STATISTICAL EVALUATION OF THE EFFECTS OF IRRIGATION ON CHEMICAL QUALITY OF GROUND WATER AND BASE FLOW IN THREE RIVER VALLEYS IN NORTH-CENTRAL KANSAS

By Timothy B. Spruill

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CONVERSION FACTORS

For those readers who would prefer to use the International System of Units (SI) rather than the inch-pound units given in this report, the following conversion factors are presented:

Multiply inch-pound unit	By	To obtain SI unit
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
acre	4,047	square meter
gallon (gal)	3.785	liter
acre-foot (acre-ft)	1,233	cubic meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
degree Fahrenheit (°F)	°C = 5/9 (°F-32)	degree Celsius (°C)

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ABSTRACT

Agricultural irrigation practices have caused long-term changes in the chemical quality of ground water and base flow in Prairie Dog Creek, and the Republican and Smoky Hill River valleys in north-central Kansas. All three areas had been irrigated for 10 or more years with both surface and ground water. Although concentrations of certain chemical constituents were significantly larger due to irrigation practices in all three areas, chemical quality of water in the Almena and Kansas-Bostwick Units generally met U.S. Environmental Protection Agency primary and secondary drinking-water standards during 1981-82. Concentrations of sulfate were, however, larger than the 250 milligrams per liter, the Federal secondary drinking-water standard, in 80 percent of the wells sampled in the vicinity of the Cedar Bluff Unit during 1981-82. Of the three areas investigated, the Cedar Bluff Unit in the Smoky Hill River valley had the most severe ground-water and base-flow degradation due to application of water with large concentrations of calcium, sulfate, and dissolved solids from Cedar Bluff Reservoir. Leaching of sodium and chloride from soils by applied irrigation water also caused increased concentrations of these constituents in ground water and base flow in the vicinity of the Cedar Bluff Unit. No long-term increases in nitrate concentration in ground water, significant at the 10-percent level, were observed in any of the three river valleys. Data collected from ground- and surface-water sampling sites indicate that irrigation has not caused contamination of ground water in the alluvium with organic pesticides for which analyses were performed.

INTRODUCTION

Irrigation is the principal use of ground and surface water in Kansas. Ninety-two percent of the ground water pumped and 44 percent of all surface water diverted in the State were used for irrigation during 1975-80 (Solley and others, 1983). During this period, about 6.3 million acre-feet of irrigation water from ground and surface sources were applied annually on 3 million acres of land.

Irrigation-water applications have increased substantially in Kansas since 1955 (fig. 1). Considering the large quantities of irrigation water applied, along with fertilizers and pesticides that have been and are being applied to land in Kansas, the potential exists for changes in chemical quality of both ground and surface water due to agricultural irrigation practices.

Potential effects of irrigation on water quality in Kansas are: (1) Contamination of surface and ground water with salts derived from irrigation water or irrigated soils, (2) contamination of surface and ground water with fertilizers or soil nutrients and pesticides by irrigation water percolating to the water table, and (3) induced movement of saline water from brackish-water aquifers underlying freshwater alluvial aquifers due to pumpage of freshwater (Balsters and Anderson, 1979). Although nationally, particularly in the Western States, much research has been conducted examining the effects of irrigation on ground- and surface-water quality, there have been relatively few studies in Kansas on this topic. Most of the available studies are relatively site specific in nature and have not addressed whether there are statistically discernible effects of irrigation throughout large geographic areas.

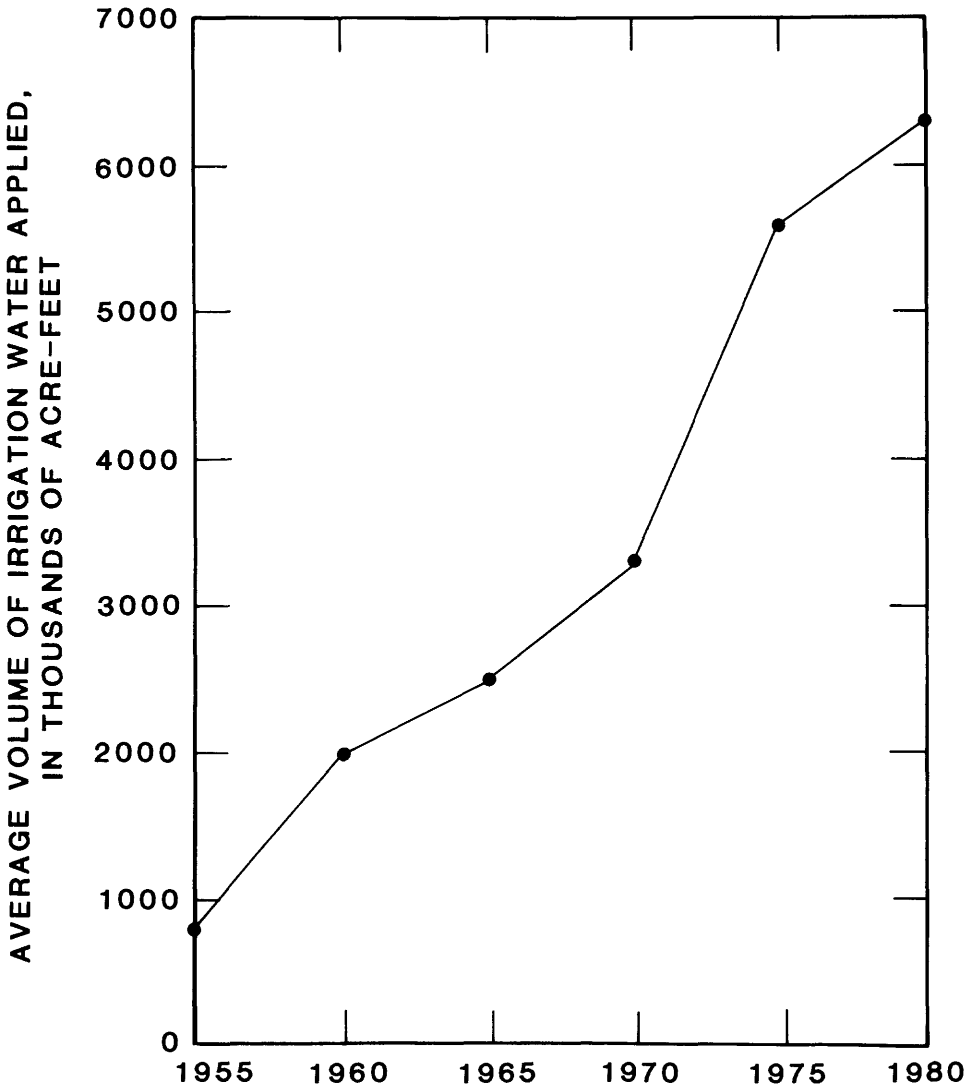

Figure 1.--Average volume of irrigation water applied annually in Kansas for 5-year increments, 1955-80 (data from MacKichan, 1957; MacKichen and Kammerer, 1961; Murray, 1968; Murray and Reeves, 1972, 1977; Solley and others, 1983).

During the fall of 1981, the U.S. Geological Survey, in cooperation with the Kansas Department of Health and Environment, began an investigation of possible areal effects of irrigation on the chemical quality of ground water and base flow in river valleys in north-central Kansas (fig. 2). The term "preirrigation period" used in this report refers to the period before large-scale irrigation began. "Postirrigation period" refers to the period after large-scale irrigation began. The three areas to be investigated were in the vicinity of irrigation districts, which were established by the U.S. Bureau of Reclamation in the late 1950's and early 1960's. Irrigation water was derived largely from reservoirs constructed by the Bureau in each of the irrigation districts, although ground water also was used for irrigation. Water released from the reservoirs was distributed to fields within the established irrigation district through series of canals. The three study areas, shown in figure 2, are: the Almena Unit in the Prairie Dog Creek valley in Norton and Phillips Counties, the Kansas-Bostwick Unit in the Republican River valley in Jewell and Republic Counties, and the Cedar Bluff Unit in the Smoky Hill River valley in Ellis and Trego Counties.

The objectives of this investigation were: (1) To statistically summarize and describe chemical quality of ground water and base flow and (2) to detect possible long-term effects of irrigation on the chemical quality of ground water and base flow in the vicinity of the three irrigation districts. Ground-water samples from domestic, stock, irrigation, and public-supply wells, and low-flow, surface-water-quality samples were collected, and discharge measurements on the streams and their tributaries were made for 1 year ending in the fall of 1982. Ground-water chemical-quality data are presented in tables 14-16, and surface-water chemical-quality data are presented in tables 17-19 in the "Supplementary Information" section at the end of this report.

Statistical summarizes of ground-water and base-flow chemical-quality data, and discussions of water quality with respect to possible sources of chemical constituents are presented in the report. The ground-water chemical-quality data also are compared to regional background concentrations where information was available. In addition, ground-water chemical-quality data from previous studies were statistically compared to newly collected data to evaluate long-term effects of irrigation.

METHODS OF SAMPLE COLLECTION AND LABORATORY ANALYSIS

Ground-water samples were collected, and onsite measurements of pH and specific conductance were made at irrigation, domestic, stock, and public-supply wells according to methods described by Wood (1976). Surface-water samples to be analyzed for inorganic chemical constituents were collected according to methods described in Brown and others (1970). Unfiltered water samples for organic-pesticide determinations were collected in 1-gallon, brown-glass bottles. Water samples for inorganic constituents collected from wells before 1975 may not have been filtered, whereas water samples collected from wells during 1981-82 were filtered through a 0.45 micrometer membrane filter. Comparative quality-control information on laboratory analytical techniques for selected chemical constituents in water samples collected before 1975 and during 1981-82 are shown in table 1.

All analytical determinations for this investigation were performed by the Division of Laboratories, Kansas Department of Health and Environment, Topeka, Kansas. Earlier analyses of ground-water samples from the Prairie Dog Creek valley (Frye and Leonard, 1949) and the Smoky Hill River valley (Leonard and Berry, 1961) were performed by the U.S. Geological Survey laboratory in Lincoln, Nebraska. Historical analyses of ground-water samples from the Republican River valley and surface-water samples from Prairie Dog Creek and the Smoky Hill River were made by the Kansas Department of Health and Environment.

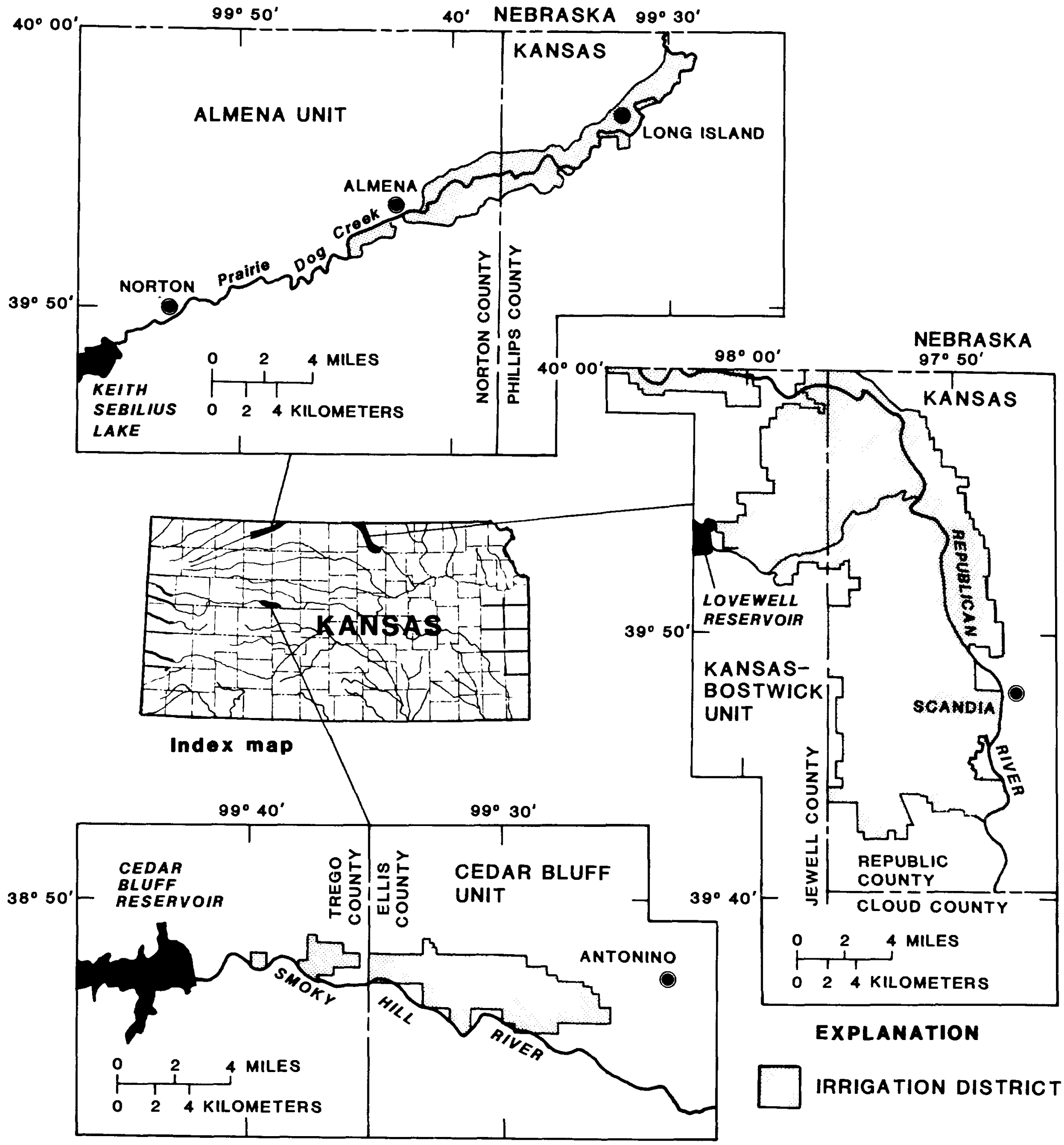

Figure 2.--Location of study areas.

Table 1.--*Comparative quality-control information on laboratory analytical techniques for selected chemical constituents, physical properties, and organic pesticides in water samples collected before 1975 and during 1981-82*

[All analyses during 1981 and 1982 were made by the Kansas Department of Health and Environment]

Chemical constituent or property	Reporting units	Method used, pre-1975	Minimum reporting unit, pre-1975	Relative standard deviation (R.S.D.) and relative error (R.E.), in percent, pre-1975 1/ R.S.D.[concentration] R.E.	Method used, 1981-82	Minimum reporting unit, 1981-82	Relative standard deviation (R.S.D.) and relative error (R.E.), in percent, 1981-82 2/ R.S.D.[concentration] R.E.
Dissolved solids	Milligrams per liter	Residue on evaporation, 180° Celsius	1	5	Computed 3/	1	ND
Calcium	do.	Permanganate; titritmetric	1	3.5 [108] 2.8	Atomic absorption, direct	.1	11 [83] 5
Magnesium	do.	Gravimetric	-	6.3 [82] 4.9	do.	.1	7 [54] 1
Sodium	do.	Calculated as residual with potassium before 1950	1	4/E. 10 R.E.	do.	.1	5 [31.8] 1
	do.	Flame photometry	.1	17.3 [19.9] 4			
Potassium	do.	Calculated as residual with sodium before 1950	1	4/E. 10 R.E.	do.	.1	20 [6.3] 2
	do.	Flame photometry	.1	15.5 [3.1] 2.3			
Alkalinity	do.	Manual titration methyl-orange indicator	1	2/15 [217] 2	Autoanalyzer; methyl orange	1	10 [217] 2
Chloride	do.	Argentometric	.1	2/5 [31.9] 1	Argentometric	.1	5 [31.9] 1
Sulfate	do.	Gravimetric	1	4.7 [259] 1.9	Autoanalyzer; methyl-thymol blue	1	5 [400] 3

Table 1.--*Comparative quality-control information on laboratory analytical techniques for chemical constituents, physical properties, and organic pesticides in water samples before 1975 and during 1981-82*--Continued

Chemical constituent or property	Reporting units	Method used, pre-1975	Minimum reporting unit, pre-1975	Relative standard deviation (R.S.D.) and relative error (R.E.), in percent, pre-1975[1/] R.S.D.[concentration] R.E.	Method used, 1981-82	Minimum reporting unit, 1981-82	Relative standard deviation (R.S.D.) and relative error (R.E.), in percent, 1981-82[2/] R.S.D.[concentration] R.E.
Fluoride	Milligrams per liter	Alizarin visual	0.1	10.6 [.68] 1.5	Ion selective electrode	0.1	8 [1.07] 1
Nitrogen (nitrate-nitrite)	do.	Brucine	.1	8 [55] 3	Analyzer; cadmium reduction	.01	10 [0.55] 1
	do.	Phenoldisulfonic acid	.1	74 [1] 38		.01	
Total phosphorus	do.	Persulfate, Stannous chloride	.1	14.9 [0.99] 12.3	Autoanalyzer, phosphomolybdate	.01	15 [1.46] 2
Silica	do.	Molybodosilicate	1	2/27 [7.4] 1	Atomic	.1	33 [7.4] 4
Arsenic	Micrograms per liter	--	-	--	Atomic, flameless	10	19 [18] 1
Barium	do.	--	-	--	Atomic, flameless	100	28 [240] 1
Cadimum	do.	--	-	--	Atomic, direct	1	18 [9] 1
Chromium	do.	--	-	--	do.	10	30 [27] 1
Copper	do.	--	-	--	do.	10	18 [29] 1
Lead	do.	--	-	--	do.	10	14 [23] 43
Selenium	do.	--	-	--	Atomic[5/]	1	25 [11.1] 8
Iron	do.	--	-	--	Atomic, direct	10	45 [210] 2

Table 1.--*Comparative quality-control information on laboratory analytical techniques for chemical constituents, physical properties, and organic pesticides in water samples before 1975 and during 1981-82*--Continued

Chemical constituent or property	Reporting units	Method used, pre-1975	Minimum reporting unit, pre-1975	Relative standard deviation (R.S.D.) and relative error (R.E.), in percent, pre-1975[1] R.S.D.[concentration] R.E.	Method used, 1981-82	Minimum reporting unit, 1981-82	Relative standard deviation (R.S.D.) and relative error (R.E.), in percent, 1981-82[2] R.S.D.[concentration] R.E.
Manganese	Micrograms per liter	--	-	--	Atomic, direct	10	7 [220] 1
Zinc	do.	--	-	--	do.	10	10 [100] 1
				19			
Dieldrin	do.					.05	ND[6]
Lindane	do.					.025	ND
Methoxychlor	do.					.20	ND
Toxaphene	do.					2.0	ND
Silvex	do.					.20	ND
2,4-D	do.					.40	ND
2,4,5-T	do.					.20	ND

1 American Public Health Association (1971; 1975) unless otherwise noted.

2 U.S. Geological Survey Analytical Evaluation Program, 1979-80.

3 Dissolved solids in milligrams per liter = milligrams per liter of calcium + sodium + potassium + magnesium + [bicarbonate (milligrams per liter x 0.4917)] + sulfate + chloride + nitrate.

4 Estimated relative error (accuracy) based on known measurements of sodium and potassium in nine samples and milliequivalent values for sodium and potassium calculated as residual (see Hem, 1970, p. 234 and table 20 at the end of this report).

5 U.S. Environmental Protection Agency (1974).

6 Not determined.

SOURCES OF DISSOLVED CHEMICAL CONSTITUENTS IN GROUND WATER AND BASE FLOW

Irrigation water can be a direct source of chemical constituents in ground water beneath irrigated areas. If water from a surface-water reservoir differs in chemical composition from the ground water underlying cropland to which reservoir water is applied, concentrations of chemical constituents in the ground water can change due to simple chemical mixing. In addition, because base flow of most streams is derived from ground water, the chemical composition of base flow also may change.

In addition to irrigation water applied from the reservoirs, there are a variety of possible natural and anthropogenic sources of chemical constituents in the ground and surface water. In north-central Kansas, natural sources of calcium, magnesium, and bicarbonate are limestone fragments in the soils and alluvial sediments. Additional sources of calcium may be gypsum deposits in shale underlying the valley deposits. Bicarbonate may be derived from carbon dioxide that has been extracted from the air and liberated in soil through biochemical activity (Hem, 1970, p. 287) and from the dissolution of carbonate minerals by carbonic acid. The principal natural source of sulfate appears to be gypsum in shale of Cretaceous age, which underlie the alluvial sediments in all three areas. Eroded fragments of gypsiferous rocks in the alluvium also could be a source of sulfate in ground water. Generally, the largest concentrations of sulfate were determined in water from wells that were at least partially cased into the shale. Possible sources for sodium, potassium, and chloride are evaporite deposits in the Cretaceous rocks, Quaternary deposits, and sewage or septic systems. Possible sources of dissolved silica are silicate minerals contained in soils and rocks.

Sources of ammonia, nitrate, and phosphorus are organic material in the soils, fertilizers applied to crops, and sewage or septic systems. Sources of pesticides in ground water and base flow are the application of these compounds to crops and soils.

Sources of trace elements appear to be rocks and soils in the area. Principal sources of selenium and fluoride probably are volcanic-ash deposits associated with the Cretaceous shale. Eroded fragments of Cretaceous rocks in the alluvium also could be a source of these constituents. Iron and manganese in the alluvial sediments may be derived from organic debris or eroded rock fragments containing iron minerals. Evaporite deposits in rocks and soils are possible sources of boron. Arsenic may be derived from rocks and soils as well as from some herbicides and insecticides.

PRAIRIE DOG CREEK VALLEY, ALMENA UNIT

History of Irrigation Development

The Almena Unit is located in the Prairie Dog Creek valley, a tributary of the Republican River, in Norton and Phillips Counties (fig. 3). The irrigation district begins approximately 11 river miles downstream from

Norton Dam and ends near the Kansas-Nebraska State line. Approximately 5,350 acres were included within the irrigation-district boundaries during 1981-82 (U.S. Bureau of Reclamation, 1983). Irrigation releases from Keith Sebelius Lake began during 1967, and since that time an average of 5,800 acre-feet of water were released annually until 1979. No releases for irrigation occurred during 1979, 1981, or 1982 because of insufficient water in the lake (U.S. Bureau of Reclamation, 1982). About 1,000 acre-feet of water were released from the reservoir during 1980. In addition to irrigation with surface water, crops in the Prairie Dog Creek valley are irrigated with ground water. One hundred and forty-seven large-capacity irrigation wells were located in the valley during 1978 (Stullken, 1984).

