CHAPTER IV
STATEWIDE APPRAISAL

HISTORY

Archaeologists have discovered traces of human life 10 to 15 thousand years old in the caves and ledges of northeastern Oklahoma's Ozark Mountains, making it perhaps one of the oldest inhabited areas in the United States. Still, Oklahoma did not enter the mainstream of recorded history until the arrival of the first of the Spanish conquistadores, Francisco de Coronado, in 1541. Although Coronado never found the fabled "Seven Cities of Cibola" he sought on his expedition through Oklahoma, he claimed a vast expanse of the New World for Spain.

Long before the white man came to share the treasures of the fertile land, Indians had followed the seasons and the abundance of fish and game on the banks of Oklahoma's great rivers, creeks and fresh springs. In 1682 LaSalle navigated the Mississippi River from the north to the Gulf of Mexico and claimed for France all of its drainage area -- land ultimately acquired by the United States in the Louisiana Purchase of 1803.

Oklahoma possessed the potential for becoming one of the first states to be created from the Louisiana Purchase, but instead, its destiny was to be Indian Territory. In 1830 Congress passed a bill for the removal of the civilized tribes, a document that would set the Creeks, Cherokees, Choctaws, Chickasaws and Seminoles forth on the "Trail of Tears." By 1855 there were five separate Indian republics in Oklahoma, and the Reconstruction period brought the resettlement of still more tribes, until some 67 Indian tribes occupied the Territory by the end of the century.

Eager settlers coveting the lush prairies and abundant streams discovered that a 1.9 million acre section of land in the center of Indian Territory, called the Oklahoma District or Unassigned Lands, remained in the public domain. They began to demand that the Federal Government open it to them under the Homestead Act that President Lincoln had signed in 1862, granting 160 acres of public land to any settler who would cultivate it for five years. In 1889 a bill was passed opening the Oklahoma District for settlement beginning on April 22. On that date there was a frantic race for land, with Oklahoma City being established on the banks of the North Canadian River and Guthrie mushrooming along Cottonwood Creek. April 22 in 1889 was marked by stifling heat and dust and a strangling lack of water. A well was hurriedly dug at the corner of Main and Broadway in Oklahoma City, and federal troops guarded the precious water supply source.

Interest in water and water development bagan even before statehood. In 1902 Theodore Roosevelt signed into law the Reclamation Act to aid the arid western states, and the following year investigations were begun in Oklahoma Territory to determine how water supplies could best benefit the area. The Eighth Legislative Assembly of Oklahoma Territory enacted the first water law in 1905, outlining the procedure for acquiring water rights, regulating the use of water and creating the post of Territorial Engineer to administer the new law.

On November 16, 1907 President Theodore Roosevelt signed the Oklahoma Enabling Act, welding into a single state the "twin territories" of white and Indian land, and that year Oklahoma became the 46th state in the Union.

Oklahoma, represented by the 46th star on the flag of the United States, has a land area of 69,919 square miles, divided into 77 counties. The largest county is Osage in northeastern Oklahoma and the smallest is Marshall in the southern portion. The state boasts wide geographical diversity, from the rolling, verdant Great Plains in the west to the rugged, wooded hills of the east. Oklahoma's contrast in land surfaces is matched by broad diversities in populations, ranging from sparsely populated Panhandle farm and ranch lands to thriving metropolitan centers in central and northeastern portions. Oklahoma City is the state's capital, and along with Tulsa, these two Standard Metropolitan Statistical Areas (SMSA) represent one-half of the state's 2,811,000 residents.

Sloping gently from northwest to southeast, Oklahoma's highest elevation is 4,973 feet above mean sea level at Black Mesa in Cimarron County, and its lowest is 305 feet near Idabel in McCurtain County. Slightly south of the geographic center of the nation, Oklahoma is bordered by Texas, Kansas, New Mexico, Colorado, Missouri and Arkansas. Two great river basins --the Red and the Arkansas and their tributaries --traverse the state from border to border and contribute to the state's wealth of water resources.

Oklahoma's abundance of resources has nurtured healthy social and economic growth. In 1977, the state's 10.7 million acres of agricultural land produced nearly $2 billion worth of crops and livestock. In that same year raw mineral production in Oklahoma was valued at $3.5 billion, with mineral industries active in 76 of the 77 counties and oil and gas produced in 71 counties. The McClellan-Kerr Navigation System on which more than 10 million tons of commodities were shipped during 1978 is just one example of Oklahoma's extensive water resource development.

CLIMATE

Oklahoma is divided into two basic climatic regions, the humid east and semiarid west. Summers are long and hot, while winters are shorter and less rigorous than those of the plains states lying farther north. However, recent winters have been increasingly severe, registering record snowfalls and temperature readings. Moist air currents from the Gulf of Mexico temper the weather during most of the year, but cool, moist air masses from the Pacific and cold, dry Canadian air masses influence Oklahoma's winter temperatures.

Maximum precipitation occurs in the spring, when thunderstorms frequently spawn the damaging funnels

FIGURE 6 CLIMATOLOGICAL SUMMARY
Combined Period of Record 1915-1974

REGION / STATION	LENGTH OF RECORD, YEARS	TEMPERATURE							PRECIPITATION (INCHES)		
		MEANS			EXTREMES						
		YEARLY AVG.	DAILY AVG.	DAILY MIN.	MAX.	(DATE)	MIN.	(DATE)	YEARLY AVG.	GREATEST DAILY	(DATE)
SOUTHEAST											
Ada	30	62.4	73.6	51.1	112	8/16/43	-6*	1/4/47	39.40	7.80	9/29/26
Atoka	30	62.6	74.6	50.5	115	8/16/43	-8	2/2/51	40.78	8.10	7/13/27
Coalgate	30	63.0	75.3	50.7	112	9/2/51	-5	1/8/40	41.15	9.54	7/15/53
Durant	30	63.3	75.3	51.2	113	8/7/56	-4	2/2/51	40.47	7.40	8/17/26
Hugo	24	63.8	75.5	52.0	110	8/5/64	-6	2/2/51	47.13	7.05	10/1/54
Tishomingo	30	62.9	75.2	50.5	120	7/26/43	-8	2/2/51	38.95	8.62	7/14/27
CENTRAL											
Oklahoma City (AP)	30	60.3	70.5	50.1	108	7/19/66	1	12/31/68	30.82	4.82	10/3/55
Shawnee	24	61.4	74.0	48.8	112	8/15/56	-6*	1/5/59	35.89	6.56	5/25/57
SOUTH CENTRAL											
Ardmore	30	64.3	75.9	52.7	110	8/16/43	-4	1/14/47	35.83	8.80	7/14/27
Duncan	23	62.9	75.0	50.8	110	8/9/46*	-8	1/3/47	32.90	9.85	5/4/55
Madill	30	63.2	74.2	52.1	111	8/5/64	1	2/2/51	39.16	6.57	6/2/57
Marietta	30	63.8	75.9	51.7	112	8/16/56	-3	1/4/47	36.04	5.83	10/12/37
Pauls Valley	30	62.5	75.1	49.9	112	8/16/56	-9	1/4/47	34.79	5.90	10/8/70
Sulphur	30	62.5	75.0	50.0	111	8/15/56	-10	1/9/44	37.47	11.61	10/8/70
Waurika	24	64.1	77.5	50.6	116	8/6/64	-5	1/23/66	30.16	4.70	4/12/67
SOUTHWEST											
Frederick	24	64.2	77.9	50.5	115	8/6/64	-4*	2/1/51	25.57	5.90	9/22/69
Hobart	24	60.6	72.7	48.4	113	7/25/54	-3*	2/1/51	24.39	5.73	9/19/65
Hollis	24	62.8	77.5	48.1	117	6/14/53	-10	1/23/66	21.53	4.66	5/17/51
Lawton	30	62.3	75.2	49.2	112*	8/3/43	-7	1/4/47	30.16	6.25	10/20/53
Mangum	24	62.2	76.5	47.8	113	8/6/64	-7	1/23/66	23.41	5.46	9/23/70
Sayre	24	60.5	74.3	46.6	114	6/14/53	-7	1/23/66	22.32	4.22	10/9/68
Walters	50	63.6	75.9	51.3	114	8/11/36	-10*	1/18/30	29.69	7.50	10/2/41
Weatherford	24	60.6	72.9	48.2	111*	8/6/53	-4*	2/1/51	27.14	6.25	9/24/59
NORTHEAST											
Bartlesville	24	59.6	72.4	46.7	115	7/14/54	-13	1/5/59	35.53	5.88	9/4/53
Miami	24	59.7	71.4	47.8	116	7/14/54	-8	12/23/63	41.76	9.15	7/7/58
Muskogee	40	61.4	72.6	50.1	114	7/14/54	-3*	12/23/63	41.92	7.16	7/15/61
Pryor	22	59.6	71.7	47.4	112	7/13/54	-9	12/23/63	37.53	5.20	7/15/61
Spavinaw	24	60.9	71.9	49.7	111	7/13/54	-8	12/23/63	41.79	8.35	8/14/61
Tulsa (AP)	30	59.7	70.6	48.8	110	8/5/64	-3	12/23/63	37.08	7.54	7/2/63
Wagoner	24	61.0	73.0	48.9	115	7/13/54	-6	12/23/63	40.76	6.15	7/15/61
EAST CENTRAL											
McAlester	30	61.9	73.3	50.5	113	8/16/43	-9	1/11/62	41.08	7.12	5/9/43
Poteau	24	62.3	74.3	50.2	111*	8/17/52	-7	2/2/51	44.67	7.82	5/14/68
NORTH CENTRAL											
Enid	30	60.3	72.0	48.7	113	7/14/54	-10	1/4/47	30.04	8.30	7/25/60
Hennessey	24	60.4	72.8	47.9	114*	8/6/64	-10	1/4/59	28.59	9.78	5/15/57
Jefferson	24	59.8	72.6	47.0	115	7/14/54	-9	1/4/59	30.01	10.00	10/11/73
Newkirk	24	59.3	71.0	47.6	117	7/14/54	-8	1/4/59	32.99	6.23	9/13/61
Ponca City	24	60.5	72.9	48.1	115	7/14/54	-5*	1/1/51	33.85	5.75	7/25/67
Stillwater	24	60.0	72.2	47.7	113	7/14/54	-6*	12/14/58	32.68	7.00	5/21/57
NORTHWEST											
Beaver	24	57.6	72.5	42.6	111*	6/28/60	-23	1/4/59	19.50	4.45	5/14/51
Goodwell	24	56.8	72.2	41.3	111*	6/28/68	-22	1/4/59	15.89	3.86	8/7/59
Kenton	24	56.0	72.2	39.8	109	6/29/57	-23	1/4/59	15.41	6.37	10/17/65
Woodward	24	59.6	73.3	45.8	111*	8/6/64	-14	1/4/59	22.98	3.82	8/28/74

*Also on earlier dates.

