. During the time of the synoptic surveys conducted for this study, none of the wastewater-treatment plants in the study unit disinfected (chlorinated) effluent before discharge into receiving streams. The drainage areas of all sampling sites in these subbasins contained one to several treatment plants; however, most of these plants serve small communities and typically have permitted-discharge rates of less than 0.10 Mgal/d. Therefore, their potential effect may be limited to sites within several stream miles of the discharge point and may have only minimal effect at sites farther downstream. The effect of larger facilities, greater than 1.0 Mgal/d, is most evident at the West Fork Big Blue River near Hastings, Nebr. (site 16), where an *E. coli* density of 260,000 col/100 mL was determined. Site 16 is approximately 2 mi downstream from the Hastings municipal wastewater-treatment plant, which has a permitted discharge of 2.75 Mgal/d. Site 16 also was characterized by DO concentrations in violation of 1-day minimum criteria (table 3) and by large nutrient concentrations (table 8) as previously explained in the "Dissolved-Oxygen Concentrations" section of this report. Other sites in the Big Blue River and Little Blue River systems that appear to have *E. coli* densities affected by close proximity to point-source discharges include Lincoln Creek near Aurora, Nebr. (site 9); School Creek near Sutton, Nebr. (site 18); Beaver Creek near York, Nebr. (site 21); Big Blue River near Crete, Nebr. (site 26); Big Sandy Creek near Davenport, Nebr. (site 41); and Little Blue River near Fairbury, Nebr. (site 44).

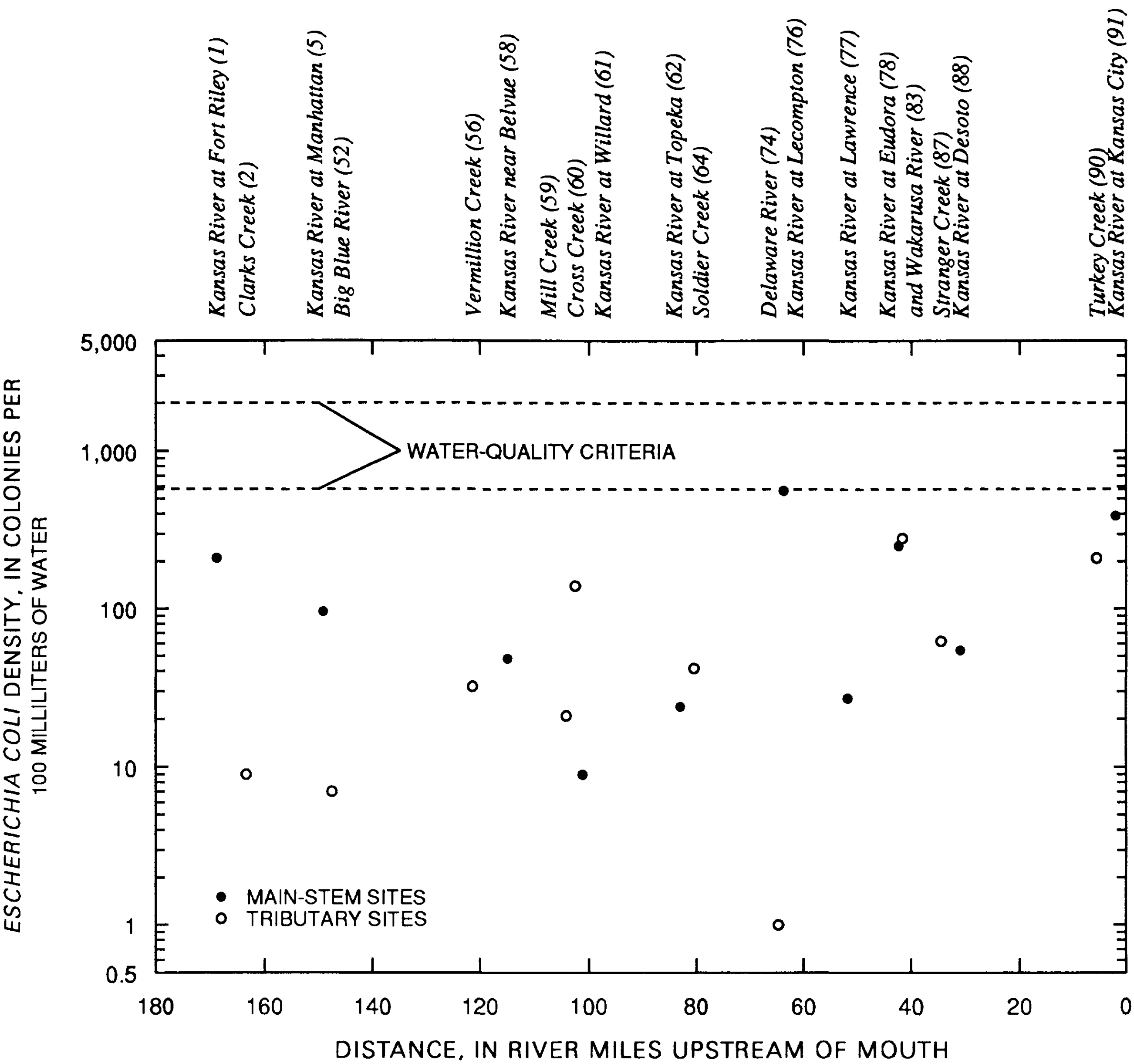

Figure 17. Distribution of *Escherichia coli* densities in water from the Kansas River and its major tributaries for synoptic survey of July 24–29, 1988. [Number in parentheses is synoptic-sampling site number. Water-quality criteria established by U.S. Environmental Protection Agency (1986) and Kansas Department of Health and Environment (Fromm and Wilk, 1988).]

Regional Patterns

Previously presented information indicate regional patterns in *E. coli* densities. These regional patterns are most evident in a comparison of median values (50th percentile), figure 18, of the July 1988 samples from the 19 sites in the Big Blue River subbasin (2,400 col/100 mL), the 11 sites in the Little Blue River subbasin (940 col/100 mL), and the 27 sites in the Kansas River subbasin (88 col/100 mL). The

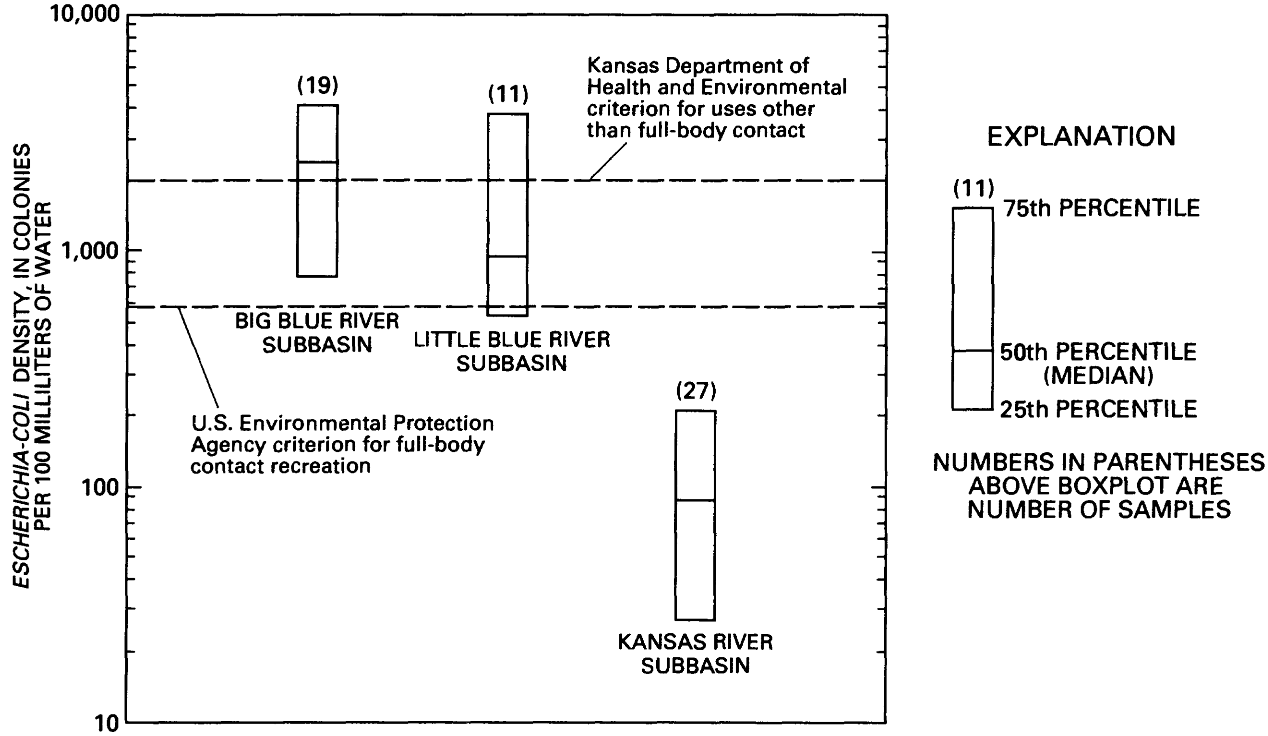

Figure 18. Comparison of the 25th, 50th (median), and 75th percentiles of *Escherichia coli* densities in the Big Blue River, Little Blue River, and Kansas River subbasins for synoptic survey of July 24–29, 1988 [water-quality criteria established by U.S. Environmental Protection Agency, 1986, and Kansas Department of Health and Environment (Fromm and Wilk, 1988)].

median *E. coli* density in samples from the Big Blue River subbasin was 2.6 times larger than in samples from the Little Blue River subbasin and 27.3 times larger than in samples from the Kansas River subbasin.

Although point-source discharges may be responsible for large *E. coli* densities at specific sites during base-flow conditions and *E. coli* may be carried to some sites farther downstream, it appears that additional factors may be responsible for the generally larger *E. coli* densities in the Big Blue River and Little Blue River subbasins compared to those determined in the Kansas River subbasin. The Kansas River subbasin contains many wastewater-treatment plants with large and small permitted discharges located on large and small streams, similar to the situation in the Big Blue River and Little Blue River subbasins. However, with only one exception, *E. coli* densities in the Kansas River subbasin were less than water-quality criteria during the July 1988 survey. The large *E. coli* densities in the Big Blue River and Little Blue River subbasins probably is most attributable to the production of domestic livestock.

Domestic livestock production may increase *E. coli* densities in streams in several ways: (1) direct access to streams used as a water source by the livestock, (2) overland runoff from pastures and feedlots, (3) ground-water discharge in areas where feedlots may be in close proximity to streams, and (4) runoff as a result of rainfall or irrigation on cropland where manure was applied as a fertilizer or soil amendment.

Livestock may contribute fecal material and *E. coli* directly to streams when those streams are used as a water source. This may occur more frequently in areas where livestock are pastured instead of confined to feedlots. Direct access to streams, however, may not be a major cause of E. coli loading. The Kansas River subbasin has more than twice the percentage of pasture and rangeland than the other major subbasins examined in this report (fig. 5). However, it had the smallest median *E. coli* density (88 col/100 mL) of any subbasin.

Feedlots may contribute to the occurrence of *E. coli* in streams because of uncontrolled surface runoff or because *E. coli* is transported downward by infiltrating rain to shallow ground water and then laterally to nearby streams. As previously described in the "Livestock Production" section of this report, counties with the largest percentage of cattle in confined feeding operations and the greatest densities of cattle and hogs are located in the headwater or middle-stream reaches of the Big Blue, West Fork Big Blue, and Little Blue Rivers (figs. 7 and 8).

