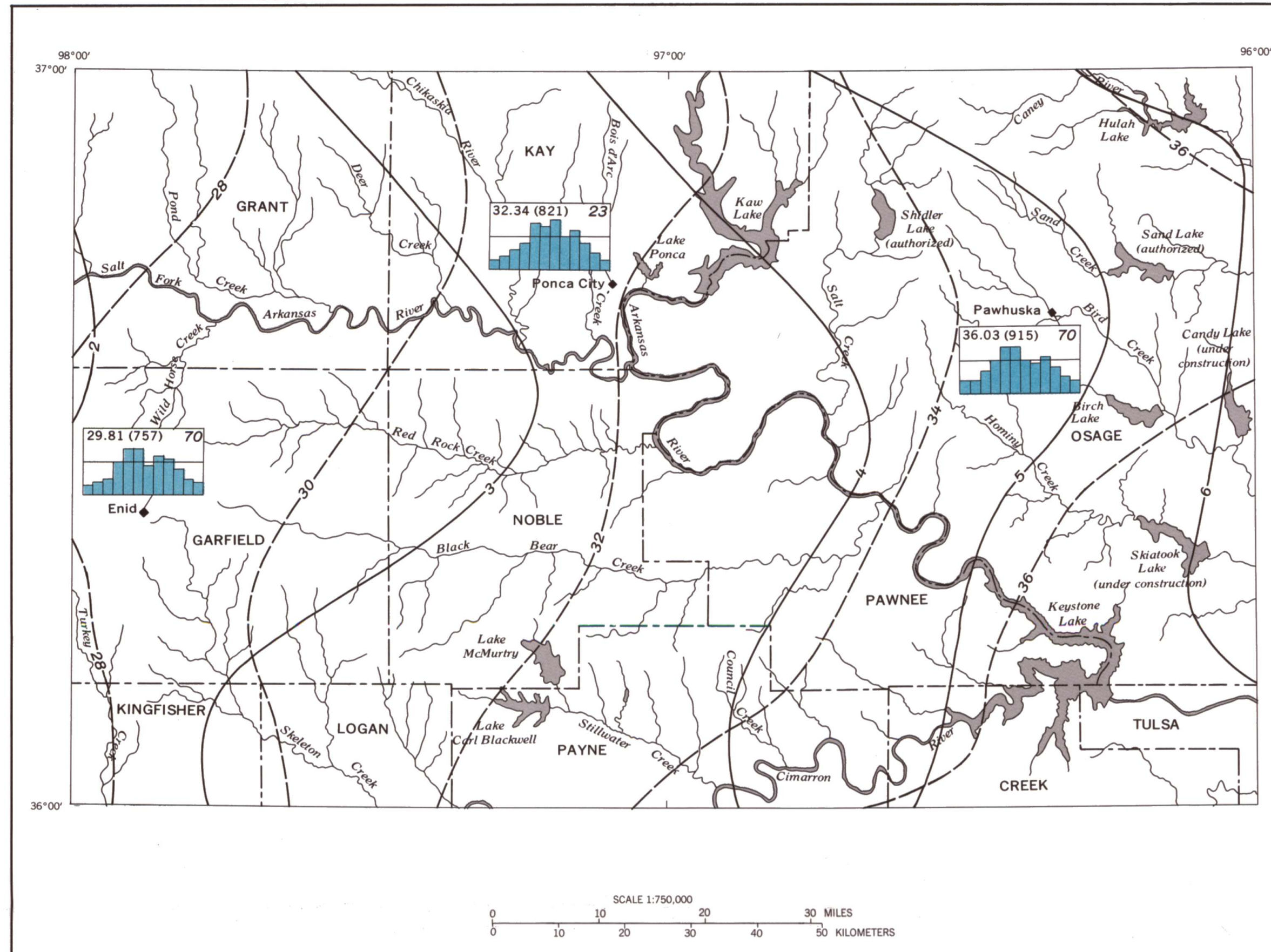

Figure 8. Map showing distribution of precipitation and runoff.

EXPLANATION

(Precipitation data from the National Oceanic and Atmospheric Administration)

32

Line of equal mean annual precipitation, in inches, based on normal annual precipitation, 1931-60; precipitation interval, 2 inches (50.8 mm)

3

Line of equal average annual runoff, in inches; runoff interval, 1 inch (25.4 mm)

29.81 (757) 70

Graph of average monthly precipitation, shown as percent of average annual precipitation

Figure in upper left of graph is average annual precipitation, in inches (and millimeters), for available period of record; figure in upper right of graph is number of years for which records are available

◆ Enid

Weather station

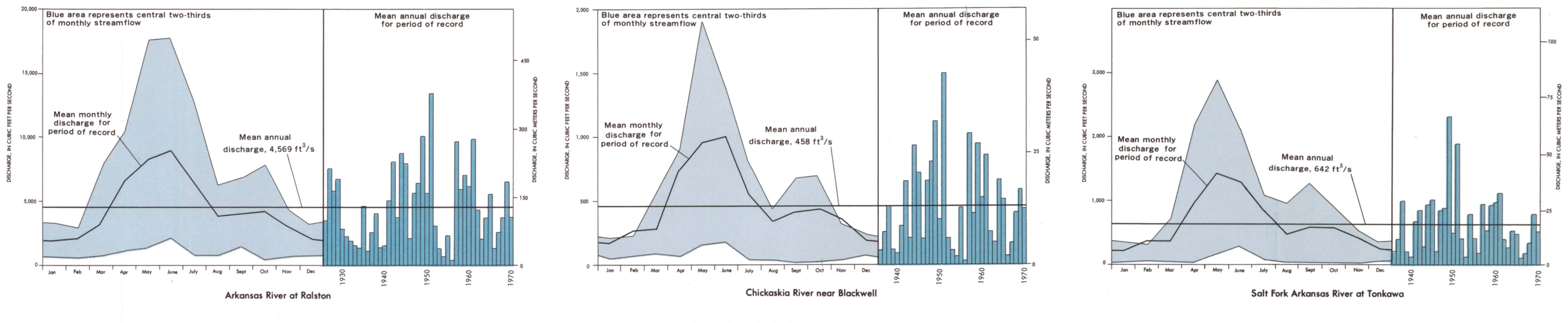

Figure 9. Monthly and yearly discharge at selected gaging stations.