FIGURE 7 MEAN ANNUAL TEMPERATURE (In °F)
Period 1931-1960

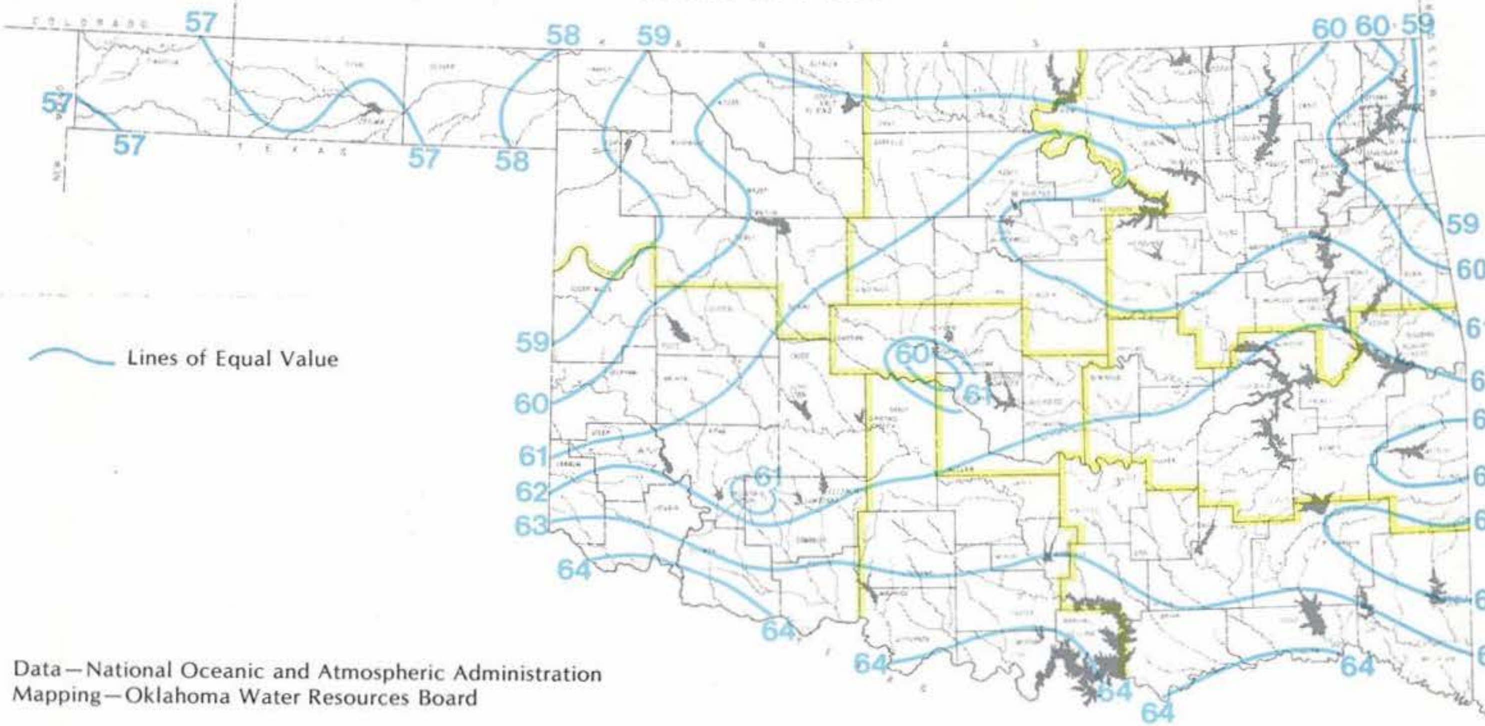


FIGURE 8 AVERAGE ANNUAL PRECIPITATION (In Inches)
Period 1931-1960

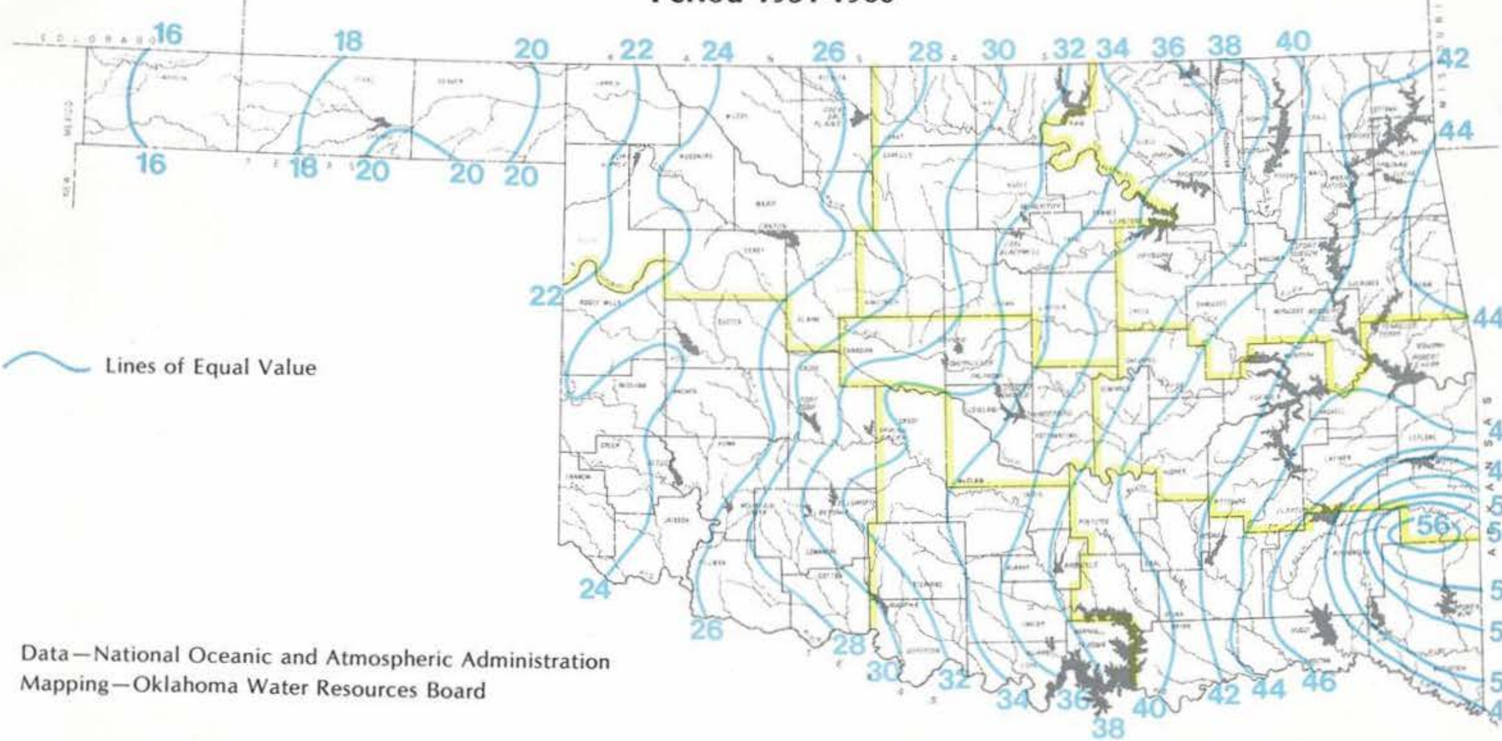
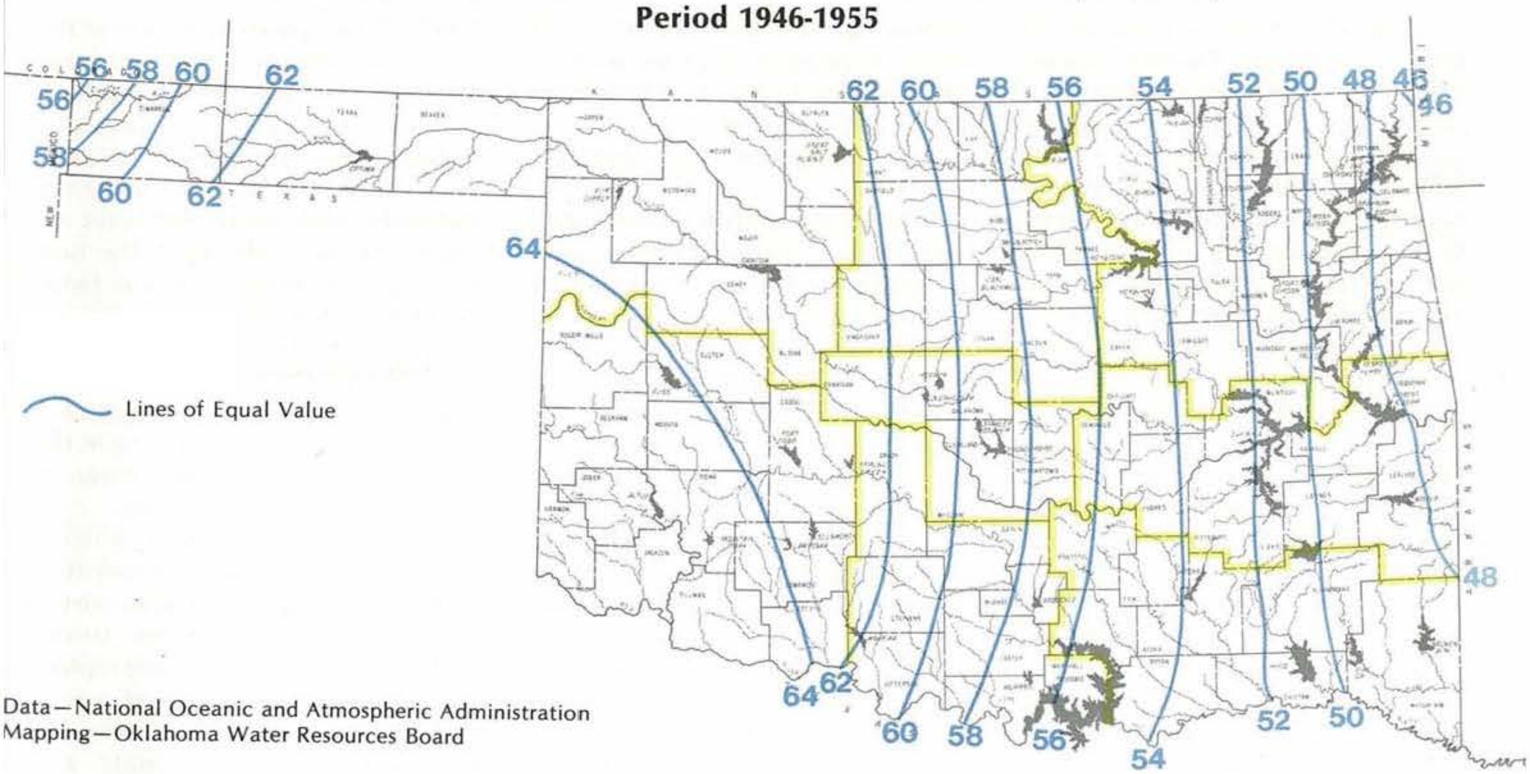


FIGURE 9 AVERAGE ANNUAL LAKE EVAPORATION (In Inches)
Period 1946-1955



Data—National Oceanic and Atmospheric Administration
Mapping—Oklahoma Water Resources Board

that cause Oklahoma to record the highest concentration of tornadoes in the world. May is usually the wettest month and rainfall decreases through the summer until fall, the second wettest season. January ranks as Oklahoma's driest month.

