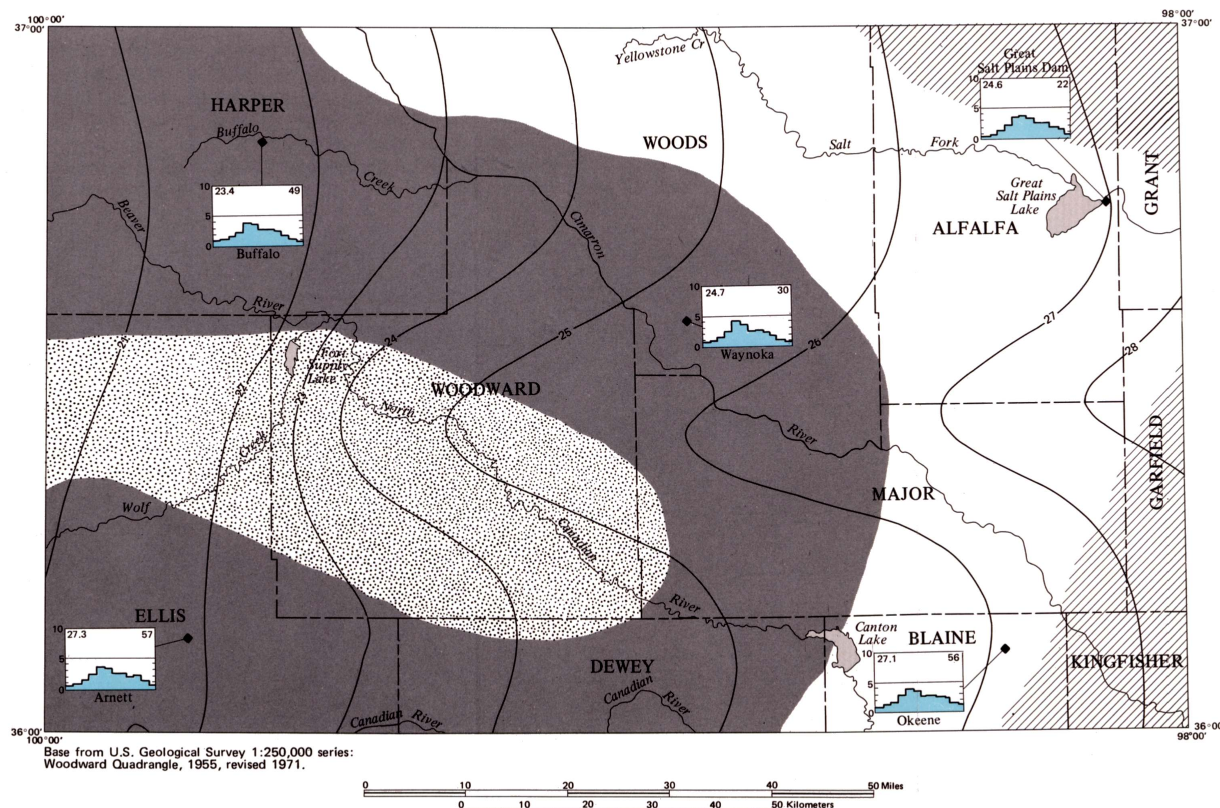

FIGURE 6: MAP SHOWING DISTRIBUTION OF PRECIPITATION AND RUNOFF

EXPLANATION

Lines of equal annual precipitation, for base period 1931-1960. Interval: 1 inch

Figure in upper left of graph is average annual precipitation for the period of record, in inches; figure in upper right is years of record.

Weather station

AVERAGE ANNUAL RUNOFF, IN INCHES

2-3

1-2

0.5-1

less than 0.5

PRECIPITATION AND RUNOFF

The amount of net runoff is determined by many factors such as amount of precipitation, topography, geology, season of the year and man's activities evidence by retaining structures, and the excessive withdrawal of ground water by numerous high-capacity wells. The increase in both precipitation and runoff from west to east (fig. 6) shows that the amount of runoff generally is related to precipitation. Figure 6 is generalized, and local precipitation or runoff may depart significantly from that shown. Except for short reaches of Wolf Creek, Salt Fork of the Arkansas River, and the North Canadian River, streams within the study area generally are unregulated, and runoff represents natural conditions.