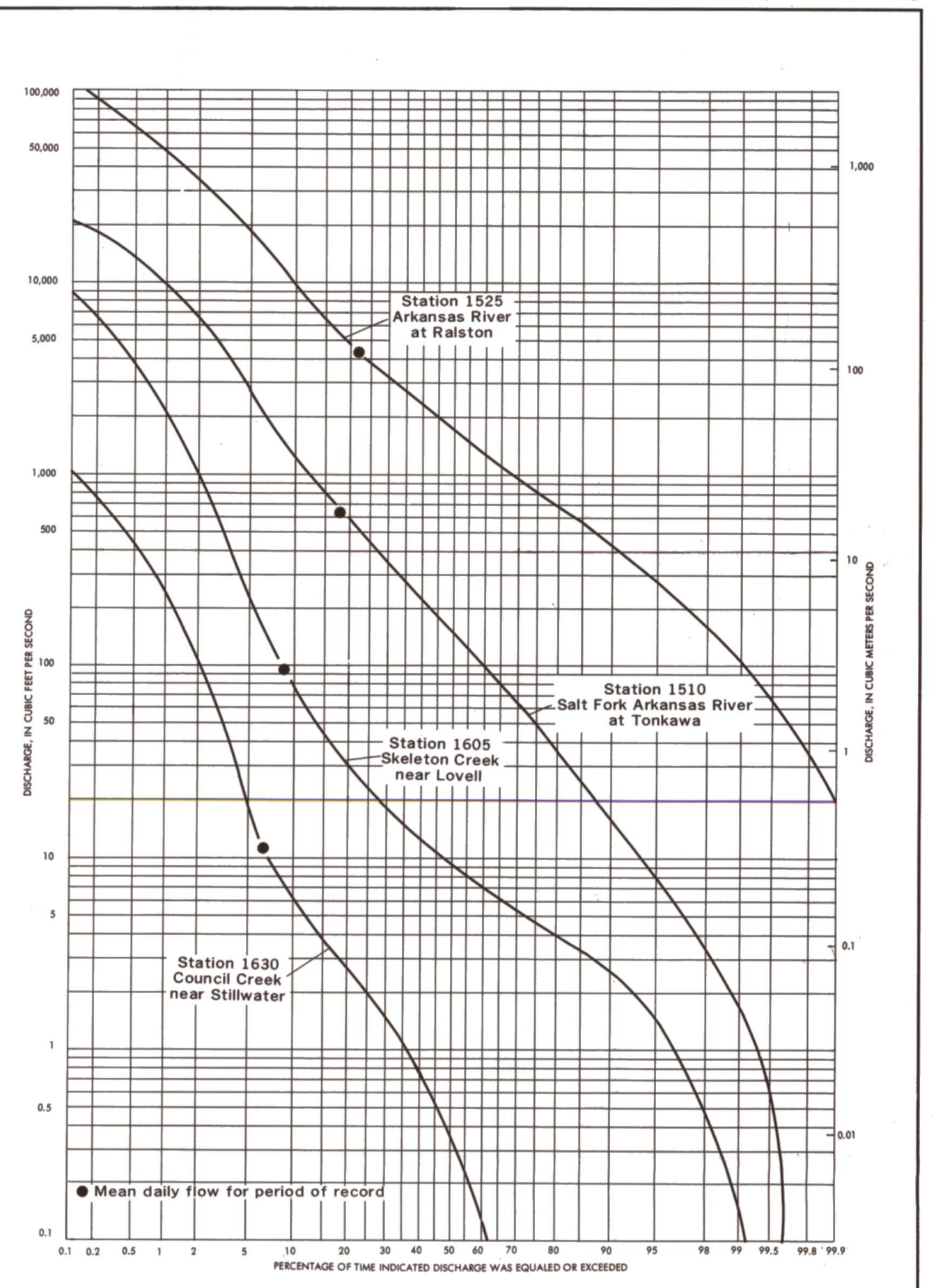

Figure 10. Flow-duration curves for selected streams.