One stream that may indicate the effect of livestock feeding and production operations is Lincoln Creek (fig. 1) in the extreme northern part of the study unit. Three sampling sites (sites 9, 10, and 11, table 4) were located on Lincoln Creek. The upstream-most site, near Aurora, Nebr. (site 9), is approximately 1.25 mi downstream of the Aurora wastewater-treatment facility, which probably is the main source of the 2,600 col/100 mL of *E. coli* measured at site 9. The instantaneous load of *E. coli* organisms at site 9 was 250,000 organisms per second (org/s). Instantaneous load is computed by multiplying *E. coli* density (col/100 mL) by streamflow rate (ft^3/s) by a unit conversion factor of 283.2 based on the assumption that one colony developed from one *E. coli* organism. At the site near York, Nebr. (site 10), which is 42 stream mi downstream of site 9, *E. coli* density had decreased to 1,900 col/100 mL. However, instantaneous load of *E. coli* had increased by a factor of almost 18 to 4,400,000 org/s. There are no known point-source discharges between site 9 and 10. At site 11 near Seward, Nebr., 47.3 stream mi downstream of site 10, *E. coli* density had increased to 5,500 col/100 mL, and instantaneous load had increased by more than an order of magnitude to 47,000,000 org/s. The only known point-source discharge between sites 10 and 11 is the 0.02 Mgal/d permitted discharge from the Gresham, Nebr., wastewater-treatment plant located on a tributary to Lincoln Creek many miles upstream of Seward.

From these results it appears that large numbers of bacteria are entering Lincoln Creek between sites 9 and 11 from nonpoint sources. The intensity of feedlot operations and large cattle and hog densities in the Lincoln Creek Basin probably account for a large part of the *E. coli* load in Lincoln Creek. This load of *E. coli* may be a result of cattle and hogs wading in Lincoln Creek or its tributaries, *E. coli* entering streams with ground water affected by feedlot operations, or the load may be an artifact of recent rainfall runoff (between 5–14 days before the survey, table 5).

Gary and others (1983) found that when at least 150 cattle were grazed in a pasture in central Colorado, fecal coliform densities in stream water bisecting the pasture were significantly larger than those in an adjacent, ungrazed pasture. After removal of cattle or when 40 head of cattle were grazing, bacterial counts decreased to levels similar to the ungrazed pasture. Also, they concluded that about 5 percent of the total manure produced by cattle contributed to contamination of the stream. Obviously, this percentage depends upon factors such as soil type, soil porosity, topography, land cover, and rainfall characteristics.

Stephenson and Street (1978) determined that the occurrence of fecal coliforms at stream sites in a rangeland watershed in southwest Idaho was related directly to the presence of cattle on summer range and winter pastures. Fecal coliform counts were found to increase soon after cattle were pastured and remained large for several months after cattle were removed.

Feedlot operations may have an indirect effect on stream water quality. In any confined feeding operation (cattle or hogs), large quantities of manure will be produced creating a disposal problem. One disposal solution is to apply the manure to cropland as a low-grade fertilizer or soil amendment. This application may be in late fall after harvest or early spring before planting. Subsequent rainfall or irrigation runoff may transport organic material and *E. coli* into nearby streams. If this practice is widespread, it may have a substantial effect on *E. coli* densities in streams in intensively irrigated areas.

In the Big Blue River and Little Blue River subbasins, percentages of land used for irrigated row crops were 25.1 percent and 18.5 percent, respectively (fig. 5). These percentages generally are much larger for the upper part of each subbasin, where *E. coli* densities were largest, as most of the range or pastureland shown in figure 5 occurs in the Plains Border and Dissected Till Plains physiographic sections (fig. 2) south of the Kansas-Nebraska border. In contrast, irrigated row crops in the Kansas River subbasin accounted for much less than 1 percent (too small to show in fig. 5), whereas in the Delaware River subbasin irrigated row crops totaled only 1.5 percent of the total land use. This information indicates that the possibility of irrigation-water runoff affecting *E. coli* densities would be greatest for the Big Blue River and Little Blue River subbasins. Irrigation-water runoff was observed entering Turkey Creek immediately upstream of the sampling site near Wilber, Nebr. (site 28), during the July 1988 synoptic survey. Considering the extent of irrigation in the Big Blue River and Little Blue River subbasins, many other streams in these subbasins may have been receiving irrigation-water runoff.

Further evidence of the effect of livestock production on bacterial densities is presented in Jordan and Stamer (1991). In examining historical bacteriological data, they reported moderate fecal coliform and large fecal streptococci densities in water from Lincoln Creek near Seward, Nebr. (site 11). They indicated that, on the basis of a study done by Geldreich and Kenner (1969), when fecal streptococci were present in greater numbers than fecal coliform bacteria, the originating source of fecal material was "farm animals, dogs, cats, and various wild animals." When the converse situation occurs, the originating source is human. In addition to the potential contribution of bacteria from livestock production, irrigation-water runoff, as previously discussed, could contribute to bacteria loading along Lincoln Creek. With the data currently available, it is impossible to quantify the contribution of either source; however, given the extent of livestock production, it is believed that this activity is the source of most of the nonpoint-source loading of bacteria. The situation on Lincoln Creek is not unique and also could apply to many other streams in the Big Blue River and Little Blue River subbasins.

In July 1989, 36 of the 57 sites sampled in July 1988 were resampled in an attempt to verify the distributional pattern and magnitude of *E. coli* densities determined in July 1988. Sites sampled in July 1989 and *E. coli* densities are listed in table 4. Making this verification survey comparable to the data collected in 1988 required conditions similar to those during the July 1988 survey; however, as previously discussed, precipitation (table 5) and hydrologic conditions (table 6) during the July 1989 sampling were, in many instances, very dissimilar from those in July 1988. With the exception of Big Indian Creek near Wymore, Nebr. (site 34), streamflow at all sampling sites in the Big Blue and Little Blue River subbasins upstream of Tuttle Creek Lake was affected by overland runoff from recent rain. This is especially true in the Little Blue River subbasin (sites 37–49) where streamflows were as much as two orders of magnitude larger (site 38) than those observed in July 1988.

Densities of *E. coli* determined in July 1989 generally were larger than those in July 1988 and ranged from 5 col/100 mL in the Delaware River below Perry Dam, Kans. (site 74), to 790,000 col/100 mL in the West Fork Big Blue River near Hastings, Nebr. (site 16). These two sites also had the minimum and maximum densities, respectively, of all sites sampled in July 1988. The larger densities determined in July 1989 appear to be the result of nonpoint-source contamination from overland runoff caused by rainfall during the 14 days prior to survey. The largest densities in July 1989 were at sites located in the Big Blue and Little Blue River subbasins, a situation similar to that observed in July 1988.

Although the July 1989 *E. coli* data set is not adequate for verifying the results of the stable, low-flow conditions of July 1988, it does provide insight into the relation between runoff and bacterial densities. This relation is most evident in the Little Blue River subbasin, particularly at main-stem sites where flows were many times larger than those observed in July 1988. In July 1988, the median *E.coli* density at main-stem Little Blue River sites was 940 col/100 mL, whereas in July 1989 the median density was 17,000 col/100 mL. The intense livestock production in the Little Blue and Big Blue River subbasins is a major contributor to fecal contamination of streams receiving overland runoff in these areas.

Densities of *E. coli* in the Kansas River subbasin were considerably larger in July 1989 than in July 1988 but not at the magnitude observed in the Little Blue and Big Blue River subbasins. The larger densities in July 1989 were probably the result of nonpoint-source contribution from overland runoff caused by considerable rainfall during and just before the start of sampling (table 5). The largest densities determined in the Kansas River subbasin were at main-stem sites downstream of Topeka (sites 76, 78, and 88), which received nearly 3 in. of rain during this period. The 10,000-col/100 mL density determined at Kansas River at Lecompton, Kans. (site 76), probably represents a combination of nonpoint sources from overland runoff and discharge from the Topeka wastewater-treatment plant.

SUMMARY

In 1986, the Congress appropriated funds for the U.S. Geological Survey to test and refine concepts for a National Water-Quality Assessment (NAWQA) Program. The 15,300-mi^2 lower Kansas River Basin in Kansas and Nebraska was one of four pilot studies in this program. This report describes the sanitary quality of streams in the lower Kansas River Basin. Sanitary quality is evaluated on the basis of concentrations of dissolved oxygen (DO) and densities of a fecal-indicator bacterium, *Escherichia coli* (*E. coli*).

Sixty-one surface-water sampling sites were chosen for this investigation. Criteria for site selection included long-term, fixed-station sampling locations, locations of potential degradation in sanitary quality, locations on streams representing areas with reasonably homogeneous land use, sites at the confluence of major tributaries, and additional sites on the main stem Kansas River and major tributary streams to provide a resolution of no more than 50 river mi between sites. Synoptic surveys were conducted at these sites in July 1988, November 1988, March 1989, and May 1989, to define the concentrations, and diel and seasonal variability in concentrations of DO. Synoptic surveys were conducted in July 1988 and July 1989 to define densities of *E. coli*. Ancillary data included measurements of specific conductance, pH, water temperature, barometric pressure, and concentrations of nutrients, total organic carbon, chlorophyll, and suspended sediment. Surveys generally were conducted during stable-flow, dry-weather conditions.

To define the maximum potential for DO deficiencies, a synoptic survey was conducted in July 1988 when water temperatures were expected to be near annual maximums and streamflows near annual minimums. Because DO fluctuates as a result of daytime photosynthesis (production of oxygen) and nighttime respiration (consumption of oxygen) by algae and aquatic plants, 31 sites were sampled within about 2 hours before dawn when DO concentrations were anticipated to be at minimum in the diel cycle. Of these 31 sites, 5 had DO concentrations less than the U.S. Environmental Protection Agency (USEPA) 5.0-mg/L, 1-day minimum warmwater criterion for early life stages, and 4 of these 5 predawn concentrations were less than the USEPA 3.0-mg/L criterion for all other life stages. These five sites were Lincoln Creek near Aurora, Nebr., West Fork Big Blue River near Hastings, Nebr., Delaware River near Fairview, Kans., Stranger Creek at Easton, Kans., and Turkey Creek at Kansas City, Kans. The small DO concentrations at the sampling sites on Lincoln Creek, West Fork Big Blue River, and Turkey Creek were mainly the result of upstream municipal wastewater discharges. Small DO concentrations in Stranger Creek and the Delaware River were mainly the result of algal respiratory demands coupled with reduced physical reaeration associated with extreme low flow.

In addition to those sites identified in the July 1988 synoptic survey with DO concentrations less than criteria, concentrations at four additional sites identified in subsequent surveys were less than criteria: Beaver Creek near York, Nebr., on May 31, 1989 (4.9 mg/L); Cross Creek at Rossville, Kans., on June 1, 1989 (4.7 mg/L); Wakarusa River near Berryton, Kans., on May 31, 1989 (4.5 mg/L); and Wakarusa River near Lawrence, Kans., on November 16, 1988 (2.7 mg/L). The small DO concentration at the site on Beaver Creek appeared to be the result of municipal wastewater discharge, whereas the small concentrations in Cross Creek and Wakarusa River near Berryton, Kans., probably were caused by algal respiratory demands coupled with reduced physical reaeration associated with extreme low flow. The small DO concentration at Wakarusa River near Lawrence, Kans., was possibly the result of localized runoff carrying oxygen-demanding material into the stream.

Concentrations of DO in violation of water-quality criteria are localized occurrences and do not reflect regional patterns in DO. Generally, the most severe DO deficiencies are the result of discharges from municipal wastewater-treatment plants into small tributary streams with inadequate dilution or assimilation capacity. Algal respiratory demand in combination with reduced physical reaeration associated with extreme low flow probably also contributes to temporary, localized deficiencies. Comparisons among mean predawn DO concentrations at sites on the Big Blue River, Little Blue River, and Kansas River, showed little appreciable difference between the streams (6.23, 6.60, and 6.36 mg/L, respectively). Of all DO concentrations determined (392) in conjunction with all synoptic surveys, nine determinations (2.3 percent) were less than water-quality criteria.

Diel variability in DO concentrations was measured at 11 sites in the study unit. DO determinations were made at 4- or 6-hour intervals during an approximately 24-hour period. Concentrations of DO less than the 5.0-mg/L criterion were not observed at any of the diel-study sites. On the basis of these diel studies, it appears that diel DO fluctuations in streams not affected by localized problems such as point-source discharges are basically a function of photosynthesis and respiration.