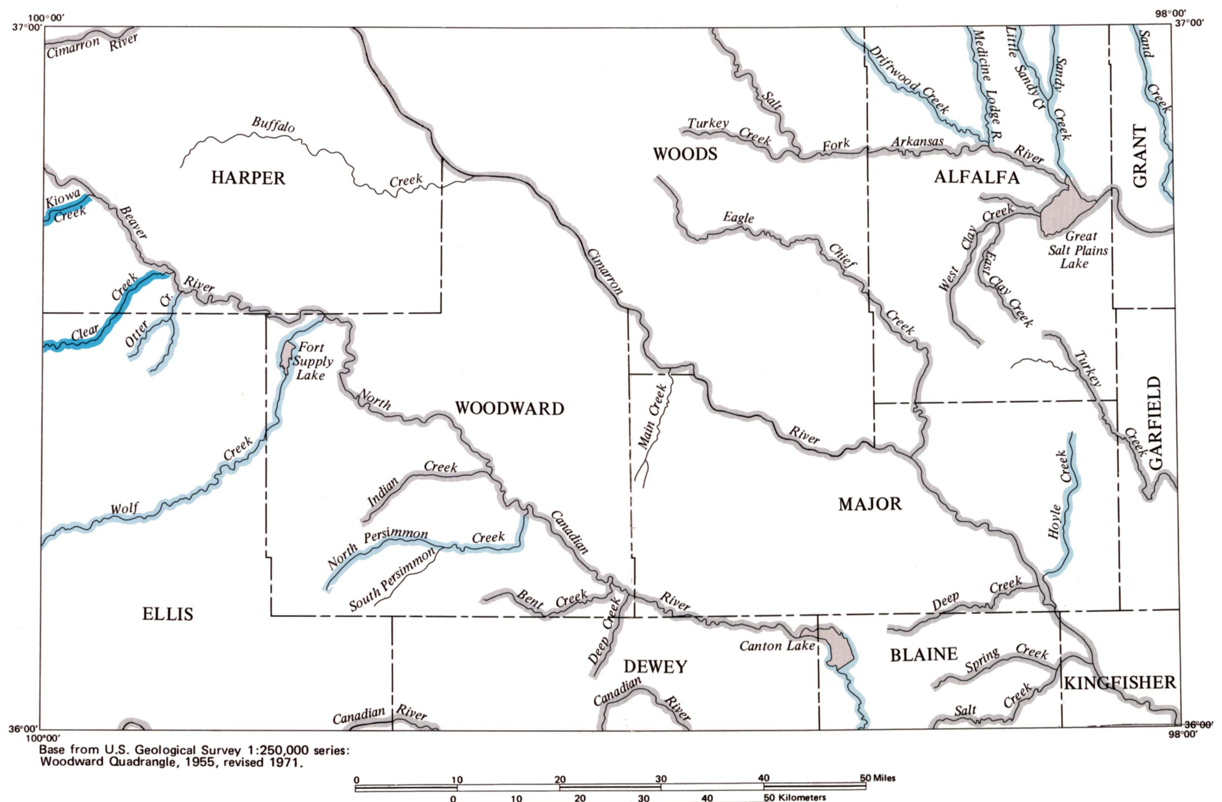

FIGURE 11: MAP SHOWING SURFACE-WATER-QUALITY RATING FOR MUNICIPAL USE.