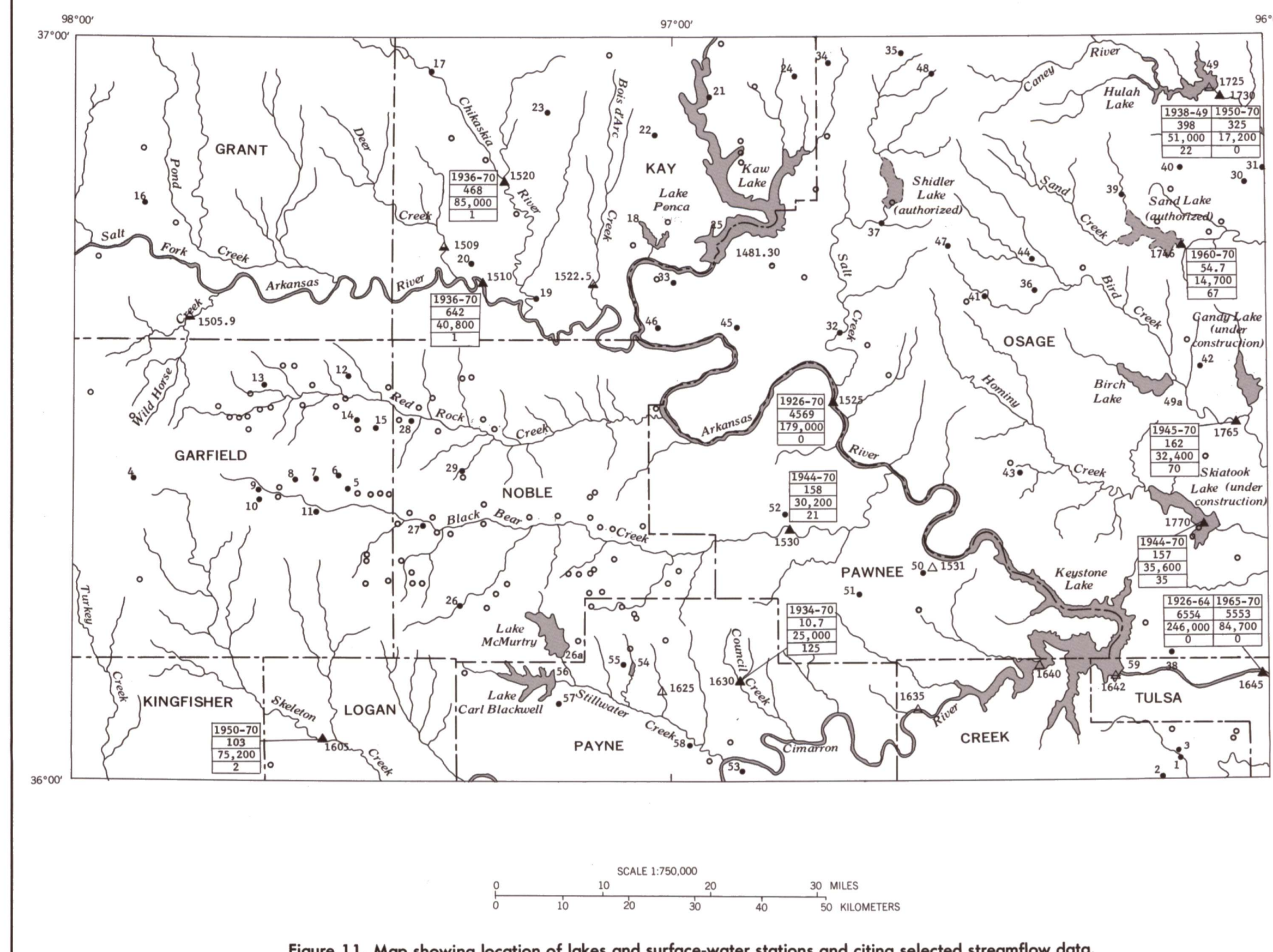

Figure 11. Map showing location of lakes and surface-water stations and citing selected streamflow data.

EXPLANATION

(Data for mapped points given in accompanying tables)

▲1510 Active stream gage and number

△1625 Discontinued stream gage and number

△1509 Active low-flow station and number

△1725 Active lake-stage gage and number

●45 18 Lakes of 25 acres or more and reference number (Where possible, lake outline is shown)

○ Lakes 10 to 24 acres

Lakes authorized for construction

Selected streamflow data for active gaging stations

1944–70	Years of record for data on this map
158	Average daily flow, in cubic feet per second
30,200	Maximum daily flow, in cubic feet per second
21	Average number of days per year with no flow

TABLE 1. — SURFACE WATER STATIONS IN THE ENID QUADRANGLE

STATION NUMBER[1]	STATION NAME	PERIOD OF RECORD (CALENDAR YEARS)
7–1481.30	Arkansas River at Kaw Dam	1978–
1510	Salt Fork Arkansas River at Tonkawa	1903–05[2], 1936–
1520	Chikaskia River near Blackwell	1936–
1525	Arkansas River at Ralston	1926–
1530	Black Bear Creek at Pawnee	1944–
1531	Ranch Creek at Cleveland Lake near Cleveland	1944–63
1605	Skeleton Creek near Lovell	1950–
1625	West Fork Brush Creek near Stillwater	1934–37
1630	Council Creek near Stillwater	1934–
1635	Cimarron River at Oilton	1934–45
1640	Cimarron River at Mannford	1938–50, 1959–63
1645	Arkansas River at Tulsa	1926–
1730	Caney River near Hulah	1938–
1746	Sand Creek at Okesa	1960–
1765	Bird Creek at Avant	1945–
1770	Hominy Creek near Skiatook	1944–
	LOW-FLOW PARTIAL-RECORD STATIONS	
7–1505.9	Wild Horse (Sand) Creek near Pond Creek	1965–72
1509	Deer Creek near Tonkawa	1965–73
1522.5	Bois d'Arc Creek near Ponca City	1953, 1965–73

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[1] From USGS national system of downstream order numbers.
[2] Gage heights only.

TABLE 2. — MAJOR MULTI-PURPOSE LAKES IN ENID QUADRANGLE

LAKE NAME	DRAINAGE AREA (SQUARE MILES)	FLOOD-CONTROL STORAGE (ACRE-FEET)	CONSERVATION AND SEDIMENT STORAGE (ACRE-FEET)	MAXIMUM STORAGE (ACRE-FEET)	AREA OF PERMANENT POOL (ACRES)	LAKE USE[1]
Birch Lake	66	39,000	19,200	58,200	1,137	FC, WS, R, FW, WQC
Hulah Lake	732	257,900	34,700	292,600	3,600	FC, WS, R, FW, WQC
Kaw Lake	7,250	919,400	428,600	1,348,000	17,000	FC, WS, WQC, R, FW, F
Keystone Lake	74,500	1,216,000	663,000	1,879,000	26,300	FC, P, N, R
LAKES UNDER CONSTRUCTION OR AUTHORIZED FOR CONSTRUCTION						
Candy Lake	43	31,260	44,160	75,420	2,170	FC, WS, R, FW, WQC
Sand Lake	137	51,700	39,300	91,000	1,940	FC, WS, R, FW, WQC
Shilder Lake	99	49,900	58,200	108,100	2,450	FC, WS, R
Skiatook Lake	354	182,300	331,200	513,500	10,540	FC, WS, R, FW, WQC

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[1] FC, flood control; R, recreation; FW, fish and wildlife; P, power; N, navigation; WQC, water-quality control; WS, water supply.

TABLE 3. — LAKES OF 25 ACRES OR MORE IN THE ENID QUADRANGLE
(Data provided by the Oklahoma Water Resources Board and the U.S. Department of Agriculture, Soil Conservation Service.)