Densities of *E. coli* were determined at 57 surface-water sampling sites during the synoptic survey in July 1988. Results indicate large regional differences in *E. coli* densities within the study unit. The median *E. coli* density in the Big Blue River subbasin was 2,400 col/100 mL and ranged from 120 to 260,000 col/100 mL. The median *E. coli* density in the Little Blue River subbasin was 940 col/100 mL and ranged from 100 to 30,000 col/100 mL. The median *E. coli* density in the Kansas River subbasin was 88 col/100 mL and ranged from less than 1 to 1,000 col/100 mL.

Of the 19 sites sampled in the Big Blue River subbasin upstream of Tuttle Creek Lake, stream water at 16 (84 percent) of those sites exceeded the USEPA criterion for *E. coli* densities (576 col/100 mL) for infrequently used full-body contact recreation, and 10 sites (53 percent) exceeded the 2,000-col/100 mL fecal coliform criterion for uses other than full-body contact established by the Kansas Department of Health and Environment. Eight (73 percent) of the 11 sites sampled in the Little Blue River subbasin exceeded the 576-col/100 mL full-body criterion, and 4 sites (36 percent) exceeded the 2,000-col/100 mL fecal coliform criterion for other than full-body contact. In the Kansas River subbasin, the 576-col/100 mL criterion was exceeded at only one site.

Point-source discharges from municipal wastewater-treatment plants mainly were responsible for the large *E. coli* densities measured at specific sites in the study unit; however, nonpoint-source contamination probably was responsible for the generally larger *E. coli* densities in the Big Blue and Little Blue River subbasins compared to those in the Kansas River subbasin. This nonpoint-source contamination may have been the result of greater livestock production in the Big Blue River and Little Blue River subbasins compared to that in the Kansas River subbasin. More grazing and a greater number of confined feeding operations could increase *E. coli* densities in streams in several ways: (1) direct access to streams used as a water source by livestock, (2) overland runoff from pastures and confinement areas, (3) groundwater discharge from confinement areas in close proximity to streams, and (4) rainfall or irrigation runoff from cropland where manure was applied as fertilizer or soil amendment.

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SUPPLEMENTAL INFORMATION

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin

[mg/L, milligrams per liter, µg/L, micrograms per liter; <, less than; --, no data]

Site map-index number (fig. 10)	Date	Time (24-hour)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+ NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total (mg/L as N)	Nitrogen, ammonia plus organic, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)
1	07-27-88	1300	<0.01	<0.01	0.06	1.3	0.40	0.16	0.05	0.04
	11-15-88	1205	<.01	<.10	.05	1.3	.60	.20	.03	.02
	03-08-89	1000	.02	.20	.03	.90	.50	.16	.05	.04
	06-01-89	1010	<.01	<.10	.04	.80	.60	.15	.02	<.01
2	07-27-88	1150	<.01	<.10	.04	.40	.20	.10	.08	.06
	11-15-88	1050	<.01	<.10	.06	.60	.50	.09	.06	.04
	03-08-89	1140	<.01	<.10	.02	.50	.50	.03	.02	<.01
	06-01-89	0830	<.01	<.10	.02	.70	.50	.09	.04	.04
5	07-24-88	1020	.04	.80	.05	1.0	.70	.32	.16	.14
	11-16-88	0850	<.01	<.10	.04	1.1	.40	.17	.09	.06
	03-09-89	0930	.02	<.10	.02	1.6	.40	.28	.05	.04
	06-02-89	0820	<.01	<.10	.02	.70	.60	.14	<.01	<.01
6	07-26-88	0730	.05	.93	.15	2.0	.80	.42	.19	.17
	11-14-88	1200	.02	.94	.20	2.3	1.5	.43	.19	.07
	03-08-89	1015	.10	3.1	1.2	3.6	3.6	.98	.74	.69
	05-31-89	1445	.10	.47	.13	1.1	.80	.20	.06	.06
9	07-26-88	0945	.19	.40	2.0	2.8	2.0	.51	.32	.28
	07-26-88	2150	--	--	--	--	--	--	--	--
	07-27-88	0550	--	--	--	--	--	--	--	--
	11-15-88	0815	.07	.49	7.2	22	13	4.6	4.2	3.9
	03-07-89	1015	.57	3.2	3.4	.60	.60	2.2	1.9	1.5
	05-31-89	0930	.03	<.10	6.9	11	6.4	--	--	2.8
10	07-26-88	0900	--	--	--	.90	1.8	.31	.28	--
	07-26-88	1300	.05	2.4	.07	.50	1.5	.31	.28	.26
	07-26-88	1700	.05	2.3	.04	.30	1.0	.31	.27	.25
	07-26-88	2100	.05	2.2	.08	.90	.90	.33	.27	.23
	07-27-88	0100	.04	2.1	.07	.70	1.2	.32	.30	.25

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total (mg/L as N)	Nitrogen, ammonia plus organic, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)
10	07-27-88	0500	0.04	2.1	0.07	1.5	1.3	0.34	0.27	0.23
	07-27-88	0900	.04	2.2	.09	.80	1.6	.35	.27	.22
	11-14-88	1345	<.01	.11	.06	1.4	1.4	.38	.15	.05
	03-07-89	1000	.05	1.6	3.2	5.4	5.2	1.0	.77	.71
	05-31-89	1330	.04	.17	.35	1.0	1.1	.58	.52	.47
11	07-26-88	0845	.01	2.9	.05	1.4	.50	.57	.39	.36
	11-14-88	1050	.04	2.8	.05	.50	.50	.29	.26	.13
	03-08-89	1215	.10	3.1	.68	2.6	2.	.65	.46	.42
	05-31-89	1600	.14	2.9	.19	.40	<.50	.37	.36	.38
12	07-26-88	1000	.05	2.3	.15	1.9	1.0	.73	.47	.30
	07-26-88	1005	.04	2.6	.14	.60	.60	.52	.32	.32
	07-26-88	1400	.04	2.6	.05	.70	.40	.53	.34	.34
	07-26-88	1800	.05	2.5	.06	.60	.50	.51	.33	.31
	07-26-88	2200	--	--	--	--	--	--	--	--
	07-27-88	0200	.40	2.5	.08	.80	.40	.43	.31	.34
	07-27-88	0600	.04	2.4	.08	.30	.20	.40	.30	.26
	11-14-88	0845	.03	1.9	.04	1.5	.40	.33	.23	.09
	03-08-89	1130	.06	3.1	.58	2.0	2.0	.58	.42	.38
16	07-26-88	0630	.16	.80	.77	8.4	8.2	4.4	3.8	3.4
	07-26-88	1800	--	--	--	--	--	--	--	--
	07-27-88	1215	--	--	--	--	--	--	--	--
	09-06-88	1145	--	--	--	--	--	--	--	--
	11-15-88	1015	.01	.10	18	21	18	6.6	6.1	4.2
	03-07-89	1600	.21	.39	15	18	--	5.9	5.4	4.6
	05-30-89	1145	.05	.15	14	14	--	--	--	4.9

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+ NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total (mg/L as N)	Nitrogen, ammonia plus organic, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)
17	07-25-88	1230	0.03	1.9	0.02	1.5	0.50	0.93	0.75	0.71
	07-26-88	1300	.06	3.0	.07	.80	.50	1.2	1.1	1.1
	07-26-88	1700	.05	2.5	.04	.70	.50	1.1	.95	.92
	07-26-88	2100	.07	3.0	.05	.80	.80	1.2	1.0	.98
	07-27-88	0100	.07	3.1	.06	.60	.60	1.3	1.0	.99
	07-27-88	0500	.07	2.7	.07	.50	.40	1.3	1.1	1.0
	07-27-88	0900	.06	2.8	.06	.80	.30	1.3	1.2	1.0
	07-27-88	1300	.05	2.5	.06	.50	.50	1.3	1.1	1.0
	11-15-88	1130	.20	6.4	4.9	6.3	5.2	5.2	4.4	4.1
	03-07-89	1300	.01	1.0	11	11	11	3.3	3.3	3.3
18	07-25-88	1130	.22	1.3	.29	1.1	1.0	.79	.77	.73
	11-15-88	1230	.18	4.9	.23	1.2	1.2	4.6	4.6	4.0
	03-07-89	1445	.20	14	1.5	4.5	4.5	5.3	4.2	4.4
	05-30-89	1445	1.0	3.3	3.3	3.8	4.3	3.7	3.1	2.8
19	07-25-88	1200	--	--	--	1.7	1.2	.66	.58	--
	11-15-88	1300	.10	2.9	.05	1.0	1.1	1.1	1.0	.96
	03-07-89	1245	.02	2.5	4.2	5.3	5.3	1.7	1.6	1.3
	05-31-89	1100	.57	4.4	.47	--	--	1.0	.86	.88
21	07-26-88	1010	--	--	--	2.1	1.6	1.6	1.5	--
	09-06-88	1440	--	--	--	--	--	--	--	--
	11-14-88	1425	.10	8.5	<.01	2.1	1.4	3.6	3.3	3.1
	03-07-89	1145	.18	10	.80	.80	.80	3.9	3.5	3.5
	05-31-89	1245	.32	2.7	.55	1.6	1.6	3.6	3.1	2.5
23	07-25-88	1245	.02	2.3	.06	1.5	.50	.67	.52	.50
	08-08-88	1115	.04	2.5	.04	1.3	--	.74	--	.49
	08-31-88	1400	.01	1.9	.04	1.2	--	.62	--	.42
	10-12-88	1230	.05	1.9	.12	1.0	--	.55	--	.50
	11-07-88	1200	.03	2.0	.04	.50	--	.45	--	.35

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total (mg/L as N)	Nitrogen, ammonia plus organic, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)
23	11-15-88	1420	0.03	2.0	0.07	0.50	0.50	0.56	0.44	0.41
	12-06-88	1000	.03	2.6	.06	.60	--	.57	--	.48
	01-03-89	1130	.03	2.2	.53	1.1	--	.74	--	.65
	02-07-89	1000	.02	2.2	.61	1.0	--	.64	--	.56
	03-07-89	1400	.03	2.8	1.1	1.6	--	.79	--	.73
	03-08-89	1345	.05	2.5	.85	1.7	.70	.80	.62	.61
	04-04-89	0955	.02	1.6	.01	.40	--	.47	--	.35
	05-02-89	0830	.03	1.6	.04	.30	--	.45	--	.34
	05-31-89	1430	.12	2.6	.11	1.1	.60	.63	.54	.52
26	07-25-88	1030	.03	1.6	.09	2.0	.50	.66	.47	.43
	09-07-88	0840	--	--	--	--	--	--	--	--
	11-14-88	1530	.03	1.6	.21	.70	<.20	.54	.42	.37
	03-08-89	1500	.06	2.7	.83	2.2	2.2	.74	.57	.55
	05-31-89	1300	.06	2.2	.04	1.7	.70	.44	.35	.32
27	07-25-88	1325	--	--	--	2.4	2.4	1.0	.88	--
	11-15-88	1110	.02	.93	.07	2.4	1.2	.85	.59	.55
	03-07-89	1345	.05	3.2	.92	.20	.20	1.6	1.5	1.3
	05-30-89	1445	.12	.41	.24	1.5	1.2	.74	.55	.50
28	07-25-88	0600	.06	2.0	.06	.70	--	.50	.35	.33
	11-14-88	1445	<.01	.64	.04	.70	.20	.50	.41	.39
	03-07-89	0855	.04	1.6	.33	.40	.30	.54	.44	.37
	05-31-89	1215	.03	.59	.06	1.5	.80	.34	.25	.22
29	07-25-88	0630	.03	1.7	.02	1.1	.60	.35	.22	.22
	11-14-88	1200	.02	1.9	.03	.70	.70	.31	.25	.22
	03-07-89	1240	.03	2.0	.27	.80	.40	.39	.30	.28
	05-31-89	1100	.06	1.4	.04	.60	.40	.40	.26	.24
	07-25-88	1330	.06	1.2	.06	1.6	.50	1.5	.55	.50