EXPLANATION

Good
0-500 mg/l dissolved solids

Fair
500-1000 mg/l dissolved solids

Poor
Above 1000 mg/l dissolved solids

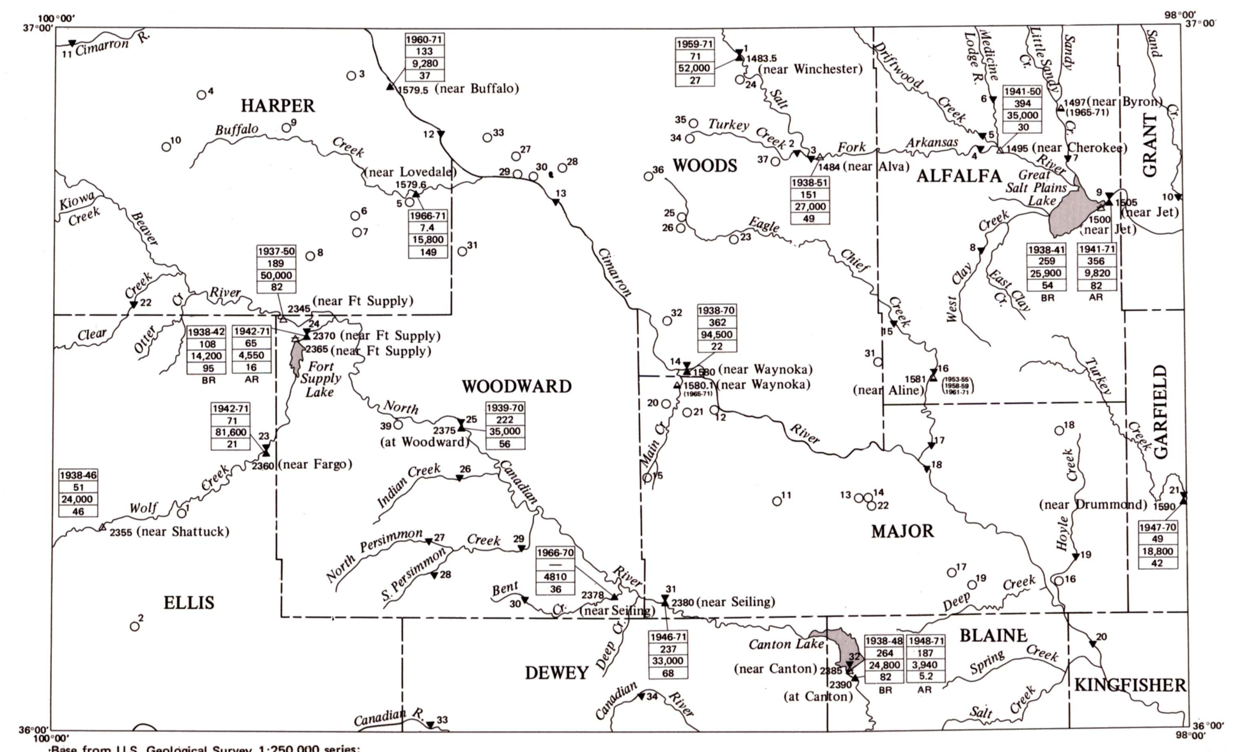

FIGURE 7: MAP SHOWING GAGING STATIONS, SURFACE-WATER-QUALITY SAMPLING SITES, SELECTED STREAMFLOW DATA, AND LAKES.

EXPLANATION

Active stream gage, abbreviated number, and name

Discontinued stream gage, abbreviated number, and name

Selected streamflow data for gaging stations
The values, from top to bottom, are: years of record; average flow, in cubic feet per second; maximum flow, in cubic feet per second; and average number of days of no-flow per year.
BR = before regulation
AR = after regulation

Low-flow partial-record station, abbreviated number, name, and years of record

Active lake-stage gage, abbreviated number, and name

Lake and number (table 3)

Major lake and name

Surface-water-quality sampling site and number (table 1)

GAGING STATIONS, SURFACE-WATER-QUALITY SAMPLING SITES, SELECTED STREAMFLOW DATA, AND LAKES

Streamflow data and surface-water-quality data are available for 19 and 34 sites, respectively, in the Woodward Quadrangle (fig. 7) and are published in reports of the U.S. Geological Survey.

Table 2 provides data for the three major lakes in the area. Because of the variability of runoff, the development of storage is necessary to provide a dependable water supply. Canton and Fort Supply Lakes store water that is used for part of the municipal supply for Oklahoma City, which is outside the Woodward Quadrangle. Poor-quality water in the Great Salt Plains Lake precludes its use for water supply. Table 3 shows data for 39 small lakes generally 50 acres or more in size and 300 acre-feet or less in capacity; 36 of these are privately used.