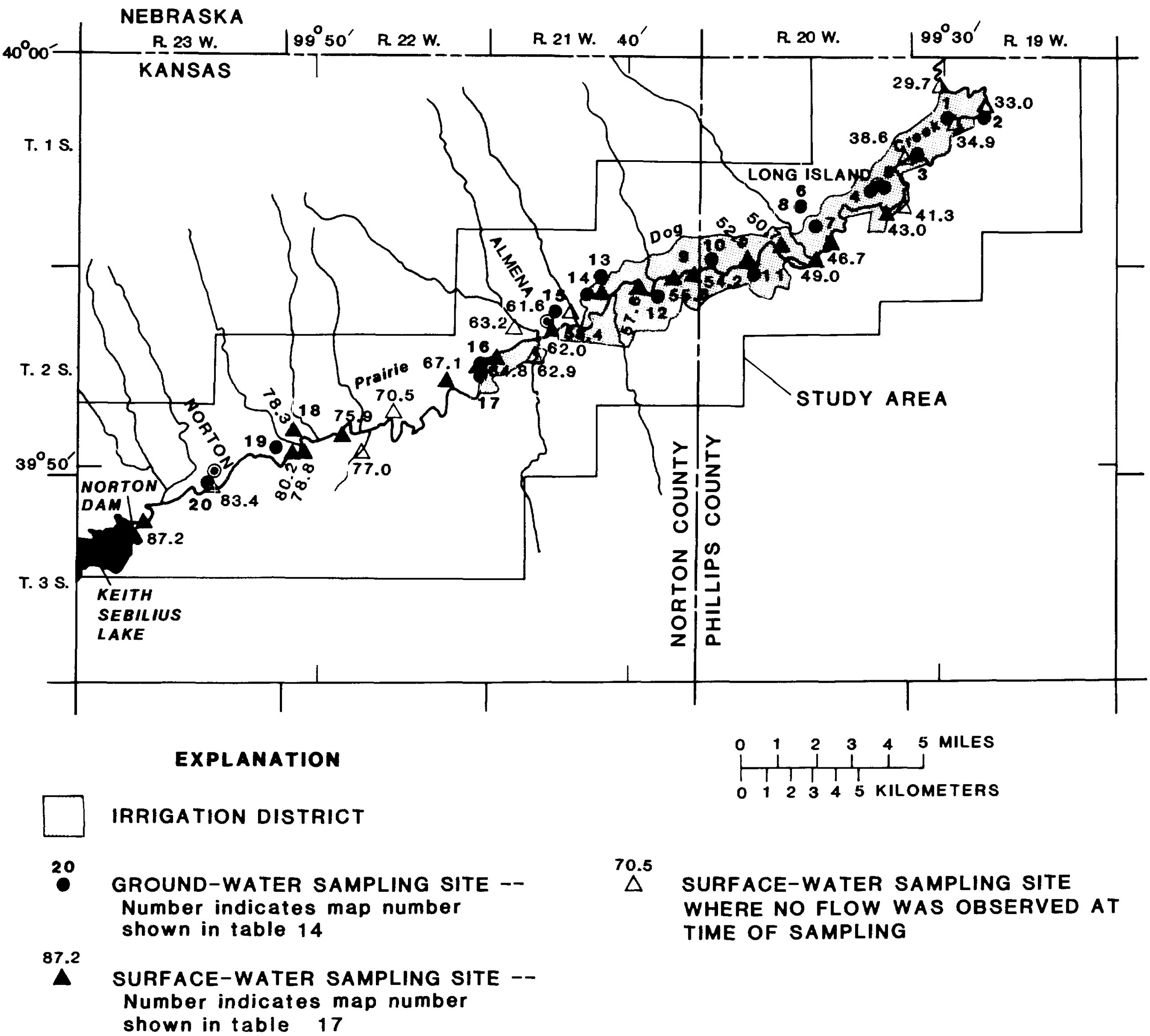

Figure 3.--Location of ground- and surface-water sampling sites in Prairie Dog Creek valley.

Hydrogeology

Terrace and alluvial deposits of Quaternary age in the Prairie Dog Creek valley comprise the principal aquifer and source of water in the valley. These deposits, which range in thickness from 20 to 80 feet, consist of sand and gravel that overlie the Niobrara Formation of Cretaceous age. The Ogallala Formation of Tertiary age surrounds the Prairie Dog Creek valley and is the major source of water for areas away from the valley. The discontinuous Pierre Shale of Cretaceous age overlies the Niobrara Formation at locations near the stream valley, where it occurs as an erosional remnant and is exposed in the northeastern part of the study area. Frye and Leonard (1949) reported that the Pierre Shale does not yield water to wells and that the Niobrara Formation was a "poor" aquifer. Dunlap (1982) showed that during the spring of 1977, the water table sloped downvalley toward the northeast, with water-table contours curved toward the creek from the valley walls. Dunlap also cites L. E. Stullken (U.S. Geological Survey, written commun., 1980) who reported that water levels had risen 5 to 10 feet between 1950 and 1970 due to irrigation-water releases from Keith Sebelius Lake.

Hydrologic Conditions and Chemical Quality of Water, 1981-82

Prairie Dog Creek was a losing[1/] stream throughout most of its length in the study area during March 1982, as indicated in figure 4. Flow upstream from site 70.5[2/] was due to discharge of treated sewage effluent from the city of Norton, 1 mile upstream from site 80.2. No streamflow was measured at site 70.5. Data in figure 4 indicate that the alluvial aquifer between sites 80.2 and 70.5 was being recharged partially by sewage effluent from the city of Norton. A streamflow of 0.004 ft^3/s was measured at site 67.1, which increased to 0.4 ft^3/s at site 55.8. The increase was due to ground-water inflow from the alluvium. Streamflow decreased to 0.002 ft^3/s at site 43.0. No flowing water was observed downstream from site 43.0 to the Kansas-Nebraska State line. No flow was observed in Prairie Dog Creek downstream from site 62.0 during November of 1981 or 1982. Ground-water withdrawals in the Prairie Dog Creek valley have caused Prairie Dog Creek to change from a perennial to an ephemeral stream.

A statistical summary of ground-water and base-flow chemical-quality data from the Prairie Dog Creek valley, 1981-82, is presented in table 2. Ground-water samples from supply wells in the Quaternary deposits and base-flow samples from the surface-water sampling sites indicate that the dominant cation and anion in the Prairie Dog Creek valley are calcium and bicarbonate, although some samples contained a large percentage of sulfate. Water samples from wells 4, 5, 6, 7, 10, 11, and 20 (table 14 at the end of this report) and surface-water site 80.2 (table 17 at the end of this report) contained more than 100 mg/L (milligrams per liter) of sulfate, substantially more than the median concentration of 64 mg/L for ground water in the valley.

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[1] A losing stream is one that loses water from the stream channel to the aquifer.

[2] Surface-water sampling-site numbers correspond to the distance upstream from the stream mouth, in river miles.

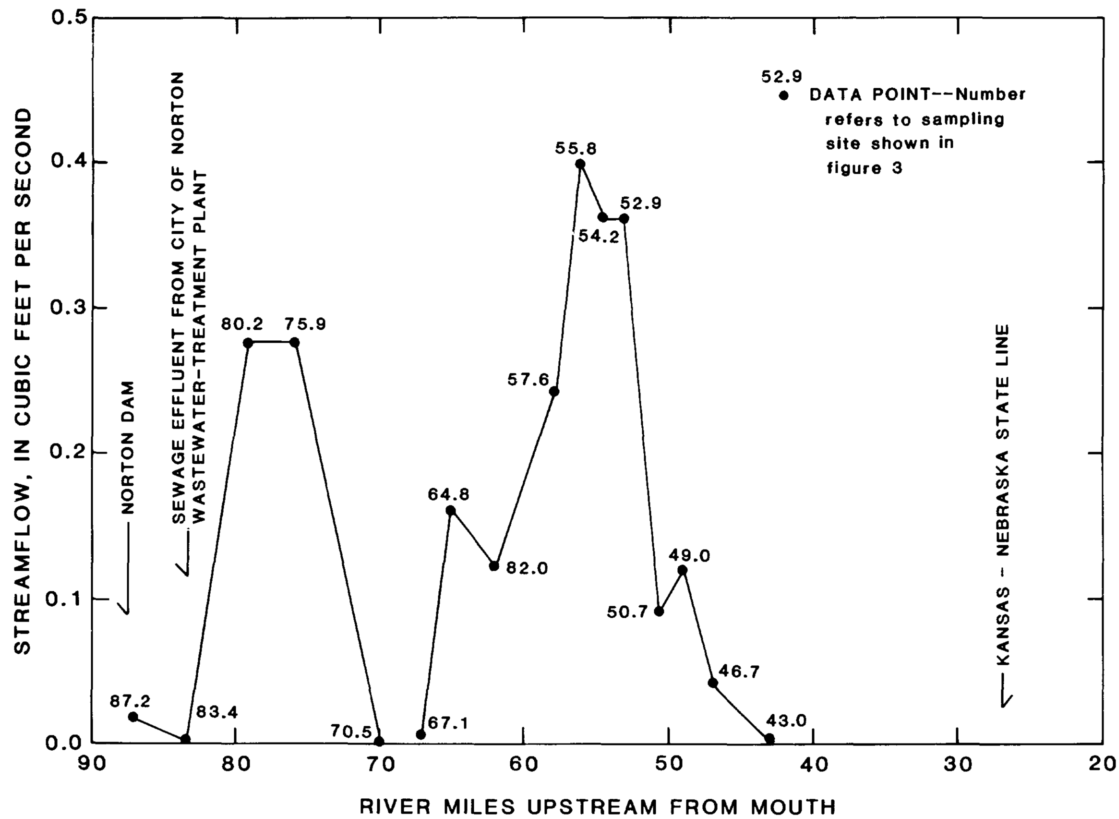

Figure 4.--Instantaneous streamflow in Prairie Dog Creek from Norton Dam to the Kansas-Nebraska State line, March 1982.

Generally, water-quality characteristics for most chemical constituents in the ground water and base flow in this valley meet Federal standards for drinking water. Median concentrations of chemical constituents shown in table 2 are less than mandatory (U.S. Environmental Protection Agency, 1976) or recommended (U.S. Environmental Protection Agency, 1977) maximum contaminant levels.

REPUBLICAN RIVER VALLEY, KANSAS-BOSTWICK UNIT

History of Irrigation Development

The Kansas part of the Bostwick Unit is located in the Republican River valley in Jewell and Republic Counties (fig. 5). The Republican River and Lovewell Reservoir on White Rock Creek, a tributary stream located on the western side of the Republican River, are the sources for irrigation water in the Kansas-Bostwick Unit. The northwestern part of the irrigation district is irrigated by water primarily from the Republican River, which is diverted at Guide Rock, Nebraska (not shown in figure 5); irrigation in this area began during the early 1950's. The southeastern part of the Kansas-Bostwick Unit is irrigated by water from Lovewell Reservoir. Releases from Lovewell began during 1958 (Fader, 1968). Based on

Table 2.--*Statistical summary of ground-water and base-flow chemical-quality data in the vicinity of the Almena Unit, Prairie Dog Creek valley, 1981-82*

Chemical constituent or property	Units	Source[1]	Sample size	Mean	Standard deviation	Minimum	First Quartile	Median	Third Quartile	Maximum
Specific conductance	μS/cm[2]	G	19	990	362	360	750	860	1,070	1,860
		B	14	630	84	450	660	700	715	1,130
pH	standard units	G	19	7.2	.1	7.1	7.2	7.2	7.3	7.4
		B	14	8.0	.4	7.3	7.6	8.1	8.2	8.7
Calcium, dissolved	mg/L[3]	G	19	140	40	100	110	120	150	260
		B	15	96	18	65	86	95	110	130
Magnesium, dissolved	do.	G	19	24	7.9	13	18	21	31	47
		B	15	20	3	16	17	20	23	25
Sodium, dissolved	do.	G	19	44	46	13	18	29	50	200
		B	15	43	31	13	25	36	42	130
Sodium-absorption-ratio	--	G	19	.9	.8	.3	.5	.6	1	4
		B	--	--	--	--	--	--	--	--
Potassium, dissolved	mg/L[3]	G	19	16	6	7	11	15	19	32
		B	15	18	6	7	15	17	19	32
Alkalinity, as $CaCO_3$	do.	G	19	370	61	260	330	350	420	500
		B	--	--	--	--	--	--	--	--
Sulfate, dissolved	do.	G	19	110	100	14	36	64	160	390
		B	15	56	25	15	46	58	60	120

Table 2.--*Statistical summary of ground-water and base-flow chemical-quality data in the vicinity of the Almena Unit, Prairie Dog Creek valley, 1981-82*--Continued

Chemical constituent or property	Units	Source[1]	Sample size	Mean	Standard deviation	Minimum	First Quartile	Median	Third Quartile	Maximum
Chloride, dissolved	mg/L[3]	G	19	35	34	7	14	24	35	110
		B	15	53	42	13	31	41	47	170
Fluoride, dissolved	do.	G	19	.3	.1	.2	.3	.3	.4	.7
		B	15	.4	.3	.2	.2	.3	.4	1.2
Solids, dissolved	do.	G	17	564	115	432	483	517	665	823
		B	13	471	123	283	426	444	514	760
Nitrogen, dissolved (NO_2 + NO_3) as N	do.	G	19	3.5	5	[4]0	0	.1	5.7	16
		B	15	.51	.89	0	0	0	.9	3
Ammonia, dissolved, N	do.	G	19	.18	.15	.07	.09	.11	.27	.55
Ammonia, total, N		B	15	.21	.09	.12	.15	.19	.22	
Phosphorus, dissolved	do.	G	19	.33	.17	.13	.17	.28	.47	.64
Phosphorus, total		B	15	.91	1.2	.05	.30	.41	.77	4.30
Arsenic, dissolved	μg/L[5]	G	19	12	7	0	10	10	15	30
Arsenic, total		B	15	9	3	0	10	10	10	10
Barium, dissolved	do.	G	19	270	110	100	200	300	350	400
Barium, total		B	15	150	64	100	100	100	200	300
Boron, dissolved	do.	G	19	180	60	60	150	170	200	380
Boron, total		B	12	180	60	130	140	170	190	340

Table 2.--*Statistical summary of ground-water and base-flow chemical-quality data in the vicinity of the Almena Unit, Prairie Dog Creek valley, 1981-82*--Continued

Chemical constituent or property	Units	Source[1]	Sample size	Mean	Standard deviation	Minimum	First Quartile	Median	Third Quartile	Maximum
Selenium, dissolved	μg/L[5]	G	19	7	9	1	2	2	6	28
Selenium, total		B	15	3	1	1	2	2	3	5
Iron, dissolved	do.	G	19	530	630	0	20	250	1,100	2,100
Iron, total		B	15	460	670	60	90	190	360	2,600
Manganese, dissolved	do.	G	19	440	470	0	10	320	780	1,400
Manganese, total		B	15	110	190	10	20	40	80	750

1 G = ground-water sample; B = base-flow sample.

2 Microsiemens per centimeter at 25 °Celsius.

3 Milligrams per liter.

4 Zero values indicate concentrations below the minimum reporting unit.

5 Micrograms per liter.

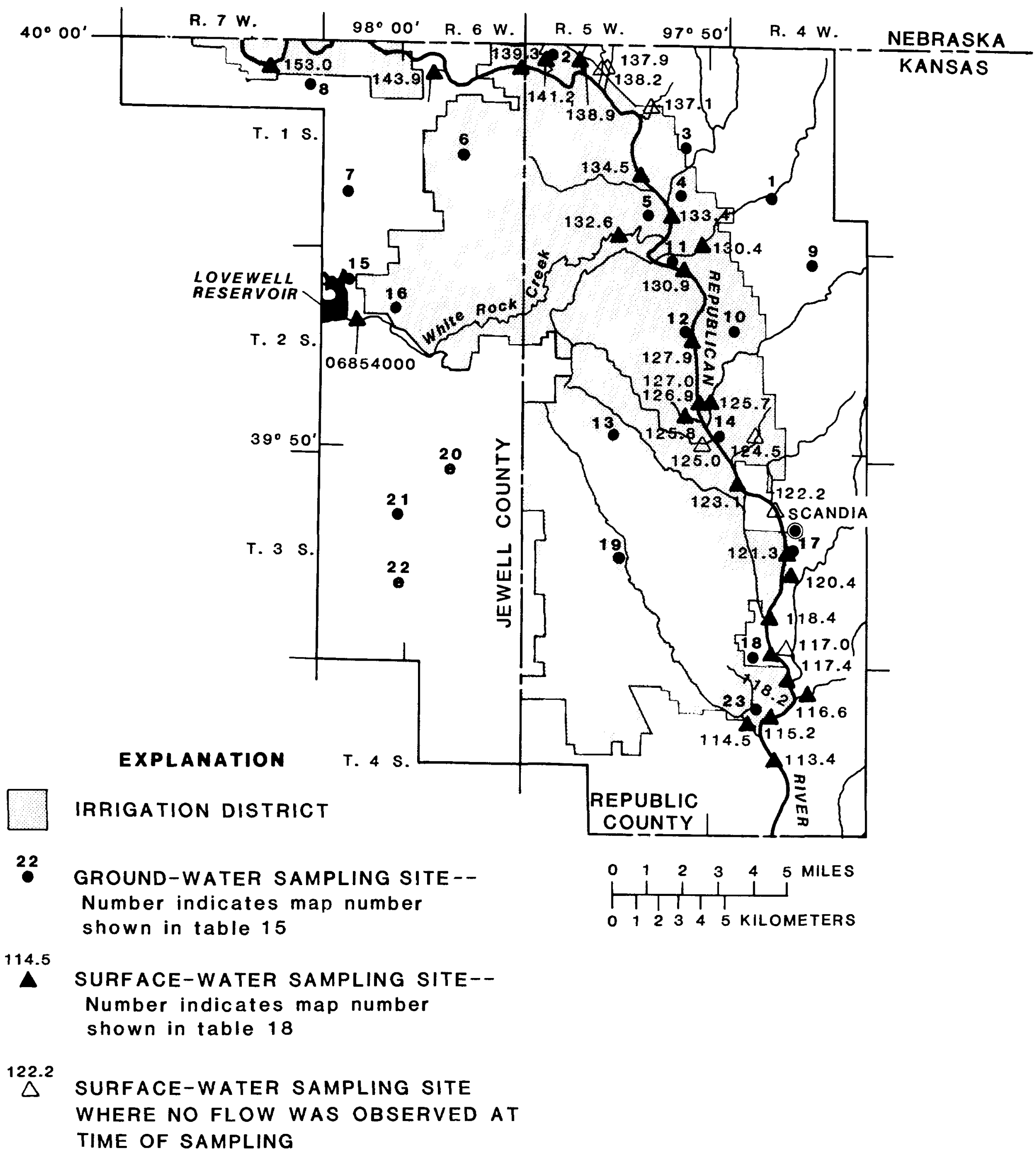

Figure 5.--Location of ground- and surface-water sampling sites in Republican River valley.

data from the U.S. Bureau of Reclamation (1970; 1980), about 66,000 acre-feet of water were diverted annually into the canals for irrigation purposes between 1961 and 1980. An average of approximately 60,000 acre-feet of water were diverted into canals during 1981 and 1982. Before

1950, very little irrigation occurred, and this primarily was with ground water. Fishel and Lohman (1948) reported that only four irrigation wells were operating at the time their investigation was conducted during the 1940's. Significant irrigation with ground water occurred within the Kansas-Bostwick Unit during 1981 and 1982. The highest density of irrigation wells are located in the southern one-half of the Kansas-Bostwick Unit.

Hydrogeology

The Kansas-Bostwick Unit is located in unconsolidated deposits of Quaternary age, which are composed of silty clay interbedded with layers of sand and medium-to-coarse gravel derived from eroded sandstone and limestone bedrock (Dunlap, 1982). Thickness of the alluvium in the valley of the Republican River is as much as 130 feet (Bayne and Walters, 1959). Rocks of Cretaceous age form the base of the alluvial aquifer. Based on lithologic logs shown in Fishel and Lohman (1948), either the Greenhorn Limestone or the underlying Graneros Shale of Cretaceous age form the base of the alluvial aquifer within the irrigation district.

The major source of ground-water supplies in the Republican River valley is the alluvial aquifer. Irrigation, public, domestic, and stock supply wells obtain water primarily from the alluvium. The Graneros Shale does not yield water to wells, and few domestic and stock supply wells obtain water from the Greenhorn Limestone. Movement of water in the valley alluvium during 1977 was to the south and downvalley, with water-table contours sloping from the valley walls indicating that the river drains the alluvial aquifer (Dunlap, 1982). Water levels in the Kansas-Bostwick Unit between Lovewell Reservoir and the Republican River rose about 25 feet between 1957 and 1977 as a result of irrigation-water applications (Dunlap, 1982).

Hydrologic Conditions and Chemical Quality of Water, 1981-82

Streamflow during April and October 1982, in the Republican River from near the Nebraska-Kansas State line to sampling site 113.4 is shown in figure 6. The Republican River is generally a gaining stream from near the State line to sampling site 121.3 near Scandia. The gain of 30 ft^3/s between sites 126.9 and 121.3 during October probably is due to ground water discharging from the irrigated fields in the southeastern part of the irrigation district; less than 20 percent (or about 5 ft^3/s) of the gain was due to tributary inflows. The Republican River did not appear to gain flow between sites 121.3 and 113.4 during both April and October. The absence of increase in flow may be due to ground-water pumpage in the valley south of site 121.3. Data from the U.S. Geological Survey's Ground-Water Site Inventory file (Lawrence, Kansas) indicate a dense concentration of irrigation wells in the Republican River valley south of site 121.3.