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+ NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total (mg/L as N)	Nitrogen, ammonia plus organic, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)
29	07-25-88	1335	0.07	1.2	0.06	1.3	0.90	0.61	0.54	0.48
	07-25-88	1730	.06	1.2	.06	1.6	.90	.67	.54	.49
	07-25-88	2100	.05	1.2	.06	1.2	.90	.63	.53	.48
	07-26-88	0200	.05	1.3	.11	2.4	2.6	.61	.55	.48
	07-26-88	0510	.05	1.2	.10	1.3	1.3	.66	.53	.52
	07-26-88	0915	.06	1.2	.09	1.6	1.3	.76	.53	.50
	11-14-88	1045	.01	.23	.06	.70	1.2	.68	.61	.55
	03-08-89	0900	.06	1.7	1.1	3.1	3.1	.61	.48	.41
	05-30-89	1630	.09	.34	.28	.90	1.0	.92	.80	.77
31	07-25-88	1330	.03	3.0	.06	1.0	1.0	.70	.61	.59
	07-25-88	1700	.02	2.9	.05	1.2	.70	.67	.60	.59
	07-25-88	2100	.03	2.9	.05	1.6	1.2	.85	.60	.60
	07-26-88	0115	.03	2.8	.09	1.7	1.2	.77	.60	.55
	07-26-88	0950	.03	2.8	.05	.70	.90	.75	.60	.57
	07-27-88	0510	.02	2.2	.06	.30	.30	.68	.59	.54
	11-14-88	0900	.08	2.8	.06	1.2	.70	.74	.60	.56
	11-14-88	0905	.08	2.7	.09	1.6	1.0	.68	.57	.53
	11-14-88	1300	.08	2.7	.04	1.1	.60	.73	.58	.55
	11-14-88	1305	.08	2.8	.04	1.1	.50	.65	.58	.56
	11-14-88	1700	.08	2.7	.05	1.1	.70	.74	.59	.57
	11-14-88	1705	.08	2.7	.05	.90	.70	.64	.58	.55
	11-14-88	2100	.07	2.7	.06	1.3	1.1	.68	.58	.55
	11-14-88	2105	.07	2.7	.07	1.2	.50	.72	.58	.55
32	11-15-88	0100	.07	2.8	.08	1.0	.90	.72	.59	.55
	11-15-88	0105	.07	2.7	.08	1.4	.80	.72	.58	.54
	11-15-88	0500	.07	2.8	.12	1.0	1.0	.64	.59	.56
	11-15-88	0505	.07	3.0	.13	1.1	.90	.73	.60	.56
	11-15-88	0900	.07	2.7	.11	1.3	.50	.71	.57	.55

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+ NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total (mg/L as N)	Nitrogen, ammonia plus organic, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)
32	11-15-88	0905	0.07	2.8	0.11	1.1	0.90	0.67	0.58	0.55
	03-07-89	1000	.06	3.3	.61	1.8	1.5	.76	.59	.57
	03-07-89	1005	.06	3.2	.61	2.1	1.1	.75	.59	.56
	03-07-89	1400	.06	3.2	.63	1.8	1.8	.75	.60	.56
	03-07-89	1405	.06	3.3	.68	2.2	2.2	.70	.59	.57
	03-07-89	1800	.06	3.3	.64	1.9	1.2	.67	.61	.57
	03-07-89	1805	.06	3.4	.65	2.4	2.1	.75	.60	.54
	03-07-89	2200	.06	3.3	.67	2.1	1.9	.99	.72	.70
	03-07-89	2205	.06	3.2	.66	2.2	2.1	.97	.79	.77
	03-08-89	0200	.06	3.1	.90	2.3	1.9	.84	.67	.63
	03-08-89	0205	.06	3.1	.90	2.2	1.1	.84	.67	.63
	03-08-89	0600	.05	3.2	.81	2.2	1.9	.73	.65	.62
	03-08-89	0605	.05	3.4	.79	2.1	1.8	.80	.66	.61
	03-08-89	1000	.05	3.4	1.1	2.2	1.8	.82	.67	.63
	03-08-89	1005	.05	3.4	.72	2.0	2.0	.81	.74	.63
	05-30-89	1000	.06	1.4	.03	2.2	.50	.63	.36	.35
	05-30-89	1005	.08	1.7	.02	3.0	.60	.56	.41	.39
	05-30-89	1500	.07	1.5	.02	2.1	.50	.53	.38	.36
	05-30-89	1505	.07	1.5	.06	2.7	1.1	.53	.39	.36
	05-30-89	1800	.09	1.8	.02	2.2	.90	.52	.38	.37
	05-30-89	1810	.09	1.8	.03	2.5	1.2	.52	.38	.37
	05-30-89	2200	.09	1.9	.04	2.4	.50	.53	.39	.37
	05-30-89	2205	.09	1.9	.03	2.9	.60	.74	.41	.38
	05-31-89	0200	.09	1.9	.03	1.5	.50	.52	.40	.38
	05-31-89	0210	.09	1.9	.02	.50	.50	.62	.40	.37
	05-31-89	0600	.07	1.4	.02	.60	.30	.48	.37	.35
	05-31-89	0610	.09	1.9	.03	.70	.70	.53	.39	.38
	05-31-89	1000	.09	1.8	.04	.90	.80	.53	.40	.38
	05-31-89	1005	.09	1.9	.04	.70	.90	.52	.40	.38

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total (mg/L as N)	Nitrogen, ammonia plus organic, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)
34	07-25-88	0650	<0.01	1.6	0.06	1.6	1.1	0.33	0.21	0.20
	07-26-88	0915	<.01	1.4	.02	1.2	.60	.27	.19	.18
	07-26-88	1045	<.01	1.4	.06	1.3	.70	.25	.20	.17
	07-26-88	1445	<.01	1.3	.06	1.0	.50	.30	.20	.16
	07-26-88	1450	<.01	1.3	.05	1.0	.70	.28	.20	.17
	07-26-88	1845	<.01	1.3	.05	1.2	.90	.29	.20	.17
	07-26-88	2230	<.01	1.2	.04	1.0	.80	.30	.21	.19
	07-27-88	0230	<.01	1.3	.04	1.1	.70	.33	.20	.17
	07-27-88	0635	.01	1.3	.07	1.8	.70	.26	.20	.18
	11-14-88	1020	<.01	.35	.11	.80	.80	.22	.20	.18
	03-07-89	1520	.01	.41	.09	.30	.30	.19	.10	.10
	05-30-89	1345	<.01	<.10	.08	.80	.60	.48	.40	.37
35	07-25-88	0540	.11	3.0	.12	2.5	2.1	.74	.54	.49
	08-09-88	0915	.09	.75	.44	1.2	--	.56	--	.41
	08-30-88	1400	.11	2.0	.23	2.5	--	.76	--	.47
	10-18-88	1000	.06	2.6	.05	.60	--	.59	--	.48
	11-08-88	1200	.03	1.8	.09	1.6	--	.70	.50	.44
	11-14-88	1145	.03	1.8	.09	1.5	.60	.55	.43	.38
	12-06-88	0900	.04	2.0	.01	1.5	--	.52	--	.34
	01-04-89	1100	.03	2.7	.03	1.8	--	.53	.43	.38
	01-31-89	1100	.05	3.3	.02	2.3	--	.66	--	.45
	03-07-89	1435	.05	2.9	.57	.50	.20	.68	.56	.53
	03-28-89	1130	.08	3.4	.47	--	--	.65	.58	.57
	04-19-89	1130	.04	.53	.06	.40	--	.24	--	.10
	05-24-89	0940	<.01	<.10	.02	2.0	--	.47	.23	.21
	05-30-89	1245	.06	.27	.41	1.3	.90	.57	.38	.34

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total (mg/L as N)	Nitrogen, ammonia plus organic, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)
36	07-25-88	1230	0.06	2.9	0.02	0.60	0.50	0.62	0.57	0.53
	11-16-88	1050	.03	1.6	.06	1.4	.50	.60	.38	.35
	03-09-89	0940	.05	2.9	.47	1.6	1.3	.64	.51	.48
	05-31-89	1240	<.01	<.10	.02	1.0	.70	.42	.21	.21
37	07-26-88	0515	.05	1.4	.07	1.9	.60	.64	.37	.36
	11-15-88	1100	.02	.66	.04	.30	.20	.29	.24	.22
	03-08-89	0800	.03	1.1	.17	.70	.70	.30	.27	.28
	05-30-89	1200	.03	.32	.07	.40	.50	.31	.29	.27
38	07-26-88	0810	.02	1.4	.02	.80	.40	.62	.40	.39
	11-15-88	0940	.03	.78	.01	.30	.20	.22.	.20	.19
	03-08-89	0920	.02	1.4	.06	1.0	.80	.34	.24	.23
	05-30-89	1320	.03	.70	.07	.50	.40	.30	.27	.26
39	07-26-88	0630	.03	1.5	.04	2.0	.90	.61	.40	.39
	11-15-88	0815	.02	.48	.02	.40	.20	.22	.19	.18
	03-08-89	1100	.02	1.3	.07	.60	.40	.24	.20	.19
	05-31-89	1030	.03	.76	.09	.30	.50	.39	.35	.34
40	07-26-88	0630	.04	.82	.02	3.0	1.2	.59	.30	.29
	11-14-88	1655	<.01	.70	.03	.70	.30	.25	.24	.22
	03-08-89	1345	.02	1.6	.09	1.3	1.1	.31	.23	.22
	05-31-89	1200	.02	1.2	.08	.30	<.20	.46	.40	.38
41	07-26-88	0600	.06	2.8	.09	1.6	.90	.46	.35	.30
42	07-26-88	0545	.02	1.7	.03	.70	.60	.54	.47	.45
	11-14-88	1730	<.01	1.5	.01	.30	.30	.24	.23	.22
	03-08-89	1250	.01	1.4	.04	.60	.60	.27	.24	.25
	05-31-89	1130	.02	1.3	.07	.30	.40	.25	.23	.22

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total (mg/L as N)	Nitrogen, ammonia plus organic, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)
44	07-25-88	0845	0.02	0.19	<0.01	1.6	1.0	0.52	0.34	0.33
	07-26-88	1320	.04	.56	.04	2.4	.50	.51	.33	.29
	07-26-88	1710	.02	.32	.07	1.9	.70	.51	.27	.27
	07-26-88	2150	.03	.41	.07	1.3	.90	.31	.30	.26
	07-27-88	0120	.04	.53	.07	1.6	.40	.54	.31	.30
	07-27-88	0545	.02	.28	.03	1.8	.20	.60	.28	.22
	11-14-88	1555	<.01	1.0	.05	.80	.50	.37	.30	.27
	03-08-89	1225	.02	1.6	.27	.70	.60	.32	.27	.27
	05-31-89	1300	.04	1.4	.32	.50	.70	.45	.42	.40
46	07-25-88	0615	.05	2.7	.10	1.8	1.7	.29	.17	.16
	07-26-88	1355	.03	2.6	.03	1.2	.50	.34	.19	.16
	07-26-88	1750	.03	2.6	.06	.60	.60	.23	.18	.17
	07-26-88	2110	.03	2.5	.02	1.7	.60	.54	.16	.14
	07-27-88	0100	.02	2.6	.05	.80	.70	.21	.17	.17
	07-27-88	0510	.02	2.5	.04	2.7	.20	.34	.19	.15
	11-14-88	1515	<.01	.98	.03	.60	.30	.13	.09	.08
	03-08-89	1200	.02	1.6	.09	.80	.30	.11	.07	.07
	05-31-89	1330	.13	1.6	.16	.70	.80	.20	.15	.14
47	07-25-88	1150	.02	.42	.04	2.1	1.2	.61	.36	.32
	07-27-88	0920	<.01	<.10	.04	1.6	--	.59	--	.20
	08-09-88	1135	.04	.37	.13	1.6	--	.31	--	.21
	08-30-88	1100	.02	.61	.02	1.1	--	.45	--	.24
	10-18-88	1300	.02	1.3	.01	.40	--	.39	--	.33
	11-09-88	1200	.02	.97	.03	.40	--	.30	--	.22