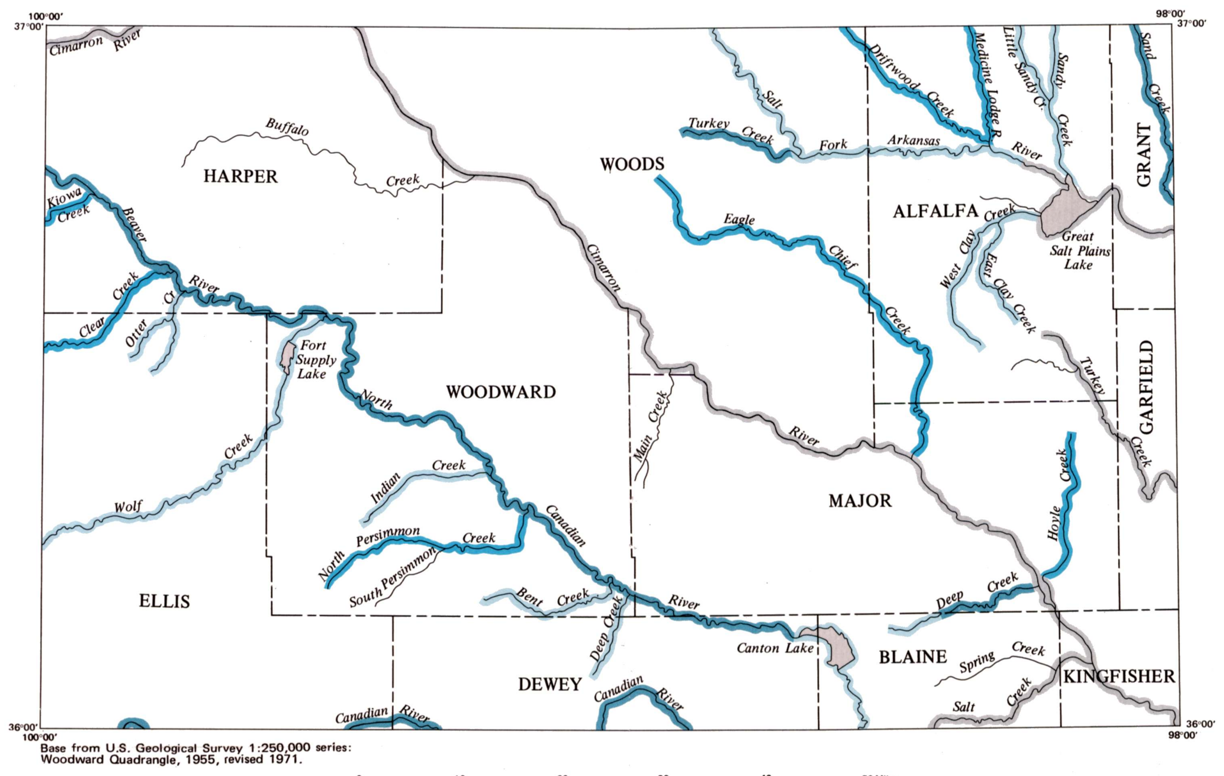

FIGURE 12: MAP SHOWING SURFACE-WATER-QUALITY RATING FOR IRRIGATION USE.

EXPLANATION

Good
0-2 SAR[1] and less than 1500 specific conductance[2]

Fair
2-4 SAR, and less than 3000 specific conductance

Fair-Poor
4-8 SAR, and less than 5000 specific conductance

Poor
More than 8 SAR, and any specific conductance value

1. Sodium adsorption ratio.
2. Micromhos per centimeter at 25°C.

CHEMICAL ANALYSIS OF SURFACE WATER

The usability of surface water for municipal, industrial, and irrigation requirements depends chiefly upon its quality. Information on the chemical quality of surface water in the Woodward Quadrangle is summarized in figures 11 and 12 and in table 1. The sodium adsorption ratio (SAR) component used in rating water for irrigation use is defined:

$$SAR = \frac{(Na^{+})}{\sqrt{(Ca^{+2}) + (Mg^{+2})/2}}$$

where ion concentrations are expressed in milliequivalents per liter. High values for SAR imply a hazard of sodium replacing adsorbed calcium and magnesium, and this replacement damages the soil structure by making the soil tight (Hem, 1970, p. 228).

The specific conductance component used in the rating is an indicator of the dissolved-solids content. A rough estimate of dissolved solids may be determined by multiplying the specific conductance by a conversion factor ranging between approximately 0.5 and 0.6 (Hem, 1970, p. 96-102).

The ratings shown in figures 11 and 12 are based in part on the analyses of water samples collected mostly during periods of low flow. Of greater significance to the ratings, however, is the percentage of time a given concentration range is maintained. For example, in figure 11, if the dissolved solids concentration is greater than 1,000 mg/l 10 percent of the time, the stream is assigned a poor rating. The U.S. Geological Survey has published an annual series of Water-Supply Papers, *Quality of Surface Waters of the United States*, from 1941 through 1963. Records for streams in the Woodward Quadrangle are in Part 7 of this series. Beginning with the 1964 water year, water-quality data are published annually as State publications and also are published every 5 years in the U.S. Geological Survey Water-Supply Paper series. Chemical-quality data published in these reports include concentrations of dissolved solids and of single constituents such as sodium, calcium, sulfate, and chloride, and such characteristics as hardness, sodium adsorption ratio, specific conductance, and pH. Water-temperature data are given only for daily observations.

Data collected by the U.S. Geological Survey provide a general picture of the chemical quality of stream waters in the Woodward Quadrangle. Most of the water is rated fair to poor for municipal use and fair to good for irrigation use. Much of the Permian bedrock in the Woodward Quadrangle contains gypsum, anhydrite, and salt. These minerals are soluble in water and therefore are the source of the sodium, sulfate, and chloride ions that degrade the chemical quality of both the surface- and ground-water supplies of the quadrangle.

REFERENCE

Hem, J. D., 1970, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water-Supply Paper 1473, 363 p.