Ground-water and base-flow chemical-quality data from the Republican River valley are summarized statistically in table 3. The dominant cation and anion in water from the alluvial deposits in the Republican River

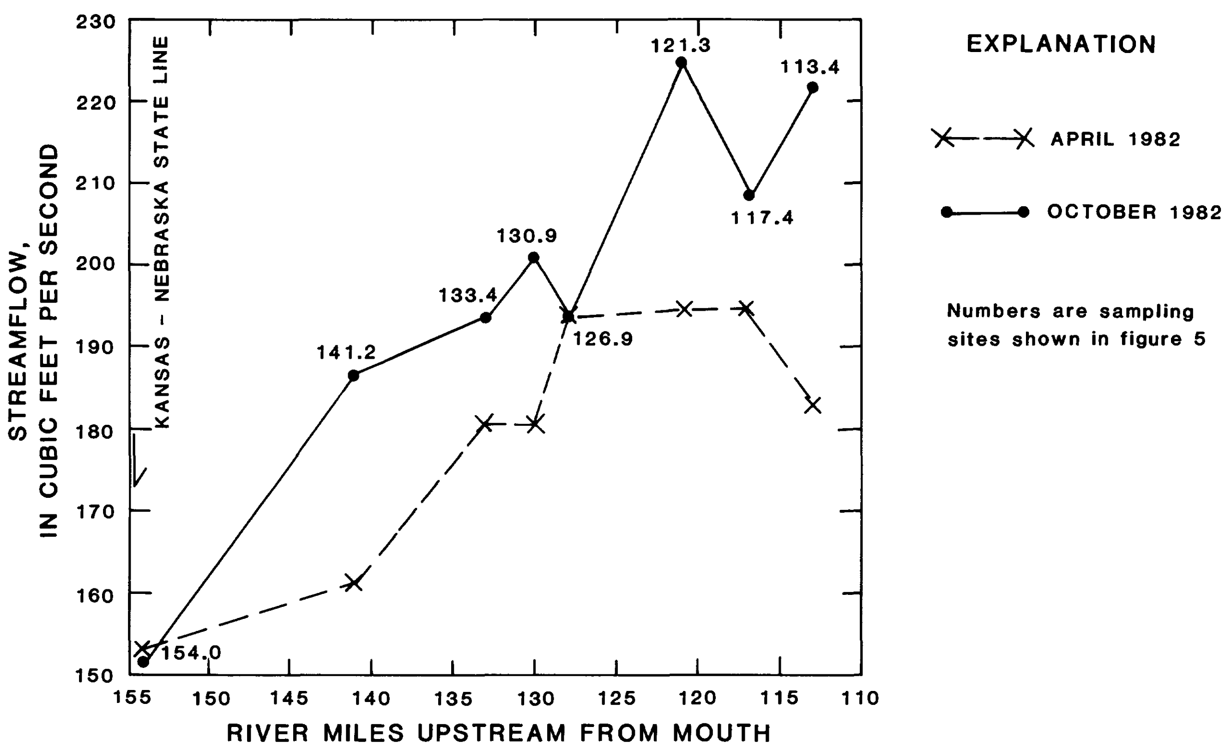

Figure 6.--Instantaneous streamflow in Republican River near the Kansas-Nebraska State line to sampling site 113.4 during April and October 1982.

valley are calcium and bicarbonate. Dissolved solids range from 317 to 843 mg/L in ground water from unconsolidated deposits (table 3). Wells developed in thin Pleistocene or alluvial deposits with screens penetrating underlying rocks of Cretaceous age (wells 13, 19, 21, and 22, shown in figure 5) contained the largest concentrations of sodium, sulfate, and chloride ions (table 15 at the end of this report); the source of these ions probably is shale of the Colorado Group (in ascending order, Graneros Shale, Greenhorn Limestone, Carlile Shale, and Niobrara Formation of Cretaceous age. Water supplies from major valley deposits generally are usable for most purposes. Median concentrations of all chemical constituents shown in table 3 are less than the maximum contaminant levels that have been established by the U.S. Environmental Protection Agency (1976, 1977). No organic pesticides shown in table 1 were detected in either ground- or surface-water samples at concentrations that were larger than primary drinking-water standards (U.S. Environmental Protection Agency, 1976). The chemical 2,4-D was, in fact, the only organic pesticide detected of those shown in table 1.

Table 3.--*Statistical summary of ground-water and base-flow chemical-quality data in the vicinity of the Kansas-Bostwick Unit, Republican River valley, 1981-82*

Chemical constituent or property	Units	Source[1]	Sample size	Mean	Standard deviation	Minimum	First quartile	Median	Third quartile	Maximum
Specific conductance	µS/cm[2]	G	23	1,000	482	470	720	810	1,130	2,400
		B								
pH	standard units	G	23	7.3	.2	6.9	7.2	7.3	7.3	7.8
		B								
Calcium, dissolved	mg/L[3]	G	23	140	66	64	94	120	150	350
		B	30	110	58	30	88	100	110	270
Magnesium, dissolved	do.	G	23	16	7.6	8	11	14	22	34
		B	30	19	7.9	6	13	18	19	39
Sodium, dissolved	do.	G	23	67	48	15	40	48	80	200
		B	30	76	57	31	40	56	74	230
Sodium-absorption-ratio	--	G	23	1	.7	.3	1	1	2	3
Potassium, dissolved	mg/L[3]	G	23	8	5	3	5	6	12	25
		B	30	10	3	3	8	11	12	17
Alkalinity, as $CaCO_3$	do.	G	23	300	67	160	260	310	360	400

Table 3.--*Statistical summary of ground-water and base-flow chemical-quality data in the vicinity of the Kansas-Bostwick Unit, Republican River valley, 1981-82*--Continued

Chemical constituent or property	Units	Source[1/]	Sample size	Mean	Standard deviation	Minimum	First quartile	Median	Third quartile	Maximum
Sulfate, dissolved	mg/L[3/]	G	23	140	170	12	40	84	130	670
		B	30	190	230	35	62	120	180	830
Chloride, dissolved	do.	G	23	55	48	11	20	32	83	170
		B	30	49	35	17	27	36	62	170
Fluoride, dissolved	do.	G	23	.3	.1	.2	.2	.3	.4	.7
		B	30	.3	0	.2	.3	.3	.3	.4
Dissolved solids	do.	G	20	544	133	317	445	515	629	843
		B	26	486	127	219	434	483	531	785
Nitrogen, dissolved,	do.	G	23	7	10	0	.4	3.7	7.6	39
$NO_2 + NO_3$		B	30	.63	.92	0	.08	.35	.63	4
Ammonia, dissolved, N	do.	G	23	.14	.11	.05	.08	.11	.16	.58
Ammonia, total, N		B	30	.16	.11	.08	.12	.14	.17	.68
Phosphorus, dissolved	do.	G	8	.22	.11	.08	.13	.22	.31	.39
Phosphorus, total		B	30	.21	.16	.04	.12	.19	.23	.78
Arsenic, dissolved	µg/L[4/]	G	23	2	4	0	0	0	0	10
Arsenic, total		B	30	5	5	0	0	10	10	10

Table 3.--*Statistical summary of ground-water and base-flow chemical-quality data in the vicinity of the Kansas-Bostwick Unit, Republican River valley, 1981-82*--Continued

Chemical constituent or property	Units	Source[1]	Sample size	Mean	Standard deviation	Minimum	First quartile	Median	Third quartile	Maximum
Barium, dissolved	µg/L[4]	G	23	270	190	0	100	200	400	800
Barium, total		B	30	210	100	100	100	200	300	400
Boron, dissolved	do.	G	23	160	70	70	100	160	200	310
Boron, total		B	30	140	60	0	110	150	180	240
Selenium, dissolved	do.	G	23	8	11	2	2	5	8	41
Selenium, total		B	30	6	7	1	2	3	5	28
Iron, dissolved	do.	G	23	180	310	10	20	50	230	1,300
Iron, total		B	30	350	180	100	220	300	440	890
Manganese, dissolved	do.	G	23	230	360	0	0	20	370	1,100
Manganese, total		B	30	130	100	20	50	100	190	430

1 G = Ground-water sample; B = base-flow sample.

2 Microsiemens per centimeter at 25 °Celsius.

3 Milligrams per liter.

4 Micrograms per liter.

History of Irrigation Development

The Cedar Bluff Unit, established during 1963 (Leonard, 1974), is located in the Smoky Hill River valley in Ellis and Trego Counties (fig. 7). The irrigation-district boundaries extend from about 3 miles downstream from Cedar Bluff Dam to about 2 miles west of Antonino. Dryland farming generally was practiced at the time of this study (1981-82). No releases for irrigation purposes have been made in the Cedar Bluff Unit since 1979 because water levels in Cedar Bluff Reservoir have been too low. However, more than 13,000 acre-feet of surface water were applied annually between 1963 and 1978, the last year releases were made from the reservoir. Ground water has been the principal source of irrigation water since 1979.

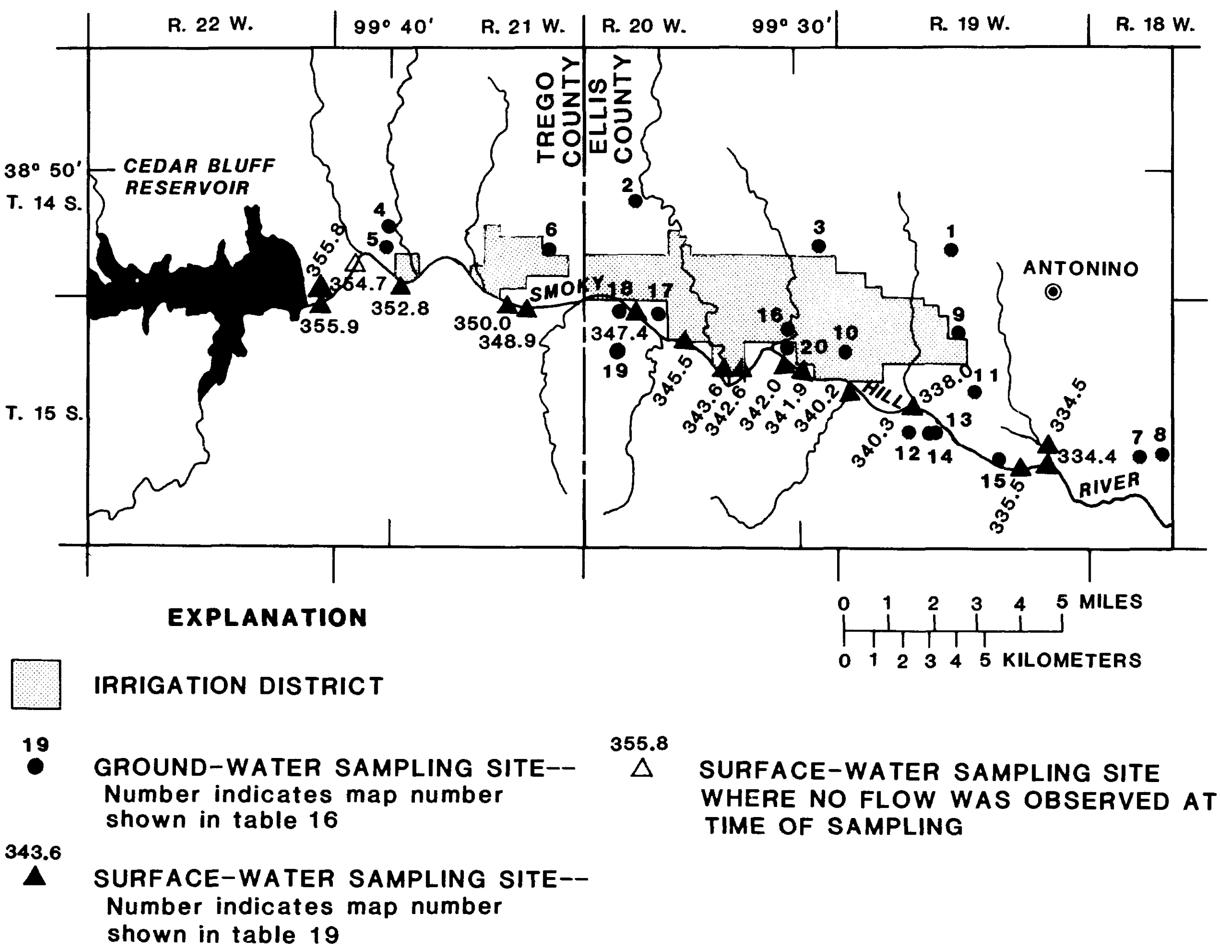

Figure 7.--Location of ground- and surface-water sampling sites in Smoky Hill River valley.

Hydrogeology

Unconsolidated terrace and alluvial deposits of Quaternary age are the major source of ground water in the valley. These deposits consist of silt, sand and gravel. Generally, the sand and gravel are overlain by silt or sandy silt (Leonard, 1974). The thickness of unconsolidated deposits near the river is about 80 feet. These deposits become thinner near the valley walls. The base of the alluvial aquifer is formed by the Greenhorn Limestone and overlying Carlile Shale of Cretaceous age (Leonard, 1974). These Cretaceous rocks generally are impervious, do not yield significant quantities of water to wells (Leonard and Berry, 1961; Leonard, 1974), and function as a lower boundary for ground-water circulation in the alluvial aquifer (Leonard, 1974). Some wells obtain water from the Dakota Formation, which lies below the Upper Cretaceous shale and limestone.

Hydrologic Conditions and Chemical Quality of Water, 1981-82

The Smoky Hill River is generally a gaining stream between sampling site 355.8 and site 335.5 (fig. 8). Instantaneous streamflow ranged from 0.06 ft^3/s at the Cedar Bluffs Dam (site 355.8) to almost 7 ft^3/s during March 1982. Ground-water inflow accounted for more than 80 percent of the gains observed for all seepage surveys. The loss in streamflow between sites 338.0 and 335.5 during August 1982, was probably due to ground-water pumpage.

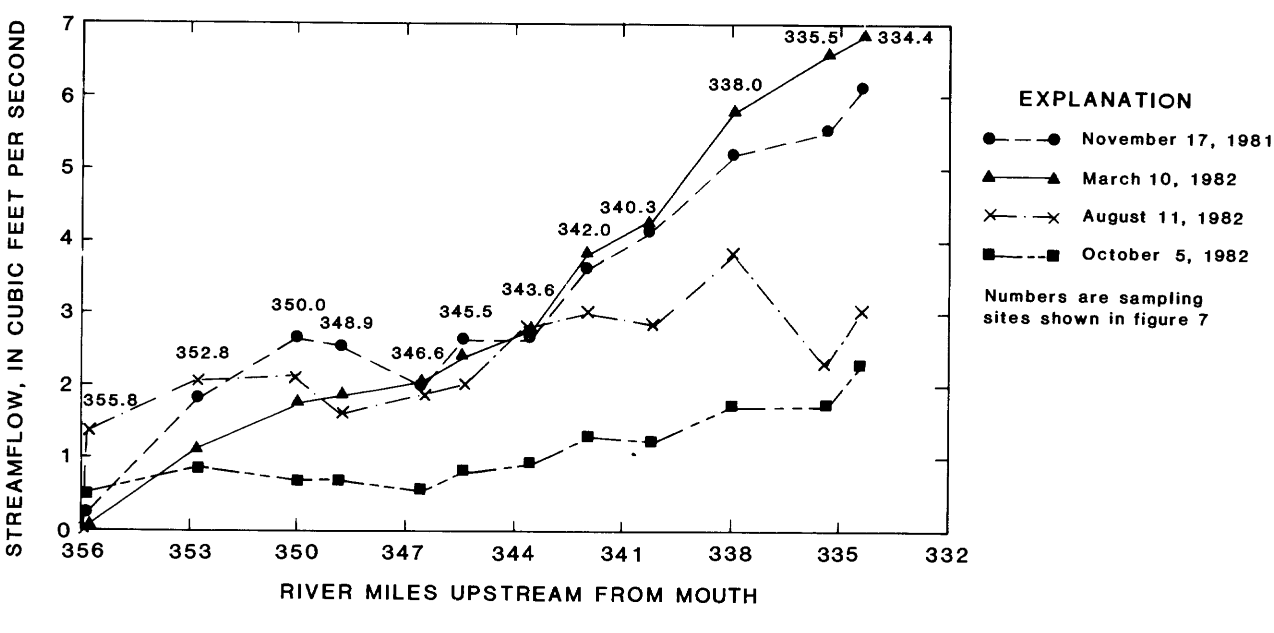

Figure 8.--Instantaneous streamflow in Smoky Hill River from Cedar Bluff Dam to sampling site 335.0, November 1981 and March, August, and October 1982.

Chemical-quality data from ground water and base flow are summarized statistically in table 4. Dominant ions in water from the valley deposits are calcium and sulfate. Dissolved-solids concentrations ranged from 550 to 960 mg/L. Water from wells developed in valley deposits generally is degraded; 80 percent of all wells sampled yielded water that contained concentrations of sulfate that were greater than the national interim secondary standard of 250 mg/L for drinking-water supplies (U.S. Environmental Protction Agency, 1977); 25 percent of the wells sampled produced water that contained sulfate concentrations larger than 500 mg/L. Hinman (1935) reported that sulfate concentrations larger than 500 mg/L are deleterious to certain crops so that the ground water may not be desirable for irrigation purposes. About 15 percent of the 20 wells sampled produced water than contained concentrations of nitrate-nitrogen that were larger than the national interim primary standard of 10 mg/L (U.S. Environmental Protection Agency, 1976).

EVALUATION OF EFFECTS OF IRRIGATION ON CHEMICAL QUALITY OF GROUND WATER AND BASE FLOW

Possible Factors Affecting Changes in Chemical Quality of Water

A variety of natural, analytical, and anthropogenic factors can cause changes in the chemical quality of water. The most likely causes for changes in ground-water quality are changes in climate or season, changes in laboratory or sampling methods, and changes in local or regional land use. Whittemore and others (1982) presented evidence that concentrations of some chemical constituents changed in ground water from Kansas wells in response to drought. Thus, a long-term change to a dry or wet climate may result in changes in chemical quality of ground water. Schmidt (1977) presented evidence from water samples collected from wells in California that nitrate concentrations changed seasonally. Differences in analytical methods used for certain chemical constituents also could account for apparent changes in concentrations through time. Kramer and Tessier (1983) determined that changes in analytical methods could be responsible for detected differences in values of alkalinity and pH before and after 1960. Changes in land use also may cause changes in ground-water quality. Changes in ground- and surface-water quality have been shown to be associated with mining, industrial sewage-disposal practices, oil operations, agricultural activities, urbanization, and other land uses (Miller, 1980).

Although a variety of factors could cause changes in water quality through time in each of the three study areas, a change from nonirrigated to irrigated agricultural land appears to be the most likely cause for changes through time in ground-water and base-flow chemical quality. No significant changes in land use have occurred in any of the areas, other than changes from nonirrigated to irrigated agriculture. No trends in climate, as measured by total annual precipitation for 1945-82, were detectable at weather stations in each of the three study areas as determined by a Spearman-rho test for trend (data not shown); there was no significant change in precipitation at the 10-percent level at weather stations at

Table 4.--*Statistical summary of ground-water and base-flow chemical-quality data in the vicinity of the Cedar Bluff Unit, Smoky Hill River valley, 1981-82*

Chemical constituent or property	Units	Source[1]	Sample size	Mean	Standard deviation	Minimum	First quartile	Median	Third quartile	Maximum
Specific conductance	μS/cm[2]	G	20	1,530	570	830	1,170	1,370	1,660	3,080
pH	standard	G	20	7.3	.2	6.8	7.3	7.3	7.4	7.5
Dissolved calcium	mg/L[3]	G	20	225	87	115	172	200	235	460
		B	13	210	12	190	210	220	220	230
Dissolved magnesium	do.	G	20	28	14	9.5	21	25	30	70
		B	13	42	6	33	37	43	46	54
Dissolved sodium	do.	G	20	86	44	38	53	73	120	200
		B	13	83	8	67	78	83	89	95
Sodium-adsorption-ratio	--	G	20	1.5	.6	.8	1.0	1.3	1.9	2.6
		B	13	--	--	--	--	--	--	--
Dissolved potassium	mg/L[3]	G	20	8.1	4.0	4	5.3	6.0	11	20
		B	13	14	5	10	11	13	17	28
Alkalinity, as $CaCO_3$	do.	G	20	220	52	110	190	220	250	350
		B	--	--	--	--	--	--	--	--
Dissolved sulfate	do.	G	20	450	250	160	290	390	530	1,200
		B	13	560	120	250	540	580	600	780
Dissolved chloride	do.	G	20	100	55	28	68	88	116	270
		B	13	86	11	65	79	88	98	100

Table 4.--*Statistical summary of ground-water and base-flow chemical-quality data in the vicinity of the Cedar Bluff Unit, Smoky Hill River valley, 1981-82*--Continued

Chemical constituent or property	Units	Source[1]	Sample size	Mean	Standard deviation	Minimum	First quartile	Median	Third quartile	Maximum
Dissolved fluoride	mg/L[3]	G	18	.41	.13	.2	.3	.4	.5	.6
		B	13	.5	.1	.4	.5	.5	.6	.8
Dissolved solids	do.	G	11	790	150	550	650	810	930	960
Nitrogen, dissolved, $NO_2 + NO_3$	do.	G	20	5.1	5.3	0	0.3	3.3	8.5	17
		B	13	.11	.11	0	0	.1	.15	.40
Ammonia, dissolved, N	do.	G	20	.15	.11	0	.09	.11	.16	.43
Ammonia, total, N		B	13	.18	.05	.14	.14	.16	.19	.34
Phosphorus, dissolved	do.	G	18	.06	.01	.05	.05	.07	.08	.10
Phosphorus, total		B	13	.05	.02	.04	.04	.05	.07	.09
Arsenic, dissolved	μg/L[4]	G	20	--	--	0	0	10	10	10
Arsenic, total		B	13	--	--	0	10	10	10	10
Barium, dissolved	do.	G	20	--	--	0	100	100	100	500
Barium, total		B	13	--	--	100	100	100	100	200
Boron, dissolved	do.	G	18	230	89	160	180	210	250	520
Boron, total		B	13	230	35	190	200	220	270	280
Selenium, dissolved	do.	G	19	11	13	3	4	7	12	60
Selenium, total		B	13	6	1	3	5	6	7	8

Table 4.--*Statistical summary of ground-water and base-flow chemical-quality data in the vicinity of the Cedar Bluff Unit, Smoky Hill River valley, 1981-82*--Continued

Chemical constituent or property	Units	Source[1]	Sample size	Mean	Standard deviation	Mini-mum	First quar-tile	Median	Third quar-tile	Maximum
Iron, dissolved	μg/L[4]	G	20	760	1,300	20	30	40	1,400	4,200
Iron, total		B	13	440	350	60	260	350	460	1,500
Manganese, dissolved	do.	G	20	160	250	0	10	10	380	810
Manganese, total		B	13	270	230	30	150	200	260	800

1 G = ground-water sample; B = base-flow sample.

2 Microsiemens per centimeter at 25 °Celsius.

3 Milligrams per liter.

4 Micrograms per liter.

Long Island (fig. 3), in the vicinity of the Almena Unit in the Prairie Dog Creek valley; at Scandia (fig. 5), in the vicinity of the Kansas-Bostwick Unit in the Republican River valley; or at Hays, located about 8 miles northeast of Antonino, in the vicinity of the Cedar Bluff Unit in the Smoky Hill River valley.