The geographical distribution of rainfall decreases sharply from east to west, ranging from an annual 56 inches measured in the southeastern corner to 15 inches in the western Panhandle. The contrast in annual rainfall is reflected in the officially recorded extremes of 6.53 inches at Regnier in Cimarron County in 1956 and 84.47 inches at Kiamichi Tower in LeFlore County in 1957. Snowfall across the state follows a general pattern of increasing from east to west. During the 1970's average snowfall accumulations ranged from six inches in the southeast to more than 19 inches in the southwest. However, despite recent heavy snowfalls in the west, winter precipitation accounts for only a small percentage of the area's annual total.

Mean annual temperature ranges from 64° F along the southern border to 60° F in the northeast, decreasing westward across the Panhandle to 57° F. High readings of 120° F have been reported at several stations, and the record low of -27° F occurred at Watts in 1930, and at Vinita in 1935. Oklahoma's average annual temperature pattern is shown in Figure 7 .

The length of the growing season, which is defined as the period between the average date of the last 32° temperature in the spring and the average date of the first 32° temperature in the fall, varies from 170 days in Cimarron County to 240 days in McCurtain County. East to west, along the northern border, the average date of the final spring freeze varies from April 5 to April 27; and in the south, from March 27 to April 5. The first fall freeze generally occurs between October 12 and October 27 in the north, and between November 5 and November 10 along the southern border, with the latest occurring in south central Oklahoma.

Annual lake evaporation averages 48 inches in the extreme east and 65 inches in the southwestern corner, as illustrated in Figure 9 . Evapotranspiration (loss of water into the air) and percolation (seepage of water into the ground) consume an average of 80 percent of the annual rainfall. Estimates of evaporation, precipitation, temperature, runoff and other variables are of great importance to planners in accurately determining reservoir yields. Careful, in-depth analyses of such data were employed in the development of the Oklahoma Comprehensive Water Plan.

SCENIC AND RECREATIONAL AREAS

Oklahoma's magnificent lakes, extensive state park system and privately developed recreational areas lure visitors from across the United States. There are 30 state parks and 23 recreational areas throughout the state under the supervision of the Oklahoma Tourism and Recreation Department. They offer camping facilities, entertainment, lodging and a variety of other recreational and social activities. South central Oklahoma's Chickasaw National Recreation Area at Sulphur is a popular attraction, and Grand Lake in the northeast has been extensively developed by private interests. Grand Lake's wooded hills, scenic lake waters and luxurious vacation homes distinguish it in the Southwest.

The state boasts a panorama of scenery such as the Talimena Skyline Drive in the southeast and the Black Mesa region of the Panhandle. Southwestern Oklahoma's Wichita Mountain Wildlife Refuge is one of only four national refuges for buffalo in the nation, grazing nearly 1,000 of this one time almost extinct species. The Wichitas and Arbuckles are the oldest mountains in Oklahoma, formed about the same time as the Appalachians. Mount Scott in the Wichitas is the state's best known peak, but Rich Mountain in the Ouachitas is the highest, rising 2,900 feet above southeastern Oklahoma's plain.

Oklahoma offers the sportsman excellent hunting and fishing with an abundance of lakes and rivers stocked with a wide variety of fresh water fish. Hunting for small game is superb throughout the state, and most areas offer whitetail deer. The dry, open northwest offers the sportsman mule deer and antelope as well. There are many public hunting areas and wildlife refuges where unique species of animals are preserved and enjoyed by campers, naturalists and tourists.

Areas across the state possess unique environmental habitats supporting a wide variety of sport fish, large and small game and waterfowl. Oklahoma is a sportsman's paradise for hunting and fishing, making this form of recreation a big business in terms of revenue. These outdoor activities add millions of dollars each year to the local and state economy in the form of licensing fees, fishing and hunting equipment, lodging expenses and retail sales.

Fishing water is plentiful, as evidenced by 663,000 acres of major reservoirs, 450,000 acres of farm ponds, approximately 23,000 miles of streams, and 17 lakes owned and managed by the Oklahoma Department of Wildlife Conservation. Oklahoma ranks third in the nation in fishable fresh waters. Within these waters sportsmen fish for native species of largemouth bass, crappie, channel catfish, white bass, sunfish, flathead catfish, sauger, paddlefish, spotted bass and smallmouth bass, as well as striped bass, walleye, northern pike and Florida bass that have been introduced to Oklahoma waters to provide even greater sport fishing opportunities.

The State Wildlife Conservation Department's fish hatcheries located at Holdenville, Durant, Medicine Park and Byron provide fish for planting, restocking and research. Annual stocking exceeds 25 million fish of 16 species, with the number of species varying each year to reflect needs and the requests for research, management and pond programs.

Oklahoma's abundance of large and small game provides boundless challenge to resident hunters and out-of-state adventurers. Whitetail deer are the most abundant big game animals, and are legal game in all 77 counties. Mule deer inhabit the Panhandle and extreme northwestern counties in limited numbers. Elk are confined mainly to refuge areas in the east and southwest. Antelope are native to the Panhandle, but are temporarily off limits to allow herd expansion.

Bobwhite quail, found in central and western prairie areas along field edges and shelter belts, are the most popular game birds in Oklahoma. Mourning doves are present in generous numbers across the state, while pheasants inhabit the Panhandle and northwest. Rio Grande turkeys abound throughout the western two-thirds of the state, while where about 10,000 birds are harvested annually. Another variety of wild turkey, smaller than the Rio Grand turkey, is being successfully introduced in eastern Oklahoma. Squirrel and rabbit are plentiful throughout Oklahoma, but are most abundant in the eastern half.

Ducks, geese and sandhill cranes offer numerous opportunities for waterfowl hunters. Because the state lies on the Central Flyway extending form Canada to Mexico, about a quarter of a million ducks migrate through Oklahoma annually. The major reservoirs and Arkansas River Navigation System in the east and smaller lakes, ponds and rivers of the west provide excellent hunting. Mallards are the most abundant species, with pintails, gadwalls, widgeon, teal and divers also plentiful. Canada geese are abundant statewide, while snows and blues are found mainly in the east. The best hunting is generally in wheat fields near the Great Plains Wildlife Refuge in the northwest, and in fields surrounding Tishomingo National Wildlife Refuge in the southeast. Sandhill cranes offer good hunting in the southwest along the Red River in Jackson and Tillman Counties.

Eleven wildlife species, officially listed by the federal government as "endangered", are believed to exist in Oklahoma. These species (seven birds, three mammals and one reptile) face the immediate threat of extinction. Despite the protection afforded endangered wildlife by state and federal law, loss of habitat, pesticide poisoning, certain forestry practices and illegal shooting are applying dangerous pressures to their existence.

Oklahoma's endangered species include the gray bat, black-footed ferret, Indiana bat, bald eagle, whooping crane, Ozark big-eared bat, red-cockaded woodpecker, Bachman's warbler, American peregrine falcon and American alligator. Although not yet officially listed as endangered, one other species in Oklahoma, the leopard darter, is threatened with extinction, if present trends continue.

WETLANDS

Wetlands are areas requiring a high soil moisture content or occasional inundation, and that land adjacent to or dependent on a body of water. The Soil Conservation Service estimates there are 53,000 acres of wetlands in Oklahoma, occurring along the flood plains of major streams and supporting countless varieties of fish, wildlife and plants.

Most of these wetland areas have been altered drastically by clearing for agricultural, residential and industrial development or inundated by water development pro-

FIGURE 10 OKLAHOMA POPULATION PROJECTIONS

PLANNING REGION / YEAR	1970[1]	1977[2]	1980	1990	2000	2010	2020	2030	2040
Southeast	130,954	144,000	160,700	181,000	197,800	212,700	227,300	239,700	250,100
Central	699,092	768,500	886,900	1,059,100	1,193,800	1,301,900	1,397,500	1,478,300	1,550,500
South Central	158,592	180,500	192,700	219,600	240,000	258,600	276,200	291,600	303,900
Southwest	268,369	284,500	286,600	306,100	325,900	343,200	360,900	377,300	391,800
East Central	172,734	190,600	191,800	208,600	224,900	240,300	255,700	269,000	280,300
Northeast	796,733	877,800	907,900	1,030,900	1,168,900	1,304,900	1,435,100	1,557,400	1,664,200
North Central	236,270	262,800	269,200	298,700	325,000	349,100	372,800	393,600	412,100
Northwest	96,719	102,000	105,800	112,700	119,600	123,500	127,400	131,300	135,200
STATE TOTAL	2,559,463	2,809,900	3,001,600	3,416,700	3,795,900	4,134,200	4,452,900	4,738,200	4,988,100

[1]U.S. Census of Population, 1970 Oklahoma P.C. (1) -338.

[2]Oklahoma Employment Security Commission estimate.

jects. Few tracts remain undisturbed, the most extensive of these lying in the flood-plain of the Deep Fork River in Okmulgee, Creek and Okfuskee Counties.

ARCHEOLOGICAL AND HISTORICAL SITES

There are over 6,500 verified archeological sites located throughout Oklahoma's 77 counties, with Comanche, LeFlore, Cimarron, McCurtain and Osage Counties offering the greatest numbers. The locations of these counties indicate the wide distribution of archeological sites across the state.