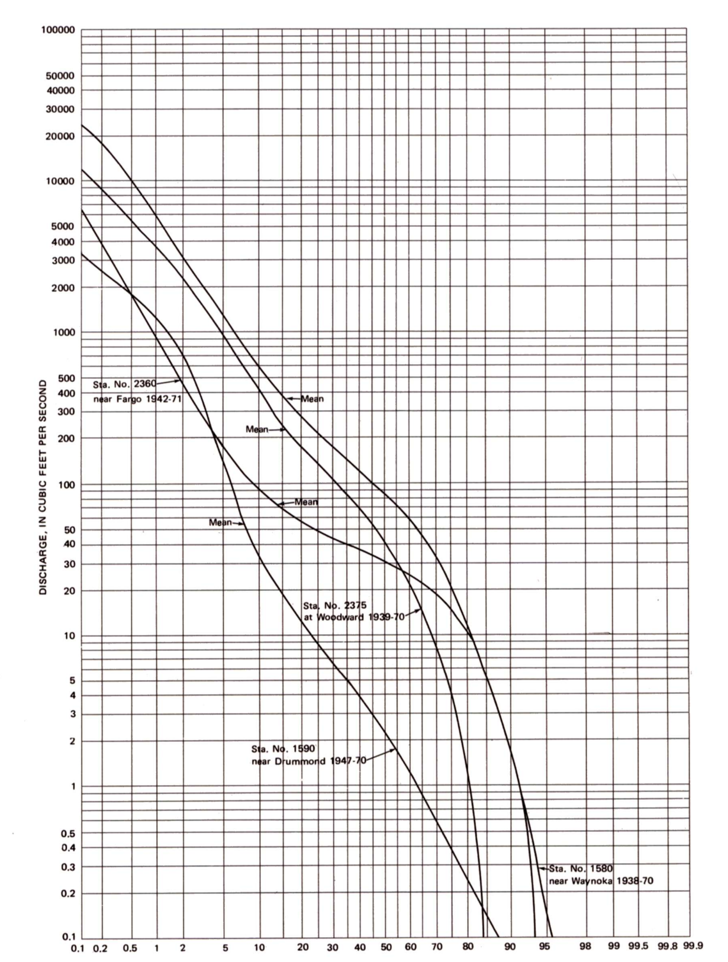

FIGURE 8: FLOW-DURATION CURVES FOR SELECTED STREAMS.

FLOW-DURATION CURVES FOR SELECTED STREAMS

During dry weather, streams are fed by ground water draining from aquifers underlying the stream basins. Streamflow derived from ground water is called base flow. The amount of base flow is a function of the aquifer characteristics and the amount of recharge. Reliability of flow of the streams for a given discharge rate is determined from figure 8. For example, for the period of record, 10 percent of the time a flow of 600 cfs (cubic feet per second), or more, occurred for the Cimarron River near Waynoka; 50 percent of the time a flow of 86 cfs, or more, occurred; and about 96 percent of the time a flow of 0.1 cfs, or more, occurred. For convenience, flow duration can be expressed in reverse of the above. For example, 55 percent of the time a flow of less than 3 cfs occurred for Turkey Creek near Drummond. The curves for the Cimarron and North Canadian Rivers and Turkey Creek show that the flow in these streams is highly variable near the stations indicated and that flow mostly is from direct runoff. Flow in Wolf Creek also is variable but is sustained somewhat in the midrange (10-175 cfs) indicating that part of the flow is from ground-water storage. The alluvium and terrace deposits along Wolf Creek overlie the Ogallala Formation, and the three deposits behave as a single hydrologic unit with good aquifer characteristics; hence the better sustained flow for Wolf Creek 80 percent of the time. About 20 percent of the time (80 to 99.9 percent duration) the flow is reduced considerably and represents dry periods when the water table is low and its gradient becomes too flat to support sustained ground-water discharge to the streams in a significant amount. All curves have extremely steep slopes in the low range, indicating little or no sustained base flow.

REFERENCE

Searcy, J. K., 1959, Flow-duration curves: U.S. Geological Survey Water-Supply Paper 1542-A, 33 p.