LOCATION NUMBER[1]	DESIGNATION	USE[2]	AREA (ACRES)	CAPACITY (ACRE-FEET)
	CREEK COUNTY			
1	Sahoma Lake	M	485	4,850
2	Sapulpa Lake	M	96	800
3	Pretty Water Lake	R	30	150
	GARFIELD COUNTY			
4	Lake Hellums	R	35	300
	Upper Black Bear Watershed			
5	Site 28	F,R,	34	233
6	Site 29	F,R,	37	233
7	Site 30	F,R	36	228
8	Site 31	F,R	29	303
9	Site 34	F,R	35	202
10	Site 35	F,R	34	160
11	Site 40	F,R	45	238
	Upper Red Rock Creek Watershed			
12	Site 18	F,R	32	151
13	Site 24	F,R	63	287
14	Site 44	F,R	59	302
15	Site 46	F,R	30	166
	GRANT COUNTY			
16	Three Lakes	P	64	600
	KAY COUNTY			
17	Blackwell Lake	M	300	3,600
18	Lake Ponca	M	805	4,140
19	Vanselous	R	100	800
20	Diversion Dam	M	28	142
21	Newkirk City Lake	M	30	370
22	Newkirk Club Lake	R	44	264
23	Wentz Lake	P	27	67
24	Olsen Lake	P	25	200
25	Kaw Lake	F,E,M,R	17,000	428,600
	NOBLE COUNTY			
26	Lake Perry	M	338	4,137
26a	Lake McMurtry	M,R	1,155	19,967
	Upper Black Bear Creek Watershed			
27	Site 45	F	25	129
	Upper Red Rock Creek Watershed			
28	Site 50	F	70	294
29	Site 54	F	33	153
	OSAGE COUNTY			
30	Hudson Lake	M	335	5,300
31	Bar Du Lake	R	40	720
32	Fairfax Lake	M	101	1,795
33	Indian Hills Lake	P	48	800
34	Lake Ellen	P	27	369
35	Lohman Lake	P	33	138
36	Pawhuska Lake	M	95	2,850
37	Phillips Lake	I	70	1,224
38	Shell Creek Lake	I	640	15,300
39	Sunset Lake	P	100	1,824
40	W. F. Friend	P	30	1,080
41	Oxley Ranch	P	50	275
42	Lake Waxhoma	M	140	2,000
43	City of Hominy	M	200	5,000
44	Bluestem Lake	M	800	17,000
45	C. A. Marchesoni	P	25	150
46	Klinger Lake	P	36	350
47	Drummond Lake	P	30	200
48	Adams Airport Lake	P	25	125
49	Hulah Lake	F,M,I	3,600	34,700
49a	Birch Lake	M,F	1,137	19,200
	PAWNEE COUNTY			
50	Cleveland Lake	M	64	2,212
51	Marmec Lake	I	34	272
52	Pawnee Lake	M	257	3,855
	PAYNE COUNTY			
53	Cushing Lake	M	440	4,567
54	Boomer Lake	M	260	2,486
55	Stillwater Lake	M	25	115
56	Lake Carl Blackwell	M	3,264	58,752
	Stillwater Creek Watershed			
57	Site 46	F	43	346
58	Site 55	F	33	123
	TULSA COUNTY			
59	Keystone Lake	F,E	26,300	663,000

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[1] See Figure 11.
[2] M, municipal; P, private; R, recreation; I, industrial; E, electrical power; F, flood control.

TABLE 4. — SURFACE-WATER-QUALITY SAMPLING STATIONS IN THE ENID QUADRANGLE

LOCATION NUMBER[1]	STATION NAME	PERIOD OF RECORD	YEARS OF RECORD	SAMPLING[2] FREQUENCY
1	Beaver Creek near Kaw City	1950–55	3	P
2	Arkansas River at Kaw City	1949–51	3	D
3	Crooked Creek near Medford	1958–59	2	P
4	Pond Creek near Medford	1958–59	2	P
5	Osage Creek near Medford	1962	1	P
6	Polecat Creek near Numa	1958–59	2	P
7	Deer Creek near Deer Creek	1958–59	2	P
8	Deer Creek near Tonkawa	1958–62	3	P
9	Salt Fork Arkansas River at Tonkawa	1948–63	14	D,P
10	Chikaskia River near Braman	1958–59	2	P
11	Bitter Creek near Braman	1958–59	2	P
12	Bitter Creek near Sumpter	1958–59	2	P
13	Chikaskia River at Blackwell	1951–63	13	D,P
14	Chickaskia River near Tonkawa	1948–63	9	P
15	Duck Creek near Kildare	1958	1	P
16	Duck Creek near Tonkawa	1953–62	2	P
17	Salt Fork Arkansas River near Marland	1954-63	5	P
18	Bois d'Arc Creek near Kildare	1958–59	2	P
19	Bois d'Arc Creek near Ponca City	1953–63	7	P
20	Red Rock Creek near Red Rock	1951–63	11	P
21	Salt Creek near Shidler	1950–63	7	P
22	Arkansas River at Ralston	1950–59	17	D
23	Black Bear Creek near Shea	1958–59	2	P
24	Black Bear Creek near Perry	1958–59	2	P
25	Skedee Creek at Pawnee Lake near Pawnee	1952–56	4	P
26	Black Bear Creek at Pawnee	1952–67	13	P
27	Keystone Lake near Cleveland	1966–67	2	P
28	Skeleton Creek near Lovell	1951–55	5	D
29	Cimarron River at Mannford	1950–63	7	D,P
30	Keystone Lake near Sand Springs	1965–67	2	P
31	Arkansas River at Sand Springs Bridge near Tulsa	1946–67	22	D
32	Buck Creek near Boulangerville	1952	1	P
33	Caney River near Boulangerville	1952–53	2	P
34	Pond Creek near Boulangerville	1952	1	P
35	Caney River near Hulah	1952–64	7	P
36	Sand Creek near Pawhuska	1952–53	2	P
37	Sand Creek at Okesa	1951–62	8	P
38	Bird Creek near Pawhuska	1952–53	2	P
39	Bird Creek near Barnsdall	1949–53	4	P
40	Birch Creek near Barnsdall	1965–66	2	P
41	Bird Creek at Avant	1965–66	2	P
42	Candy Creek near Avant	1965–66	2	P
43	Hominy Creek near Hominy	1950–66	7	P
44	Hominy Creek near Skiatook	1948–66	8	D,P
45	Delaware Creek near Sperry	1952–53	2	P

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[1] See figures 12 and 13.
[2] D, daily; P, periodic.