There are 237 Oklahoma historical sites in 57 counties recorded in the National Register of Historical Places. These sites attract millions of visitors to Oklahoma each year, offering glimpses of Oklahoma's colorful history. Prominent among the attractions are the National Cowboy Hall of Fame in Oklahoma City, Tsa-La-Gi Cherokee Indian Village in Tahlequah, the Creek Council House in Okmulgee, the Philbrook Museum in Tulsa, the Will Rogers Museum in Claremore and the Quanah Parker Star House near Cache.

Coordination of historical and archeological site identification and preservation is accomplished at the state level with valuable assistance from local and regional societies. These local and regional societies assist by erecting historical markers, increasing public awareness, and by organizing local fund-raising efforts for site acquisition.

SOCIO-ECONOMIC CHARACTERISTICS

Oklahoma has experienced rapid social and economic growth in recent decades, evidenced by marked escalations in population, incomes, agricultural production and industrial development. Economists attribute such increases to the state's abundant natural resources (including available land and water) and its favorable labor and tax climates.

As part of the nation's "Sunbelt" region, Oklahoma can expect further development and growth, if it can continue to offer the water, land, energy and capital needed by new residents and industries without succumbing to adverse social and environmental impacts.

The rising and falling cycle of population figures over the past century is directly related to land. Prior to the 1920's the open lands of Oklahoma brought a steady in-migration, but the dust bowl days of the 1930's saw a drastic out-migration, as settlers abandoned their farms and homesteads to seek lands of greater promise. In-migration resumed in the 1960's, and the growth trend continued in the early 1970's. Today the Tulsa and Oklahoma City metropolitan areas account for almost half the state's population. Smaller cities --those over 2,000 --have maintained their populations or grown slightly, while rural areas and towns under 2,000 have shown delines in recent census estimates.

The population increased nearly 1,000 percent, rising from 258,657 to 2,811,000 between 1890 and 1977, at the same time showing a definite trend toward urban concentration. In 1910 only 19.2 percent of the population lived in cities or towns of 2,500 or more, but by 1940 this figure had increased to 37.6 percent, and in the 1970's had reached 68 percent.

Based on projections from the Oklahoma Employment Security Commission, the state's population is expected to reach 2.9 million by 1980; 3.7 million by 2000; and almost five million by the year 2040. Projections number the state's 2090 population in excess of six million, which is expected to be heavily concentrated in urban areas. See Figure 10.

Employment, Labor and Personal Income

Oklahoma has traditionally experienced a higher percentage of employed persons, or conversely, a lower unemployment rate, than the national average, an indication of the generally healthy condition of the state's economy and its relative immuity to short-term fluctuations in the national economy. In 1977 Oklahoma's average unemployment rate was five percent, with 1,166,000 of the total labor force of 1,227,000 employed. The national seasonally adjusted unemployment rate was seven percent during the same year.

Although Oklahoma boasts a favorable overall employment ratio, the distribution of employment indicates certain areas sustain much higher unemployment rates than others. Southeastern Oklahoma historically suffers high unemployment rates and northwestern Oklahoma nominal rates; a variation explained in part by the nature of the industry in each region. While the southeast's manufacturing and mining industries are sensitive to drop-offs in demand and register subsequent layoffs, the northwest's farmers are forced by their large personal capital investments to remain in agricultural pursuits despite market down trends. Population densities also influence the unemployment rate by determining the size of the labor force. Southeastern Oklahoma's higher concentration of people makes labor available in excess of demand, resulting in a higher unemployment rate than in the sparsely populated northwest, where the labor supply and demand are approximately balanced.

Covered employment is defined as the number of workers on the payroll for the period including the twelfth of each month, and who are employed by employers subject to the Oklahoma Employment Security Act. In 1977 the highest covered employment was recorded in wholesale and retail trade, which employed 231,696; manufacturing, which employed 163,902; and service industries, which employed 135,494. These three industries accounted for two-thirds of the average covered employment.

In terms of income, Oklahoma ranks somewhat below the national average of $7,026, with a 1977 per capita personal income of $6,269. Personal income is defined as current income received by residents from all sources, measured before the deduction of personal and income taxes, but after the deduction of personal contributions for Social Security, government retirement and other social insurance programs.

FIGURE 11 MAJOR INDUSTRIES

INDUSTRIAL GROUP	TOTAL NUMBER ESTABLISHMENTS	TOTAL NUMBER EMPLOYEES	AVERAGE WEEKLY EARNINGS
Lumber & Wood Products	146	3,687	174.46
Furniture & Fixtures	86	2,378	160.42
Stone, Clay & Glass	230	9,894	223.55
Primary Metal Industries	70	4,457	239.96
Fabricated Metal Products	438	19,737	227.67
Machinery, Except Electrical	511	25,652	231.25
Electrical Machinery	115	11,483	206.54
Food	319	16,183	199.52
Apparel	133	13,171	115.82
Printing & Publishing	565	9,463	181.19
Chemicals & Allied Products	100	2,814	270.48
Refining & Coal Products	36	8,807	292.86
Other Manufacturing	489	28,655	218.90
TOTAL	3,272	156,381	210.97

SOURCE: Research and Planning Division, Oklahoma Employment Security Commission, 1976.

Coinciding with the pattern of employment across the state, personal income is lower in the southeast and higher in metropolitan areas and the west. However, due to extensive employment in the oil and gas industry, Washington County in northeastern Oklahoma exhibits the highest 1977 per capita personal income at $9,972. Total personal income for the state in 1977 was $17,622,000,000.

Lower establishment costs, plentiful natural resources, an abundance of labor and lower living costs have attracted business and industry to Oklahoma, spurring rapid and highly diversified industrial growth in recent years. Today Oklahoma ranks thirty-second in the nation in industrial development.

In 1976 there were 3,272 major industries in Oklahoma with an annual payroll of over $1.7 billion. Wood and pulp manufacturing industries find bountiful supplies of water needed in processing, and vast oil and gas deposits lend themselves to all facets of energy production, as well as the manufacture of allied products.

Since Oklahoma is predominantly an agricultrual state, agribusiness firms have also migrated to the region, opening profitable markets in farm machinery, seed supplies and fertilizer products. Processing, packing and canning operations have also flourished in the state.

Agricultural Development

Since Land Run days, Oklahoma's climate, soil, water and available lands have attracted farmers and ranchers, and products of the soil in the form of cattle, grain and feed seed crops have made major contributions to the state's economy. In 1976 the state ranked second in the nation in winter wheat production, fifth in grain sorghum, sixth in peanuts for nuts, and sixth in cattle, achieving a total agricultural production value of almost $1.8 billion. The record for production value was established in 1973 with a figure of over $2.1 billion.

There were approximately 86,000 farms in Oklahoma in 1976, averaging 428 acres in size. The most recent complete farm census in 1974 indicated Oklahoma had 38,449 full owners of farms, 22,847 part owners of farms and 8,423 tenants on farms, with figures in all three categories down from previous censuses. These statistics support the trends in evidence throughout the western United States of (1) migration from farms to urban areas, and (2) increase in farm sizes in an attempt to lower unit costs through increased production to defray escalating costs of farm machinery.

Significant portions of the state's industrial economy have grown in response to agricultural development and are dependent upon it. These agribusinesses constitute a multibillion dollar contribution to the state's total economy and include canning and processing of foods and by-products; agricultural supplies, equipment and services; and transportaion and marketing services.

According to the Oklahoma State University Extension Service, irrigated agriculture is on the rise in Oklahoma. The slight decrease registered between 1975 and 1977 is attributed to greater precipitation, higher fuel costs and depressed crop prices, and is not considered indicative of a future trend. See Figure 13. In 1977, 895,802 acres were irrigated, almost 400,000 of them located in the Panhandle counties of Cimarron, Texas and Beaver. Wheat, grain sorghum and alfalfa were the top three irrigated crops. In addition to providing greater crop yields per acre and allowing crops to be grown in areas where they could not be grown under natural conditions, irrigation stimulates local economies by opening new markets for sprinkler systems, fertilizers and other related products.

FIGURE 12 GEOLOGIC TIME SCALE

GEOLOGIC ERA	GEOLOGIC PERIOD	BEGINNING (MILLION YEARS AGO)
Cenozoic	Quaternary	1
	Tertiary	70
Mesozoic	Cretaceous	135
	Jurassic	180
	Triassic	220
Paleozoic	Permian	270
	Pennsylvanian	320
	Missippian	350
	Devonian	400
	Silurian	430
	Ordovician	490
	Cambrian	600
Precambrian		4,500

GEOLOGY

Most of the rocks that outcrop in Oklahoma are of sedimentary origin, consolidated from sediments deposited during the Paleozoic era and covering about 75 percent of the state. Locally, some Paleozoic formations achieve a thickness of 40,000 feet. The oldest of these are the Precambrian granites and rhyolites formed 1.05 to 1.35 billion years ago. Precambrian and Cambrian igneous and metamorphic rocks underlie all of the state, and provide the "floor" upon which all younger rocks rest.