Seasonal variations in concentrations of chemical constituents in ground water also would not appear to be a factor in accounting for any statistically determined differences. No differences in spring, summer, or fall concentrations of calcium, sodium plus potassium, sulfate, bicarbonate, chloride, or nitrate, were detected at the 10-percent level in any of the three areas using a Kruskal-Wallis test [a nonparametric one-way analysis of variance procedure (Klugh, 1970)] on data collected from wells shown in tables 14-16 during March-April (spring), August (summer), or October (fall) of 1982.

Changes in sampling and analytical techniques also could account for possible changes in water quality. However, with the exception of sodium plus potassium and nitrate, analytical precision and accuracy of data for other major chemical constituents analyzed by methods used before 1960 and during 1981-82 are similar and indicate that the data generally are comparable for the pre- and postirrigation periods.

Sodium-plus-potassium concentrations before 1950 were determined indirectly by subtracting the millequivalent sum of calcium and magnesium from the total millequivalent sum of sulfate, chloride, nitrate, and bicarbonate and then dividing this residual by 0.043. Estimates of the accuracy of this technique were made using nine sample analyses randomly obtained from a U.S. Geological Survey report (1979), for which concentrations of sodium plus potassium were known (table 20 in the "Supplementary Information" section). The median relative error from these 9 samples was -10 percent. Thus, older analyses, which had sodium plus potassium determined by this method when compared to more recent analyses, could tend to have smaller concentrations. Sodium-plus-potassium concentrations for older analyses, which were computed indirectly, therefore were adjusted by adding 10 percent to the reported concentrations before the statistical comparisons were made.

Based on data presented by the U.S. Geological Survey (1975), the method used for nitrate determination by the State laboratory in older analyses was phenoldisulfonic acid (American Public Health Association, 1971), which tends to have a large bias (the method determines nitrate contrations larger than the true concentration). Thus, comparison of old with recent data would tend to show a decrease in concentration.

Methods of Statistical Analysis

Ground-Water Chemical Quality

Data collected from water-supply wells for the preirrigation period were compiled from studies by Frye and Leonard (1949) for the Prairie Dog Creek valley, Fishel and Lohman (1948) for the Republican River valley, and Leonard and Berry (1961) for the Smoky Hill River valley. Data from well waters sampled during 1981-82 were compared with data from well waters sampled before 1960. Wells used in the pre- and postirrigation comparisons were developed in the same geologic material and generally had about the same well depth. The well number and data from wells selected for the comparisons are shown in tables 21-23 in the "Supplementary Information" section at the end of this report. Data were compared from wells that were matched as closely as possible by location (generally within 0.25 mile) to decrease variance caused by spatial differences in water quality. A single median concentration was computed from all available concentrations (generally 3 to 4) for each chemical constituent for each well sampled between 1981 and 1982. A single concentration existed for each well sampled during the preirrigation period. Chemical-quality data from the matched wells then were compared using a Wilcoxon Matched-Pairs test (Conover, 1980) to test the null hypothesis that concentrations of constituents in ground water for the preirrigation period were equal to concentrations of constituents for the postirrigation period. Sodium plus potassium concentrations for pre-1950 analyses were adjusted by adding 10 percent to the reported concentration. If the probability was less than 10 percent that the difference was due to chance alone, then the null hypothesis was rejected.

Base-flow Chemical Quality

Base-flow data from each area were analyzed by one of three different methods depending on the type and quantity of data. The specific analytical procedures used on base-flow data from each area are described in the following paragraphs.

Prairie Dog Creek Valley - Almena Unit

Although four seepage-salinity surveys were conducted between November 1981 and October 1982 on Prairie Dog Creek, the stream had flow within the irrigation-district boundaries only during March 1982. Thus, the postirrigation-period concentrations were represented by data collected only during March 1982. Data from a seepage-salinity survey conducted during May 1964 (table 24, "Supplementary Information" section) was selected for comparison because it was the only preirrigation-period spring seepage survey available.

The statistical comparison was conducted in two steps. First, correlations between streamflow and concentration were established for the preirrigation-period seepage survey using a Spearman-rho test (Conover, 1980). Because tributaries did not contribute to streamflow between sites 62.0 and 43.0 (fig. 3), gains in streamflow during 1964 primarily were due to ground-water inflows from the alluvium. Therefore, either lack of correlation or a significant negative correlation between streamflow and concentration at stations between sites 62.0 and 43.0 during 1964 meant that the ground water was approximately equal in concentration or less concentrated than the water in the stream (that is, the stream-water quality was being diluted or not being affected by ground-water inflow).

This technique established a baseline for ground-water quality. Because only ground water contributed to flow between sites 62.0 and 43.0 during 1982, the hypothesis could be tested then by use of a Wilcoxon Matched-Pairs test that concentrations in this reach during the spring of 1982 were equal to concentrations in the reach during the spring of 1964. Results of the Wilcoxon Matched-Pairs test would indicate either that ground-water discharging from the valley deposits in the irrigation reach between sites 62.0 and 43.0 during 1982 was either more concentrated, equal in concentration, or more diluted than ground-water discharging to the reach during 1964.

Republican River Valley - Kansas-Bostwick Unit

Seepage-salinity data before 1981 were not available for the Republican River within the Kansas-Bostwick Unit. However, chemical-quality data for 1966-71 and 1982 were available from two sites; site 154.0 near Guide Rock, Nebraska (not shown in fig. 5), located upstream of the Kansas-Bostwick Unit, and from site 121.3 near Scandia, Kansas, located within the Kansas-Bostwick Unit (fig. 5).

A simple evaluation of trends at the station upstream from the irrigation district and within the irrigation district could be used to evaluate whether irrigation-water applications within the district appeared to affect concentrations of selected chemical constituents through leaching of salts. Thus, no trend at the station upstream of the irrigation district and a positive trend at the downstream station would indicate that irrigation could be affecting water quality. No trend at both stations would indicate that irrigation was not affecting water quality. Positive trends at both stations would indicate that some factor, possibly irrigation upstream of the Kansas-Bostwick irrigation district, was causing increased concentrations in the river through time.

A Spearman-rho test for trend (Conover, 1980) was conducted on selected chemical constituents at both the upstream (site 154.0) and downstream (site 121.3) sites. Before the test for trend could be conducted, however, chemical-quality data were selected that were collected during low flow when the discharge did not differ by more than about 30 percent of the discharge measured during 1982 at both the upstream and downstream sites. This technique allowed for meaningful trend comparisons through time by minimizing variations in water quality due to correlation of concentration to discharge.

Smoky Hill River Valley - Cedar Bluff Unit

Several seepage-salinity surveys were conducted in the Smoky Hill River valley between 1964 and 1971 (Leonard and Stoltenberg, 1972). Data collected during the same months for each year of record from two sampling sites upstream from the major part of the Cedar Bluff Unit (sites 352.8 and 350.0, fig. 7) and two sampling sites downstream from the Cedar Bluff Unit (sites 338.0 and 335.5, fig. 7) were selected for comparison. Concentrations of several chemical constituents were tested for trends through time at all four sites using a Spearman-rho test for trend. A one-way analysis of variance test (Klugh, 1970) was applied to the data from each site to determine if concentrations at any of the sites differed significantly. A Duncan's multiple-range test (Klugh, 1970) then was used to determine which sites had concentrations that were significantly different or were statistically the same.

Effects of Irrigation, Almena Unit, Prairie Dog Creek Valley

Results of Statistical Tests

Results of the Wilcoxon Matched-Pairs test comparing pre- and postirrigation ground-water quality are shown in table 5. Concentrations of sulfate were significantly larger at the 10-percent level during the postirrigation period. No significant differences were detected in dissolved calcium, sodium plus potassium, bicarbonate, chloride, and nitrate, or dissolved-solids concentrations.

Results of the Spearman-rho test for correlation between streamflow and concentrations of chemical constituents during May 1964 are shown in table 6. Calcium, sulfate, and nitrate were not significantly correlated with streamflow, whereas sodium, chloride, and dissolved solids were negatively correlated with streamflow at the 10-percent level. Results of the Wilcoxon Matched-Pairs test (Conover, 1980) shown in table 7 indicate that concentrations of dissolved sodium, sulfate, chloride, and solids were significantly larger in base flow during the postirrigation period than during the preirrigation period. Nitrate concentrations were, however, significantly smaller during the postirrigation period.

Table 5.--*Results of Wilcoxon Matched-Pairs test comparing pre- and postirrigation-period concentrations of selected dissolved chemical constituents in water from supply wells in the Almena Unit*

[Levels of significance of less than 0.10 indicate that a statistically significant difference in concentration was determined and is marked with an asterisk]

Dissolved chemical constituent	Number of sample pairs	Value of T	Direction of change[1]	Level of significance (two-tail)
Calcium	5	3	0	Greater than 010
Sodium plus potassium	5	2	0	Greater than 010
Bicarbonate	5	5	0	Greater than 010
Sulfate	5	1	+	Less than 010*
Chloride	4	4.5	0	Greater than 010
Nitrate	5	5	0	Greater than 010
Dissolved solids	5	5	0	Greater than 010

[1] A plus (+) indicates a larger postirrigation-period concentration; a minus (-) indicates a smaller postirrigation concentration; a zero (0) indicates no difference between pre- and postirrigation concentrations.

Table 6.--*Results of Spearman-rho test for correlation between streamflow and concentrations of selected chemical constituents, Prairie Dog Creek, between sampling sites 62.0 and 43.0, May 1964*

[Minus (-) indicates negative correlation significant at the 10-percent level. Zero (0) indicates no significant correlation at the 10-percent level]

	Calcium	Sodium	Sulfate	Chloride	Nitrate	Dissolved solids
Sample pairs	9	9	9	9	9	9
Spearman-rho	-.39	-.72	-.20	-.64	.29	-.71
Level of significance	0	-	0	-	0	-

Table 7.--*Results of Wilcoxon Matched-Pairs test (Conover, 1980) comparing pre- and postirrigation-period concentrations of selected dissolved chemical constituents in base flow of Prairie Dog Creek between sampling sites 62.0 and 43.0*

[Levels of significance of less than 0.10 indicate a statistically significant difference in concentration was determined and is marked with an asterisk]

Dissolved chemical constituent	Number of sample pairs	Value of T	Direction of change[1]	Level of significance (two-tail)
Calcium	8	13.5	0	Greater than 0.10
Sodium	9	1	+	Less than 0.01*
Sulfate	9	0	+	Less than 0.01*
Chloride	9	0	+	Less than 0.01*
Nitrate	9	0	-	Less than 0.01*
Dissolved solids	9	6	+	Less than 0.10*

[1] A plus (+) indicates a larger postirrigation-period concentration; a minus (-) indicates a smaller postirrigation concentration; a zero (0) indicates no difference between pre- and postirrigation concentrations.

Interpretation of Results

Results from the Wilcoxon Matched-Pairs test (Conover, 1980) conducted on the chemical-quality data from water-supply wells indicate that irrigation practices caused significant increases in sulfate concentrations in the ground water in the vicinity of the Almena Unit in Prairie Dog Creek valley. Possible differences in other chemical constituents tested were apparently too small to detect with the sample size used.

However, significantly larger concentrations of dissolved sodium, sulfate, chloride, and dissolved solids existed in the base-flow samples collected during the spring of 1982 than during the spring of 1964 as indicated by results shown in table 7 from the Wilcoxon Matched-Pairs test (Conover, 1980). These results suggest that during 1982 larger concentrations of chemical constituents shown in table 7 existed in ground water discharging to Prairie Dog Creek in the irrigation district than during 1964.

The larger concentrations of chemical constituents in base flow during 1982, shown in table 7, may be due either to leaching by applied irrigation water or possibly, in the case of sodium, chloride, and dissolved solids, to increases through time in these constituents in water applied from the reservoir, as indicated by results of a Spearman-rho test for trend on concentrations of selected constituents in water released from Keith Sebelius Lake, shown in table 8 (data used in the analysis are given in table 25 at the end of this report).

A significantly smaller nitrate concentration was determined in base flow during 1982 than during 1964, as indicated by results from the Wilcoxon Matched-Pairs test in table 7. The decrease in nitrate concentration during the postirrigation period is due at least in part to the change in laboratory analytical techniques; the phenoldisulfonic-acid method, which as noted had a positive bias, was used to determine nitrate concentrations during the preirrigation period.

Thus, irrigation practices appear to have caused significant increases in concentrations of dissolved calcium, sodium, sulfate, and chloride, and dissolved solids in base flow as indicated by pre- and postirrigation-period comparisons of base-flow chemical-quality data. Using only the available small sample of chemical analyses from supply wells, however, only sulfate concentrations appeared to have increased significantly; these results indicate that sulfate concentrations in ground water have undergone the largest increase due to irrigation practices. However, water quality in the Prairie Dog Creek valley at the completion of this investigation (1982) generally met national interim drinking-water standards (U.S. Environmental Protection Agency, 1976). No concentrations of organic pesticides shown in tables 14-16 in the "Supplementary Information" section were detected, as of 1982, in any of the ground-water samples. However, 2,4-D was detected at a concentration of 1.4 μg/L in a sample collected from site 80.2 (table 17).

Table 8.--*Results of Spearman-rho test for trend in concentrations of selected dissolved chemical constituents in water released from Keith Sebelius Lake for 1971-82*

[Samples collected in July of each year. Data from U.S. Geological Survey (1971-74; 1979-82). A minus (-) indicates a decreasing trend, significant at the 10-percent level; zero (0) indicates no trend at the 10-percent level; a plus (+) indicates a positive trend, significant at the 10-percent level. A one-tailed test for positive trend was used]

	Calcium	Sodium	Sulfate	Chloride	Nitrate	Dissolved solids
Sample pairs	8	8	8	8	6	8
Spearman-rho	.19	.85	.19	.56	.54	.60
Level of significance	0	+	0	+	0	+

Effects of Irrigation, Kansas-Bostwick Unit, Republican River Valley

Results of Statistical Tests

Results of the Wilcoxon Matched-Pairs test (Klugh, 1970) on pre- and postirrigation ground-water-quality data are shown in table 9. Concentrations of calcium, bicarbonate, sulfate, and dissolved solids were significantly greater at the 10-percent or lower level during the postirrigation period than during the preirrigation period. Results from the Spearman-rho test for trend conducted on surface-water-quality data from sites 121.3 and 154.0 showed increasing trends in the chemical constituents for both sites (table 10).

Interpretation of Results

Concentrations of dissolved calcium, bicarbonate, and sulfate, and dissolved solids, were significantly larger in the ground water for the postirrigation period. Increased concentrations of other chemical constituents shown in table 9 were not detected, possibly because sample sizes were too small. The determined increases in concentrations of chemical constituents in the ground water may be due, at least in part, to irrigation practices. Irrigation water is a possible source of increased ionic concentrations in ground water because positive trends in all chemical constituents shown in table 10 were detected at the upstream sampling site (site 154.0, table 10); water is diverted through canals from Guide Rock, Nebraska, for irrigation of the area upstream from Lovewell Dam in the northern part of the Kansas-Bostwick Unit. Positive trends also were determined in these chemical constituents and appeared more pronounced at site 121.3, which is located within the Kansas-Bostwick

Table 9.-- *Results of Wilcoxon Matched-Pairs test comparing pre- and post-irrigation-period concentrations of selected dissolved chemical constituents in ground-water supplies from the Kansas-Bostwick Unit, Republican River valley*

[Levels of significance of less than 0.10 indicate that a statistically significant difference in concentration was determined and is marked with an asterisk]

Dissolved chemical constituent	Number of sample pairs	Value of T	Direction of change[1]	Level of significance (two tail)
Calcium	7	1	+	Less than or equal to 0.02*
Sodium plus potassium	7	11	0	Greater than 0.10
Bicarbonate	7	3	+	Less than or equal to 0.05*
Sulfate	6	2	+	Less than or equal to 0.05*
Chloride	7	8	0	Greater than 0.10
Nitrate	7	6	0	Greater than 0.10
Dissolved solids	7	0	+	Less than or equal to 0.01*

1 A plus (+) indicates a larger postirrigation-period concentration; a minus (-) indicates a smaller postirrigation concentration; a zero (0) indicates no difference between pre- and postirrigation concentrations.

Table 10.-- *Results of Spearman-rho test for trend in concentrations of selected dissolved chemical constituents at sampling sites upstream and within the Kansas-Bostwick Unit, Republican River valley, 1966-82*

[All Spearman-rho values indicate significant positive trends]

Site 154.0 (located upstream of Kansas-Bostwick Unit, figure 5)

	Calcium	Sodium	Bicarbonate	Sulfate	Chloride	Nitrate	Dissolved solids
Sample pairs	7	7	7	7	7	7	7
Spearman-rho	.88	.88	.89	.82	.95	.81	.81
Significance level	≤.01	≤.01	≤.01	≤.01	≤.01	≤.01	≤.01

Site 123.1 (located within Kansas-Bostwick Unit, figure 5)

	Calcium	Sodium	Bicarbonate	Sulfate	Chloride	Nitrate	Dissolved solids
Sample pairs	7	7	7	7	7	7	7
Spearman-rho	.92	.93	.89	.96	.75	1.0	.96
Significance level	≤.01	≤.01	≤.01	≤.01	≤.05	≤.001	≤.01

Unit; the slightly larger Spearman-rho (indicating a more pronounced trend) at site 121.3 suggests that leaching by applied irrigation waters could be responsible. Sampling site 121.3 receives irrigation return flows from the southern part of the Kansas-Bostwick Unit, which receives irrigation water from Lovewell Dam. However, because no water-quality data have been collected downstream from Lovewell Dam for most of the period it has operated, no trend analysis could be conducted.

Whereas concentrations of some chemical constituents have increased in ground water in the alluvium, apparently due to irrigation practices, ground water and base flow are still generally usable for most purposes in the Republican River valley. Median concentrations of dissolved sulfate, chloride, and dissolved solids in ground water in the Republican River valley alluvium during 1981-82 are similar to the regional concentrations of dissolved sulfate, chloride, and dissolved solids reported by Spruill (1983). Additionally, median concentrations of all chemical constituents presented in table 3 are less than U.S. Environmental Protection Agency drinking-water standards (1976, 1977). No pesticides listed in table 1 were detected in any of the samples collected.

Effects of Irrigation, Cedar Bluff Unit, Smoky Hill River Valley

Results of Statistical Tests

Results of the Wilcoxon Matched-Pairs test (Klugh, 1970) comparing chemical quality of pre- and postirrigation ground-water supplies in the Cedar Bluff Unit are shown in table 11. These results indicate significantly larger concentrations (at the 0.01-percent level) of the chemical constituents shown, except bicarbonate and nitrate, for the postirrigation period.

Results of the Spearman-rho test for trend (Conover, 1980) conducted on low-flow data collected between 1963 and 1982 (table 12) indicate significant positive trends in the chemical constituents shown, except for nitrate and phosphorus, at both the upstream (352.8 and 350.0) and downstream (338.0 and 335.5) sampling sites. Concentrations of sodium and chloride (table 13) were significantly greater at the sites downstream from the irrigation district, as determined by a one-way analysis of variance and Duncan's Multiple-Range test (Klugh, 1970).

Interpretation of Results

The significantly larger concentrations of calcium, sodium plus potassium, sulfate, chloride, and dissolved solids in ground water during the postirrigation period suggest that irrigation caused degradation of ground-water quality in the Smoky Hill River valley. Water in the valley deposits before irrigation began was a calcium bicarbonate type, usable for most purposes. Application of large quantities of calcium sulfate type irrigation water, with increasing concentrations of dissolved constituents, caused water in the valley deposits to change to a calcium-sulfate type. Concentrations of sulfate in the preirrigation analyses were less than

Table 11.--*Results of Wilcoxon Matched-Pairs test comparing pre- and postirrigation-period concentrations of selected dissolved chemical constituents in ground-water supplies in the Cedar Bluff Unit*

[Levels of significance of less than 0.10 indicate that a statistically significant difference in concentration was determined and is marked with an asterisk]

Dissolved chemical constituent	Sample pairs	Value of T	Direction of change[1]	Level of significance
Calcium	6	0	+	0.001*
Sodium plus potassium	6	0	+	.001*
Bicarbonate	6	9	0	.100
Sulfate	6	0	+	.001*
Chloride	6	0	+	.001*
Nitrate	6	8	0	.100
Dissolved solids	6	0	+	Less than .001*

1 A plus (+) indicates a larger postirrigation-period concentration; a minus (-) indicates a smaller postirrigation concentration; a zero (0) indicates no difference between pre- and postirrigation concentrations.

Table 12.--*Results of Spearman-rho test for trend in concentrations of selected dissolved chemical constituents at sampling sites upstream (sampling sites 352.8 and 350.0) and downstream (338.0 and 335.5) from the Cedar Bluff Unit*

[A plus (+) indicates a significant positive trend at the 0.01 level. A zero (0) indicates no trend significant at the 0.10 level]

	Dissolved chemical constituents							
Sampling site (shown in figure 7)	Calcium	Sodium	Bicarbonate	Sulfate	Chloride	Nitrate	Phosphorus	Dissolved solids
352.8	+	+	+	+	0	0	0	+
350.0	+	+	0	+	+	0	0	+
338.0	+	+	+	+	+	0	0	+
335.5	+	+	+	+	+	0	0	+

Table 13.--*Results of one-way analysis of variance and Duncan's Multiple-Range test on comparison of concentrations of selected dissolved chemical constituents at sampling sites upstream (sites 352.8 and 350.0) and downstream (sites 338.0 and 335.5) from the Cedar Bluff Unit*

[Samples with the same numeric symbol have statistically similar mean concentrations. Means are numbered in order of increasing concentration. Number of samples = 10 per site. Data from Leonard and Stoltenberg, 1972]

	Dissolved chemical constituents							
Sampling site (river mile)	Calcium	Sodium	Bicarbonate	Sulfate	Chloride	Nitrate	Phosphorus	Dissolved solids
352.8	0	0	0	0	0	0	0	0
350.0	0	1	1	0	0	0	0	0
338.0	0	2	1	0	1	0	0	0
335.5	0	2	1	0	1	0	0	0

250 mg/L, the standard listed for public drinking-water supplies (U.S. Environmental Protection Agency, 1977). Concentrations of sulfate in water samples in all six of the postirrigation-period wells exceeded 250 mg/L, whereas only one of the wells produced water that contained more than 250 mg/L during the preirrigation period.