AVAILABILITY OF SURFACE WATER

The part of north-central Oklahoma shown on the Enid quadrangle is within the Arkansas River basin. In addition to the Arkansas River, the Chikaskia River, Salt Fork of the Arkansas River, Cimarron River, and their tributaries form the drainage network for most of the region. The rivers are normally perennial, but many of their tributaries commonly go dry for brief periods each year as a result of seasonal variations in precipitation.

Precipitation averages about 28 inches (700 mm) per year in the west and about 36 inches (900 mm) per year in the east (fig. 8). Monthly precipitation varies seasonally, with the wettest period occurring in the spring and the driest period occurring in the winter. Significant rainfall usually occurs during short, intense thunderstorms that are associated with squall-line activity ahead of a frontal passage. During a normal year, the number of days with 0.1 inch (2.5 mm) or more of precipitation ranges from 45 in Grant County to 50 in Osage County, and the number of days with 1.0 inch (25 mm) or more of precipitation ranges from 7 in Grant County to 10 in Osage County.

VARIATIONS IN STREAMFLOW

The bar graphs in figure 9 illustrate the variability of annual streamflow caused by fluctuations in precipitation, using the Salt Fork of the Arkansas River at Tonkawa, Chickaskia River near Blackwell, and Arkansas River at Ralston as examples. On the left of the graph, the blue area indicates the range of monthly streamflows expected about two-thirds of the time, and the central line is the mean (or average) monthly discharge for the period of record (table 1). On the right of the graph, the vertical bars represent the mean (or average) discharge for each year that records are available, and the line represents the average discharge for the entire period of record.

Most precipitation never becomes surface runoff because of interception by vegetation, evaporation, infiltration, and storage in local depressions. Average annual runoff ranges from about 2.0 inches (51 mm), or 7 percent of average annual rainfall, in the west to about 6.0 inches (150 mm), or 17 percent of average annual rainfall, in the east (fig. 8).

Base flow in streams is generally provided by ground water. During the wet period in the spring, most rocks underlying the stream basin receive water in their recharge area in excess of the amount that can move through them, thus water levels in the rocks reach their annual high. After the wet season, the excess water in the rocks drains slowly into the adjacent stream and provides base flow during part of the summer. Such drainage, in combination with evapotranspiration, causes the water level to decline to a point at which water stops flowing from the rocks and into some streams. Thus, for some period during most years, small streams in the area have no flow. In some streams, such as Skeleton Creek, base flows probably are sustained or prolonged by discharge of sewage and industrial wastes.

Flow-duration curves of four selected streams in the area show the variability of streamflow that is typical of the region (fig. 10). These curves show the percentage of time that a given flow is expected to be equaled or exceeded at a particular site in a stream reach. For example, the flow of Skeleton Creek near Lovell equaled or exceeded 9.2 ft³/s (0.3 m³/s) 50 percent of the time during the period 1950-71. The curve also shows the flow was greater than 0.1 ft³/s (0.003 m³/s), about 99.2 percent of the time, and greater than the mean daily flow of 99.4 ft³/s (2.8 m³/s), 8 percent of the time.

The flow-duration curves also show that the Arkansas River at Ralston has sustained flow all the time; whereas, the Salt Fork of the Arkansas River near Tonkawa has sustained flow about 99.6 percent of the time, and Council Creek near Stillwater has sustained flow about 60 percent of the time.

AVAILABILITY OF STREAMFLOW RECORDS

Streamflow data are available for 15 gaging stations in the area (fig. 11). The summary of streamflow stations (table 1) gives the station numbers, names and locations, and the periods of published records.

Prior to 1961, the records of streamflow and major reservoir contents were published in the annual series of U.S. Geological Survey Water-Supply Papers entitled *Surface-Water Supply of the United States*. The records for Oklahoma are combined in Part 7 of that series. The records for the 5-year period, 1961 through 1965, are contained in Part 2 of a 2-volume publication of the same series.

Beginning in 1961, streamflow records have been published in annual reports on a state-by-state basis. These basic-data reports are for local use and are available from the District Office, U.S. Geological Survey, Water Resources Division, Oklahoma City, Oklahoma.

LAKES

Lakes (fig. 11) with a surface area greater than 10 acres (4 hm²) impound more than 1.23 million acre-feet (1.52 km³) of water. Three U.S. Corps of Engineers multi-purpose lakes — Hulah, Kaw, and Keystone — are the major impoundments in the area (table 2). These lakes provide a total permanent storage for 1.13 million acre-feet (1.39 km³) with additional capacity to regulate 2.39 million acre-feet (2.95 km³) of flood water.

Hulah Dam was completed in 1951 as a unit in the comprehensive development of the Verdigris and Arkansas River basins. Hulah Lake reduces flooding along the lower Verdigris River, supplies about 1 million gallons/day (3,785 m³/s) for municipal water supply, and aids in water-quality control downstream. Kaw Dam, completed in 1975, provides flood control, hydroelectric-power generation, water supply, water-quality control, and public recreation. Keystone Dam was completed for flood-control operation in 1965 and by 1969 was generating an average annual energy output of more than 230 million kilowatt hours. Keystone Lake provides protection from flooding along the Arkansas River in the vicinity of Tulsa, aids in navigation on the McClelland-Kerr Arkansas River Navigation System by maintenance of regulated flows, and is the major recreational lake of the region.

In addition to the multi-purpose lakes already constructed, four lakes are under construction or authorized for construction in Osage County; these are Candy, Sand, Shidler, and Skiatook Lakes (table 2). The lakes will provide a total permanent storage capacity for 0.47 million acre-feet (0.58 km³) of water with additional capacity to regulate 0.32 million acre-feet (0.39 km³). Birch Lake in Osage County was completed in March 1977, and the conservation pool filled in March 1978. Birch Lake uses include water supply, water-quality control, flood control, and recreation.