The three principal mountain belts -- southern Oklahoma's Ouachitas, Arbuckles and Wichitas – were formed by folding, faulting and

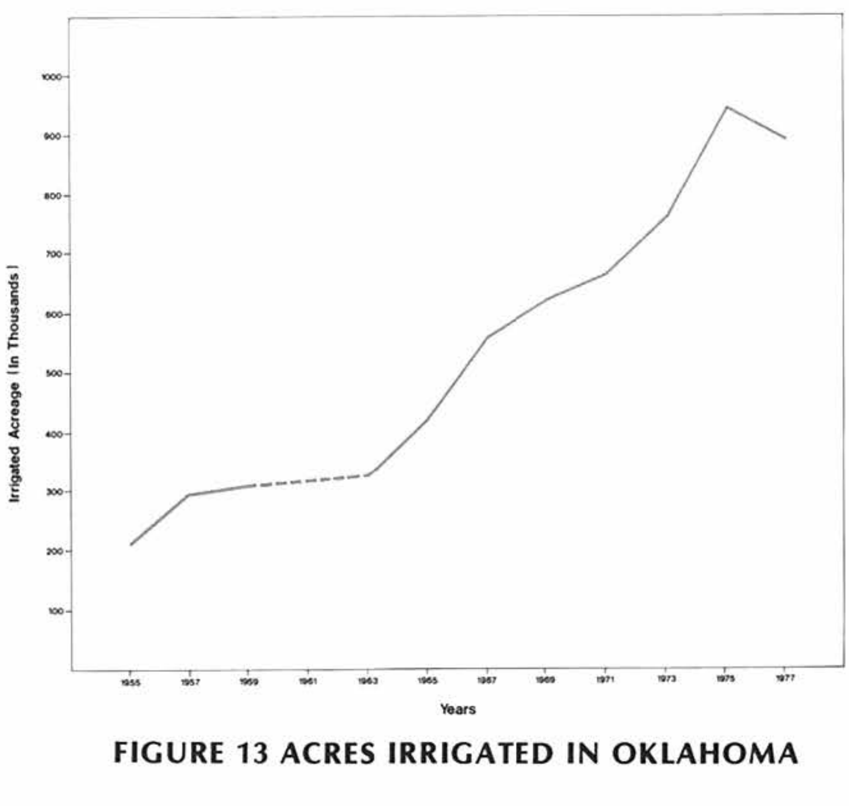
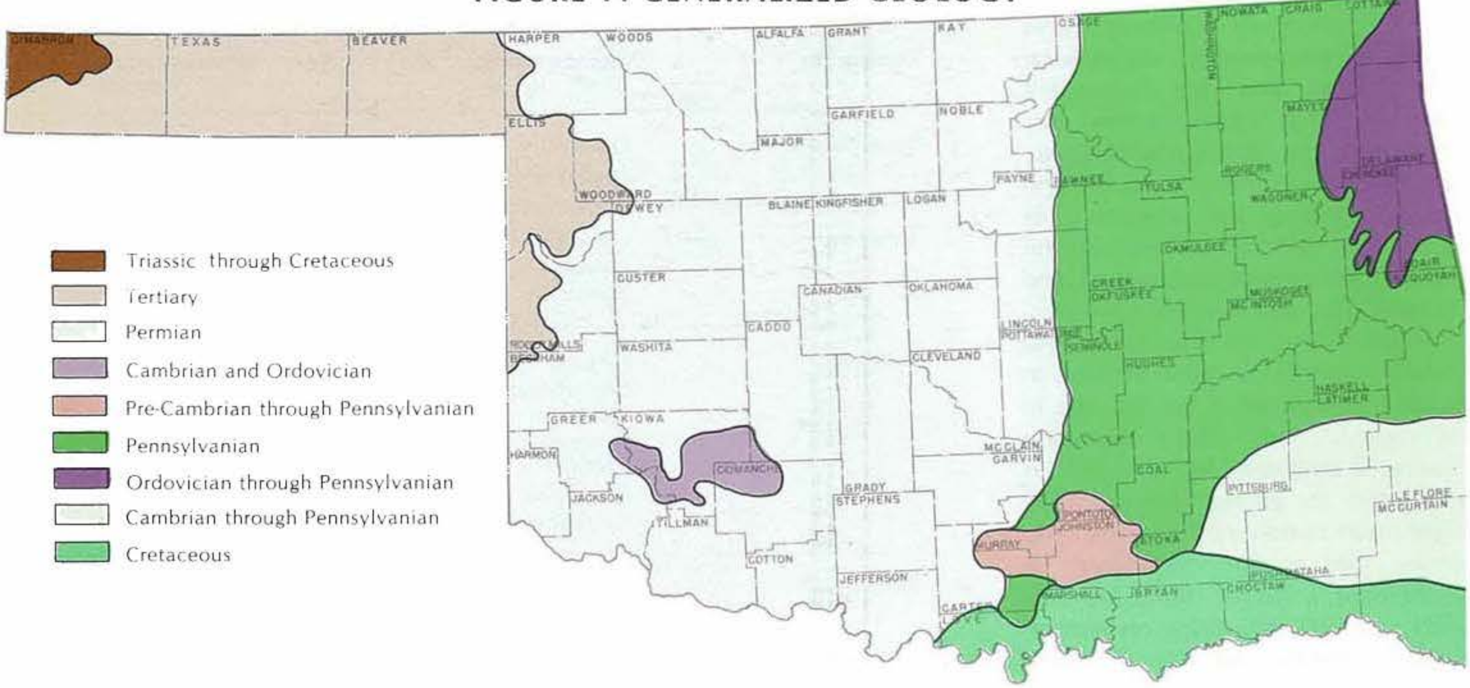


FIGURE 13 ACRES IRRIGATED IN OKLAHOMA

FIGURE 14 GENERALIZED GEOLOGY



uplift during the Pennsylvanian period. North of these mountain uplifts lie the deep Anadarko and Arkoma basins, and still farther north, the relatively undisturbed shelf areas of northern Oklahoma.

Nonmarine shales and sandstones characterize the Mesozoic sedimentary rocks of Oklahoma. Shallow seas covered southern and western Oklahoma during some of the era's Cretaceous period, and marine deposits resulted in limestone and shale.

Since the beginning of the Tertiary period, none of the state has been covered by sea water. Oklahoma's land surface sloped down to the east and southeast, and extensive deposits of Tertiary sand and gravel were washed in by large rivers flowing from the newly formed Rocky Mountains.

The Quaternary period through the present is characterized as a time of erosion. Rocks and loose sediment at the surface are being weathered to soil, then the soil particles are carried away to streams and rivers. In this way, hills and mountains are worn down, and the sediment is either carried to the sea or at least temporarily deposited on the banks and in the bottoms of rivers and lakes.

LAND RESOURCES

Oklahoma has a total area of 44,748,160 acres, with 43,762,176 land acres as of January 1978. Of this land area, 1,727,778 acres are classified as built-up and urban land; 14,488,295 acres as rangeland; 10,751,304 acres as cropland; 6,896,928 acres as pastureland; and 6,764,249 acres as forestland. There were 895,802 acres under irrigation in 1977, with most of the total lying in western Oklahoma.

The Federal Government owns 1,098,939 acres in the state, with

FIGURE 15 MAJOR AGRICULTURAL LAND USES
(In Acres)

PLANNING REGION	CROPLAND	PASTURELAND	FORESTLAND	RANGELAND	WATER 40 ACRES	WATER 40 ACRES	TOTAL
Southeast	163,363	1,636,516	2,132,679	626,655	103,055	19,016	4,618,284
Central	525,389	434,340	207,955	694,904	49,190	17,006	1,928,784
South Central	556,863	561,238	468,002	1,654,344	102,300	20,419	3,363,166
Southwest	3,047,122	310,223	241,446	2,503,917	117,385	66,909	6,287,002
East Central	175,350	1,299,333	1,901,975	707,831	176,900	20,212	4,281,601
Northeast	613,835	2,144,468	1,567,869	2,015,923	214,960	59,462	6,616,317
North Central	2,091,128	392,965	142,902	1,742,719	78,430	34,131	4,488,275
Northwest	3,578,254	117,845	101,421	4,542,202	143,764	33,324	8,516,810
STATE TOTAL	10,751,304	6,896,928	6,764,249	14,488,295	985,984	270,479	40,157,239

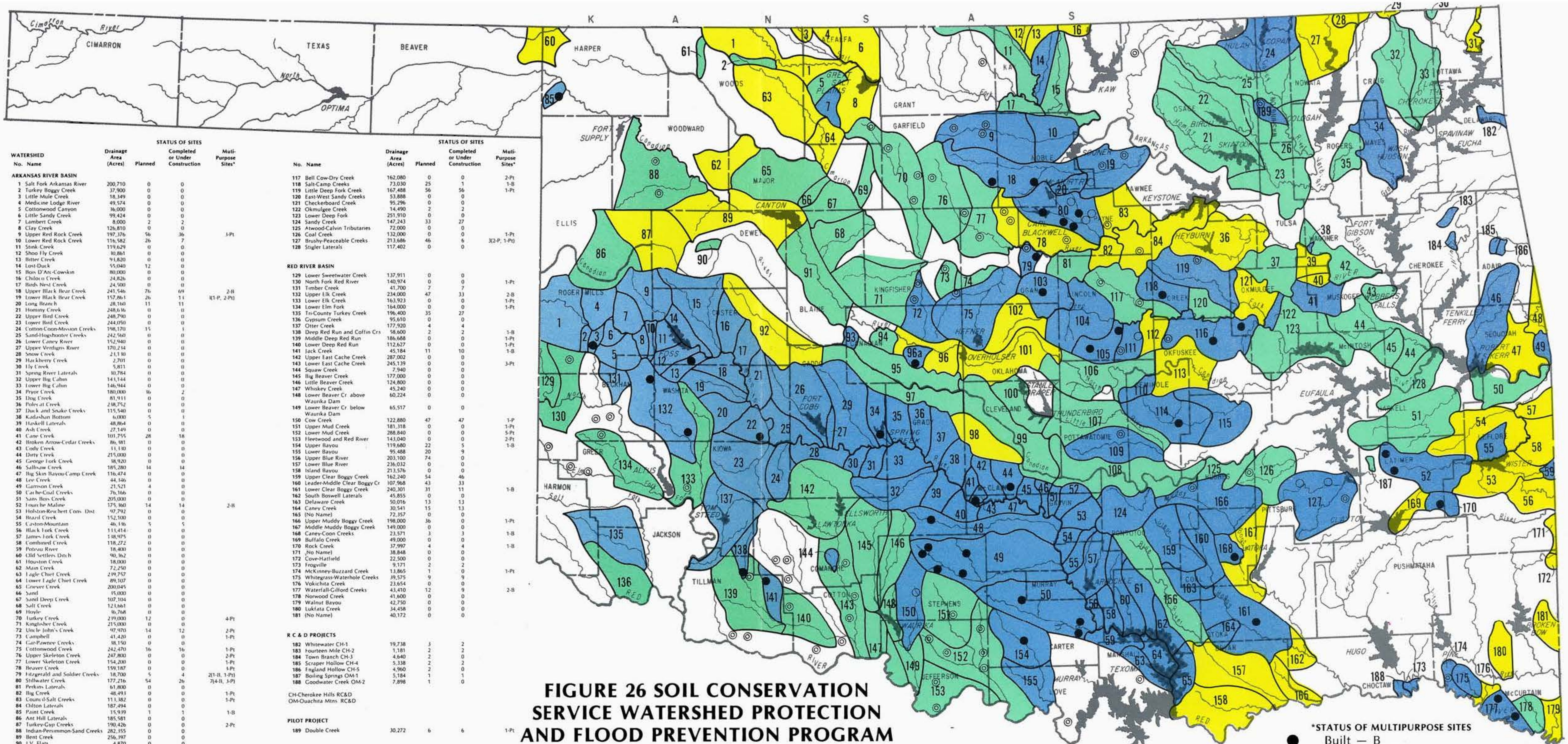


FIGURE 26 SOIL CONSERVATION SERVICE WATERSHED PROTECTION AND FLOOD PREVENTION PROGRAM

STATUS OF WATERSHEDS

- Complete or Under Construction
- Planned
- Potential

*STATUS OF MULTIPURPOSE SITES

- Built — B
- Planned — P
- Potential — Pt.