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+ NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total (mg/L as N)	Nitrogen, ammonia plus organic, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)
47	11-14-88	1350	0.01	1.0	0.02	0.30	0.30	0.24	0.23	0.21
	12-06-88	1300	.02	1.5	<.01	.30	--	.25	--	.20
	01-10-89	1050	.03	2.0	.12	.50	--	.23	--	.19
	02-07-89	1115	.02	2.4	.18	.60	--	.27	--	.21
	03-07-89	1100	.20	1.8	.18	.60	--	.27	--	.25
	03-08-89	1040	.02	1.6	.20	.40	.20	.30	.24	.23
	04-05-89	0955	.03	.78	.03	.20	--	.25	--	.21
	05-01-89	1200	.02	.71	.05	<.20	--	.23	--	.17
	05-31-89	1420	.04	1.4	.06	.40	.60	.41	.36	.34
48	07-26-88	1215	.01	.15	.07	.60	.60	.13	.07	.06
	11-16-88	1400	<.01	<.10	.11	1.1	.80	.15	.08	.06
	03-09-89	0830	<.01	.64	.04	1.0	.80	.06	.03	.02
	05-31-89	1415	<.01	<.10	.03	.30	.60	.15	.08	.05
49	07-25-88	1400	.02	1.0	.03	.60	.50	.42	.32	.30
	11-16-88	1130	.02	.88	.23	.80	.80	.40	.31	.27
	11-16-88	1135	.02	.91	.23	1.1	.80	.40	.31	.28
	03-08-89	1630	.02	1.7	.12	.90	.90	.25	.18	.15
	03-08-89	1635	.02	1.7	.15	.90	.50	.26	.18	.16
	03-08-89	1715	.02	1.7	.13	1.2	.80	.28	.18	.17
	03-08-89	1720	.02	1.8	.14	1.0	1.0	.27	.19	.16
	05-31-89	1540	.03	.63	.03	<.20	<.20	.32	.27	.25
	05-31-89	1545	.03	.63	.02	<.20	.30	.33	.26	.25
	05-31-89	1550	.03	.63	.03	.60	.40	.31	.25	.25
	05-31-89	1555	.03	.63	.03	1.1	.50	.31	.25	.25

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+ NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total (mg/L as N)	Nitrogen, ammonia plus organic, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)
50	07-24-88	1320	0.04	0.48	0.04	1.2	5.0	0.28	0.15	0.14
	11-16-88	1340	<.01	<.10	.03	.90	.60	.27	.19	.13
	11-16-88	1350	<.01	.17	.05	.80	.40	.32	.20	.18
	11-16-88	1355	--	--	--	--	--	--	--	--
	03-09-89	1130	.01	.35	.04	.50	.40	.11	.06	.06
	05-31-89	1055	.02	.11	.03	.60	.70	.22	.18	.15
51	07-24-88	1445	<.01	<.10	.04	1.2	.80	.16	.06	.04
	11-16-88	0940	<.01	<.10	.10	.70	.50	.12	.06	.05
	03-09-89	1115	<.01	<.10	.04	.70	.70	.06	.01	<.01
	05-31-89	1730	.02	<.10	.12	1.0	.60	.10	.08	.06
52	07-24-88	1045	.04	.70	.07	.60	.70	.08	.07	.06
	11-15-88	1445	<.01	.83	.06	.60	.60	.12	.09	.07
	03-08-89	1430	.02	.77	.51	1.4	1.1	.21	.13	.11
	06-02-89	1030	.03	.80	.06	.60	.50	.09	.06	.06
55	07-27-88	0930	.01	<.10	.01	1.0	.80	.19	.10	.08
	11-15-88	1330	<.01	.20	.06	1.1	.90	.17	.05	.04
	03-08-89	1345	<.01	<.10	.47	.90	.70	.24	.20	.18
	05-31-89	0900	<.01	<.10	.04	.50	.60	.07	.03	.02
56	07-27-88	1120	<.01	<.10	.05	1.2	.30	.07	.03	.03
	11-15-88	1115	<.01	.11	.05	.60	.60	.12	.04	.03
	03-08-89	1100	.01	<.10	.03	.30	.30	.04	.01	.01
	06-01-89	1450	<.01	<.10	.02	.70	.50	.06	.02	.01
57	07-29-88	0815	<.01	.57	.02	.60	.60	.12	.12	.04
	03-08-89	1645	.01	.44	.04	.40	.20	.05	.03	.02
	06-01-89	1645	.02	.71	.07	.60	.60	.11	.08	.07

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total (mg/L as N)	Nitrogen, ammonia plus organic, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)
58	07-27-88	0910	0.03	0.41	0.08	0.30	<0.20	0.14	0.05	0.04
	11-15-88	1445	<.01	.30	.04	.90	.50	.15	.09	.08
	03-10-89	1110	.02	.44	.04	1.3	.90	.21	.07	.06
	05-30-89	1845	.10	.98	.16	.80	.90	.30	.14	.13
59	07-27-88	1010	.01	1.2	.06	.50	.50	.06	.04	.02
	11-15-88	1100	<.01	<.10	.03	.60	.40	.06	.02	.02
	03-08-89	1310	<.01	<.10	.07	.30	.80	.06	.03	..02
	06-01-89	1145	<.01	<.10	.05	.50	.40	.04	.02	.01
60	07-29-88	0535	.02	.15	.07	.80	.60	.11	.04	.03
	11-15-88	1240	<.01	<.10	.06	1.5	.70	.20	.09	.06
	03-09-89	1230	<.01	<.10	.02	.60	.30	.03	.01	.02
	06-01-89	1310	<.01	.14	.11	.70	.50	.07	.03	.04
61	07-28-88	1745	<.01	<.10	.02	1.3	.30	.07	.02	<.01
	07-29-88	0415	<.01	<.10	.03	.90	.70	.12	.01	<.01
	11-15-88	1030	<.01	.26	.03	.90	<.20	.13	.09	.08
	03-08-89	1030	.02	.67	.20	1.2	1.2	.32	.24	.20
	05-31-89	1710	.08	.92	.07	.40	.60	.28	.13	.13
62	07-28-88	1815	<.01	<.10	.02	.40	.30	.16	.02	.01
	07-29-88	0530	<.01	<.10	.02	.80	.80	.15	.02	<.01
	07-29-88	0535	<.01	.25	.02	.70	.70	.10	.02	<.01
	11-15-88	0755	<.01	.29	.03	.70	.40	.13	.09	.08
	03-07-89	1510	.02	.39	.12	2.0	1.3	.19	.09	.07
	06-01-89	1815	.05	.79	.05	.50	.60	.15	.13	.11
63	07-29-88	0910	<.01	<.10	.02	.90	.30	.07	.02	<.01
	11-14-88	1000	<.01	<.10	.08	.30	.30	.06	.01	.02
	03-07-89	1010	<.01	<.10	.04	1.2	.60	.02	.01	.01
	06-01-89	1300	<.01	<.10	.04	.70	.60	.06	.03	.02

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total (mg/L as N)	Nitrogen, ammonia plus organic, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)
64	07-28-88	1230	<0.01	<0.10	0.02	0.80	<0.20	0.09	0.03	0.02
	07-28-88	1235	<.01	<.10	.02	1.0	.40	.09	.03	.02
	07-28-88	1830	<.01	<.10	.03	.70	.30	.10	.03	.02
	07-29-88	0005	<.01	.10	.03	.30	.50	.09	.04	.02
	07-29-88	0435	<.01	.11	<.01	.70	.60	.08	.04	.03
	11-14-88	1530	<.01	.31	.03	.70	.40	.07	.02	<.01
	03-07-89	1230	<.01	.19	.02	1.6	.60	.07	.02	.01
	03-07-89	1235	<.01	.20	.03	1.6	1.6	.06	.02	.01
	03-07-89	1330	<.01	.23	.03	3.7	1.7	.05	.02	.02
	03-07-89	1335	<.01	.19	.02	1.0	1.0	.05	.02	<.01
	05-31-89	1430	<.01	<.10	.03	.50	.40	.11	.05	.04
	05-31-89	1435	<.01	<.10	.03	.30	.50	.10	.06	.04
71	07-27-88	0610	<.01	<.10	.11	1.3	.40	.21	.09	.08
	11-17-88	1230	.02	.44	.09	1.0	.80	.54	.49	.41
	03-09-89	1100	.03	1.3	2.5	3.3	3.3	1.0	.87	.81
	06-01-89	1445	.02	<.10	.19	.70	.90	.60	.53	.49
72	07-27-88	0745	<.01	<.10	.03	.60	.50	1.2	.04	.03
	08-31-88	1025	--	<.01	.04	.80	--	.20	.07	--
	10-05-88	1000	--	<.01	.02	.40	--	.10	.04	--
	11-09-88	1020	--	<.01	<.01	--	--	.17	.10	--
	11-17-88	1020	<.01	<.10	.08	.80	.70	.10	.15	.13
	12-21-88	1010	--	.21	.03	.40	--	.11	.10	--
	01-25-89	1220	--	--	.08	--	--	.10	.06	--
	02-15-89	1035	--	.29	<.01	--	--	.20	.02	--
	03-09-89	1230	<.01	.12	.03	.60	.60	.14	.08	.07
	03-15-89	1135	--	.05	.05	--	--	.05	<.01	--
	04-19-89	0925	--	.11	.11	--	--	.13	<.01	--
	05-17-89	1320	--	<.01	<.01	--	--	.23	.06	--
	06-02-89	0945	<.01	<.10	.03	1.6	.80	.12	.08	.06

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+ NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total (mg/L as N)	Nitrogen, ammonia plus organic, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)
73	07-27-88	0810	0.01	0.18	0.17	0.80	0.50	1.8	0.12	0.10
	11-17-88	1300	.05	.75	1.5	3.0	2.6	1.3	.98	.95
	11-17-88	1305	.05	.70	1.5	3.1	2.6	1.2	1.0	.96
	11-17-88	1345	.05	.69	1.4	3.0	2.5	1.2	1.0	.95
	11-17-88	1350	.05	.69	1.4	3.1	2.5	1.2	1.0	.94
	03-09-89	1400	.06	.87	1.1	2.0	1.5	.87	.73	.66
	03-09-89	1405	.06	.86	.99	1.2	1.2	.87	.75	.67
	03-09-89	1440	.06	.85	1.0	1.6	--	.87	.73	.67
	03-09-89	1445	.06	.85	.98	2.2	1.4	.82	.73	.67
	06-02-89	1100	.06	.15	.15	1.0	.90	.57	.58	.51
	06-02-89	1105	.06	.15	.15	.80	.90	.61	.54	.52
74	07-29-88	1020	<.01	<.10	.67	1.3	1.3	.32	.03	.06
	08-10-88	1300	--	<.01	.71	1.1	--	.79	.10	--
	08-31-88	1320	--	<.01	.06	.70	--	.09	.06	--
	10-05-88	1300	--	.14	<.01	.40	--	.05	<.01	--
	11-09-88	1310	--	.17	.03	--	--	.03	.03	--
	11-15-88	1430	<.01	.17	.05	.60	.60	.05	.02	.02
	12-21-88	1315	--	.39	.06	.50	--	.02	<.01	--
	01-25-89	0845	--	<.01	.12	--	--	.07	<.01	--
	02-15-89	1335	--	<.01	.22	--	--	.16	.06	--
	03-07-89	0800	<.01	<.10	.08	.60	.60	.03	.01	.02
	03-15-89	0845	--	.10	.09	--	--	<.01	<.01	--
	04-19-89	1235	--	<.01	.04	--	--	<.01	<.01	--
	05-17-89	1045	--	.02	.13	--	--	.06	.09	--
	05-31-89	1630	.01	.25	.15	.70	.80	.05	.03	.01