Table 1. - - Inventory of Surface-Water-Quality Sampling Stations

Location number	Station name	Sampling frequency,[1/] year, number of analyses
1	Salt Fork Arkansas River near Winchester	I, 1960(39); I, 1961(20); I, 1962(5)
2	Turkey Creek near Alva	I, 1962(2)
3	Salt Fork Arkansas River at Alva	I, 1950(1); D, 1951(59); I, 1952(13); I, 1953(10); I, 1954(7); I, 1962(5)
4	Salt Fork Arkansas River near Ingersoll	D, 1962(59)
5	Driftwood Creek near Driftwood	I, 1962(3)
6	Medicine Lodge River near Driftwood	I, 1962(5)
7	Sandy Creek near Ingersoll	I, 1962(2)
8	West Clay Creek near Yewed	I, 1962(3)
9	Salt Fork Arkansas River near Jet	I, 1951(5); I, 1952(10); I, 1953(20); I, 1954(25); I, 1955(26); D, 1956(43); D, 1957(56); D, 1958(31); D, 1959(31); I, 1960(4); I, 1961(3); D, 1962(55); D, 1963(34); I, 1968(14)
10	Sand Creek near Hawley	I, 1962(3)
11	Cimarron River near Rosston	I, 1953(2)
12	Cimarron River near Buffalo	I, 1953(2); I, 1960(25); I, 1961(12); I, 1963(29); I, 1968(9)
13	Cimarron River near Freedom	I, 1953(2)
14	Cimarron River near Waynoka	I, 1951(4); I, 1952(15); I, 1953(31); I, 1954(31); I, 1955(28); I, 1956(20); I, 1957(25); I, 1958(14); I, 1959(10); I, 1960(22); I, 1961(11); I, 1963(27); I, 1968(13)
15	Eagle Chief Creek near Carmen	I, 1953(8); I, 1954(8)
16	Eagle Chief Creek near Aline	I, 1953(9); I, 1954(1); I, 1955(1); I, 1958(6); I, 1959(3)
17	Eagle Chief Creek near Cleo Springs	I, 1952(10); I, 1953(9); I, 1954(8); I, 1955(1)
18	Cimarron River near Cleo Springs	I, 1953(2); I, 1957(1)
19	Hoyle Creek near Ames	I, 1952(8); I, 1953(5); I, 1954(4)
20	Cimarron River near Okeene	I, 1953(2)
21	Turkey Creek near Drummond	D, 1948(67); I, 1952(8); I, 1953(13); I, 1954(7); I, 1955(15); I, 1956(10); I, 1957(16); I, 1958(14); I, 1959(9)
22	Clear Creek near May	I, 1954(3); I, 1955(4); I, 1956(4); I, 1957(2); I, 1958(4); I, 1960(4)
23	Wolf Creek near Fargo	I, 1958(5); I, 1960(6); I, 1961(4); I, 1962(7); I, 1963(27)
24	Wolf Creek near Fort Supply	I, 1952(8); I, 1953(3); I, 1954(6); I, 1955(6); I, 1956(3); I, 1957(4); I, 1958(2); I, 1960(2)
25	North Canadian River at Woodward	I, 1955(1); 1958(5); I, 1959(2); I, 1961(5); I, 1962(8); I, 1963(21)
26	Indian Creek near Woodward	I, 1953(3); I, 1954(2); I, 1955(3); I, 1956(4); I, 1957(1)
27	North Persimmon Creek near Sharon	I, 1956(2)
28	South Persimmon Creek near Sharon	I, 1956(2)
29	Persimmon Creek near Mutual	I, 1952(1); I, 1958(6)
30	Bent Creek near Mutual	I, 1956(2)
31	North Canadian River near Seiling	I, 1951(4); I, 1953(1); I, 1954(31); I, 1955(27); I, 1956(18); I, 1957(21); I, 1958(15); I, 1959(3); I, 1968(12)
32	North Canadian River at Canton Lake	I, 1951(4); D, 1952(12); D, 1953(11); I, 1954(6); I, 1955(6); I, 1956(10); I, 1957(12); I, 1958(12); I, 1959(12)
33	Canadian River near Camargo	I, 1952(1); I, 1953(2)
34	Canadian River near Talóga	I, 1953(2)
--	Persimmon Creek near Sharon	I, 1956(1)
--	Sand Creek near Woodward	I, 1956(1)