Indicates number of sites only, not exact location

*Other potential multipurpose sites which appear on map are not in a designated watershed and therefore are not listed in this legend.

Data—Soil Conservation Service
Drafting—Oklahoma Water Resources Board

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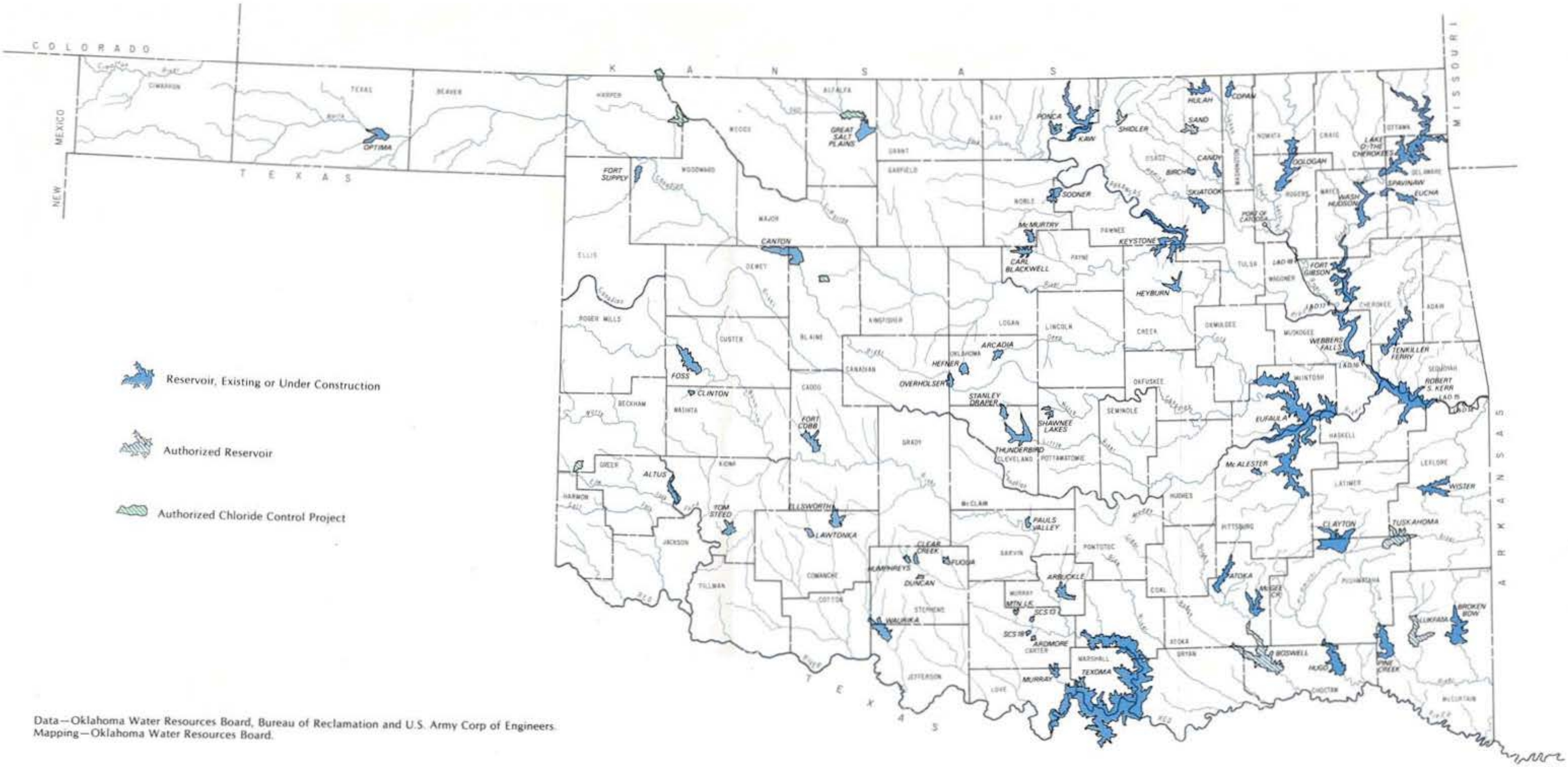
No.	Name	Drainage Area (Acres)	STATUS OF SITES: Planned	Completed or Under Construction	Muti-Purpose Sites*
	ARKANSAS RIVER BASIN				
1	Salt Fork Arkansas River	200,710	0	0	
2	Turkey Boggy Creek	37,900	0	0	
3	Little Mule Creek	18,349	0	0	
4	Medicine Lodge River	49,574	0	0	
5	Cottonwood Canyon	36,000	0	0	
6	Little Sandy Creek	99,424	0	0	
7	Lambert Creek	8,000	2	2	
8	Clay Creek	126,810	0	0	
9	Upper Red Rock Creek	197,376	56	36	3-Pt
10	Lower Red Rock Creek	116,582	26	7	
11	Stink Creek	119,629	0	0	
12	Shoo Fly Creek	30,861	0	0	
13	Bitter Creek	93,820	0	0	
14	Lost-Duck	55,040	12	0	
15	Bois D'Arc-Cowskin	80,000	0	0	
16	Chilocco Creek	24,826	0	0	
17	Birds Nest Creek	24,500	0	0	
18	Upper Black Bear Creek	241,546	76	69	2-B
19	Lower Black Bear Creek	157,863	26	11	3(1-P, 2-Pt)
20	Long Branch	28,160	11	11	
21	Hominy Creek	248,636	0	0	
22	Upper Bird Creek	248,790	0	0	
23	Lower Bird Creek	244,050	0	0	
24	Cotton-Coon-Mission Creeks	198,170	15	1	
25	Sand-Hogshooter Creeks	242,560	0	0	
26	Lower Caney River	152,940	0	0	
27	Upper Verdigris River	170,234	0	0	
28	Snow Creek	23,130	0	0	
29	Hackberry Creek	2,701	0	0	
30	Fly Creek	5,811	0	0	
31	Spring River Laterals	30,784	0	0	
32	Upper Big Cabin	143,144	0	0	
33	Lower Big Cabin	146,944	0	0	
34	Pryor Creek	180,000	16	2	
35	Dog Creek	81,911	0	0	
36	Polecat Creek	238,752	0	0	
37	Duck and Snake Creeks	115,540	0	0	
38	Kadashan Bottom	6,000	5	3	
39	Haskell Laterals	48,864	0	0	
40	Ash Creek	27,149	0	0	
41	Cane Creek	101,755	28	18	
42	Broken Arrow-Cedar Creeks	86,381	0	0	
43	Cody Creek	33,130	0	0	
44	Dirty Creek	215,000	0	0	
45	George Fork Creek	38,920	0	0	
46	Sallisaw Creek	185,280	14	14	
47	Big Skin Bayou-Camp Creek	116,474	0	0	
48	Lee Creek	44,346	0	0	
49	Garrison Creek	21,521	4	0	
50	Cache-Coal Creeks	76,166	0	0	
51	Sans Bois Creek	205,000	0	0	
52	Fourche Maline	175,360	14	14	2-B
53	Holston-Reichert Cons. Dist.	97,792	0	0	
54	Brazil Creek	152,100	0	0	
55	Caston-Mountain	46,136	5	5	
56	Black Fork Creek	133,414	0	0	
57	James Fork Creek	138,975	0	0	
58	Combined Creek	118,272	0	0	
59	Poteau River	18,400	0	0	
60	Old Settlers Ditch	90,362	0	0	
61	Houston Creek	18,000	0	0	
62	Main Creek	72,250	0	0	
63	Eagle Chief Creek	239,757	0	0	
64	Lower Eagle Chief Creek	89,107	0	0	
65	Greever Creek	200,045	0	0	
66	Sand	35,000	0	0	
67	Sand Deep Creek	107,104	0	0	
68	Salt Creek	123,661	0	0	
69	Hoyle	36,768	0	0	
70	Turkey Creek	239,000	12	0	4-Pt
71	Kingfisher Creek	215,000	0	0	
72	Uncle John's Creek	97,970	14	12	2-Pt
73	Campbell	41,420	0	0	1-Pt
74	Gar-Pawnee Creeks	38,150	0	0	
75	Cottonwood Creek	242,470	16	16	1-Pt
76	Upper Skeleton Creek	247,800	0	0	2-Pt
77	Lower Skeleton Creek	154,200	0	0	1-Pt
78	Beaver Creek	159,187	0	0	1-Pt
79	Fitzgerald and Soldier Creeks	18,700	5	4	2(1-B, 1-Pt)
80	Stillwater Creek	177,216	54	26	7(4-B, 3-P)
81	Perkins Laterals	61,800	0	0	
82	Big Creek	48,493	0	0	1-Pt
83	Council-Salt Creeks	113,382	0	0	1-Pt
84	Oilton Laterals	187,494	0	0	
85	Paint Creek	15,939	1	1	1-B
86	Ant Hill Laterals	185,581	0	0	
87	Turkey-Gyp Creeks	190,426	0	0	2-Pt
88	Indian-Persimmon-Sand Creeks	282,355	0	0	
89	Bent Creek	256,397	0	0	
90	J.V. Flats	4,870	0	0	
91	Canton Laterals	235,482	0	0	
92	Deer Creek	219,648	0	0	
93	Canyon View	8,130	4	4	
94	Six Mile Creek	20,160	0	0	
95	Union City Laterals	112,512	0	0	
96	Shell-Purcell Creek	83,000	0	0	
96a	Four Mile Creek	15,360	1	1	1-B
97	Minco Laterals	174,931	0	0	
98	Walnut Creek	124,416	0	0	
99	Buckhead-Chouteau Lateral	226,016	0	0	
100	Upper Little River	77,500	0	0	
101	City Lateral	213,504	0	0	
102	Upper Deep Fork	130,560	0	0	
103	Bear-Fall-Coon Creeks	120,960	31	31	1-B
104	Kickapoo Nations	165,300	20	0	1-P
105	Quapaw Creek	100,198	44	37	2-B
106	Shan-Rock Creeks	207,782	0	0	
107	Central Little River	220,168	0	0	
108	Ash Lateral	270,861	0	0	
109	Salt Creek	152,000	49	34	1-Pt
110	Pott-Sem-Turkey Creeks	34,560	11	0	
111	Robinson Creek	40,230	11	0	2 (1-P, 1-Pt)
112	Pettiquah-Deer Creeks	47,840	0	0	
113	Gar-Snake-Sand Creeks	160,704	0	0	
114	Big Wewoka Creek	172,525	41	41	1-B
115	Little Wewoka Creek	122,445	16	16	
116	Okfuskee Co. Tributaries	201,575	35	23	3(2-B, 1-Pt)
117	Bell Cow-Dry Creek	162,080	0	0	2-Pt
118	Salt-Camp Creeks	73,030	25	1	1-B
119	Little Deep Fork Creek	167,488	56	56	1-Pt
120	East-West Sandy Creeks	53,888	0	0	
121	Checkerboard Creek	95,296	0	0	
122	Okmulgee Creek	14,490	2	2	
123	Lower Deep Fork	251,910	0	0	
124	Sandy Creek	147,243	33	27	
125	Atwood-Calvin Tributaries	72,000	0	0	
126	Coal Creek	132,000	0	0	1-Pt
127	Brushy-Peaceable Creeks	213,686	46	6	3(2-P, 1-Pt)
128	Stigler Laterals	117,402	0	0	
	RED RIVER BASIN				
129	Lower Sweetwater Creek	137,911	0	0	
130	North Fork Red River	140,974	0	0	1-Pt
131	Timber Creek	41,700	7	7	
132	Upper Elk Creek	234,000	47	33	2-B
133	Lower Elk Creek	163,923	0	0	1-Pt
134	Lower Elm Fork	164,000	0	0	1-Pt
135	Tri-County Turkey Creek	196,400	35	27	
136	Gypsum Creek	95,610	0	0	
137	Otter Creek	177,920	4	4	
138	Deep Red Run and Coffin Crs	58,600	2	2	1-B
139	Middle Deep Red Run	186,688	0	0	1-Pt
140	Lower Deep Red Run	112,627	0	0	1-Pt
141	Jack Creek	45,184	11	10	1-B
142	Upper East Cache Creek	287,002	0	0	
143	Lower East Cache Creek	245,139	0	0	3-Pt
144	Squaw Creek	7,940	0	0	
145	Big Beaver Creek	177,000	0	0	
146	Little Beaver Creek	124,800	0	0	
147	Whiskey Creek	45,240	0	0	
148	Lower Beaver Cr. above Waurika Dam	60,224	0	0	
149	Lower Beaver Cr. below Waurika Dam	65,517	0	0	
150	Cow Creek	122,880	47	47	1-P
151	Upper Mud Creek	181,318	0	0	1-Pt
152	Lower Mud Creek	288,840	0	0	5-Pt
153	Fleetwood and Red River	143,040	0	0	2-Pt
154	Upper Bayou	119,680	22	5	1-B
155	Lower Bayou	95,488	20	9	
156	Upper Blue River	203,100	74	0	
157	Lower Blue River	236,032	0	0	
158	Island Bayou	213,576	0	0	
159	Upper Clear Boggy Creek	162,240	54	46	
160	Leader-Middle Clear Boggy Cr	107,968	43	33	
161	Lower Clear Boggy Creek	240,301	31	11	1-B
162	South Boswell Laterals	45,855	0	0	
163	Delaware Creek	50,016	13	13	
164	Caney Creek	30,541	15	13	
165	(No Name)	72,357	0	0	
166	Upper Muddy Boggy Creek	198,000	36	0	1-Pt
167	Middle Muddy Boggy Creek	149,000	0	0	
168	Caney-Coon Creeks	23,571	3	3	1-B
169	Buffalo Creek	49,000	0	0	
170	Rock Creek	37,997	4	4	1-B
171	(No Name)	38,848	0	0	
172	Cove-Hatfield	22,500	0	0	
173	Frogville	9,171	2	2	
174	McKinney-Buzzard Creek	13,865	1	0	1-Pt
175	Whitegrass-Waterhole Creeks	39,575	9	9	
176	Vokichita Creek	23,654	0	0	
177	Waterfall-Gilford Creeks	43,410	12	9	2-B
178	Norwood Creek	41,600	0	0	
179	Walnut Bayou	42,750	0	0	
180	Lukfata Creek	34,458	0	0	
181	(No Name)	40,172	0	0	
	R C & D PROJECTS				
182	Whitewater CH-1	19,738	3	2	
183	Fourteen Mile CH-2	1,181	2	2	
184	Town Branch CH-3	4,640	2	0	
185	Scraper Hollow CH-4	5,338	2	2	
186	England Hollow CH-5	4,960	2	0	
187	Boiling Springs OM-1	5,184	1	1	
188	Goodwater Creek OM-2	7,898	1	0	