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+ NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total (mg/L as N)	Nitrogen, ammonia plus organic, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)
76	07-27-88	1805	<0.01	<.010	0.03	1.3	0.60	0.20	0.03	0.01
	07-28-88	0025	<.01	<.10	.03	1.4	.40	.10	.04	.01
	07-28-88	0615	<.01	<.10	.03	1.4	<.20	.26	.03	.01
	07-28-88	1215	<.01	<.10	.01	1.0	.40	.20	.03	.01
	07-28-88	1220	<.01	<.10	.01	1.3	.20	.24	.02	.01
	11-14-88	0600	.02	.57	.08	.80	.60	.25	.19	.16
	11-14-88	0610	.02	.56	.08	.80	.60	.24	.19	.16
	11-14-88	1000	.03	.54	.10	.90	.70	.28	.22	.20
	11-14-88	1005	.03	.54	.10	.90	.70	.29	.20	.19
	11-14-88	1400	.03	.54	.19	.80	.60	.28	.21	.19
	11-14-88	1410	.03	.58	.20	1.0	.80	.28	.20	.19
	11-14-88	1800	.03	.49	.14	1.0	.70	.20	.19	.17
	11-14-88	1805	.03	.50	.14	.80	.60	.26	.19	.17
	11-14-88	2200	.03	.47	.10	.80	.70	.25	.18	.16
	11-14-88	2205	.03	.46	.10	1.0	.60	.23	.18	.16
	11-15-88	0200	.02	.42	.04	.70	.70	.20	.14	.13
	11-15-88	0205	.02	.42	.05	.80	.80	.19	.13	.13
	11-15-88	0605	.03	.50	.06	.90	.60	.24	.22	.19
	03-07-89	0615	.04	.61	.38	1.0	.80	.35	.25	.21
	03-07-89	1010	.03	.56	.46	1.1	1.0	.32	.25	.22
	03-07-89	1015	.03	.57	.47	1.3	.90	.32	.26	.21
	03-07-89	1400	.03	.52	.56	1.2	1.0	.31	.22	.19
	03-07-89	1405	.03	.52	.37	1.1	1.0	.29	.22	.19
	03-07-89	1410	.03	.57	.57	1.3	.70	.29	.22	.19
	03-07-89	1800	.03	.53	.59	1.1	1.1	.29	.22	.19
	03-07-89	1805	.03	.53	.61	1.4	1.0	.30	.23	.20
	03-07-89	2200	.03	.55	.57	1.5	1.0	.32	.24	.20
	03-07-89	2205	.03	.56	.54	.80	.80	.35	.23	.21
	03-08-89	0200	.03	.54	.36	1.2	.70	.27	.20	.17

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+ NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total (mg/L as N)	Nitrogen, ammonia plus organic, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)
76	03-08-89	0205	0.03	0.54	0.37	1.1	1.0	0.27	0.20	0.17
	03-08-89	0600	.04	.62	.38	1.8	.80	.33	.22	.19
	03-08-89	0605	.04	.66	.42	1.4	1.4	.33	.24	.19
	05-31-89	1845	.19	.97	.71	1.2	1.2	.33	.28	.25
77	07-27-88	1825	<.01	<.10	.02	1.2	.40	.15	<.01	.01
	07-28-88	0605	<.01	<.10	.01	1.8	.30	.14	.03	.01
	11-14-88	1030	.02	.58	.12	.70	.70	.20	.14	.13
	03-07-89	1345	.03	.48	.51	1.2	1.0	.27	.18	.16
	06-03-89	0935	.15	.87	.13	.50	.60	.26	.15	.14
78	07-28-88	0515	.01	<.10	.04	1.2	1.0	.26	.08	.06
	11-14-88	1440	.03	.84	.11	.90	.20	.31	.30	.31
	03-07-89	1030	.07	1.1	.47	1.3	1.1	.41	.30	.26
	06-01-89	1800	.20	.98	.41	1.1	1.0	.70	.61	.43
79	07-29-88	0645	<.01	.21	.04	.50	.40	.09	.03	.01
	03-07-89	1600	<.01	<.10	.04	.60	.50	.05	.01	<.01
	05-31-89	0930	<.01	<.10	.05	.80	.80	.10	.05	.02
83	07-29-88	0530	<.01	.11	.03	1.0	.80	.04	<.01	.02
	08-10-88	1500	--	<.01	.14	.60	--	.44	<.01	--
	08-31-88	1500	--	<.01	.04	1.1	--	.16	.05	--
	10-05-88	1500	--	.18	.04	.60	--	.04	<.01	--
	11-09-88	1555	--	.04	<.01	--	--	.07	.03	--
	11-16-88	1520	--	--	--	--	--	--	--	--
	12-21-88	1515	--	.04	.03	.50	--	.03	<.01	--
	01-25-89	1605	--	.64	.25	--	--	--	.02	--
	02-15-89	1535	--	.09	.04	--	--	.17	.20	--
	03-07-89	1300	<.01	.15	.04	.60	.50	.04	.01	.01

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+ NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total (mg/L as N)	Nitrogen, ammonia plus organic, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)
83	03-15-89	1435	--	0.11	0.05	--	--	0.12	<0.01	--
	04-19-89	1450	--	<.01	.07	--	--	<.01	<.01	--
	05-17-89	0755	--	<.01	<.01	--	--	.22	.02	--
	05-31-89	1045	<0.01	<.10	.03	0.40	0.60	.04	.02	0.01
86	07-28-88	0615	<.01	<.10	.16	1.2	.90	.13	.06	.03
	07-28-88	0620	<.01	<.10	.16	1.3	.80	.13	.05	.02
	07-28-88	1200	<.01	<.10	.03	1.8	.80	.25	.04	.01
	03-08-89	1200	<.01	<.10	.01	.80	.30	.07	.03	.03
	06-02-89	1250	.02	<.10	.08	.70	.90	.06	.03	.02
87	07-28-88	0445	<.01	<.10	.03	1.0	1.0	.13	.01	.03
	07-28-88	1500	<.01	<.10	.04	1.0	.80	.16	.05	.04
	11-14-88	1345	<.01	<.10	.03	.90	.60	.14	.05	.04
	11-14-88	1350	<.01	<.10	.03	1.3	.60	.15	.04	.03
	03-08-89	1415	<.01	<.10	.01	.60	.50	.09	.03	.03
	06-02-89	1530	.12	1.5	.35	1.7	1.5	.19	.08	.08
88	07-27-88	1815	<.01	<.10	.03	.90	.50	.16	.04	.03
	07-27-88	2400	<.01	<.10	.01	1.4	.70	.20	.02	.03
	07-28-88	0610	<.01	<.10	.02	.50	.40	.18	.06	.04
	07-28-88	1220	.01	<.10	.04	1.4	<.20	.20	.06	.04
	07-28-88	1225	.01	<.10	.03	1.1	.70	.15	.06	.04
	11-16-88	1510	.03	.71	.05	.90	.60	.35	.30	.26
	11-16-88	1515	.03	.71	.13	.90	.50	.35	.30	.27
	03-07-89	1550	.04	1.1	.36	1.2	1.2	.35	.23	.20
	03-07-89	1555	.04	1.0	.34	1.4	1.2	.38	.25	.20
	03-07-89	1630	.04	--	.36	1.1	1.3	.36	.27	.22
	03-07-89	1635	.04	1.1	.36	1.3	1.0	.39	.28	.22
	05-30-89	1905	.12	.74	.03	.60	.30	.53	.23	.18
	05-30-89	1910	.12	.73	.03	.70	.60	.29	.22	.18

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+ NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total (mg/L as N)	Nitrogen, ammonia plus organic, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)
90	07-29-88	0510	0.72	8.8	--	14	--	8.7	8.2	6.7
	07-29-88	0515	.67	8.2	5.1	14	7.7	8.5	7.7	6.3
	11-14-88	1210	.68	--	--	7.5	6.3	6.9	6.3	5.1
	11-14-88	1215	.69	5.3	4.6	7.2	7.0	6.8	6.2	4.9
	11-14-88	1315	.67	6.8	4.4	6.9	6.4	7.2	6.8	5.3
	11-14-88	1320	.66	6.5	4.2	7.5	6.8	7.5	6.7	5.4
	03-07-89	0925	.45	4.5	11	3.6	13	7.3	6.7	5.4
	06-02-89	1440	.62	5.3	2.0	5.9	5.0	3.4	3.7	3.2
91	07-29-88	0615	.06	.59	.77	.60	1.0	.55	.34	.50
	11-14-88	1000	.04	1.4	.48	.80	.80	.41	.30	.27
	03-07-89	1320	.04	.98	.33	1.4	1.2	.43	.22	.20
	06-02-89	1145	.05	.25	.71	1.7	1.6	.53	.36	.33

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Carbon, organic, total (mg/L as C)	Chlorophyll-*a* phyto-plankton, chromo-fluorometer (µg/L)	Chlorophyll-*b* phyto-plankton, chromo-fluorometer (µg/L)	Sediment, suspended (mg/L)
1	07-27-88	1300	15	56	9.6	121
	11-15-88	1205	10	44	1.0	119
	03-08-89	1000	5.2	33	12	18
	06-01-89	1010	9.9	110	3.8	213
2	07-27-88	1150	5.9	12	3.4	137
	11-15-88	1050	5.5	4.9	.1	9
	03-08-89	1140	2.8	2.7	.6	21
	06-01-89	0830	5.6	15	1.8	34
5	07-24-88	1020	8.6	27	2.8	210
	11-16-88	0850	7.7	30	.6	45
	03-09-89	0930	8.2	51	23	20
	06-02-89	0820	7.6	78	3.5	187
6	07-26-88	0730	16	45	12	68
	11-14-88	1200	14	16	1.0	62
	03-08-89	1015	17	1.1	.6	86
	05-31-89	1445	15	63	21	53
9	07-26-88	0945	9.0	12	5.0	34
	07-26-88	2150	--	--	--	--
	07-27-88	0550	--	--	--	--
	11-15-88	0815	25	11	.9	33
	03-07-89	1015	54	9.9	7.6	107
	05-31-89	0930	26	71	12	39
10	07-26-88	0900	11	24	5.6	163
	07-26-88	1300	--	--	--	--
	07-26-88	1700	--	--	--	--
	07-26-88	2100	--	--	--	--
	07-27-88	0100	--	--	--	--

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Carbon, organic, total (mg/L as C)	Chlorophyll-*a* phyto-plankton, chromo-fluorometer (µg/L)	Chlorophyll-*b* phyto-plankton, chromo-fluorometer (µg/L)	Sediment, suspended (mg/L)
10	07-27-88	0500	--	--	--	--
	07-27-88	0900	--	--	--	--
	11-14-88	1345	20	12	1.0	52
	03-07-89	1000	24	1.7	.8	44
	05-31-89	1330	11	1.5	.2	10
11	07-26-88	0845	22	39	9.7	251
	11-14-88	1050	3.5	4.9	.3	70
	03-08-89	1215	14	2.2	.3	98
	05-31-89	1600	7.1	45	4.4	145
12	07-26-88	1000	29	68	21	222
	07-26-88	1005	--	--	--	--
	07-26-88	1400	--	--	--	--
	07-26-88	1800	--	--	--	--
	07-26-88	2200	--	--	--	--
	07-27-88	0200	--	--	--	--
	07-27-88	0600	--	--	--	--
	11-14-88	0845	6.6	100	3.0	56
	03-08-89	1130	9.9	1.6	.3	73
16	07-26-88	0630	9.2	1.6	<.3	18
	07-26-88	1800	--	--	--	--
	07-27-88	1215	--	--	--	--
	09-06-88	1145	--	--	--	--
	11-15-88	1015	18	4.6	.7	2
	03-07-89	1600	18	1.3	1.8	21
	05-30-89	1145	15	17	4.5	3
17	07-25-88	1230	9.3	50	14	194
	07-26-88	1300	--	--	--	--
	07-26-88	1700	--	--	--	--
	07-26-88	2100	--	--	--	--
	07-27-88	0100	--	--	--	--