1/ I, Intermittent; D, daily

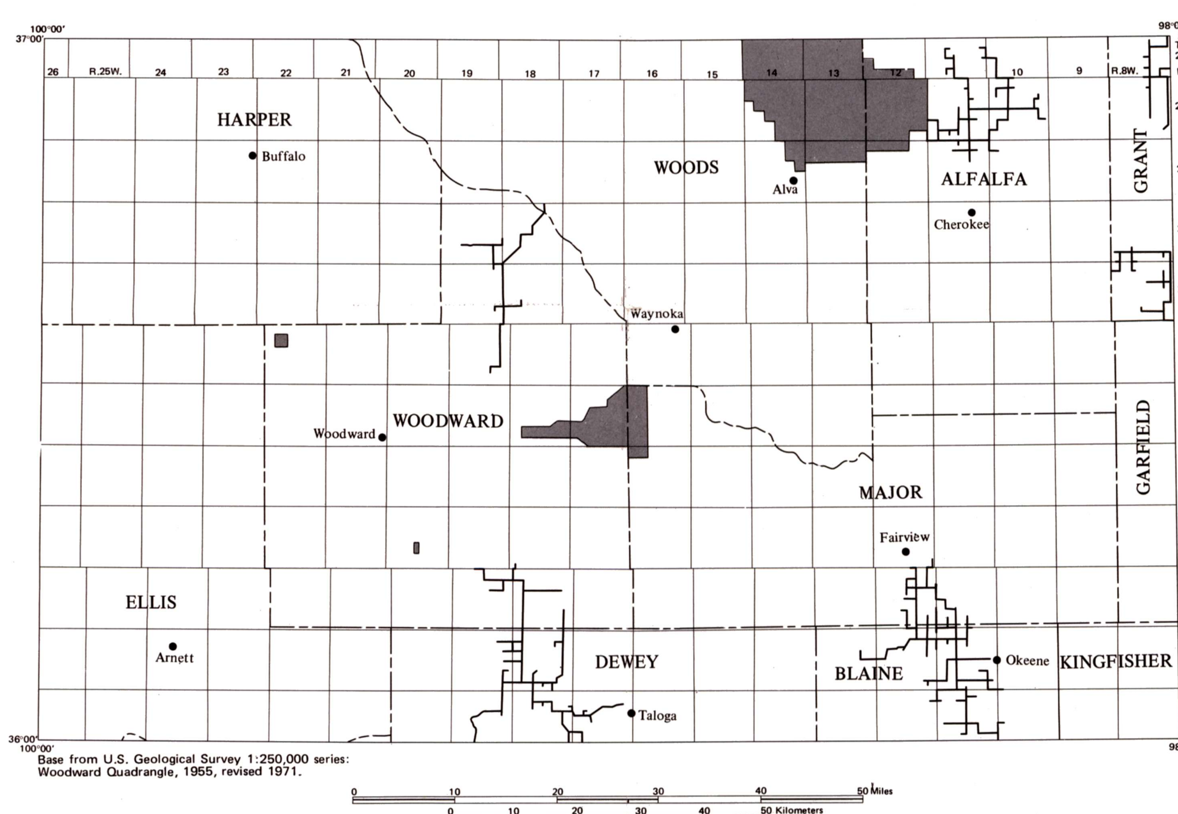

FIGURE 13: MAP SHOWING RURAL WATER DISTRICTS.

EXPLANATION

Pipelines

District Boundary (Pipelines not shown)

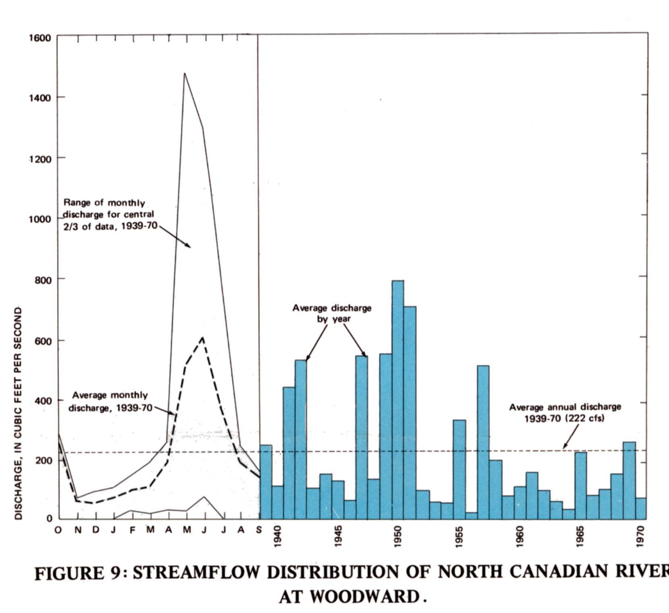

FIGURE 9: STREAMFLOW DISTRIBUTION OF NORTH CANADIAN RIVER AT WOODWARD.

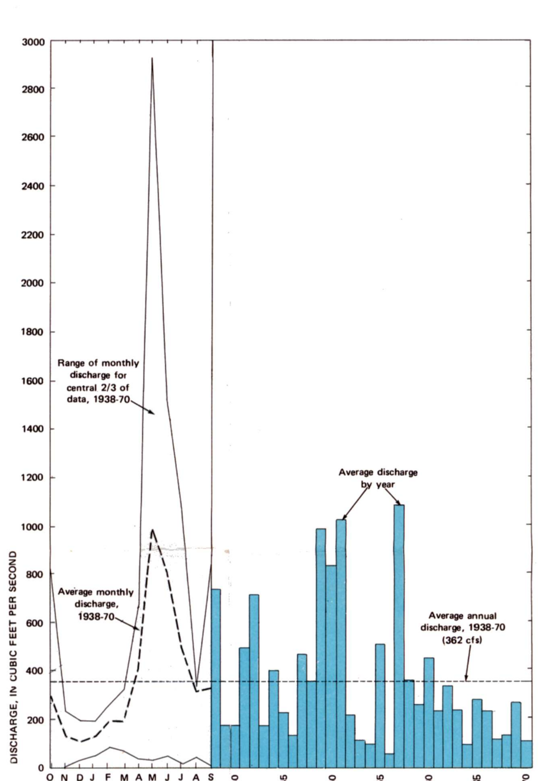

FIGURE 10: STREAMFLOW DISTRIBUTION OF CIMARRON RIVER NEAR WAYNOKA.

WATER USE

Ground water provides about 93.5 percent of the water used in the Woodward Quadrangle. Because of poor quality, virtually the only surface water used within the quadrangle is for irrigation; an estimated 2.1 billion gallons of surface water was used for this purpose in 1971, which is about 8.2 percent of irrigation use and 6.5 percent of all uses. The table shows water use according to six major categories.