CH-Cherokee Hills RC&D
OM-Ouachita Mtns. RC&D

No.	Name	Drainage Area (Acres)	Planned	Completed or Under Construction	Muti-Purpose Sites*
	PILOT PROJECT				
189	Double Creek	30,272	6	6	1-Pt
	WASHITA RIVER				
1	Upper Washita River	471,730	31	31	
2	Broken Leg Creek	10,523	3	3	
3	Sergeant Major Creek	19,684	6	6	1-B
4	Dead Indian-Wildhorse Creek	64,862	11	11	
5	Sandstone Creek	65,013	24	24	
6	Beaver Dam Creek	27,620	6	6	
7	Nine Mile Creek	54,315	18	18	
8	Big Kiowa Creek	25,922	6	6	
9	Quartermaster Creek	123,377	38	36	
10	Whiteshield Creek	17,384	20	19	
11	Panther Creek	47,216	6	6	
12	Soldier Creek	44,748	9	9	
13	Turkey Creek	47,320	12	12	1-B
14	Butler Laterals (Reach II)	47,114	8	6	
15	Barnitz Creek	178,674	69	69	
16	Beaver Creek	56,605	16	15	
17	Bear Creek	53,605	10	8	
18	South Clinton Laterals	50,817	6	6	
19	Boggy Creek	74,043	36	36	
20	Cavalry Creek	69,952	30	30	
21	Gyp Creek (Reach II)	71,828	2	1	
22	Oak Creek	46,394	11	11	1-B
23	Rainy Mountain Creek	209,959	43	27	
24	Saddle Mountain Creek	72,420	7	7	
25	Cowden Laterals (Reach II)	81,884	14	10	
26	Cobb Creek	207,161	10	10	
27	Cobb (Fast Runner) Creek	7,735	10	10	
28	Ft. Cobb Laterals (Reach II)	77,520	13	8	
29	Sugar Creek	189,076	42	42	
30	Tonkawa Creek	30,640	12	12	
31	Delaware Creek	36,879	3	2	
32	Little Washita River	150,808	50	43	
33	Line Creek	50,516	0	0	
34	Spring Creek	53,492	1	1	1-B
35	Ionine Creek	54,521	17	0	
36	Salt Creek	63,265	0	0	
37	Bitter Creek	73,243	22	18	
38	Winter Creek	61,722	25	24	
39	Roaring Creek	67,995	32	32	
40	Round Creek	46,702	9	9	
41	Colbert Creek	14,812	3	3	
42	Criner Creek	42,480	22	22	
43	Bear-Hybarger Creek	23,357	11	11	1-B
44	Firn Creek	58,636	36	34	1-B
45	Wayne Creek	20,574	2	2	
46	Owl Creek	14,545	15	15	
47	Maysville Creek Laterals	44,234	27	21	
48	Rush Creek	191,557	49	47	1-B
49	Wildhorse Creek, Upr & Lwr	427,943	116	99	5-B
50	Caddo Creek	263,349	29	28	3-B
51	Washington Creek	17,488	3	0	
52	Peavine Creek	38,645	10	10	
53	Cherokee Sandy Creek	46,291	21	15	
54	Kickapoo Sandy Creek	41,662	22	20	
55	Chigley Sandy Creek	29,349	14	14	
56	Big Canyon Laterals	24,689	0	0	
57	Rock Creek	109,043	17	17	
58	Oil Creek	40,762	0	0	
59	Mansville Laterals	56,064	0	0	
60	Mill Creek	77,739	18	18	
61	Pennington Creek	82,605	3	3	
62	Big Sandy Creek	40,119	0	0	
63	Glasses Creek, Big and Little	47,731	0	0	
64	West Laterals to Texoma	37,033	0	0	
65	East Laterals to Texoma	38,062	0	0	



Data—Oklahoma Water Resources Board, Bureau of Reclamation and U.S. Army Corp of Engineers.
Mapping—Oklahoma Water Resources Board.

FIGURE 25 WATER RESOURCES DEVELOPMENT

FIGURE 16 OKLAHOMA LAND INVENTORY SUMMARY
(In Acres)

PLANNING REGION	TOTAL AREA	WATER AREA[1]	URBAN AREA	AREA IN ROADS AND RAILROADS	FEDERAL AND STATE LAND AREA[2]	PRIVATELY OWNED RURAL LAND
Southeast	5,068,160	103,055	62,625	48,786	199,838	4,653,856
Central	2,268,160	49,190	207,342	32,818	73,553	1,905,257
South Central	3,711,360	102,300	59,226	46,675	83,691	3,419,468
Southwest	7,043,840	117,385	90,155	160,811	336,734	6,338,755
East Central	5,010,560	176,900	84,819	66,599	310,215	4,372,027
Northeast	7,548,160	214,960	326,658	110,906	290,312	6,605,324
North Central	4,920,960	78,430	97,849	129,053	213,127	4,402,501
Northwest	9,176,960	143,764	38,926	164,530	510,466	8,319,274
STATE TOTAL	44,748,160	985,984	967,600	760,178	2,017,936	40,016,462

[1]Includes bodies of water greater than 40 acres in size and riverbeds more than one-eighth mile wide.

[2]Includes only state and federal owned lands. Does not include leased lands.

almost half owned by the Corps of Engineers through its major water reservoir projects. The State of Oklahoma holds 918,997 acres, with over 80 percent of it in school lands. Figure 16 shows present land use in the state as determined by the Soil Conservation service in its Oklahoma Land Inventory of January 1978.

The principal agricultural industry in the state is beef production, followed by wheat and dairy cattle. This predominance of beef production prevails throughout western, central and east central Oklahoma, but the northeast and southeast show more diversified production including barley and oats, sorghum, soybeans, corn and hay. In the northeast soybean production has doubled every 10 years since 1940, while east central and south central Oklahoma boast thriving commercial timber and wood products industries.