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Carbon, organic, total (mg/L as C)	Chlorophyll-*a* phyto-plankton, chromo-fluorometer (μg/L)	Chlorophyll-*b* phyto-plankton, chromo-fluorometer (μg/L)	Sediment, suspended (mg/L)
17	07-27-88	0500	--	--	--	--
	07-27-88	0900	--	--	--	--
	07-27-88	1300	--	--	--	--
	11-15-88	1130	13	2.5	0.2	65
	03-07-89	1300	12	1.4	.7	48
18	07-25-88	1130	13	7.4	1.6	175
	11-15-88	1230	9.2	5.4	.3	42
	03-07-89	1445	9.5	.8	<.5	183
	05-30-89	1445	13	57	17	87
19	07-25-88	1200	14	43	12	308
	11-15-88	1300	5.3	8.9	.3	29
	03-07-89	1245	7.5	.7	.4	24
	05-31-89	1100	25	29	3.1	525
21	07-26-88	1010	8.3	14	3.1	66
	09-06-88	1440	--	--	--	--
	11-14-88	1425	9.5	5.5	<.1	21
	03-07-89	1145	10	7.4	1.1	76
	05-31-89	1245	12	10	1.0	60
23	07-25-88	1245	18	31	7.0	211
	08-08-88	1115	--	--	--	179
	08-31-88	1400	--	--	--	74
	10-12-88	1230	--	--	--	106
	11-07-88	1200	--	--	--	14
	11-15-88	1420	4.0	5.3	.1	--
	12-06-88	1000	--	--	--	9
	01-03-89	1130	--	--	--	12
	02-07-89	1000	--	--	--	12
	03-07-89	1400	--	--	--	41

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Carbon, organic, total (mg/L as C)	Chlorophyll-*a* phyto-plankton, chromo-fluorometer (µg/L)	Chlorophyll-*b* phyto-plankton, chromo-fluorometer (µg/L)	Sediment, suspended (mg/L)
23	03-08-89	1345	8.4	2.1	0.8	84
	04-04-89	0955	--	--	--	120
	05-02-89	0830	--	--	--	43
	05-31-89	1430	11	29	4.3	258
26	07-25-88	1030	13	110	9.4	205
	09-07-88	0840	--	--	--	--
	11-14-88	1530	4.8	20	.4	21
	03-08-89	1500	11	.5	.4	72
	05-31-89	1300	13	43	3.7	413
27	07-25-88	1325	17	19	5.4	201
	11-15-88	1110	11	29	3.5	75
	03-07-89	1345	22	3.1	.6	53
	05-30-89	1445	12	50	11	128
28	07-25-88	0600	18	12	2.5	353
	11-14-88	1445	7.3	.9	<.1	30
	03-07-89	0855	10	.9	<.2	32
	05-31-89	1215	9.9	71	6.2	155
29	07-25-88	0630	9.9	52	7.0	196
	11-14-88	1200	3.6	1.4	<.1	52
	03-07-89	1240	7.5	.6	<.2	29
	05-31-89	1100	8.0	34	3.2	122
31	07-25-88	1330	--	--	--	--
	07-25-88	1335	--	--	--	--
	07-25-88	1730	--	--	--	--
	07-25-88	2100	--	--	--	--
	07-26-88	0200	--	--	--	--
	07-26-88	0510	12	14	3.6	58
	07-26-88	0915	--	--	--	--
	11-14-88	1045	8.9	.7	<.1	2
	03-08-89	0900	17	1.7	<.2	10
	05-30-89	1630	8.3	14	6.5	6

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Carbon, organic, total (mg/L as C)	Chlorophyll-*a* phyto-plankton, chromo-fluorometer (µg/L)	Chlorophyll-*b* phyto-plankton, chromo-fluorometer (µg/L)	Sediment, suspended (mg/L)
32	07-25-88	1330	12	47	9.2	262
	07-25-88	1700	12	39	8.8	242
	07-25-88	2100	12	36	8.0	215
	07-26-88	0115	13	--	--	210
	07-26-88	0950	12	--	--	253
	07-27-88	0510	9.4	80	13	158
	11-14-88	0900	5.7	25	1.0	29
	11-14-88	0905	--	--	--	--
	11-14-88	1300	--	--	--	--
	11-14-88	1305	--	--	--	--
	11-14-88	1700	--	--	--	--
	11-14-88	1705	--	--	--	--
	11-14-88	2100	--	--	--	--
	11-14-88	2105	--	--	--	--
	11-15-88	0100	--	--	--	--
	11-15-88	0105	--	--	--	--
	11-15-88	0500	--	--	--	--
	11-15-88	0505	--	--	--	--
	11-15-88	0900	--	--	--	--
	11-15-88	0905	--	--	--	--
	03-07-89	1000	11	1.0	.5	59
	03-07-89	1005	--	--	--	--
	03-07-89	1400	--	--	--	--
	03-07-89	1405	--	--	--	--
	03-07-89	1800	--	--	--	--
	03-07-89	1805	--	--	--	--
	03-07-89	2200	--	--	--	--
	03-07-89	2205	--	--	--	--
	03-08-89	0200	--	--	--	--

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Carbon, organic, total (mg/L as C)	Chlorophyll-*a* phyto-plankton, chromo-fluorometer (μg/L)	Chlorophyll-*b* phyto-plankton, chromo-fluorometer (μg/L)	Sediment, suspended (mg/L)
32	03-08-89	0205	--	--	--	--
	03-08-89	0600	--	--	--	--
	03-08-89	0605	--	--	--	--
	03-08-89	1000	--	--	--	--
	03-08-89	1005	--	--	--	--
	05-30-89	1000	13	77	9.1	101
	05-30-89	1005	--	--	--	--
	05-30-89	1500	--	--	--	--
	05-30-89	1505	--	--	--	--
	05-30-89	1800	--	--	--	--
	05-30-89	1810	--	--	--	--
	05-30-89	2200	--	--	--	--
	05-30-89	2205	--	--	--	--
	05-31-89	0200	--	--	--	--
	05-31-89	0210	--	--	--	--
	05-31-89	0600	--	--	--	--
	05-31-89	0610	--	--	--	--
	05-31-89	1000	--	--	--	--
	05-31-89	1005	--	--	--	--
34	07-25-88	0650	10	7.1	.6	123
	07-26-88	0915	--	--	--	--
	07-26-88	1045	--	--	--	--
	07-26-88	1445	--	--	--	--
	07-26-88	1450	--	--	--	--
	07-26-88	1845	--	--	--	--
	07-26-88	2230	--	--	--	--
	07-27-88	0230	--	--	--	--
	07-27-88	0635	--	--	--	--
	11-14-88	1020	6.0	5.3	.3	111
	03-07-89	1520	5.5	2.9	.6	54
	05-30-89	1345	6.7	16	2.1	145

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Carbon, organic, total (mg/L as C)	Chlorophyll-*a* phyto-plankton, chromo-fluorometer (μg/L)	Chlorophyll-*b* phyto-plankton, chromo-fluorometer (μg/L)	Sediment, suspended (mg/L)
35	07-25-88	0540	10	15	3.1	96
	08-09-88	0915	--	--	--	30
	08-30-88	1400	--	--	--	105
	10-18-88	1000	--	--	--	69
	11-08-88	1200	--	--	--	32
	11-14-88	1145	7.9	62	1.1	23
	12-06-88	0900	--	--	--	19
	01-04-89	1100	--	--	--	16
	01-31-89	1100	--	--	--	23
	03-07-89	1435	8.9	1.2	.6	40
	03-28-89	1130	--	--	--	46
	04-19-89	1130	--	--	--	51
	05-24-89	0940	--	--	--	36
	05-30-89	1245	10	26	4.1	22
36	07-25-88	1230	8.5	20	3.1	161
	11-16-88	1050	8.3	44	1.7	41
	03-09-89	0940	8.5	2.2	.9	48
	05-31-89	1240	7.7	72	8.1	19
37	07-26-88	0515	10	18	4.7	224
	11-15-88	1100	2.1	6.2	.1	2
	03-08-89	0800	2.3	.8	.5	6
	05-30-89	1200	5.6	.5	.2	1
38	07-26-88	0810	9.7	32	7.6	170
	11-15-88	0940	2.4	3.3	<.1	3
	03-08-89	0920	3.6	1.6	.4	88
	05-30-89	1320	3.4	1.4	.3	61
39	07-26-88	0630	16	70	19	294
	11-15-88	0815	2.9	2.7	<.1	25
	03-08-89	1100	1.7	.7	<.2	32
	05-31-89	1030	7.0	6.2	.6	201

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Carbon, organic, total (mg/L as C)	Chlorophyll-*a* phyto-plankton, chromo-fluorometer (μg/L)	Chlorophyll-*b* phyto-plankton, chromo-fluorometer (μg/L)	Sediment, suspended (mg/L)
40	07-26-88	0630	16	120	30	149
	11-14-88	1655	2.5	3.0	<.1	13
	03-08-89	1345	3.7	.9	.5	77
	05-31-89	1200	8.1	6.4	.7	232
41	07-26-88	0600	18	19	4.1	700
42	07-26-88	0545	5.2	2.9	.4	65
	11-14-88	1730	1.1	1.1	<.1	6
	03-08-89	1250	1.0	.5	.4	7
	05-31-89	1130	1.5	1.0	.3	10
44	07-25-88	0845	13	89	24	122
	07-26-88	1320	--	--	--	--
	07-26-88	1710	--	--	--	--
	07-26-88	2150	--	--	--	--
	07-27-88	0120	--	--	--	--
	07-27-88	0545	--	--	--	--
	11-14-88	1555	2.9	1.8	<.1	14
	03-08-89	1225	2.9	.7	.4	28
	05-31-89	1300	5.2	9.6	.9	113
46	07-25-88	0615	19	5.1	.9	728
	07-26-88	1355	--	--	--	--
	07-26-88	1750	--	--	--	--
	07-26-88	2110	--	--	--	--
	07-27-88	0100	--	--	--	--
	07-27-88	0510	--	--	--	--
	11-14-88	1515	3.4	1.8	<.1	94
	03-08-89	1200	4.7	.6	<.2	48
	05-31-89	1330	7.0	33	5.0	176

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Carbon, organic, total (mg/L as C)	Chlorophyll-*a* phyto-plankton, chromo-fluorometer (μg/L)	Chlorophyll-*b* phyto-plankton, chromo-fluorometer (μg/L)	Sediment, suspended (mg/L)
48	07-25-88	1150	12	98	20	197
	07-27-88	0920	--	--	--	134
	08-09-88	1135	--	--	--	76
	08-30-88	1100	--	--	--	57
	10-18-88	1300	--	--	--	120
	11-09-88	1200	--	--	--	20
	11-14-88	1350	2.8	2.7	.1	16
	12-06-88	1300	--	--	--	21
	01-10-89	1050	--	--	--	18
	02-07-89	1115	--	--	--	46
	03-07-89	1100	--	--	--	33
	03-08-89	1040	2.9	.7	<.2	47
	04-05-89	0955	--	--	--	79
	05-01-89	1200	--	--	--	51
	05-31-89	1420	5.6	17	2.1	135
	07-26-88	1215	8.7	13	2.4	--
	11-16-88	1400	8.0	1.6	.1	58
	03-09-89	0830	4.1	2.7	.5	27
	05-31-89	1415	7.8	26	6.3	59
49	07-25-88	1400	14	61	15	222
	11-16-88	1130	5.0	5.7	.1	32
	11-16-88	1135	4.3	<.1	.2	40
	03-08-89	1630	3.9	1.0	<.3	69
	03-08-89	1635	4.0	1.1	<.3	65
	03-08-89	1715	4.5	1.2	<.3	52
	03-08-89	1720	3.9	1.1	.4	56
	05-31-89	1540	8.2	48	6.2	122
	05-31-89	1545	7.2	57	6.9	121
	05-31-89	1550	7.6	58	8.6	118
	05-31-89	1555	5.6	53	7.6	122