More than 180 lakes have been constructed in the area (fig. 11). The surface area of these lakes ranges from 10 acres to more than 3,200 acres (4 hm² to more than 1,300 hm²), and the lakes have a total storage capacity of 0.11 million acre-feet (0.14 km³) of water. Lakes with surface areas of 25 acres (10 hm²) or more are listed in table 3. In addition, there are an estimated 17,000 farm and erosion-control ponds that have a surface area of 10 acres (4 hm²) or less.

CHEMICAL QUALITY OF SURFACE WATER

Data collected and published by the U.S. Geological Survey provide a general description of the chemical quality of surface water at selected sites in the Enid quadrangle. From 1941 through 1965, data were published in an annual series of Water-Supply Papers entitled *Quality of Surface Waters in the United States*. Records for Oklahoma are in Part 7 of that series. Beginning with the 1964 water year, water-quality data have also been published in a series of annual releases on a state-by-state basis. Data given in these reports include concentrations of certain dissolved constituents such as sodium, sulfate, and chloride; chemical characteristics such as hardness, sodium-adsorption ratio, specific conductance and pH; fluvial and sediment information including suspended-sediment discharges, and particle-size distribution of suspended sediment and bed material; and daily water-temperature observations.

Geology, streamflow characteristics, and activities of man affect the chemical quality of surface water. Under natural conditions the chemical quality of water depends upon the abundance and solubility of minerals in the rocks underlying the stream basin and upon the variability of streamflow. Maximum concentrations of dissolved minerals occur during low-flow periods when streamflow is maintained primarily by ground-water seepage from gypsum and salt-bearing formations, west of the area, and by discharge of sewage and industrial waste. Minimum concentrations of dissolved solids occur during periods of heavy rainfall and high runoff.

Man's activities can profoundly alter the chemical quality of lake and stream water. The production of oil, municipal- and industrial-waste disposal, feedlots, irrigation, and use of pesticides and fertilizers result in discharges of effluent that degrade water quality. Organic and nutrient materials also degrade water quality chiefly by creating problems related to entrophication and eutrophication.

Figures 12 and 13 provide information on selected water-quality parameters for streams in the area. These parameters can be used to assess the suitability of the water for municipal, industrial, and irrigation use. A summary of surface-water-quality sampling stations is given in table 4.

Restrictions on the use of water from major streams in the area for public-water supplies and some types of industrial and agricultural uses occur because of excessive concentrations of sulfate, sodium, and chloride. Those constituents are mainly from gypsum and salt-bearing formations west of the area. Water from most of the smaller streams also contains excessive concentrations of sulfate, sodium, and chloride; exceptions are the upper reaches of streams in northern Osage County and tributaries to the Cimarron River in the south-central part of the area. In the eastern two-thirds of the area, the excessive concentrations of sulfate, sodium, and chloride are probably derived from man's activities.

In most of the area of the Enid quadrangle, storm runoff impounded in reservoirs is the primary surface-water source for public-water supplies, and for industrial and agricultural uses.

WATER USE

Surface water, primarily lakes, is the major source of water used in north-central Oklahoma. The total amount of water used in 1971 is estimated at 119,500 acre-feet (147 hm³). Approximately 75 percent of this amount, or about 89,300 acre-feet (110 hm³), was taken from the lakes of the area; the remaining 30,200 acre-feet (37.2 hm³) was provided by ground water. The major use of water was for municipal and industrial purposes, which together accounted for 107,200 acre-feet (132 hm³). Rural domestic use of about 3,500 acre-feet (4.3 hm³) is included with municipal use as shown in the table. Irrigation and secondary oil recovery accounted for the remaining 12,300 acre-feet (15.3 hm³) of water used in 1971. Most of Tulsa and Sapulpa are outside the area; thus, only part of their water use is included in the table.

Water Use in Enid Quadrangle, 1971
(Amounts shown in acre-feet)

USE	SOURCE OF SUPPLY: GROUND WATER	SOURCE OF SUPPLY: SURFACE WATER	PERCENTAGE OF TOTAL (ROUNDED)
Municipal and rural	12,800	42,100	46
Industrial	7,500	44,800	44
Irrigation	6,000	2,300	7
Secondary oil recovery	3,900	100	3
TOTALS	30,200	89,300	100

Of the 57 municipal water-supply systems in the area (fig. 14), in 1971, 33 obtained water from ground-water sources, 18 utilized surface water, and 6 depended on both surface-water and ground-water sources.

Wells in alluvium and terrace deposits supply water for 18 of the 33 towns that use ground water for their municipal supply; the remaining 15 towns depend on wells in bedrock aquifers. Enid is the largest town in the quadrangle that uses only ground water. The sources of Enid's water are terrace deposits at Enid and near Ringwood, approximately 20 miles (32 km) west of Enid. The 17 smaller towns depend on alluvium and terrace deposits along the major streams and some of their tributaries. Alluvium and terrace deposits along the Salt Fork of the Arkansas and Arkansas Rivers provide most of the ground water used for irrigation, industry, and secondary oil recovery.

Adequate amounts of water of suitable quality for rural domestic water supplies are difficult to obtain in some areas. Consequently, water districts have been developed in many of those areas to furnish domestic water supplies (fig. 14). Many of those districts will probably be expanded and new ones established to meet the increasing need for adequate amounts of water of suitable quality for use in rural areas.