Increases through time in concentrations of calcium, sodium, bicarbonate, sulfate, and dissolved solids in water released from the Cedar Bluff Reservoir probably partially account for positive trends determined in low-flow samples collected at sites 352.8, 350.0, 338.0, and 335.5 (table 12). This is indicated by increased concentrations through time (between 1964 and 1982) for dissolved calcium (from 100 to 260 mg/L), sodium (from 32 to 75 mg/L), bicarbonate (from 156 to 195 mg/L), sulfate (from 280 to 700 mg/L), and dissolved solids (from 578 to 1,300 mg/L) at site 355.9 located about 0.5 mile downstream from the dam. Thus, the results indicate that changes in these constituents were due to concomitant increases in concentrations of chemical constituents in water being released from Cedar Bluff Reservoir and were not due primarily to leaching.

Leaching by applied irrigation waters did, however, appear to affect concentrations of sodium and chloride. This is indicated by results shown in table 13. Significantly larger concentrations of sodium and chloride occurred in samples collected at sites 338.0 and 335.5, which are located downstream from the irrigation district.

No significant difference in either nitrate or phosphorus concentrations was detected between the stations upstream and downstream from the irrigation district (table 13). In addition, no trends in either nitrate or phosphorus were detected in the base-flow samples at any of the surface-water sampling sites (table 12). These data suggest that irrigation practices have not had any significant long-term effect on concentrations of these two chemical constituents in the Smoky Hill River valley in the vicinity of the Cedar Bluff Unit. Denitrification processes may prevent accumulation of nitrate in the ground water. It also is possible that crop uptake of nitrate and phosphorus may prevent leaching to the water table.

Results of tests conducted for this investigation are consistent with that of an earlier study by Leonard (1974), who concluded that the composition of the ground water would become similar to the applied irrigation water (Leonard, 1974, p. 71). Leonard also concluded, based on concentration ratios of chloride and sodium in water samples from the Smoky Hill River to concentrations in the applied irrigation water, that application of the irrigation water leached sodium and chloride ions into the ground water (Leonard, 1974, p. 49). Although application of irrigation water has caused large increases through time in concentrations of dissolved calcium, sodium plus potassium, sulfate, and chloride, and dissolved solids, irrigation has not apparently contaminated the ground water in the valley deposits with nitrate and phosphorus. No concentrations of organic pesticides listed in table 1 were detected in the ground- or surface-water samples.

CONCLUSIONS

Irrigation has caused changes in the chemical quality of ground water and base flow in three alluvial valleys in north-central Kansas. All three areas had been irrigated for 10 or more years. Statistical comparison of base-flow chemical-quality data collected during the spring of 1982 with data collected during the spring of 1964, before large-scale irrigation began, from sites on Prairie Dog Creek within the Almena Unit indicate that concentrations of sodium, sulfate, chloride, and dissolved solids have increased. Using only data collected from water-supply wells in the Almena Unit, sulfate concentrations had a significant increase at the 10-percent level; the sample used was possibly too small to detect significant changes in other chemical constituents tested. Concentrations of calcium, bicarbonate, sulfate, and dissolved solids in ground water in the Kansas-Bostwick Unit in the Republican River valley and calcium, sodium plus potassium, sulfate, chloride, and dissolved solids in ground water in the Cedar Bluff Unit in the Smoky Hill River valley were significantly larger during 1981-82 than before large-scale irrigation began.

Although concentrations of certain chemical constituents were significantly larger due to irrigation practices in all three areas, chemical quality of water in the Almena and Kansas-Bostwick Units generally met U.S. Environmental Protection Agency drinking-water standards during 1981-82. The Cedar Bluff Unit, however, had severe ground-water- and base-flow-quality degradation due to application of water with large concentrations of calcium, sulfate, and dissolved solids from Cedar Bluff Reservoir. Postirrigation-period sulfate concentrations in water from all six wells used in statistical comparison of pre- and postirrigation-period water quality were larger than the secondary drinking-water standard of 250 mg/L (U.S. Environmental Protection Agency, 1977). Leaching of sodium and chloride from soils by applied irrigation water also contributed to changes in ground-water quality in the Cedar Bluff Unit. Between 1963 and 1982 significantly larger concentrations of sodium and chloride were determined in base-flow samples collected from sites downstream than were determined in samples collected from sites upstream from the main part of the irrigation district.

An interesting finding of this investigation is that pre- and postirrigation nitrate concentrations in ground water were not significantly different at the 10-percent level in either the Almena or Cedar Bluff Units (where nitrate data were judged to be comparable based on the laboratory analytical techniques used). These results suggest that nitrogen may be utilized by irrigated crops, that denitrification processes may prevent accumulation of nitrate in the ground water, or simply that possible changes in concentration were too small to detect with the sample sizes used. A decrease in nitrate concentrations determined in base flow during the postirrigation period in Prairie Dog Creek probably was due, at least in part, to a change in laboratory analytical methods.

Data collected from ground- and surface-water sampling sites for this investigation indicate that irrigation has not caused contamination of ground water in the alluvium with organic pesticides for which analyses were performed. Pesticides that have U.S. Environmental Protection Agency primary drinking-water standards were detected at only one surface-water sampling site and at no ground-water sampling sites. Organic pesticides typically are not readily soluble and would be expected to sorb onto the soil in the unsaturated zone. However, even those pesticides, such as 2,4-D, which are readily soluble in water and are applied in Kansas, generally were not detected or were observed at concentrations near the minimum detection limit. These data suggest that organic pesticides were adsorbed, degraded, or were applied in quantities insufficient to be leached to the ground water.

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SUPPLEMENTARY INFORMATION

For tables 14 through 19, values are given in μS/cm, microsiemens per centimeter at 25 °C; deg. °C, degrees Celsius; mg/L, milligrams per liter; μg/L, micrograms per liter; and ft^3/s, cubic feet per second. Dashes (--) indicate that value is less than minimum reporting unit; ND indicates that value was not determined.

Table 14.--*Ground-water chemical-quality data, Prairie Dog Creek valley*

Map number (fig. 3)	Station number	Date	Specific conductance (µS/cm)	pH (standard units)	Temperature (deg. °C)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as mg)	Sodium, dissolved (mg/L as Na)	Percent sodium	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity field (mg/L as $CaCO_3$)	Sulfate dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)
1	395840099295101	81-11-18	740	7.6	13.5	110	20	25	13	0.6	14	180	60	14
		82-03-11	795	7.2	7.0	110	19	24	12	.6	14	340	43	13
		82-08-19	750	7.3	14.0	110	18	24	12	.6	15	340	46	11
		82-10-05	780	7.1	17.5	110	19	24	12	.6	14	338	49	14
2	395843099283901	82-03-11	810	7.2	5.0	120	13	21	11	.5	9.0	510	13	7.9
		82-08-19	720	7.3	16.5	120	13	21	11	.5	9.0	340	23	5.2
		82-10-05	800	6.8	16.0	130	13	21	10	.5	9.0	350	14	7.0
3	395738099304701	82-03-12	2,700	7.2	10.0	320	48	230	33	3	23	420	860	99
		82-08-19	2,540	7.3	14.0	310	46	250	35	4	39	420	850	95
		82-10-06	2,480	6.9	13.5	320	46	250	35	4	23	420	870	96
4	395643099320601	81-11-18	960	7.6	13.0	130	24	45	18	1	16	340	130	26
		82-03-09	975	7.2	13.0	130	23	46	19	1	17	340	120	24
		82-08-19	1,800	7.1	13.0	260	46	92	18	1	37	440	360	100
		82-10-06	1,090	6.4	12.5	160	27	53	18	1	18	356	180	38
5	395702099315701	81-11-18	1,840	7.4	13.0	260	48	93	19	1	25	420	410	110
		82-03-09	1,960	7.0	13.5	270	50	97	19	1	22	450	400	120
		82-08-19	1,070	7.2	12.0	150	26	54	19	1	22	350	170	36
		82-10-06	1,690	6.8	12.5	260	46	87	18	1	24	444	380	96
6	395557099335501	82-08-18	1,460	7.3	18.0	180	32	110	28	2	32	450	270	62
7	395550099335501	81-11-18	1,770	8.9	13.5	160	33	200	44	4	22	490	280	110
		82-03-11	2,180	7.0	13.0	200	40	220	41	4	24	500	300	200
		82-08-19	1,840	7.3	13.0	180	32	180	38	3	36	500	260	110
		82-10-06	1,880	6.8	13.0	170	32	200	43	4	22	500	270	100
8	395623099342001	82-08-18	665	7.5	13.0	100	16	18	11	.5	7.0	260	37	28
		82-10-06	741	7.0	13.5	100	17	18	11	.5	7.0	264	33	29
		82-03-12	650	7.4	12.5	98	17	17	10	.4	7.0	260	37	25
9	395504099372501	81-11-18	770	7.4	13.0	110	22	30	14	.7	17	390	35	6.8
		82-03-11	860	7.2	6.0	110	22	29	14	.7	16	390	27	8.8
		82-08-18	1,080	7.2	13.0	150	30	44	15	.9	25	440	120	33
		82-10-05	928	6.9	19.5	110	22	29	14	.7	17	400	34	8.0
10	395458099373301	81-11-18	1,020	7.0	13.0	140	30	42	16	.9	19	440	100	27
		82-03-11	1,080	7.1	12.0	150	32	42	15	.8	18	450	110	25
		82-08-18	1,050	7.3	15.0	150	30	44	15	.9	26	440	120	32
		82-10-05	1,180	6.7	18.5	150	31	44	15	.9	19	446	110	27
11	395451099360101	82-03-12	1,050	7.2	13.0	150	24	27	11	.6	16	390	140	23
		82-08-18	975	7.6	13.0	150	24	29	11	.6	23	390	130	19
		82-10-06	1,030	6.9	12.0	160	24	29	11	.6	17	400	140	19
12	395406099385701	82-03-12	740	7.3	12.5	120	20	31	15	.7	12	380	40	16
		82-08-19	865	7.2	12.0	130	20	31	14	.7	14	400	44	16
		82-10-06	860	6.6	12.0	130	20	31	14	.7	12	400	48	11
13	395432099405301	82-08-19	800	7.3	15.0	130	21	16	8	.4	10	350	31	14
		82-10-06	740	6.9	14.0	110	18	16	9	.4	9.0	316	31	15
		82-03-12	590	7.4	13.0	94	17	14	9	.4	8.0	280	20	12
14	395406099410101	82-08-18	760	7.4	13.5	120	18	23	11	.5	12	330	64	15
15	395340099420801	81-11-18	890	8.6	13.5	130	23	29	13	.6	17	360	64	34
		82-03-12	840	7.2	13.0	130	23	29	13	.6	17	360	67	36
		82-08-18	905	7.3	14.0	140	24	29	12	.6	22	360	65	35
		82-10-05	1,030	6.9	14.0	130	23	28	12	.6	18	356	65	34
16	395221099442101	81-11-18	640	7.4	13.0	53	18	13	11	.4	9.0	300	35	10
		82-03-12	620	7.1	6.5	100	19	14	8	.4	8.0	280	37	12
		82-08-18	650	7.5	13.0	100	18	13	8	.3	9.0	300	38	11
		82-10-06	570	7.4	13.0	100	18	13	8	.3	9.0	296	38	12
17	395215099443001	82-08-18	730	7.3	12.5	120	20	18	9	.4	15	300	65	24
18	395036099505801	81-11-18	750	7.8	12.0	120	19	16	8	.4	11	330	32	20
		82-03-12	750	6.6	6.0	120	20	16	8	.4	11	370	31	22
		82-08-18	800	7.5	13.0	120	22	21	10	.5	17	320	64	31
		82-10-06	630	7.3	13.0	110	18	16	9	.4	10	336	30	8.6
19	395030099485601	81-11-18	800	7.3	12.0	110	21	22	11	.5	12	340	33	28
		82-03-12	740	6.9	13.0	110	21	22	11	.5	13	340	34	30
		82-08-18	790	7.3	12.0	120	20	24	12	.6	14	340	42	30
		82-10-06	740	7.1	18.0	130	20	16	8	.4	11	340	38	21
20	394918099533116	81-11-18	1,310	7.4	11.5	190	30	46	14	.9	23	410	180	89
		82-08-18	1,650	7.2	13.5	240	34	70	16	1	40	470	200	170
		82-10-06	1,290	7.1	12.5	210	31	64	17	1	25	424	200	120
		82-03-12	1,360	6.7	13.0	150	29	43	15	.9	22	400	160	86

Table 14.--*Ground-water chemical-quality data, Prairie Dog Creek valley*--Continued

Map number fig. 3)	Station number	Date	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, No_2+NO_3, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Endrin, total (μg/L)	Lindane, total (μg/L)	Methoxychlor, total (μg/L)	Toxaphene, total (μg/L)	Silvex, total (μg/L)	2,4,5-T total (μg/L)	2,4-D total (μg/L)
1	395840099295101	81-11-18	--	55	410	0.10	--	ND	ND	ND	ND	ND	ND	ND
		82-03-11	0.3	54	480	.00	--	ND	ND	ND	ND	ND	ND	ND
		82-08-19	.4	60	490	.10	--	ND	ND	ND	ND	ND	ND	ND
		82-10-05	.3	60	490	.40	--	ND	ND	ND	ND	ND	ND	ND
2	395843099283901	82-03-11	.8	44	540	6.00	--	--	--	--	--	--	--	--
		82-08-19	.2	49	440	6.90	--	--	--	--	--	--	--	--
		82-10-05	.7	52	460	6.70	2.40	--	--	--	--	--	--	--
3	395738099304701	82-03-12	.4	29	1,900	14.0	--	--	--	--	--	--	--	--
		82-08-19	.4	32	1,900	16.0	--	--	--	--	--	--	--	--
		82-10-06	.4	32	1,900	16.0	--	--	--	--	--	--	--	--
4	395643099320601	81-11-18	--	45	620	6.40	--	--	--	--	--	--	--	--
		82-03-09	.24	44	610	6.30	--	--	--	--	--	--	--	--
		82-08-19	.4	45	1,200	9.10	--	--	--	--	--	--	--	--
		82-10-06	.2	48	740	6.00	--	--	--	--	--	--	--	--
5	395702099315701	81-11-18	--	44	1,200	15.0	--	--	--	--	--	--	--	--
		82-03-09	.2	41	1,300	16.0	--	--	--	--	--	--	--	--
		82-08-19	.3	46	710	1.30	--	--	--	--	--	--	--	--
		82-10-06	.2	47	1,200	16.0	--	--	--	--	--	--	--	--
6	395557099335501	82-08-18	.3	54	1,000	.10	--	ND	ND	ND	ND	ND	ND	ND
7	395550099335501	81-11-18	--	49	1,100	15.0	--	--	--	--	--	--	--	--
		82-03-11	.3	49	1,300	17.0	--	--	--	--	--	--	--	--
		82-08-19	.3	51	1,100	19.0	--	--	--	--	--	--	--	--
		82-10-06	.3	53	1,100	14.0	--	--	--	--	--	--	--	--
8	395623099342001	82-08-18	.3	45	410	5.70	--	ND	ND	ND	ND	ND	ND	ND
		82-10-06	.3	48	410	5.30	--	ND	ND	ND	ND	ND	ND	ND
		82-03-12	.3	44	400	2.20	--	ND	ND	ND	ND	ND	ND	ND
9	395504099372501	81-11-18	--	54	510	.00	--	--	--	--	--	--	--	--
		82-03-11	.3	52	500	.00	--	--	--	--	--	--	--	--
		82-08-18	.3	57	730	.00	--	--	--	--	--	--	--	--
		82-10-05	.3	60	520	.00	--	--	--	--	--	--	--	--
10	395458099373301	81-11-18	--	54	680	.00	--	--	--	--	--	--	--	--
		82-03-11	.3	53	700	.00	--	--	--	--	--	--	--	--
		82-08-18	.3	59	730	.00	--	--	--	--	--	--	--	--
		82-10-05	.3	59	710	.10	--	--	--	--	--	--	--	--
11	395451099360101	82-03-12	.3	53	670	.00	--	--	--	--	--	--	--	--
		82-08-18	.3	58	670	.00	--	--	--	--	--	--	--	--
		82-10-06	.3	58	690	.00	--	--	--	--	--	--	--	--
12	395406099385701	82-03-12	.4	52	520	.00	--	ND	ND	ND	ND	ND	ND	ND
		82-08-19	.4	55	550	.00	--	--	--	--	--	--	--	--
		82-10-06	.4	55	550	.00	--	--	--	--	--	--	--	--
13	395432099405301	82-08-19	.4	54	490	9.40	ND	ND	ND	ND	ND	ND	ND	ND
		82-10-06	.3	53	440	5.70	ND	ND	ND	ND	ND	ND	ND	ND
		82-03-12	.4	49	380	2.20	ND	ND	ND	ND	ND	ND	ND	ND
14	395406099410101	82-08-18	.3	54	500	2.90	ND	ND	ND	ND	ND	ND	ND	ND
15	395340099420801	81-11-18	--	45	560	5.20	--	--	--	--	--	--	--	--
		82-03-12	.3	46	570	4.00	ND	ND	ND	ND	ND	ND	ND	ND
		82-08-18	.3	50	580	4.60	ND	ND	ND	ND	ND	ND	ND	ND
		82-10-05	.3	49	560	4.90	ND	ND	ND	ND	ND	ND	ND	ND
16	395221099442101	81-11-18	--	54	370	.10	--	--	--	--	--	--	--	--
		82-03-12	.5	55	420	.00	--	--	--	--	--	--	--	--
		82-08-18	.5	57	430	.00	--	--	--	--	--	--	--	--
		82-10-06	.4	59	430	.00	--	--	--	--	--	--	--	--
17	395215099443001	82-08-18	.4	61	510	.00	ND	ND	ND	ND	ND	ND	ND	ND
18	395036099505801	81-11-18	--	40	460	6.00	--	--	--	--	--	--	--	--
		82-03-12	.5	41	480	5.00	--	--	--	--	--	--	--	--
		82-08-18	.4	48	520	2.00	--	--	--	--	--	--	--	--
		82-10-06	.4	52	450	.10	--	--	--	--	--	--	--	--
19	395030099485601	81-11-18	--	49	480	.00	--	--	--	--	--	--	--	--
		82-03-12	.4	52	490	.10	--	--	--	--	--	--	--	--
		82-08-18	.4	56	510	.00	--	--	--	--	--	--	--	--
		82-10-06	.4	45	490	6.20	--	--	--					
20	394918099533116	81-11-18	--	34	840	.10	ND	ND	ND	ND	ND	ND	ND	ND
		82-08-18	.4	31	1,100	.00	ND	ND	ND	ND	ND	ND	ND	ND
		82-10-06	.2	31	940	.00	ND	ND	ND	ND	ND	ND	ND	ND
		82-03-12	.3	32	760	.10	ND	ND	ND	ND	ND	ND	ND	ND

Table 15.--*Ground-water chemical-quality data, Republican River valley*

Map number (fig. 5)	Station number	Date	Specific conductance (μS/cm)	pH (standard units)	Temperature (deg. °C)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Percent sodium	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity field (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)
1	395524097490501	82-04-13	872	7.2	14.0	110	13	76	33	2	6.0	270	70	47
		82-08-25	660	7.6	14.0	94	9.5	51	28	1	6.0	220	42	29
		82-10-05	570	7.0	13.0	70	8.0	41	29	1	5.0	190	32	22
2	400005097545101	82-04-13	805	7.1	13.5	130	16	46	20	1	6.0	170	100	29
		82-08-25	750	7.2	14.0	110	13	43	22	1	6.0	280	81	26
		82-10-05	760	7.3	13.0	110	14	45	22	1	7.0	294	74	27
3	395735097503801	82-04-13	645	6.9	15.5	83	12	41	25	1	5.0	220	48	37
		82-08-25	650	7.1	14.0	84	12	45	27	1	5.0	230	40	33
		82-10-05	630	7.1	14.5	81	12	42	26	1	6.0	226	35	31
4	395636097504601	82-04-13	710	7.3	10.0	99	11	42	23	1	6.0	300	45	23
		82-08-25	660	7.3	15.5	94	10	45	26	1	6.0	300	32	22
		82-10-05	655	7.3	16.0	91	10	43	25	1	7.0	288	27	22
5	395550097515401	82-04-13	820	7.4	11.0	130	18	40	17	0.9	16	340	83	20
		82-08-25	790	7.5	13.5	110	15	43	21	1	17	340	71	20
		82-10-06	780	7.6	12.5	110	15	43	21	1	17	332	70	20
6	395728097580401	82-04-13	470	6.7	15.5	66	8.5	27	22	.9	4.0	160	54	13
		82-06-03	505	7.0	13.0	64	8.0	29	24	.9	4.0	160	49	14
		82-07-06	430	6.4	15.5	65	8.0	28	23	.9	5.0	160	57	13
		82-08-25	470	7.0	14.0	64	8.5	29	24	.9	4.0	160	43	13
		82-10-05	460	6.9	14.0	62	8.0	28	24	.9	4.0	150	37	14
7	395616098013301	82-08-25	785	7.3	14.5	140	9.0	18	9	.4	5.0	290	20	14
		82-10-05	740	7.2	15.0	140	8.0	14	7	.3	5.0	280	16	11
		82-04-13	760	7.0	14.0	140	9.0	15	8	.3	5.0	270	30	11
8	395913098025701	82-04-13	685	7.2	14.5	100	14	42	22	1	6.0	150	38	33
		82-06-03	760	7.6	12.5	94	13	44	25	1	5.0	260	43	32
		82-07-06	650	6.7	14.5	93	13	45	25	1	6.0	240	38	30
		82-08-25	720	7.3	13.5	93	12	49	27	1	6.0	270	34	23
		82-10-05	740	7.3	13.0	97	13	48	26	1	6.0	270	33	22
9	395452097462501	82-08-25	810	7.3	21.0	120	8.5	41	21	1	5.0	260	22	86
		82-10-04	800	7.3	14.0	120	8.5	40	20	1	5.0	256	16	83
		82-04-13	930	7.2	15.0	120	8.5	40	20	1	5.0	270	31	78
10	395307097490501	82-04-13	950	7.4	14.5	130	16	53	22	1	12	340	120	24
		82-08-24	930	7.3	12.0	140	16	56	22	1	13	350	100	24
		82-10-04	930	7.3	13.0	140	16	56	22	1	12	352	110	24
11	395452097505501	82-04-13	820	7.3	13.0	130	25	16	7	.4	13	340	93	17
		82-06-03	825	7.5	13.0	120	22	19	9	.4	12	340	85	16
		82-07-06	705	6.8	17.0	120	22	21	10	.5	13	330	81	16
		82-08-24	790	7.4	15.5	120	22	20	10	5	14	330	74	16
		82-10-06	795	7.4	15.5	120	23	20	10	.5	14	330	84	18
12	395208097502901	82-04-13	1,260	7.1	13.0	140	17	130	40	3	8.0	410	180	39
		82-08-24	1,030	7.3	14.0	120	14	99	37	2	8.0	360	130	32
		82-10-06	1,230	7.2	13.0	150	18	120	36	3	9.0	420	160	52
13	395031097525301	82-08-24	2,400	7.2	14.5	350	30	190	29	3	6.0	350	670	140
		82-04-13	2,800	9.5	15.0	370	34	200	29	3	5.0	370	720	140
		82-10-06	2,330	7.2	13.0	330	30	210	32	3	6.0	384	660	130