Use	Estimated use in 1971 (billion gallons)	Percent of total
Irrigation	25.2	79.1
Municipal	2.9	9.0
Livestock	2.7	8.3
Industrial	.7	2.2
Rural domestic (nonwater district)	.3	1.0
Rural water districts	.1	.4
TOTALS	31.9	100.0

Because of the difficulty in obtaining sufficient water of good quality in many parts of the area, 11 rural water districts, shown in figure 13, were operating by the end of 1971. These districts supplied water in the amount estimated above to about 7,000 people; ground water was the source of this water. Many of the districts will be expanded and new ones established, especially in the eastern two-thirds of the area, to meet the increasing demand for sufficient amounts of good-quality water.

Table 2. - - Summary of Data at Gaged Lakes

Lakes	Gaging station number	Date of closure	Total capacity[1/] (acre-feet)	Range of recorded contents since lake closure: Maximum contents (acre-feet)	Date	Minimum contents (acre-feet)	Date	Uses[2/]
Great Salt Plains Lake near Jet	07150000	1941	280,000	189,400	7- 2-51	20,900	1-17-55	Flood control; wildlife refuge
Fort Supply Lake near Fort Supply	07236300	1942	101,800	97,930	6-25-57	0[3/]	11/42 to 1/43	Flood control; water supply
Canton Lake near Canton	07238500	1948	383,800	258,600	5-25-51	867	5-05-55	Flood control; water supply

1/ At spillway crest or top of flood gates.
2/ Recreation is secondary benefit at most large lakes.
3/ Intermittently.

STREAMFLOW DISTRIBUTION

Streamflow varies with time — daily, monthly, and yearly. Variations in discharge of the North Canadian and Cimarron Rivers are representative of variations of other streams in the Woodward Quadrangle (figs. 9, 10). The high discharge rate during spring and summer months coincides with increased precipitation during this period of the year. Historically the average annual discharge is highly variable for both streams, but beginning in 1958, and except for one year thereafter, the average discharge per year has remained at or below the average yearly discharge for 1939-70. The cause of the consistently smaller flow from 1958 to 1970 is not known, but several factors probably are involved. Because the average annual precipitation for the Waynoka and Woodward weather stations for 1958-70 is 0.16 inch above normal and 1.90 inches below normal, respectively, the amount of precipitation near the Waynoka and Woodward gaging stations does not explain the reduced flow for 1958-70. A contributing factor, however, is the amount of precipitation within the respective watersheds for many miles upstream. Also the distribution of precipitation in time is significant, because precipitation spread relatively evenly throughout the year results in a lower discharge year. The increase in irrigation wells and other high-capacity wells within the watersheds may cause a net decline of the water table with a consequent possible reduction in discharge contributed by base flow in the North Canadian and Cimarron Rivers and all tributaries.

Table 3. - - Lakes in the Woodward Quadrangle

Map number	County and designation	Use[2/]	Area (acres)	Capacity (acre-feet)
	ELLIS			
1	Gage City Lake	M	14	112
2	Lloyd Vincent	P	160	448
	HARPER			
3	Craig Lake	P	42	157
4	Hieronymus Lake	P	26	260
5	Bob Selman	P	10	78
6	Dick Cooper	P	10	56
7	Dick Cooper	P	12	45
8	Hall Cooper	P	15	124
9	James Fossey	P	10	30
10	W. N. Miller	P	24	125
	MAJOR			
11	Clark Lake	P	25	125
12	Collison Lake	P	12	60
13	Penner Lake	P	18	90
14	Edwards Lake	P	15	75
15	M. V. Barnes	P	10	50
16	Bowman Lake	P	10	50
17	Kliewer Lake	P	35	175
18	B. W. Koehn	P	12	60
19	M. Ewing Lake	P	11	55
20	Sokey's Interprize	P	15	75
21	B. Bell Lake	P	11	55
22	A. Penner Lake No. 2	P	10	50
	WOODS			
23	Avard Lake	P	10	100
24	Alva Club Lake	P	1	50
25	Gene McGill	P	50	300
26	Gene McGill	P	30	222
27	Robert Frei	P	15	80
28	Merritt Mason	P	10	50
29	F. Nickelson	P	15	75
30	F. Nickelson	P	20	100
31	G. D. Solvachter, Jr.	P	10	50
32	Sand Pit Lake	R	40	200
33	J. T. Schroeder	P	10	50
34	Omar Parker	P	18	100
35	Jumbo Schupbach	P	10	50
36	Mort Benson	P	11	55
37	E. W. Meyer	P	15	80
	WOODWARD			
38	Crystal Lake	P	10	64
39	Southern Great Plains Station	I	34	262

1/Data provided by Oklahoma Water Resources Board, U.S. Department of Agriculture Soil Conservation Service, and U.S. Army Corps of Engineers.
2/M, municipal; P, private; R, recreation; I, industrial.

RECONNAISSANCE OF THE WATER RESOURCES OF THE WOODWARD QUADRANGLE, NORTHWESTERN OKLAHOMA

By
Robert B. Morton
U.S. Geological Survey

1980