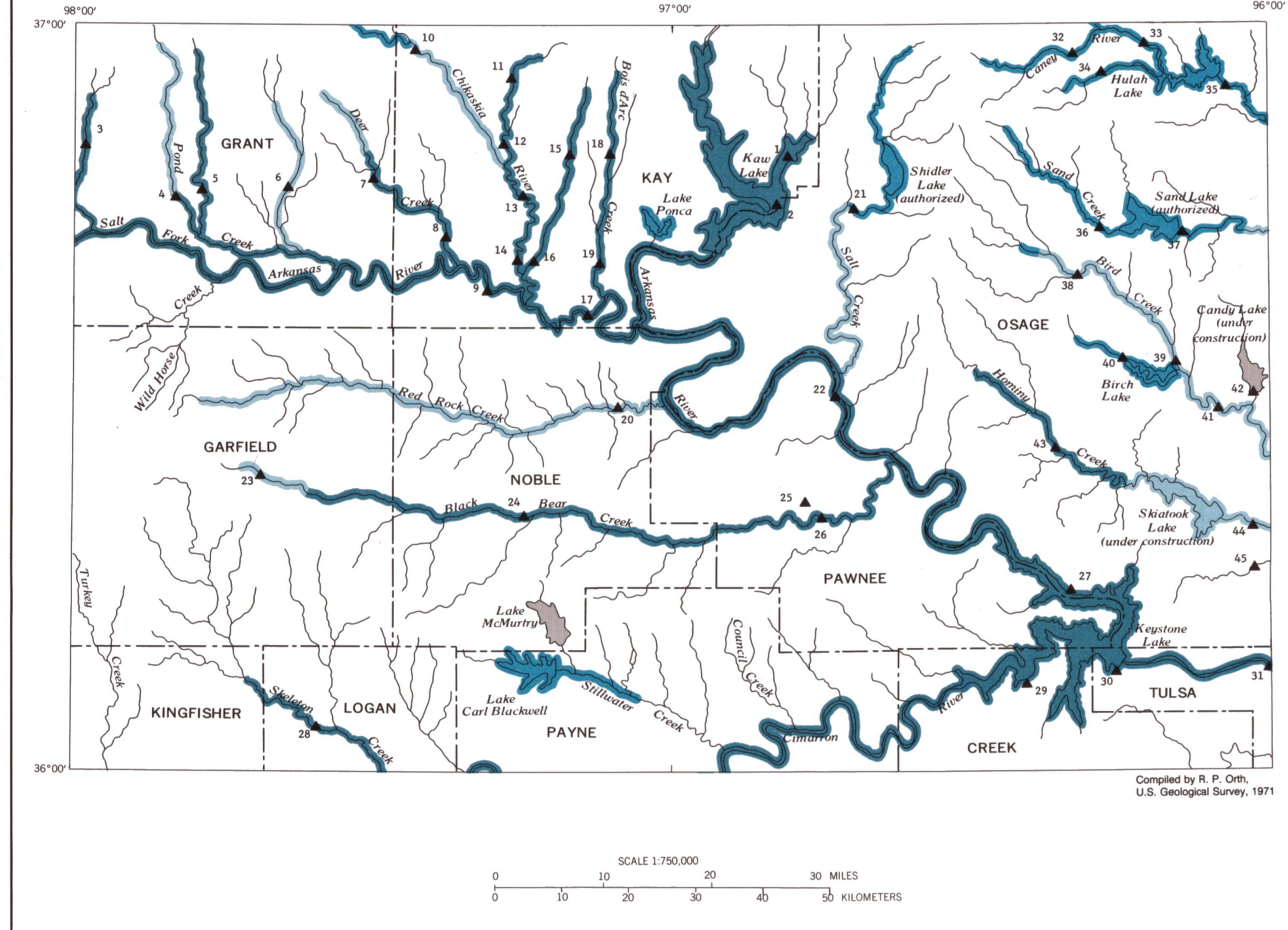

Figure 12. Map showing location of surface-water-quality sampling stations and dissolved concentrations of streams during low-flow periods.