Table 15.--*Ground-water chemical-quality data, Republican River valley*--Continued

Map number (fig. 5)	Station number	Date	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Endrin, total (μg/L)	Lindane, total (μg/L)	Methoxychlor, total (μg/L)	Toxaphene, total (μg/L)	Silvex, total (μg/L)	2,4,5-T total (μg/L)	2,4-D total (μg/L)
1	395524097490501	82-04-13	0.2	28	510	21.0	--	--	--	--	--	--	--	--
		82-08-25	.3	31	400	10.0	--	--	--	--	--	--	--	--
		82-10-05	.2	31	320	8.10	--	--	--	--	--	--	--	--
												--	--	--
2	400005097545101	82-04-13	.3	24	510	0.90	--	--	--	--	--	--	--	--
		82-08-25	.4	26	470	.20	--	--	--	--	--			
		82-10-05	.3	27	480	.40	--	--	--	--	--	--	--	--
												--	--	--
3	395735097503801	82-04-13	.2	28	390	5.00	--	--	--	--	--	--	--	--
		82-08-25	.3	31	390	5.70	--	--	--	--	--	--	--	--
		82-10-05	.2	33	380	5.70	--	--	--	--	--	--	--	--
4	395636097504601	82-04-13	.3	34	440	.10	--	--	--	--	--	--	--	--
		82-08-25	.4	40	430	.00	--	--	--	--	--	--	--	--
		82-10-05	.3	42	420	.10	--	--	--	--	--	--	--	--
												--	--	--
5	395550097515401	82-04-13	.5	30	540	.00	--	--	--	--	--	--	--	--
		82-08-25	.4	31	510	.60	--	--	--	--	--			
		82-10-06	.4	31	510	.00	--	--	--	--	--	--	--	--
6	395728097580401	82-04-13	.2	36	310	5.50	--	--	--	--	--	--	--	--
		82-06-03	.2	29	290	4.60	--	--	--	--	--	--	--	--
		82-07-06	.2	37	310	4.90	--	--	--	--	--	--	--	--
		82-08-25	.3	37	300	5.90	--	--	--	--	--	--	--	--
		82-10-05	.2	41	280	6.80	--	--	--	--	--	--	--	--
7	395616098013301	82-08-25	.2	50	430	25.0	--	ND	ND	ND	ND	ND	ND	ND
		82-10-05	.2	52	410	20.0	--	ND	ND	ND	ND	ND	ND	ND
		82-04-13	.2	44	420	10.0	--	ND	ND	ND	ND	ND	ND	ND
8	395913098025701	82-04-13	.3	37	360	11.0	--	--	--	--	--	--	--	--
		82-06-03	.3	32	420	13.0	--	--	--	--	--	--	--	--
		82-07-06	.3	38	410	7.90	--	--	--	--	--	--	--	--
		82-08-25	.3	40	420	13.0	--	--	--	--	--	--	--	--
		82-10-05	.3	43	420	14.0	--	--	--	--	--	--	--	--
9	395452097462501	82-08-25	.3	32	470	2.90	0.11	ND	ND	ND	ND	ND	ND	ND
		82-10-04	.2	34	460	2.80	.14	ND	ND	ND	ND	ND	ND	ND
		82-04-13	.2	30	480	3.20	.12	ND	ND	ND	ND	ND	ND	ND
10	395307097490501	82-04-13	.3	39	600	4.80	.12	--	--	--	--	--	--	--
		82-08-24	.4	42	600	6.20	.61	--	--	--	--	--	--	--
		82-10-04	.2	46	620	6.60	.36	--	--	--	--	--	--	--
11	395452097505501	82-04-13	.7	31	530	.20	.22	--	--	--	--	--	--	--
		82-06-03	.7	27	510	.10	.16	--	--	--	--	--	--	--
		82-07-06	.7	34	510	.10	.22	--	--	--	--	--	--	--
		82-08-24	.8	32	500	.10	.16	--	--	--	--	--	--	--
		82-10-06	.8	38	520	.20	.22	--	--	--	--	--	--	--
12	395208097502901	82-04-13	.4	20	780	7.60	.05	--	--	--	--	--	--	--
		82-08-24	.5	21	640	3.70	.07	--	--	--	--	--	--	--
		82-10-06	.4	25	790	9.60	.13	--	--	--	--	--	--	--
13	395031097525301	82-08-24	.4	24	1,600	41.0	.20	ND	ND	ND	ND	ND	ND	ND
		82-04-13	.3	21	1,700	39.0	.07	ND	ND	ND	ND	ND	ND	ND
		82-10-06	.2	26	1,600	28.0	.25	ND	ND	ND	ND	ND	ND	ND

Table 15.--*Ground-water chemical-quality data, Republican River valley*--Continued

Map number (fig. 5)	Station number	Date	Specific conductance (μS/cm)	pH (standard units)	Temperature (deg. °C)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Percent sodium	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity field (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)
14	395024097491401	81-07-08	880	7.4	15.0	120	33	23	10	0.5	24	370	100	22
		82-04-12	870	7.2	14.0	130	31	26	--	.6	--	370	110	16
		82-08-24	950	7.2	14.0	120	40	24	9	.5	27	390	85	15
		82-10-04	970	7.2	13.0	130	35	27	11	.6	25	386	100	16
15	395406098013401	82-06-03	750	7.6	14.5	96	13	55	29	1	3.0	310	12	64
		82-08-25	745	7.6	19.0	95	13	56	29	1	3.0	310	3.7	62
		82-10-05	760	7.6	17.0	97	13	54	28	1	3.0	312	1.8	59
		82-04-13	740	7.4	14.0	110	15	53	25	1	3.0	310	13	60
		82-07-06	735	6.8	19.0	96	13	55	29	1	3.0	310	15	65
16	395333098001001	82-04-13	1,360	7.8	9.0	190	26	76	22	1	12	390	130	140
		82-08-25	1,300	7.8	13.0	180	24	83	24	2	13	350	110	140
		82-10-05	1,350	7.8	12.0	180	24	80	24	2	12	392	110	140
17	394709097471501	82-04-13	1,180	7.3	14.0	170	18	77	25	2	11	320	190	86
		82-08-24	1,040	7.3	13.0	160	18	44	16	.9	13	310	180	52
		82-10-04	1,130	7.4	13.0	160	17	72	24	2	12	308	170	89
18	394445097481501	82-04-15	1,150	7.1	11.0	150	11	110	36	2	5.0	410	130	59
		82-08-20	1,170	7.1	18.0	150	11	110	36	2	6.0	250	130	70
		82-10-04	1,120	7.2	14.0	140	10	110	38	3	6.0	408	110	62
19	394708097524403	82-04-13	2,000	7.1	12.5	280	32	130	25	2	2.0	180	600	160
		82-05-27	1,900	7.4	12.0	240	26	130	28	2	4.0	190	500	170
		82-06-30	1,950	8.0	14.0	270	31	130	26	2	3.0	330	600	170
		82-08-24	1,880	7.2	13.0	260	30	130	27	2	3.0	300	560	170
		82-10-05	1,850	7.3	13.0	250	30	140	29	2	3.0	202	550	170
20	394853097594501	82-04-13	700	7.3	10.5	92	11	37	22	1	7.0	250	80	20
		82-08-25	600	7.2	19.5	80	11	39	25	1	8.0	200	79	17
		82-10-05	620	7.2	17.0	83	11	38	24	1	8.0	216	75	19
21	394636098000201	81-07-09	2,080	7.3	14.5	240	24	180	36	3	5.0	360	400	140
		82-08-25	1,950	7.2	13.0	240	25	180	36	3	6.0	370	390	150
		82-10-06	2,000	7.1	13.0	250	25	190	36	3	6.0	366	390	150
		82-04-13	1,940	7.1	12.5	250	25	180	35	3	5.0	360	400	140
		82-05-27	2,030	7.3	12.0	240	24	170	34	3	5.0	460	380	140
22	394432097474901	82-04-15	2,710	7.1	13.0	260	38	320	46	5	11	430	560	350
		82-08-20	2,390	7.1	14.0	320	45	210	31	3	14	460	770	110
		82-10-04	3,300	7.3	13.5	200	32	480	62	9	11	404	350	680
23	394327097483201	82-05-27	915	7.5	14.5	120	12	79	33	2	3.0	330	98	39
		82-08-20	800	7.3	16.5	120	12	47	22	1	3.0	320	60	26
		82-10-04	890	7.4	15.0	120	12	73	31	2	4.0	326	88	33
		82-04-13	840	8.4	16.0	120	13	81	33	2	4.0	330	96	37
		82-06-30	930	8.0	16.5	120	12	79	33	2	4.0	330	95	36

Table 15.--*Ground-water chemical-quality data, Republican River valley*--Continued

Map number (fig. 5)	Station number	Date	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, sum of constituents dissolved (mg/L)	Nitrogen, No_2+No_3 dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Endrin, total (μg/L)	Lindane, total (μg/L)	Toxaphene, total (μg/L)	Silvex, total (μg/L)	2,4,5-T total (μg/L)	2,4-D total (μg/L)
14	395024097491401	81-07-08	0.7	35	590	--	0.05	ND	ND	ND	ND	ND	ND
		82-04-12	.6	35	--	1.50	.07	--	--	--	--	--	--
		82-08-24	.7	32	580	9.50	.37	--	--	--	--	--	--
		82-10-04	.7	37	600	5.60	.29	--	--	--	--	--	--
15	395406098013401	82-06-03	.3	14	450	.10	.05	--	--	--	--	--	--
		82-08-25	.3	19	440	.10	.42	ND	ND	ND	ND	ND	ND
		82-10-05	.3	20	440	.00	.12	ND	ND	ND	ND	ND	ND
		82-04-13	.3	17	460	.10	.03	ND	ND	ND	ND	ND	ND
		82-07-06	.3	19	450	.10	.03	ND	ND	ND	ND	ND	ND
16	395333098001001	82-04-13	.2	31	840	3.50	.62	--	--	--	--	--	--
		82-08-25	.2	36	800	4.40	.66	--	--	--	--	--	--
		82-10-05	.2	37	820	3.70	.12	--	--	--	--	--	--
								--	--	--	--	--	--
17	394709097471501	82-04-13	.4	28	780	.40	.07	--	--	--	--	--	--
		82-08-24	.5	28	680	1.30	.40	--	--	--	--	--	--
		82-10-04	.4	30	740	2.00	.18	--	--	--	--	--	--
18	394445097481501	82-04-15	.5	25	740	2.10	.03	--	--	--	--	--	--
		82-08-20	.5	24	650	1.20	.38	--	--	--	--	--	--
		82-10-04	.5	29	710	1.50	.04	--	--	--	--	--	--
19	394708097524403	82-04-13	.5	16	1,300	.00	.02	--	--	--	--	--	--
		82-05-27	.5	13	1,200	.00	.02	--	--	--	--	--	--
		82-06-30	.6	35	1,400	.00	.00	--	--	--	--	--	--
		82-08-24	.5	17	1,400	.00	.34	--	--	--	--	--	--
		82-10-05	.5	19	1,300	.70	.07	--	--	--	--	--	--
20	394853097594501	82-04-13	.3	32	430	2.40	.24	--	--	--	--	--	--
		82-08-25	.3	30	380	1.70	.65	--	--	--	--	--	--
		82-10-05	.3	30	390	2.50	.79	--	--	--	--	--	--
21	394636098000201	81-07-09	.2	25	1,400	--	.07	--	--	--	--	--	--
		82-08-25	.3	27	1,200	30.0	.59	ND	ND	ND	ND	ND	ND
		82-10-06	.3	28	1,300	31.0	.14	ND	ND	ND	ND	ND	ND
		82-04-13	.3	24	1,200	33.0	.06	ND	ND	ND	ND	ND	ND
		82-05-27	.3	20	1,300	32.0	.05	ND	ND	ND	ND	ND	ND
22	394432097474901	82-04-15	.9	36	1,800	.00	.03	--	--	--	--	--	--
		82-08-20	.5	36	1,800	.10	.26	--	--	--	--	--	--
		82-10-04	1.2	29	2,000	.00	.04	--	--	--	--	--	--
23	394327097483201	82-05-27	.2	21	570	7.60	.11	ND	ND	ND	ND	ND	ND
		82-08-20	.3	29	490	7.80	.31	ND	ND	ND	ND	ND	ND
		82-10-04	.3	28	550	7.70	.14	ND	ND	ND	ND	ND	ND
		82-04-13	.2	25	570	6.60	.12	ND	ND	ND	ND	ND	ND
		82-06-30	.3	26	570	5.90	.10	ND	ND	ND	ND	ND	ND

Table 16.--*Ground-water chemical-quality data, Smoky Hill River*

Map number (fig. 7)	Station number	Date	Specific conductance (μS/cm)	pH (standard units)	Temperature (deg. °C)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Percent sodium	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity field (mg/L as $CaCO_3$)	Sulfate dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)
1	384707099272701	82-03-11	1,140	7.2	12.0	180	29	50	16	1	6.0	190	320	130
		82-08-11	1,300	7.4	16.5	200	29	53	16	1	5.0	180	310	120
		82-10-04	1,320	7.4	15.0	190	30	50	15	0.9	5.0	179	330	110
2	384813099332501	82-03-11	1,080	7.3	10.0	160	20	64	22	1	4.0	220	280	52
		82-08-10	1,150	7.3	16.5	180	21	72	22	1	4.0	260	300	59
		82-10-04	1,310	7.5	18.0	180	21	70	22	1	4.0	266	290	59
3	384714099304701	82-03-11	1,220	7.2	14.0	190	22	76	22	1	6.0	210	390	72
		82-08-10	1,280	7.4	16.0	200	22	77	22	1	6.0	200	380	69
		82-10-04	1,300	7.6	17.0	190	21	73	22	1	6.0	203	370	66
4	384732099422701	82-08-10	1,460	7.3	17.0	240	33	59	15	1	13	109	580	50
5	384713099421001	81-11-16	950	7.8	14.0	120	19	42	19	1	4.0	210	160	68
		82-03-11	910	6.9	8.5	130	19	41	18	.9	4.0	210	150	69
		82-08-10	890	7.4	22.0	130	18	44	19	1	4.0	210	160	65
		82-10-04	840	7.6	20.0	130	19	43	19	1	7.0	216	150	66
6	384707099380201	81-11-16	2,720	7.6	14.0	360	71	170	23	2	14	270	1,000	160
		82-03-11	2,600	7.8	6.5	380	75	160	21	2	13	270	1,000	170
		82-08-10	2,480	7.1	20.0	370	68	140	20	2	12	270	930	160
		82-10-04	2,260	7.2	20.0	350	63	150	22	2	12	264	880	160
7	384305099195401	81-11-16	1,540	7.3	16.0	180	29	88	25	2	12	180	490	120
		82-03-09	1,500	7.3	15.0	210	29	84	22	2	12	170	520	90
		82-08-11	1,480	7.3	16.0	210	29	82	21	1	12	210	500	97
		82-10-04	1,600	7.5	15.5	220	28	90	22	2	12	184	480	110
8	384259099192101	81-11-16	1,490	7.5	14.5	190	30	84	23	2	12	170	510	82
		82-03-09	1,610	7.3	14.5	230	33	84	20	1	13	180	550	90
		82-08-11	1,500	7.4	14.5	220	31	83	21	1	12	340	510	97
		82-10-04	1,550	7.2	14.0	210	30	82	21	1	11	178	480	90
9	384615099255601	82-03-11	1,980	6.8	14.0	370	36	84	14	1	6.0	370	420	270
		82-08-11	2,940	8.1	18.0	16	5.0	650	95	38	8.0	350	280	560
		82-10-04	2,180	6.3	16.0	370	35	88	15	1	5.0	336	460	270
10	384548099290801	81-11-16	1,690	7.3	15.0	210	26	140	32	3	9.0	220	550	97
		82-03-10	1,850	7.4	15.0	220	26	140	31	2	9.0	230	540	99
		82-10-04	1,550	7.6	15.0	210	24	150	34	3	9.0	228	540	90
		82-08-11	1,710	7.3	14.5	220	24	150	33	3	9.0	120	530	91
11	384509099254101	82-03-11	1,250	7.2	13.0	210	23	57	17	1	6.0	220	340	81
		82-08-11	1,340	7.2	16.5	220	23	64	18	1	6.0	250	340	88
		82-10-04	1,440	6.7	16.5	220	24	64	18	1	6.0	292	290	97
12	384424099272101	81-11-16	2,300	7.2	14.0	320	25	140	25	2	4.0	230	670	160
13	384424099265601	81-11-16	1,340	7.7	15.5	210	26	50	15	.9	8.0	190	430	76
		82-08-11	1,400	7.3	15.0	240	27	52	14	.9	9.0	200	480	72
		82-10-04	1,380	6.7	15.0	220	27	48	13	.8	9.0	190	480	62
14	384417099264001	81-11-16	3,400	7.2	17.0	480	58	220	25	3	21	310	1,300	190
		82-03-11	3,560	7.1	13.5	570	73	280	26	3	23	290	1,400	260
		82-08-11	2,710	7.0	18.0	430	53	170	22	2	19	330	1,000	140
		82-10-04	2,760	6.7	15.5	440	53	180	23	2	19	328	1,000	150
15	384338099245201	81-11-17	1,090	7.5	15.0	160	9.5	54	21	1	6.0	240	180	82
16	384628099302301	82-03-10	1,290	7.4	12.5	170	16	51	18	1	6.0	200	250	78
		82-08-11	1,160	7.3	22.5	190	17	58	19	1	6.0	200	270	88
		82-10-04	1,230	7.6	17.0	190	18	56	18	1	6.0	205	250	92
17	384649099334301	82-03-10	1,840	7.4	14.0	190	22	150	36	3	7.0	220	400	180
		82-08-10	1,440	7.4	24.0	190	21	110	30	2	6.0	220	410	88
		82-10-04	1,340	7.6	19.0	180	20	130	34	3	6.0	214	390	99
18	384649099345901	82-08-10	1,040	7.3	16.0	160	25	38	14	.8	8.0	200	300	44
19	384603099345101	81-11-16	690	7.7	13.5	89	15	37	22	1	5.0	230	88	20
		82-03-11	880	7.3	5.0	120	18	51	23	1	5.0	220	170	41
		82-08-10	875	7.3	23.0	120	17	60	26	1	5.0	220	190	31
		82-10-04	790	7.3	18.5	110	16	54	25	1	5.0	252	140	25
20	384555099304001	82-03-10	1,280	7.7	10.0	170	21	88	27	2	6.0	160	390	79
		82-08-11	1,360	7.5	13.5	190	20	94	27	2	8.0	220	380	89
		82-10-04	1,360	7.5	20.0	170	21	90	27	2	9.0	244	290	93