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Carbon, organic, total (mg/L as C)	Chlorophyll-*a* phyto-plankton, chromo-fluorometer (µg/L)	Chlorophyll-*b* phyto-plankton, chromo-fluorometer (µg/L)	Sediment, suspended (mg/L)
50	07-24-88	1320	9.4	58	7.1	120
	11-16-88	1340	7.7	1.5	.1	93
	11-16-88	1350	7.5	1.6	<.1	82
	11-16-88	1355	--	--	--	--
	03-09-89	1130	4.0	1.3	.3	60
	05-31-89	1055	8.7	46	8.7	119
51	07-24-88	1445	11	40	5.0	47
	11-16-88	0940	5.2	5.3	.4	63
	03-09-89	1115	3.9	8.3	2.7	25
	05-31-89	1730	9.4	4.3	.6	12
52	07-24-88	1045	13	3.3	.3	28
	11-15-88	1445	5.0	3.6	<.1	22
	03-08-89	1430	4.4	2.6	.2	7
	06-02-89	1030	5.1	8.9	1.1	42
55	07-27-88	0930	8.0	22	3.9	48
	11-15-88	1330	8.5	11	.3	144
	03-08-89	1345	4.8	.8	.7	28
	05-31-89	0900	7.5	18	3.8	76
56	07-27-88	1120	5.3	11	2.1	136
	11-15-88	1115	8.0	4.5	.2	74
	03-08-89	1100	3.6	.9	<.3	46
	06-01-89	1450	9.4	52	11	74
57	07-29-88	0815	32	6.6	1.4	68
	03-08-89	1645	2.5	.8	<.3	34
	06-01-89	1645	2.7	8.1	1.5	29
58	07-27-88	0910	6.9	34	3.7	59
	11-15-88	1445	6.4	16	.4	76
	03-10-89	1110	8.0	16	21	--
	05-30-89	1845	15	32	4.6	436

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Carbon, organic, total (mg/L as C)	Chlorophyll-*a* phyto-plankton, chromo-fluorometer (µg/L)	Chlorophyll-*b* phyto-plankton, chromo-fluorometer (µg/L)	Sediment, suspended (mg/L)
59	07-27-88	1010	4.0	11	2.1	109
	11-15-88	1100	3.7	2.0	.1	21
	03-08-89	1310	2.6	1.3	.7	69
	06-01-89	1145	5.1	9.8	1.1	65
60	07-29-88	0535	32	23	3.6	179
	11-15-88	1240	8.5	9.3	<.1	35
	03-09-89	1230	3.0	3.2	1.0	20
	06-01-89	1310	7.5	23	3.8	79
61	07-28-88	1745	--	--	--	--
	07-29-88	0415	8.6	44	4.4	109
	11-15-88	1030	6.5	12	.3	139
	03-08-89	1030	5.2	3.7	2.3	47
	05-31-89	1710	12	61	7.7	122
62	07-28-88	1815	--	--	--	--
	07-29-88	0530	10	27	4.1	198
	07-29-88	0535	8.9	38	5.7	199
	11-15-88	0755	5.6	6.8	.3	41
	03-07-89	1510	6.9	4.9	.7	94
	06-01-89	1815	11	65	10	35
63	07-29-88	0910	4.9	23	9.4	48
	11-14-88	1000	3.7	.5	<.1	68
	03-07-89	1010	3.2	2.9	.1	28
	06-01-89	1300	6.9	18	1.8	52
64	07-28-88	1230	5.7	13	5.8	66
	07-28-88	1235	5.7	12	4.7	98
	07-28-88	1830	--	--	--	--
	07-29-88	0005	--	--	--	--
	07-29-88	0435	--	--	--	--

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Carbon, organic, total (mg/L as C)	Chlorophyll-*a* phyto-plankton, chromo-fluorometer (µg/L)	Chlorophyll-*b* phyto-plankton, chromo-fluorometer (µg/L)	Sediment, suspended (mg/L)
64	11-14-88	1530	4.2	9.3	0.3	19
	03-07-89	1230	5.9	4.2	.6	37
	03-07-89	1235	4.0	3.8	.6	46
	03-07-89	1330	3.1	2.7	.5	37
	03-07-89	1335	3.0	2.4	.3	62
	05-31-89	1430	7.8	32	6.1	32
	05-31-89	1435	7.6	31	5.3	30
71	07-27-88	0610	6.0	15	2.1	130
	11-17-88	1230	6.3	1.1	<.1	24
	03-09-89	1100	6.7	2.2	.5	3
	06-01-89	1445	9.1	42	6.8	76
72	07-27-88	0745	6.0	17	3.5	48
	08-31-88	1025	--	--	--	42
	10-05-88	1000	--	--	--	16
	11-09-88	1020	--	--	--	--
	11-17-88	1020	8.4	5.5	.2	38
	12-21-88	1010	--	--	--	27
	01-25-89	1220	--	--	--	--
	02-15-89	1035	--	--	--	--
	03-09-89	1230	5.9	3.5	.4	9
	03-15-89	1135	--	--	--	--
	04-19-89	0925	--	--	--	--
	05-17-89	1320	--	--	--	--
	06-02-89	0945	8.5	22	3.5	24
73	07-27-88	0810	5.9	4.4	1.6	--
	11-17-88	1300	11	11	.5	21
	11-17-88	1305	11	7.3	.3	26
	11-17-88	1345	15	7.6	.2	29
	11-17-88	1350	14	8.8	.3	22

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Carbon, organic, total (mg/L as C)	Chlorophyll-*a* phyto-plankton, chromo-fluorometer (µg/L)	Chlorophyll-*b* phyto-plankton, chromo-fluorometer (µg/L)	Sediment, suspended (mg/L)
73	03-09-89	1400	6.1	6.8	1.2	10
	03-09-89	1405	7.1	6.9	1.4	12
	03-09-89	1440	6.7	6.7	1.0	14
	03-09-89	1445	6.7	6.8	1.3	13
	06-02-89	1100	7.1	2.3	.4	13
	06-02-89	1105	--	2.0	.4	13
74	07-29-88	1020	6.2	1.7	.4	44
	08-10-88	1300	--	--	--	52
	08-31-88	1320	--	--	--	10
	10-05-88	1300	--	--	--	11
	11-09-88	1310	--	--	--	--
	11-15-88	1430	4.8	2.1	<.1	12
	12-21-88	1315	--	--	--	7
	01-25-89	0845	--	--	--	--
	02-15-89	1335	--	--	--	--
	03-07-89	0800	5.9	5.5	1.3	5
	03-15-89	0845	--	--	--	--
	04-19-89	1235	--	--	--	--
	05-17-89	1045	--	--	--	--
	05-31-89	1630	5.7	.9	.2	55
76	07-27-88	1805	--	--	--	--
	07-28-88	0025	--	--	--	--
	07-28-88	0615	10	75	10	90
	07-28-88	1215	--	--	--	--
	07-28-88	1220	--	--	--	--

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Carbon, organic, total (mg/L as C)	Chlorophyll-*a* phyto-plankton, chromo-fluorometer (µg/L)	Chlorophyll-*b* phyto-plankton, chromo-fluorometer (µg/L)	Sediment, suspended (mg/L)
76	11-14-88	0600	--	--	--	--
	11-14-88	0610	--	--	--	--
	11-14-88	1000	--	--	--	26
	11-14-88	1005	--	--	--	31
	11-14-88	1400	5.6	--	--	26
	11-14-88	1410	--	--	--	--
	11-14-88	1800	--	--	--	--
	11-14-88	1805	--	--	--	--
	11-14-88	2200	--	--	--	--
	11-14-88	2205	--	--	--	--
	11-15-88	0200	--	--	--	--
	11-15-88	0205	--	--	--	--
	11-15-88	0605	--	--	--	--
	03-07-89	0615	--	--	--	--
	03-07-89	1010	--	--	--	--
	03-07-89	1015	--	--	--	--
	03-07-89	1400	5.9	5.7	0.5	59
	03-07-89	1405	5.8	5.8	.5	42
	03-07-89	1410	5.4	4.8	.5	52
	03-07-89	1800	--	--	--	--
	03-07-89	1805	--	--	--	--
	03-07-89	2200	--	--	--	--
	03-07-89	2205	--	--	--	--
	03-08-89	0200	--	--	--	--
	03-08-89	0205	--	--	--	--
	03-08-89	0600	--	--	--	--
	03-08-89	0605	--	--	--	--
	05-31-89	1845	14	46	4.6	93

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Carbon, organic, total (mg/L as C)	Chlorophyll-*a* phyto-plankton, chromo-fluorometer (μg/L)	Chlorophyll-*b* phyto-plankton, chromo-fluorometer (μg/L)	Sediment, suspended (mg/L)
77	07-27-88	1825	--	--	--	--
	07-28-88	0605	9.3	30	5.1	103
	11-14-88	1030	5.6	22	1.0	28
	03-07-89	1345	5.8	2.7	.8	188
	06-03-89	0935	11	67	6.7	125
78	07-28-88	0515	8.0	34	5.5	42
	11-14-88	1440	5.9	7.8	.4	20
	03-07-89	1030	6.4	1.7	.7	31
	06-01-89	1800	10	52	6.1	--
79	07-29-88	0645	7.2	16	2.7	28
	03-07-89	1600	8.0	3.2	.2	22
	05-31-89	0930	9.0	3.8	.5	22
83	07-29-88	0530	6.3	12	0.8	48
	08-10-88	1500	--	--	--	44
	08-31-88	1500	--	--	--	90
	10-05-88	1500	--	--	--	24
	11-09-88	1555	--	--	--	--
	11-16-88	1520	--	--	--	--
	12-21-88	1515	--	--	--	6
	01-25-89	1605	--	--	--	--
	02-15-89	1535	--	--	--	--
	03-07-89	1300	5.5	1.3	.1	9
	03-15-89	1435	--	--	--	--
	04-19-89	1450	--	--	--	--
	05-17-89	0755	--	--	--	--
	05-31-89	1045	6.1	7.5	.5	92
86	07-28-88	0615	9.8	12	1.3	56
	07-28-88	0620	9.8	11	1.2	56
	07-28-88	1200	14	93	14	--
	03-08-89	1200	5.2	3.6	.7	13
	06-02-89	1250	9.1	11	2.6	10

Table 8. Results of ancillary chemical analyses of water samples collected July 1988 through June 1989 in the lower Kansas River Basin—Continued

Site map-index number (fig. 10)	Date	Time (24-hour)	Carbon, organic, total (mg/L as C)	Chlorophyll-*a* phyto-plankton, chromo-fluorometer (µg/L)	Chlorophyll-*b* phyto-plankton, chromo-fluorometer (µg/L)	Sediment, suspended (mg/L)
87	07-28-88	0445	10	16	2.2	75
	07-28-88	1500	--	--	--	--
	11-14-88	1345	9.8	1.5	.2	32
	11-14-88	1350	10	8.8	.8	34
	03-08-89	1415	5.2	3.5	.4	12
	06-02-89	1530	7.0	23	4.6	286
88	07-27-88	1815	--	--	--	--
	07-27-88	2400	--	--	--	--
	07-28-88	0610	8.2	40	7.7	47
	07-28-88	1220	--	--	--	--
	07-28-88	1225	--	--	--	--
	11-16-88	1510	5.9	9.5	0.6	34
	11-16-88	1515	5.8	9.2	.5	33
	03-07-89	1550	6.8	3.0	1.0	14
	03-07-89	1555	6.5	3.5	.8	16
	03-07-89	1630	6.3	2.8	.8	20
	03-07-89	1635	6.4	2.9	1.1	14
	05-30-89	1905	8.5	51	5.7	15
	05-30-89	1910	9.2	57	8.0	15
90	07-29-88	0510	23	3.3	.6	10
	07-29-88	0515	19	2.5	.8	11
	11-14-88	1210	25	.3	.1	9
	11-14-88	1215	27	.3	<.1	12
	11-14-88	1315	--	.2	<.1	--
	11-14-88	1320	--	.5	<.1	--
	03-07-89	0925	32	2.0	1.3	17
	06-02-89	1440	18	.7	.1	--
91	07-29-88	0615	9.9	40	5.5	219
	11-14-88	1000	7.0	16	.6	34
	03-07-89	1320	10	9.7	3.1	24
	06-02-89	1145	8.3	23	3.2	--

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