EXPLANATION

▲3 Surface-water-quality sampling station and number

0-500 mg/l dissolved solids

500-1,000 mg/l dissolved solids

>1,000 mg/l dissolved solids

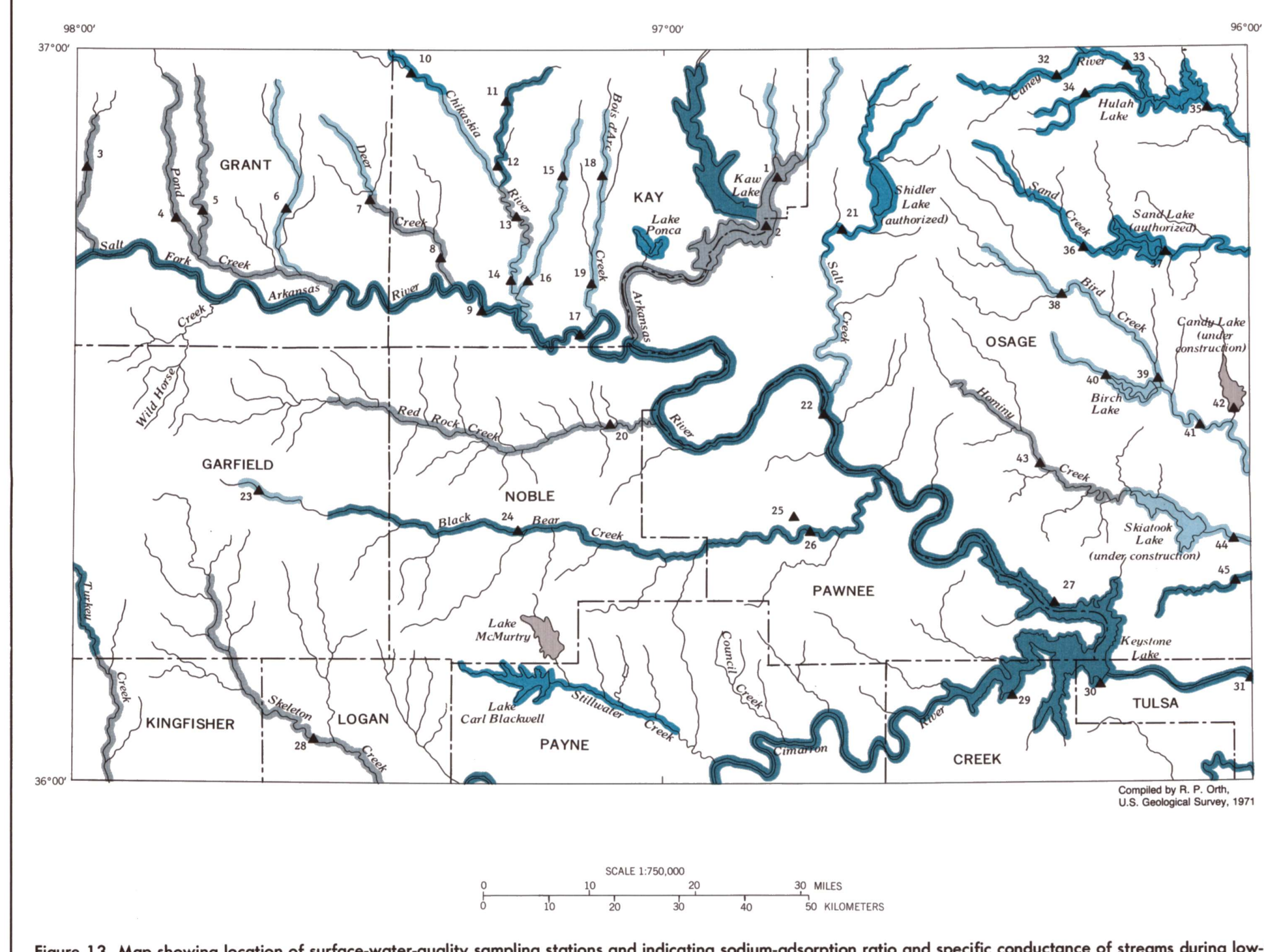

Figure 13. Map showing location of surface-water-quality sampling stations and indicating sodium-adsorption ratio and specific conductance of streams during low-flow periods.

EXPLANATION

▲3 Surface-water-quality sampling station and number

0-2 SAR (sodium-adsorption ratio) and 1,500 or less specific conductance (micromhos per centimeter at 25°C)

2-4 SAR and 3,000 or less specific conductance

4-8 SAR and 5,000 or less specific conductance

> 8 SAR with any specific conductance value

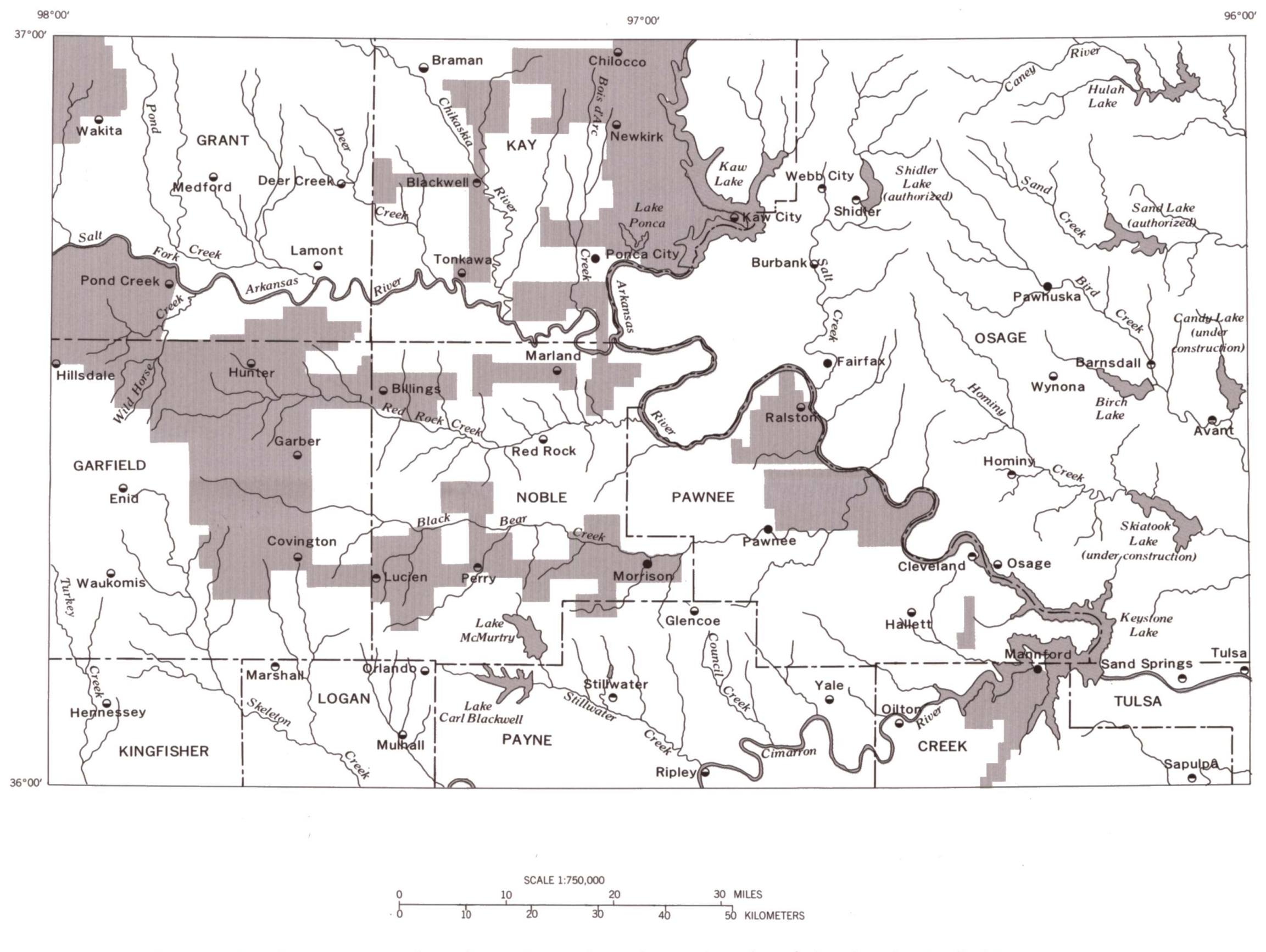

Figure 14. Map showing sources of municipal water supplies and approximate boundaries of rural water districts.

EXPLANATION

Approximate area of rural water district (RWD)

Sources of municipal water supply:

Surface water

Ground water

Combined ground and surface water

RECONNAISSANCE OF THE WATER RESOURCES OF THE ENID QUADRANGLE, NORTH-CENTRAL OKLAHOMA

By

Roy H. Bingham and DeRoy L. Bergman
U.S. Geological Survey

1980