Table 16.--*Ground-water chemical-quality data, Smoky Hill River*--Continued

Map number (fig. 7)	Station number	Date	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, sum of constituents dissolved (mg/L)	Nitrogen, No_2+No_3 dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Endrin, total (µg/L)	Lindane, total (µg/L)	Toxaphene, total (µg/L)	Silvex, total (µg/L)	2,4,5-T total (µg/L)	2,4-D total (µg/L)
1	384707099272701	82-03-11	0.4	22	850	4.70	--	--	--	--	--	--	--
		82-08-11	.4	24	850	10.0	--	--	--	--	--	--	--
		82-10-04	.3	25	850	4.10	--	--	--	--	--	--	--
2	384813099332501	82-03-11	.3	20	730	4.10	--	--	--	--	--	--	--
		82-08-10	.4	29	820	2.20	--	--	--	--	--	--	--
		82-10-04	.3	29	810	1.90	--	--	--	--	--	--	--
3	384714099304701	82-03-11	.2	26	910	4.30	--	--	--	--	--	--	--
		82-08-10	.3	31	910	3.80	--	--	--	--	--	--	--
		82-10-04	.2	31	880	13.0	--	--	--	--	--	--	--
4	384732099422701	82-08-10	.6	28	1,100	0.60	ND	ND	ND	ND	ND	ND	ND
5	384713099421001	81-11-16	--	19	560	1.10	--	--	--	--	--	--	--
		82-03-11	.5	18	560	2.30	--	--	--	--	--	--	--
		82-08-10	.5	20	570	1.10	--	--	--	--	--	--	--
		82-10-04	.4	17	560	.70	--	--	--	--	--	--	--
6	384707099380201	81-11-16	--	37	2,000	11.0	--	--	--	--	--	--	--
		82-03-11	.4	34	2,000	9.50	ND	ND	ND	ND	ND	ND	ND
		82-08-10	.4	32	1,900	6.20	ND	ND	ND	ND	ND	ND	ND
		82-10-04	.3	37	1,800	6.00	ND	ND	ND	ND	ND	ND	ND
7	384305099195401	81-11-16	--	19	1,000	.10	--	--	--	--	--	--	--
		82-03-09	.5	20	1,100	.00	--	--	--	--	--	--	--
		82-08-11	1.4	24	1,100	.10	--	--	--	--	--	--	--
		82-10-04	.4	24	1,100	.00	--	--	--	--	--	--	--
8	384259099192101	81-11-16	--	16	1,000	.00	--	--	--	--	--	--	--
		82-03-09	.4	19	1,100	.10	--	--	--	--	--	--	--
		82-08-11	.7	20	1,200	.10	--	--	--	--	--	--	--
		82-10-04	.42	20	1,000	.00	--	--	--	--	--	--	--
9	384615099255601	82-03-11	.2	20	1,400	14.0	--	--	--	--	--	--	--
		82-08-11	5.0	9.0	1,700	1.40	--	--	--	--	--	--	--
		82-10-04	.2	23	1,500	13.0	--	--	--	--	--	--	--
10	384548099290801	81-11-16	--	27	1,200	6.40	ND	ND	ND	ND	ND	ND	ND
		82-03-10	.3	24	1,200	7.80	ND	ND	ND	ND	ND	ND	ND
		82-10-04	.3	28	1,200	7.10	ND	ND	ND	ND	ND	ND	ND
		82-08-11	.3	27	1,100	7.20	ND	ND	ND	ND	ND	ND	ND
11	384509099254101	82-03-11	.3	26	880	3.60	--	--	--	--	--	--	--
		82-08-11	.3	32	920	7.20	--	--	--	--	--	--	--
		82-10-04	.2	32	910	10.0	--	--	--	--	--	--	--
12	384424099272101	81-11-16	--	24	1,500	15.0	--	--	--	--	--	--	--
13	384424099265601	81-11-16	--	25	940	.00	--	--	--	--	--	--	--
		82-08-11	.6	29	1,000	.00	ND	ND	ND	ND	ND	ND	ND
		82-10-04	.4	29	990	.20	ND	ND	ND	ND	ND	ND	ND
14	384417099264001	81-11-16	--	28	2,500	20.0	--	--	--	--	--	--	--
		82-03-11	.6	28	2,800	22.0	ND	ND	ND	ND	ND	ND	ND
		82-08-11	.7	30	2,000	11.0	--	--	--	--	--	--	--
		82-10-04	.5	32	2,100	14.0	--	--	--	--	--	--	--
15	384338099245201	81-11-17	--	24	660	.20	--	--	--	--	--	--	--
16	384628099302301	82-03-10	.3	32	720	3.00	--	--	--	--	--	--	--
		82-08-11	.3	35	780	10.0	--	--	--	--	--	--	--
		82-10-04	.3	36	770	9.80	--	--	--	--	--	--	--
17	384649099334301	82-03-10	.2	23	1,100	7.90	--	--	--	--	--	--	--
		82-08-10	.4	23	980	9.00	--	--	--	--	--	--	--
		82-10-04	.3	26	980	8.70	--	--	--	--	--	--	--
18	384649099345901	82-08-10	.6	29	730	1.40	ND	ND	ND	ND	ND	ND	ND
19	384603099345101	81-11-16	--	19	410	2.00	--	--	--	--	--	--	--
		82-03-11	.7	16	550	2.60	--	--	--	--	--	--	--
		82-08-10	.6	18	570	2.30	--	--	--	--	--	--	--
		82-10-04	.5	19	520	2.30	--	--	--	--	--	--	--
20	384555099304001	82-03-10	.2	15	870	1.60	ND	ND	ND	ND	ND	ND	ND
		82-08-11	.3	21	930	.10	--	--	--	--	--	--	--
		82-10-04	.3	29	850	.20	--	--	--	--	--	--	--

Table 17.--*Base-flow chemical-quality data, Prairie Dog Creek*

Map number (fig. 3)	Station number	Date	Streamflow, instantaneous (ft^3/s)	Specific conductance (μS/cm)	pH (standard units)	Temperature (deg. °C)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Percent sodium	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity field (mg/L as $CaCO_3$)	Sulfate dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)
87.2	06848000	82-03-26	0.02	450	7.9	4.0	69	16	18	14	0.5	9.0	220	15	30
80.2	395023099502200	81-11-18	.28	1,320	7.9	6.0	93	23	150	47	4	34	310	120	210
		82-03-26	.28	1,130	8.6	1.5	80	25	130	45	3	32	240	120	170
		82-08-12	.29	1,240	8.0	18.0	110	22	110	37	3	28	280	120	140
		82-10-06	.03	990	7.9	12.0	80	19	85	37	2	34	264	73	93
78.8	395030099505800	81-11-18	.07	530	7.9	6.0	82	17	11	8	.3	9.0	270	17	7.0
		82-03-26	.03	410	8.0	2.0	65	17	13	10	.4	7.0	220	23	13
78.3	395046099504500	82-08-12	.18	660	8.3	18.5	100	18	16	9	.4	12	370	26	10
75.9	395056099484800	81-11-18	.15	735	7.4	11.5	98	17	32	17	.8	12	330	24	36
		82-03-26	.28	990	8.0	2.0	86	21	100	39	3	27	270	85	130
		82-08-12	.02	825	7.8	19.0	110	18	41	20	1	14	320	24	57
67.1	395202099444700	81-11-18	.03	870	7.2	13.0	96	21	25	14	.6	14	400	27	35
		82-03-26	.0	800	7.4	5.5	130	25	27	12	.6	19	400	36	38
64.8	395235099441300	81-11-18	.14	820	7.6	12.0	130	20	19	9	.4	12	350	63	27
		82-03-26	.16	695	7.3	5.0	120	19	18	9	.4	11	320	46	24
		82-08-12	.07	785	7.2	17.0	140	19	23	10	.5	12	330	61	28
		82-10-06	.03	930	7.6	11.0	140	21	24	10	.5	15	346	74	30
62.0	395327099420800	81-11-18	.18	920	7.7	10.0	130	25	26	11	.6	19	410	73	34
		83-03-26	.12	765	7.6	4.5	120	23	25	12	.6	15	330	69	31
58.4	395416099400700	82-08-12	1.3	685	7.8	18.0	130	18	15	7	.3	11	320	31	28
57.6	395425099394600	82-03-26	.24	715	8.4	4.0	97	23	43	21	1	17	270	55	56
		82-08-12	.99	725	7.8	18.0	130	18	15	7	.3	13	320	36	28
55.8	395432099384000	82-03-26	.4	710	8.1	4.5	110	21	42	19	1	17	300	59	47
		82-08-12	.81	705	7.8	19.0	120	16	18	9	.4	12	320	35	21
54.2	395451099374200	82-03-26	.36	680	8.5	5.0	94	20	40	21	1	16	270	58	44
		82-08-12	--	770	8.0	18.5	120	17	18	9	.4	13	320	37	25
52.9	395458099362600	82-03-26	.36	675	7.6	4.5	96	21	40	20	1	16	260	58	42
		82-08-12	.58	790	8.0	18.0	130	18	16	8	.4	13	330	36	29
50.7	395629099373300	82-03-26	.09	665	8.1	7.0	95	17	36	19	.9	16	260	52	43
		82-08-12	.82	640	8.1	18.0	140	19	21	9	.5	15	330	72	33
49.0	395458099341200	82-03-26	.12	720	8.7	8.5	90	18	37	20	1	19	450	60	41
46.7	395544099333000	82-03-26	.04	635	8.2	8.0	87	17	36	20	1	19	240	50	39
43.0	395630099315700	82-03-26	.0	700	8.0	9.5	100	17	34	17	.9	23	280	59	41

Table 17.--*Base-flow chemical-quality data, Prairie Dog Creek*--Continued

Map-number (fig. 3)	Station number	Date	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, No_2+No_3 dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Endrin, total (µg/L)	Lindane, total (µg/L)	Methoxychlor, total (µg/L)	Toxaphene, total (µg/L)	Silvex, total (µg/L)	2,4,5-T total (µg/L)	2,4-D, total (µg/L)
87.2	06848000	82-03-26	0.4	28	320	--	0.05	--	--	--	--	--	--	--
80.2	395023099502200	81-11-18	--	8.0	820	1.80	--	ND	ND	ND	ND	ND	ND	ND
		82-03-26	1.2	21	720	--	4.30	ND	ND	ND	ND	ND	ND	ND
		82-08-12	.7	26	720	10.0	6.80	ND	ND	ND	ND	ND	ND	ND
		82-10-06	.8	23	570	0.60	2.40	ND	ND	ND	ND	ND	ND	ND
78.8	395030099505800	81-11-18	--	36	340	.10	--	--	--	--	--	--	--	--
		82-03-26	.6	13	280	--	.22	--	--	--	--	--	--	--
78.3	395046099504500	82-08-12	.6	46	450	.10	.35	--	--	--	--	--	--	--
75.9	395056099484800	81-11-18	--	43	460	.20	--	--	--	--	--	--	--	--
		82-03-26	1.1	15	630	--	3.30	--	--	--	--	--	--	--
		82-08-12	.5	39	500	1.20	1.60	--	--	--	--	--	--	--
67.1	395202099444700	81-11-18	--	52	510	.10	--	--	--	--	--	--	--	--
		82-03-26	.3	25	540	--	.77	--	--	--	--	--	--	--
64.8	395235099441300	81-11-18	--	43	520	3.90	--	ND	ND	ND	ND	ND	ND	ND
		82-03-26	.3	32	460	--	.37	--	--	--	--	--	--	--
		82-08-12	.5	43	520	4.00	.44	ND	ND	ND	ND	ND	ND	ND
		82-10-06	.3	46	560	2.20	.69	ND	ND	ND	ND	ND	ND	ND
62.0	395327099420800	81-11-18	--	49	600	.10	--	--	--	--	--	--	--	--
		82-03-26	.3	18	500	--	.55	--	--	--	--	--	--	--
58.4	395416099400700	82-08-12	.4	55	480	1.60	.26	--	--	--	--	--	--	--
57.6	395425099394600	82-03-26	.3	4.0	460	--	1.10	--	--	--	--	--	--	--
		82-08-12	.4	54	490	1.50	.46	--	--	--	--	--	--	--
55.8	395432099384000	82-03-26	.3	5.0	480	--	.72	--	--	--	--	--	--	--
		82-08-12	.4	52	470	2.00	.44	--	--	--	--	--	--	--
54.2	395451099374200	82-03-26	.3	1.0	440	--	.41	--	--	--	--	--	--	--
		82-08-12	.4	51	470	1.60	.58	--	--	--	--	--	--	--
52.9	395458099362600	82-03-26	.3	1.0	430	--	.30	--	--	--	--	--	--	--
		82-08-12	.4	550	990	1.40	.21	--	--	--	--	--	--	--
50.7	395629099373300	82-03-26	.2	4.0	420	--	.35	ND	ND	ND	ND	ND	ND	ND
		82-08-12	.4	46	540	1.10	.30	--	--	--	--	--	--	--
49.0	395458099341200	82-03-26	.2	1.0	540	--	.36	--	--	--	--	--	--	--
46.7	395544099333000	82-03-26	.2	5.0	400	--	.30	--	--	--	--	--	--	--
43.0	395630099315700	82-03-26	.2	12	450	--	.51	--	--	--	--	--	--	--

Table 18.--*Base-flow chemical-quality data, Republican River valley*

Map number (fig. 5)	Station number	Date	Streamflow, instantaneous (ft^3/s)	Specific conductance (µS/cm)	pH (standard units)	Temperature (deg. °C)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Percent sodium	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity field (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)
1/154.0	400005098052100	82-04-12	153	692	8.7	19.0	94	17	35	19	0.9	11	230	100	23
		82-10-13	152	810	8.0	11.0	110	18	37	18	.9	12	266	120	25
1/153.0	395926098043000	82-04-12	0.06	445	10.5	26.0	55	9.0	38	30	1	14	140	61	22
		82-10-13	.12	510	8.6	14.0	58	13	36	27	1	10	170	60	17
1/152.4	400005098045500	82-04-12	.04	508	9.3	21.0	39	9.5	49	42	2	8.0	160	51	33
		82-10-13	.22	680	7.8	10.0	90	14	40	23	1	8.0	240	49	31
1/152.0	400005098033900	82-04-12	.59	820	8.6	17.5	87	18	60	30	2	10	260	89	49
		82-10-13	.33	660	7.6	9.0	83	14	37	22	1	14	240	35	34
1/150.0	400005098023200	82-04-12	.2	800	8.3	18.0	99	16	62	30	2	6.0	320	58	38
		82-10-13	.37	820	8.0	8.0	110	14	55	26	1	9.0	332	44	34
1/144.6	400005097581200	82-04-12	.22	875	8.5	18.0	93	20	69	32	2	9.0	250	130	51
		82-10-13	.24	880	8.1	6.5	100	18	60	28	2	12	284	110	41
143.9	395919097590200	82-04-12	1.4	560	8.3	14.5	78	12	33	22	1	7.0	240	36	17
		82-10-13	1.1	560	8.0	13.0	76	14	32	21	.9	6.0	226	32	18
141.2	06853500	82-04-12	161	690	8.6	20.5	94	17	36	20	.9	12	240	110	24
		82-10-13	187	770	8.8	10.0	110	18	38	18	.9	13	264	110	27
139.3	400005097545100	82-04-12	.0	670	8.2	22.0	66	15	62	36	2	12	240	61	47
138.9	395958097535200	82-04-12	.76	1,060	9.4	21.0	30	6.0	39	42	2	12	120	35	31
		82-10-13	.04	630	8.7	8.0	76	14	42	25	1	23	276	19	41
134.5	395642097521900	82-04-12	1.8	740	8.3	17.0	88	13	68	35	2	6.0	280	69	36
		82-10-13	3.3	800	8.6	11.0	120	15	64	27	2	7.0	--	65	38
133.4	395550097510300	82-04-12	181	1,840	8.2	18.5	98	17	38	20	1	12	250	100	24
		82-10-13	194	700	8.7	11.0	110	17	39	19	1	12	268	110	26
132.6	395531097523600	82-04-12	5.5	1,150	8.2	14.0	140	26	98	31	2	10	250	300	62
		82-10-13	8.7	1,180	8.4	11.0	180	26	90	26	2	11	362	250	57
130.9	395438097504600	82-04-12	179	760	8.6	21.0	100	18	42	21	1	12	250	120	26
		82-10-13	201	755	7.7	10.5	110	18	41	20	1	12	260	120	26
130.4	395458097501200	82-04-12	.25	610	8.0	19.0	81	13	31	20	.9	14	200	62	28
		82-10-13	.14	765	7.9	12.0	120	20	37	17	.9	13	350	69	29
127.9	395241097502100	82-04-12	.03	2,500	7.9	20.0	260	36	230	38	4	8.0	290	830	82
		82-10-13	.04	1,710	7.9	9.5	190	26	190	41	4	9.0	410	450	60
127.0	395215097495600	82-04-12	.7	780	8.6	22.0	110	18	49	23	1	14	270	120	27
		82-10-13	1.4	810	8.2	12.0	120	17	49	22	1	12	300	110	28
126.9	395123097501300	82-04-12	194	740	8.6	17.0	100	18	40	20	1	12	240	120	26
		82-10-13	194	745	7.8	10.5	110	18	40	19	1	12	260	120	25
125.8	395044097502100	82-04-12	1.1	1,730	8.3	12.0	180	29	170	39	3	7.0	230	510	110
		82-10-13	1.6	1,650	7.9	9.5	220	28	150	33	3	7.0	370	420	91
125.7	395123097493900	82-04-12	.33	1,050	7.9	16.0	140	25	60	22	1	17	320	200	41
		82-10-13	.09	950	7.3	9.5	150	20	47	18	1	15	290	190	42
123.1	394853097490500	82-04-12	2.1	2,200	8.2	14.5	270	39	220	36	3	8.0	200	820	170
		82-10-13	3.6	2,350	8.0	10.5	320	36	200	31	3	8.0	346	720	140
121.3	06854500	82-04-12	195	760	8.4	20.0	100	18	43	22	1	12	240	130	29
		82-10-13	225	825	8.3	11.0	120	20	44	19	1	12	260	130	30
120.4	394702097465900	82-04-12	.95	840	8.8	21.5	110	12	64	29	2	9.0	210	170	48
		82-10-13	.08	1,570	7.5	15.0	180	20	140	36	3	17	348	140	220
118.4	394544097475800	82-04-12	.07	1,120	8.9	22.0	100	16	140	48	4	15	280	230	71
		82-10-13	.61	1,190	8.2	14.0	130	18	120	39	3	12	296	250	60
118.2	394452097475800	82-04-12	.16	880	8.1	14.0	100	9.5	89	40	2	3.0	310	73	62
117.4	394419097465900	82-04-12	195	1,020	8.2	12.5	110	19	43	20	1	12	250	120	28
		82-10-13	209	800	8.5	15.0	110	18	42	20	1	13	260	120	29
115.2	394321097475800	82-10-13	.02	748	8.3	12.5	110	11	45	23	1	4.0	242	86	48
114.5	394307097483200	82-04-12	9.5	2,010	8.0	14.0	260	35	200	35	3	8.0	200	780	130
		82-10-13	12	2,110	8.1	10.5	290	32	190	32	3	8.0	330	700	110
113.4	394202097474100	82-04-12	183	585	8.6	21.0	100	19	51	25	1	11	240	160	35
		82-10-13	222	870	8.2	13.5	120	19	54	23	1	11	240	170	34

Table 18.--*Base-flow chemical-quality data, Republican River*--Continued

Map number (fig. 5)	Station number	Date	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Endrin, total (μg/L)	Lindane, total (μg/L)	Methoxychlor, total (μg/L)	Toxaphene, total (μg/L)	Silvex, total (μg/L)	2,4,5-T total (μg/L)	2,4-D, total (μg/L)
[1]154.0	400005098052100	82-04-12	0.3	19	440	0.30	0.16	ND	ND	ND	ND	ND	ND	ND
		82-10-13	.3	28	510	1.20	.30	ND	ND	ND	ND	ND	ND	ND
[1]153.0	395926098043000	82-04-12	.4	16	300	.10	.52	--	--	--	--	--	--	--
		82-10-13	.4	13	310	1.30	.40	--	--	--	--	--	--	--
[1]152.4	400005098045500	82-04-12	.3	6.0	290	.10	.18	--	--	--	--	--	--	--
		82-10-13	.3	15	390	4.60	.20	--	--	--	--	--	--	--
[1]152.0	400005098033900	82-04-12	.3	2.0	470	.20	.15	--	--	--	--	--	--	--
		82-10-13	.3	16	380	1.70	.53	--	--	--	--	--	--	--
[1]150.0	400005098023200	82-04-12	.3	10	480	.00	.22	--	--	--	--	--	--	--
		82-10-13	.3	25	490	.10	.40	--	--	--	--	--	--	--
[1]144.6	400005097581200	82-04-12	.3	2.0	520	.00	.10	--	--	--	--	--	--	--
		82-10-13	.4	16	530	.30	.25	--	--	--	--	--	--	--
143.9	395919097590200	82-04-12	.3	16	340	2.10	.37	--	--	--	--	--	--	--
		82-10-13	.3	17	330	1.90	.35	--	--	--	--	--	--	--
141.2	06853500	82-04-12	.3	17	450	.30	.23	--	--	--	--	--	--	--
		82-10-13	.3	27	500	1.20	.43	--	--	--	--	--	--	--
139.3	400005097545100	82-04-12	.3	2.0	410	.00	.24	--	--	--	--	--	--	--
138.9	395958097535200	82-04-12	.3	1.0	230	.00	.19	--	--	--	--	--	--	--
		82-10-13	.3	1.0	390	2.00	1.30	--	--	--	--	--	--	--
134.5	395642097521900	82-04-12	.2	10	460	4.00	.16	--	--	--	--	--	--	--
		82-10-13	.2	18	530	5.80	.28	--	--	--	--	--	--	--
133.4	395550097510300	82-04-12	.3	18	460	.40	.17	ND	ND	ND	ND	ND	ND	ND
		82-10-13	.3	26	500	1.50	.42	ND	ND	ND	ND	ND	ND	ND
132.6	395531097523600	82-04-12	.2	5.0	790	.60	.23	ND	ND	ND	ND	ND	ND	ND
		82-10-13	.3	13	840	3.20	.37	ND	ND	ND	ND	ND	ND	ND
130.9	395438097504600	82-04-12	.3	13	480	.00	.21	--	--	--	--	--	--	--
		82-10-13	.3	25	510	1.40	.45	--	--	--	--	--	--	--
130.4	395458097501200	82-04-12	.3	7.0	360	.40	.51	--	--	--	--	--	--	--
		82-10-13	.3	20	520	.20	.62	--	--	--	--	--	--	--
127.9	395241097502100	82-04-12	.3	5.0	1,600	.40	.04	--	--	--	--	--	--	--
		82-10-13	.4	9.0	1,200	.00	.25	--	--	--	--	--	--	--
127.0	395215097495600	82-04-12	.3	14	510	.10	.32	--	--	--	--	--	--	--
		82-10-13	.3	20	540	1.00	.31	--	--	--	--	--	--	--
126.9	395123097501300	82-04-12	.3	14	470	.40	.21	--	--	--	--	--	--	--
		82-10-13	.3	23	500	1.40	.45	--	--	--	--	--	--	--
125.8	395044097502100	82-04-12	.3	6.0	1,200	.50	.05	--	--	--	--	--	--	--
		82-10-13	.3	17	1,200	2.50	.28	--	--	--	--	--	--	--
125.7	395123097493900	82-04-12	.3	12	690	.10	.17	--	--	--	--	--	--	--
		82-10-13	.3	19	660	.60	.54	--	--	--	--	--	--	--
123.1	394853097490500	82-04-12	.3	2.0	1,600	2.40	.12	--	--	--	--	--	--	--
123.3	394853097490500	82-10-13	.4	17	1,600	6.20	.27	--	--	--	--	--	--	--
121.3	06854500	82-04-12	.3	18	490	.40	.19	ND	ND	ND	ND	ND	ND	1.4
		82-10-13	.3	26	540	1.50	.46	ND	ND	ND	ND	ND	ND	ND
120.4	394702097465900	82-04-12	.2	8.0	550	.70	.20	--	--	--	--	--	--	--
		82-10-13	.3	21	950	.00	.67	--	--	--	--	--	--	--
118.4	394544097475800	82-04-12	.3	0	740	1.60	.05	--	--	--	--	--	--	--
		82-10-13	.3	2.0	770	2.30	.37	--	--	--	--	--	--	--
118.2	394452097475800	82-04-12	.2	14	540	.00	.78	--	--	--	--	--	--	--
117.4	394419097465900	82-04-12	.3	14	500	.40	.23	--	--	--	--	--	--	--
		82-10-13	.4	23	510	1.40	.46	--	--	--	--	--	--	--
115.2	394321097475800	82-10-13	.3	5.0	450	1.10	.21	--	--	--	--	--	--	--
114.5	394307097483200	82-04-12	.3	2.0	1,500	2.10	.07	--	--	--	--	--	--	--
		82-10-13	.4	15	1,500	6.70	.23	--	--	--	--	--	--	--
113.4	394202097474100	82-04-12	.3	13	530	.30	.21	ND	ND	ND	ND	ND	ND	1.4
		82-10-13	.3	18	570	1.80	.45	ND	ND	ND	ND	ND	ND	ND

[1] Sampling site is not shown in figure 5.

Table 19.--*Base-flow chemical-quality data, Smoky Hill River*

Map number (fig. 7)	Station number	Date	Streamflow, instantaneous (ft³/s)	Specific conductance (μS/cm)	pH (standard units)	Temperature (deg. °C)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Percent sodium	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Alkalinity field (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)
355.9	06862000	82-08-11	0.09	1,500	7.7	19.0	260	44	75	16	1	19	160	700	60
355.8	384708099424400	81-11-17	.25	1,740	7.4	9.0	220	51	81	18	1	30	94	790	63
		82-03-10	.1	2,100	7.6	9.5	220	54	83	18	1	28	94	780	65
		82-08-11	1.5	1,440	7.9	24.0	210	40	64	16	1	25	110	620	49
		82-10-05	.5	1,420	7.4	18.0	210	42	67	17	1	27	96	650	53
354.7	384746099415300	81-11-17	--	1,570	7.3	8.0	230	41	71	17	1	19	180	640	64
		82-03-10	--	1,650	7.1	15.5	190	39	67	18	1	21	190	540	69
		82-08-11	--	1,550	7.7	19.0	230	40	71	17	1	26	190	570	65
		82-10-05	--	1.550	7.0	18.0	250	42	76	17	1	21	194	620	79
352.8	384720099402300	81-11-17	1.8	1,620	7.4	7.0	260	46	79	17	1	18	230	680	76
		82-03-10	1.3	1,950	7.3	12.5	220	49	80	18	1	17	220	660	80
		82-08-11	2.1	1,800	7.6	18.5	260	47	92	19	1	24	230	620	90
		82-10-05	.94	1,850	7.0	16.0	300	53	92	17	1	19	250	720	96
350.0	384700099380200	81-11-17	2.7	1,560	7.4	8.0	230	44	74	17	1	16	200	620	75
		82-03-10	1.8	1,570	7.4	10.0	210	45	73	18	1	16	190	580	77
		82-08-11	2.2	1,670	7.7	19.0	240	48	94	20	2	22	220	590	100
		82-10-05	.76	1,490	7.9	16.0	230	42	74	17	1	17	206	540	84
348.9	384647099370400	81-11-17	2.5	1,660	7.6	10.0	220	44	75	18	1	16	190	640	77
		82-03-10	1.9	1,660	7.8	15.0	220	46	76	18	1	15	190	610	81
		82-08-11	1.7	1,650	7.8	18.5	240	47	92	20	1	20	230	590	92
		82-10-05	.71	1,480	7.3	14.0	230	42	75	18	1	17	208	550	85
347.4	384649099343400	81-11-17	2.0	1,630	7.7	8.5	240	43	81	18	1	16	220	630	84
		82-03-10	2.0	1,720	7.9	8.0	230	44	82	19	1	13	200	250	90
		82-08-11	2.0	1,580	7.6	20.0	220	42	92	21	2	17	220	520	97
		82-10-05	.59	1,630	7.7	16.5	220	41	83	20	1	17	202	510	99
345.5	384609099333600	81-11-17	2.6	1,650	7.8	12.0	220	42	86	20	1	16	200	630	84
		82-03-10	2.5	1,730	8.0	4.0	220	44	82	19	1	13	220	580	90
		82-08-11	2.0	1,540	8.1	19.5	220	40	91	21	2	16	220	510	93
		82-10-05	.81	1,620	8.0	15.5	210	38	87	21	2	15	214	520	93
343.6	384543099322900	81-11-17	2.6	1,640	7.2	11.5	220	41	87	20	1	16	220	620	86
		82-03-10	2.8	1,750	8.2	12.0	220	43	85	20	1	13	200	580	95
		82-08-11	2.7	1,510	8.4	19.0	210	39	92	22	2	15	210	500	90
		82-10-05	.97	1,600	8.0	17.5	210	36	90	22	2	14	208	500	94
342.6	384530099315600	82-03-10	.0	1,460	8.2	14.0	190	26	91	25	2	8.0	170	490	72
		82-08-11	.02	1,500	8.1	19.5	200	32	110	27	2	10	180	520	86
342.0	384542099303200	81-11-17	3.6	1,500	7.8	14.5	210	37	87	21	2	14	200	570	84
		82-03-10	3.9	1,560	8.3	16.5	210	37	85	21	1	11	180	540	88
		82-08-11	3.0	1,450	8.2	19.5	200	33	86	22	2	14	430	470	81
		82-10-05	1.3	1,460	7.5	15.0	200	29	83	22	2	12	210	470	86
341.9	384542099302300	81-11-17	.3	1,360	7.7	14.0	170	23	100	29	2	9.0	200	420	92
		82-03-10	.2	1,400	8.4	17.0	150	23	100	31	2	8.0	190	380	99
		82-08-11	.12	1,360	8.1	18.0	180	22	100	28	2	8.0	230	380	97
		82-10-05	.1	1,280	7.7	14.0	190	23	98	27	2	8.0	238	370	98
340.3	384516099290800	81-11-17	4.1	1,620	7.9	9.0	220	36	91	22	2	13	210	570	85
		82-03-10	4.3	1,550	7.8	9.5	210	37	87	22	2	11	190	540	88
		82-08-11	2.9	1,350	7.8	19.0	210	33	84	21	1	13	210	470	79
		82-10-05	1.3	1,520	7.5	18.5	230	33	88	21	1	13	208	530	88
340.2	384522099290800	81-11-17	.08	1,970	8.3	8.0	220	25	180	37	3	10	250	650	110
		82-03-10	.1	1,810	8.0	8.0	190	25	170	39	3	8.0	250	620	110
		82-08-11	.06	1,900	8.0	17.0	240	24	160	33	3	10	290	570	95
		82-10-05	.06	1,820	7.9	17.0	240	24	180	36	3	10	286	610	110
338.0	384443099270400	81-11-17	5.2	1,620	8.2	10.0	210	34	96	24	2	12	210	560	95
		82-03-10	5.8	1,540	8.2	13.5	220	37	94	22	2	10	190	530	100
		82-08-11	3.8	1,430	8.0	19.0	210	31	90	23	2	12	210	480	90
		82-10-05	1.8	1,480	7.8	23.0	220	32	99	24	2	12	182	520	110
335.5	384325099245200	81-11-17	5.5	1,640	8.4	14.0	180	34	98	26	2	12	200	570	96
		82-03-10	6.6	1,880	8.3	14.0	210	35	95	23	2	11	180	580	100
		82-08-11	2.4	1,670	8.1	18.5	200	32	89	23	2	12	200	470	92
		82-10-05	1.8	1,480	7.7	20.0	220	32	98	23	2	12	186	520	100
334.5	384338099233800	81-11-17	.45	880	8.1	15.0	130	15	27	13	0.6	6.0	190	180	86
		82-03-10	.4	1,120	8.4	14.5	110	18	29	15	.7	5.0	160	150	100
		82-08-11	.34	1,160	7.8	19.0	150	14	30	13	.7	5.0	200	140	90
		82-10-05	.31	848	7.6	17.5	160	16	31	12	.7	7.0	204	160	100
334.4	06862700	81-11-17	6.1	1,600	8.2	16.0	210	34	96	24	2	12	190	560	96
		82-03-10	7.0	1,480	8.3	15.0	190	33	91	24	2	10	170	520	100
		82-08-11	3.1	1,490	8.2	20.0	190	28	82	23	2	11	200	420	89
		82-10-05	2.3	1,400	8.0	16.0	210	28	88	23	2	11	188	450	100

Map number (fig. 7)	Station number	Date	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Endrin, total (μg/L)	Lindane, total (μg/L)	Methoxychlor, total (μg/L)	Toxaphene, total (μg/L)	Silvex, total (μg/L)	2,4,5-T total (μg/L)	2,4-D, total (μg/L)
355.9	06862000	82-08-11	0.6	21	1,300	0.00	0.03	--	--	--	--	--	--	--
355.8	384708099424400	81-11-17	--	8.0	1,300	.10	--	ND	ND	ND	ND	ND	ND	ND
		82-03-10	.8	1.0	1,300	--	.06	ND	ND	ND	ND	ND	ND	ND
		82-08-11	.6	10	1,100	.20	.06	ND	ND	ND	ND	ND	ND	ND
		82-10-05	.6	11	1,100	.00	.09	ND	ND	ND	ND	ND	ND	ND
354.7	384746099415300	81-11-17	--	18	1,200	.40	--	--	--	--	--	--	--	--
		82-03-10	.6	7.0	1,000	--	.09	--	--	--	--	--	--	--
		82-08-11	.7	23	1,100	.40	.10	--	--	--	--	--	--	--
		82-10-05	.6	15	1,200	.60	.09	--	--	--	--	--	--	--
352.8	384720099402300	81-11-17	--	20	1,300	.30	--	--	--	--	--	--	--	--
		82-03-10	.6	9.0	1,200	--	.08	--	--	--	--	--	--	--
		82-08-11	.6	21	1,300	1.30	.20	--	--	--	--	--	--	--
		82-10-05	.6	16	1,400	.80	.23	--	--	--	--	--	--	--
350.0	384700099380200	81-11-17	--	15	1,200	.10	--	--	--	--	--	--	--	--
		82-03-10	.6	10	1,100	--	.07	--	--	--	--	--	--	--
		82-08-11	.6	19	1,200	.00	.10	--	--	--	--	--	--	--
		82-10-05	.6	17	1,100	.00	.15	--	--	--	--	--	--	--
348.9	384647099370400	81-11-17	--	14	1,200	.10	--	--	--	--	--	--	--	--
		82-03-10	.6	9.0	1,200	--	.04	ND	ND	ND	ND	ND	ND	ND
		82-08-11	.7	22	1,200	.00	.07	ND	ND	ND	ND	ND	ND	ND
		82-10-05	.6	18	1,100	.00	.06	ND	ND	ND	ND	ND	ND	ND
347.4	384649099343400	81-11-17	--	16	1,200	.10	--	--	--	--	--	--	--	--
		82-03-10	.5	10	840	--	.05	--	--	--	--	--	--	--
		82-08-11	.7	23	1,100	.00	.04	--	--	--	--	--	--	--
		82-10-05	.6	19	1,100	.00	.12	--	--	--	--	--	--	--
345.5	384609099333600	81-11-17	--	13	1,200	.10	--	--	--	--	--	--	--	--
		82-03-10	.6	11	1,200	--	.05	--	--	--	--	--	--	--
		82-08-11	.6	23	1,100	.00	.06	--	--	--	--	--	--	--
		82-10-05	.6	22	1,100	.00	.21	--	--	--	--	--	--	--
343.6	384543099322900	81-11-17	--	13	1,200	.10	--	--	--					
		82-03-10	.5	9.0	1,200	--	.04	--	--	--	--	--	--	--
		82-08-11	.7	21	1,100	.00	.06	--	--	--	--	--	--	--
		82-10-05	.5	21	1,100	.00	.08	--	--	--	--	--	--	--
342.6	384530099315600	82-03-10	.3	14	990	--	.07	--	--	--	--	--	--	--
		82-08-11	.4	16	1,100	.00	.07	--	--	--	--	--	--	--
342.0	384542099303200	81-11-17	--	14	1,100	.30	--	--	ND	ND	ND	ND	ND	ND
		82-03-10	.5	10	1,100	--	.04	ND	ND	ND	ND	ND	ND	ND
		82-08-11	.5	24	1,200	.10	.04	ND	ND	ND	ND	ND	ND	ND
		82-10-05	.5	22	1,000	.30	.10	ND	ND	ND	ND	ND	ND	ND
341.9	384542099302300	81-11-17	--	25	960	3.10	--	--	--	--	--	--	--	--
	384542099302300	82-03-10	.3	13	890	--	.06	--	--	--	--	--	--	--
		82-08-11	.4	29	950	.10	.03	--	--	--	--	--	--	--
		82-10-05	.3	31	960	.20	.05	--	--	--	--	--	--	--
340.3	384516099290800	81-11-17	--	18	1,200	.20	--	--	--	--	--	--	--	--
		82-03-10	.5	10	1,100	--	.06	--	--	--	--	--	--	--
		82-08-11	.5	22	1,000	.00	.04	--	--	--	--	--	--	--
		82-10-05	.5	20	1,100	.00	.17	--	--	--	--	--	--	--
340.2	384522099290800	81-11-17	--	24	1,400	2.80	--	--	--	--	--	--	--	--
		82-03-10	.3	14	1,300	--	.04	--	--	--	--	--	--	--
		82-08-11	.5	27	1,300	1.50	.05	--	--	--	--	--	--	--
		82-10-05	.4	28	1,400	1.80	.13	--	--	--	--	--	--	--
338.0	384443099270400	81-11-17	--	18	1,200	.20	--	--	--	--	--	--	--	--
		82-03-10	.4	11	1,100	--	.04	--	--	--	--	--	--	--
		82-08-11	.5	22	1,100	.10	.04	--	--	--	--	--	--	--
		82-10-05	.4	21	1,100	.00	.11	--	--	--	--	--	--	--
335.5	384325099245200	81-11-17	--	17	1,100	.10	--	--	--	--	--	--	--	--
		82-03-10	.4	10	1,100	--	.04	--	--	--	--	--	--	--
		82-08-11	.6	21	1,000	.00	.05	--	--	--	--	--	--	--
		82-10-05	.5	21	1,100	.00	.22	--	--	--	--	--	--	--
334.5	384338099233800	81-11-17	--	19	580	1.30	--	--	--	--	--	--	--	--
		82-03-10	.3	2.0	510	--	.05	--	--	--	--	--	--	--
		82-08-11	.4	22	570	.80	.04	--	--	--	--	--	--	--
		82-10-05	.3	24	620	1.20	.09	--	--	--	--	--	--	--
334.4	06862700	81-11-17	--	17	1,100	.10	--	--	--	--	--	--	--	--
		82-03-10	.4	9.0	1,100	--	.04	ND	ND	ND	ND	ND	ND	ND
		82-08-11	.5	21	960	.10	.03	--	--	--	--	--	--	--
		82-10-05	.4	22	1,000	.10	.27	--	--	--	--	--	--	--

Table 20.--*Estimated relative error of sodium plus potassium reported before 1950*

[Data from U.S. Geological Survey Water Resources Data for Kansas - Water Year 1978]

Sample number	Predicted sodium plus potassium	Measured sodium plus potassium	Percent from measured value
1	17	18	-4
2	26	28	-7
3	100	82	+22
4	55	63	-12
5	17	21	-19
6	52	57	-8
7	26	28	-7
8	18	10	+80
9	47	53	-10

Table 21.--*Chemical-quality data used in Matched-Pairs comparison of pre- and postirrigation-period concentrations of selected dissolved chemical constituents in water from supply wells in the Prairie Dog Creek valley in the vicinity of the Almena Unit*

[Well numbers shown for preirrigation period correspond to those given in Frye and Leonard (1949). Well numbers shown for postirrigation period correspond to sampling-site numbers given in this report. Concentrations of all constituents are given in milligrams per liter]

Well number		Calcium		Sodium plus potassium		Bicarbonate		Sulfate		Chloride		Nitrate as nitrogen		Dissolved solids	
Preirrigation	Postirrigation	Preirrigation	Postirrigation	Preirrigation[1]	Postirrigation	Preirrigation	Postirrigation	Preirrigation	Postirrigation	Preirrigation	Postirrigation	Preirrigation	Postirrigation	Preirrigation	Postirrigation
1-20-23da	4	173	145	72	68	515	430	118	160	78	32	18	6.4	880	650
2-21-8	15	104	130	29	46	436	440	15	65	34	13	.5	4.8	456	590
2-21-11	12	86	130	26	43	314	490	12	44	11	11	0	1.9	338	550
1-20-32ad	11	138	150	45	46	500	480	148	140	28	19	.2	0	682	680
1-20-30dd	10	91	150	20	62	310	540	19	110	18	27	7.8	0	393	710

[1] 10 percent was added to the value reported to adjust for negative bias.

Table 22.--*Chemical-quality data used in Matched-Pairs comparison of pre- and postirrigation-period concentrations of selected dissolved chemical constituents in water from supply wells in the Republican River valley in the vicinity of the Kansas-Bostwick Unit*

[Well numbers shown for preirrigation period correspond to those given in Fishel and Lohman (1948)[F] or Fishel an Leonard (1955)[FL]. Well numbers shown for postirrigation period correspond to sampling-site numbers given in this report. Concentrations of all constituents are given in milligrams per liter]

Well number		Calcium		Sodium plus potassium		Bicarbonate		Sulfate		Chloride		Nitrate as nitrogen		Dissolved solids	
Pre-irrigation	Post-irrigation	Pre-irrigation	Post-irrigation	Pre-irrigation[1]	Post-irrigation	Pre-irrigation	Post-irrigation	Pre-irrigation	Post-irrigation	Pre-irrigation	Post-irrigation	Pre-irrigation	Post-irrigation	Pre-irrigation	Post-irrigation
1-7-11bb[F]	8	23	94	2.3	51	57	320	11	38	6.8	30	4.9	13	101	48
53 [FL]	2	78	110	59	51	350	340	40	81	18	27	7.3	.4	434	48
63 [FL]	6	73	64	18	32	260	200	9.7	49	13	25	1.3	5.5	280	31
58 [FL]	3	49	83	24	47	160	280	15	40	20	33	4.2	5.7	228	41
107 [FL]	10	95	140	75	25	360	430	24	24	26	24	2.7	6.2	380	633
173 [FL]	17	106	160	92	46	300	380	102	86	46	86	.3	1.3	527	739
176 [FL]	18	108	150	128	88	390	500	54	62	118	62	1.3	1.5	593	752

1 10 percent was added to the value reported to adjust for negative bias.

Table 23.--*Chemical-quality data used in Matched-Pairs comparison of pre- and postirrigation-period concentrations of selected dissolved chemical constituents in water from supply wells in the Smoky Hill River valley in the vicinity of the Cedar Bluff Unit*

[Well numbers shown for preirrigation period correspond to those given in Leonard and Berry (1961). Well numbers shown for postirrigation period correspond to sample-site numbers given in this report. Concentrations of all constituents are given in milligrams per liter]

Well number		Calcium		Sodium plus potassium		Bicarbonate		Sulfate		Chloride		Nitrate as nitrogen		Dissolved solids	
Preirrigation	Postirrigation	Preirrigation	Postirrigation	Preirrigation[1]	Postirrigation	Preirrigation	Postirrigation	Preirrigation	Postirrigation	Preirrigation	Postirrigation	Preirrigation	Postirrigation	Preirrigation	Postirrigation
14-20-32aa1	17	100	190	5	136	276	270	30	400	35	99	0.44	8.7	391	990
14-20-35dc	3	86	160	32	46	264	240	40	300	30	44	9.3	1.4	422	737
14-21-35ca	5	108	190	1	82	296	240	26	380	18	69	2.2	4.3	427	931
14-21-35cd	6	226	365	89	167	374	330	648	965	41	160	5.6	7.8	1,330	1,620
15-19-7ab	10	69	215	26	154	212	270	29	540	15	94	10	7.2	498	498
15-20-12ad	16	130	190	20	62	244	270	8	250	45	88	41	9.8	628	810

1 10 percent was added to the value reported to adjust for negative bias.

Table 24.--*Streamflow and chemical-quality data from seepage-salinity survey on Prairie Dog Creek, May 1964, from sampling sites 62.0 and 43.0*

[Streamflow reported in cubic feet per second. All dissolved chemical constituents reported in milligrams per liter]

Sampling site	Streamflow	Calcium	Sodium	Sulfate	Chloride	Nitrate as nitrogen	Dissolved solids
62.0	2.52	96	28	20	27	0.9	430
57.6	3.96	95	27	21	27	.9	428
55.8	3.38	99	26	21	26	1.2	423
54.2	3.44	94	26	19	24	1.1	428
52.9	3.00	98	26	20	25	.9	430
50.7	2.72	92	27	21	27	.8	441
49.0	2.70	101	28	25	27	.5	430
46.7	2.52	98	29	24	30	.4	439
43.0	3.88	93	26	23	23	.4	424

Table 25.--*Selected chemical-quality data from Keith Sebelius Lake near Norton, Kansas*

[All samples were collected during July of each year. Concentrations are given in milligrams per liter (mg/L)]

Year samples were collected	Dissolved calcium (mg/L)	Dissolved sodium (mg/L)	Dissolved chloride (mg/L)	Dissolved sulfate (mg/L)	Dissolved nitrate (mg/L)	Dissolved solids (mg/L)
1971	47	12	11	33	--	234
1972	44	20	18	43	0.07	292
1973	50	14	15	27	.04	258
1974	50	17	17	36	.11	271
1979	47	19	11	23	.25	267
1980	52	21	15	26	.18	277
1981	39	23	20	39	--	275
1982	50	25	27	81	.09	396

Table 26.--*Selected streamflow and chemical-quality data from site 154.0 near Guide Rock, Nebraska, and site 121.3 near Scandia, Kansas*

[Data from U.S. Geological Survey (1964-70). Streamflow reported in cubic feet per second. All dissolved chemical constituents reported in milligrams per liter]

Date (month year)	Streamflow		Calcium		Sodium		Bicarbonate		Sulfate		Chloride		Nitrate as nitrogen		Dissolved solids	
	Site 154.0	Site 121.3	Site 154.0	Site 121.3	Site 154.0	Site 121.3	Site 154.0	Site 121.3	Site 154.0	Site 121.3	Site 154.0	Site 121.3	Site 154.0	Site 121.3	Site 154.0	Site 121.3
9-66	115	294	64	60	22	24	242	243	52	51	14	11	1.5	0.1	316	318
10-66	110	164	66	74	22	26	249	278	51	74	14	17	.3	1.5	331	380
9-67	132	300	61	68	23	29	239	247	53	75	15	19	2.7	1.6	312	378
9-68	150	248	75	84	28	32	264	310	85	83	17	18	1.7	1.7	382	428
10-69	150	250	75	78	25	29	273	292	78	76	17	16	1.8	2.3	381	400
11-70	127	184	82	100	26	39	283	329	70	100	17	27	2.7	4.6	394	496
10-82[1]/	152	225	113	114	37	46	334	323	119	132	25	30	5.4	7.	523	544

1 Data for the upstream site for this date was obtained from sampling site 154.0.