The first detailed soil surveys were conducted in Oklahoma County and a small area near Tishomingo in 1905. Soil survey maps and reports are available for 69 counties, with reconnaissance level work in progress for the remaining eight counties.

Oklahoma soil surveys are made according to the "series concept" of classification. A series is a group of soils with similar profile characteristics and arrangements, excluding surface texture.

Soil associations occur together naturally in a defined proportional pattern on a unique type of landscape. These associations are comprised of several series whose charactristics, including climate, parent materials and natural vegetation, are similar. Figure 17 illustrates existing soil associations and series with each association.

Broad differences exist in state soils. In the eastern part soils were developed under humid conditions where leaching is intense. These soils are low in phosphorus, lack adequate potassium and range from moderately to strongly acid. The vast western prairies, developed under lower rainfall levels, exhibit a light red color and are less leached than eastern soils. They are moderately acid, but low in phosphorus and nitrogen. Soils in the northwest region contain great amounts of lime and are neutral to alkaline at the surface, with calcium carbonate accumulations found at shallow depths. Nitrogen levels are low, but are not usually a limiting factor. Wind erosion is often the most serious soil management and crop production problem.

MINERAL RESOURCES

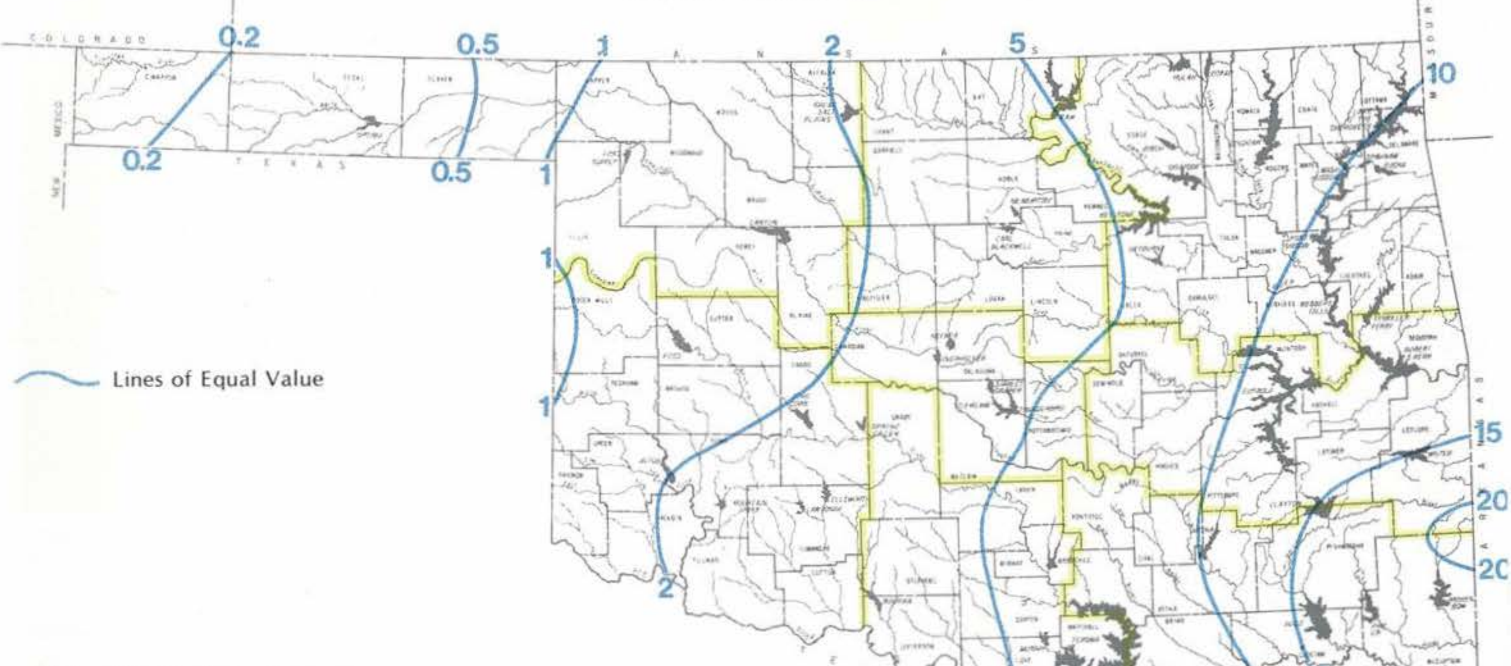
The primary mineral resource of Oklahoma is oil and gas, with a number of other minerals produced on a smaller scale. The total value of mineral production in Oklahoma, rising rapidly to reflect the worldwide escalation of oil prices, reached a record $3.5 billion in 1977, compared to $1.3 billion in 1973. About 96 percent of the 1977 value was derived from the production of fossil fuels, while produced metal and nonmetallic minerals accounted for the remaining four percent.

The tremendous gains in value of produced minerals are somewhat misleading and must be analyzed in terms of the production and value of crude oil and natural gas. According to the Bureau of Mines publication, "Minerals in the Economy of Oklahoma," the unit value of Oklahoma crude petroleum has increased approximately 162 percent since 1973, while annual production of crude oil has declined 29 percent. Unit value of natural gas was up 321 percent in 1977 over that of 1973, but production rose only three percent in 1977. Thus, as a result of the increase in crude oil and natural gas values, the total value of all mineral production is highly inflated in proportion to quantities produced. Figure 18 indicates the major oil and gas deposits in the state.

The mining of coal, a major resource in a 15,000 square-mile area of eastern Oklahoma, is gaining renewed interest. Coal beds in this region range in thickness from one to eight feet with approximately 7.2 billion tons of coal available.

Thick sequences of salt underlie most of western Oklahoma at depths of 30 to 30,000 feet, and reserves estimated at 20 trillion tons remain

FIGURE 20 AVERAGE ANNUAL RUNOFF (In Inches)
Period 1931-1960



Data—U.S. Geological Survey
Mapping—Oklahoma Water Resources Board

virtually untapped. Current salt production is from three solar evaporation plants located in Harmon and Woods Counties. Brines are obtained through relatively shallow wells drilled into salt beds. Dissolution of the salt by penetrating ground water yields natural brines that are pumped from the wells to solar evaporating pans for precipitation of crystalline salt. Underground storage facilities are easily and economically made by dissolving salt and forming cavities in salt beds.

Other resources produced in the state are dolomite, limestone, granite, sand and gravel, glass sand, gypsum, lead and zinc. Dolomite and limestone deposits are located primarily in northeastern Oklahoma and in the Arbuckle Mountains. Granite is quarried near Snyder and Granite in southwestern Oklahoma, and sand and gravel pits are located throughout the state. Glass sand, used in the manufacture of high purity glass, is produced in the south central region. Gypsum outcrops located in western Oklahoma produce 800,000 tons annually. Approximately 1.3 million tons of lead and 5.2 million tons of zinc have been mined from deposits in Ottawa County over the past 80 years. Figure 19 shows the types and locations of the mineral resources in Oklahoma.

WATER RESOURCES

Stream Water

RUNOFF

Runoff is a measure used to identify the amount of water from any form of precipitation that flows over the surface. The runoff, ranging from 0.2 inches in the Panhandle to 20 inches in the southeast corner, reflects the dramatic contrast in precipitation levels in Oklahoma. See Figure 20 . In the northwest region average runoff amounts to about 820,000 acre-feet per year, compared to six million acre-feet per year for the southeast region. Annual average runoff for the entire state is approximately 22 million acre-feet.

In an effort to accumulate relevant data on state stream water flows, the Oklahoma Water Resources Board cooperates with the U.S. Geological Survey in maintaining gaging stations on selected streams throughout the state. These gages periodically record discharge levels at reservoir sites and flow rates at other strategic stream locations. This information is utilized in determining reservoir yields and in the appropriation of stream water rights. (Appendix B, Figure 3 shows the location of these streamflow gaging stations.)

MAJOR RIVER BASINS

Oklahoma is drained by two major rivers; the Arkansas River in the north, and the Red River in the south. These two mighty rivers enter Oklahoma from neighboring states, pick up volume from several major tributaries, then flow out of the state toward their confluence with the Mississippi. The average amount of water leaving the state annually through these two basins is an estimated 34 million acre-feet; with the Arkansas River carrying 22 million acre-feet, the Little River (tributary of the Red) three million, and the Red River nine million. Despite these awesome quantities, their beneficial uses are limited by poor water quality.

The *Arkansas River* and its tributaries drain 44,491 square miles (28,762,240 acres), or about two-thirds of Oklahoma. Major tributaries of the Arkansas River are the Canadian, flowing almost the width of the state; the Illinois, Verdigris and Grand (Neosho) Rivers in the northeast, and the Poteau River in the southeast. Also among the Arkansas' major tributaries are the brackish Cimarron River and the Salt Fork. The Arkansas River enters Oklahoma from Kansas, near Newkirk in Kay County; flows southeasterly from Tulsa; continues that path to a point north of Muskogee, then flows out of the state near Fort Smith, Arkansas. It supports many major reservoirs, as well as the McClellan-Kerr Navigation System that connects the Tulsa area with the Gulf ports of the southeastern United States.

The *Red River* and its tributaries drain 24,978 square miles (15,985,920 acres), or about one-third of Oklahoma. The Red rises in the High Plains of eastern New Mexico, flows eastward across the Texas Panhandle, then marks the boundary between Texas and Oklahoma. It skirts the southern edge of the Kiamichi Mountains in southeastern Oklahoma, meanders across southwestern Arkansas and the coastal plain of Louisiana to its confluence with the Atchafalaya River, and finally joins the Mississippi River. Major tributaries of the Red in Oklahoma are the Elm, Salt and North Forks in the southwest; the Washita River which meets the Red at Lake Texoma; the Blue, Little and Kiamichi Rivers and Boggy Creek in the southeast. Lake Texoma is the only major reservoir project on the main stem of the Red River in the State of Oklahoma.

In order to effectively manage the state's large rivers and smaller streams, the Oklahoma Water Resources Board has further divided the Arkansas and Red River into 49 subbasins. Figure 1 shows the 23 subbasins of the Red and the 26 of the Arkansas. Such disaggregation facilitates the hydrologic studies necessary in the adjudication of stream water rights, implementation of the area of origin protection, reservoir operation surveys and other engineering and hydraulic analyses. (Appendix B, Figure 2 summarizes by planning region pertinent data for selected USGS stream gaging stations.)

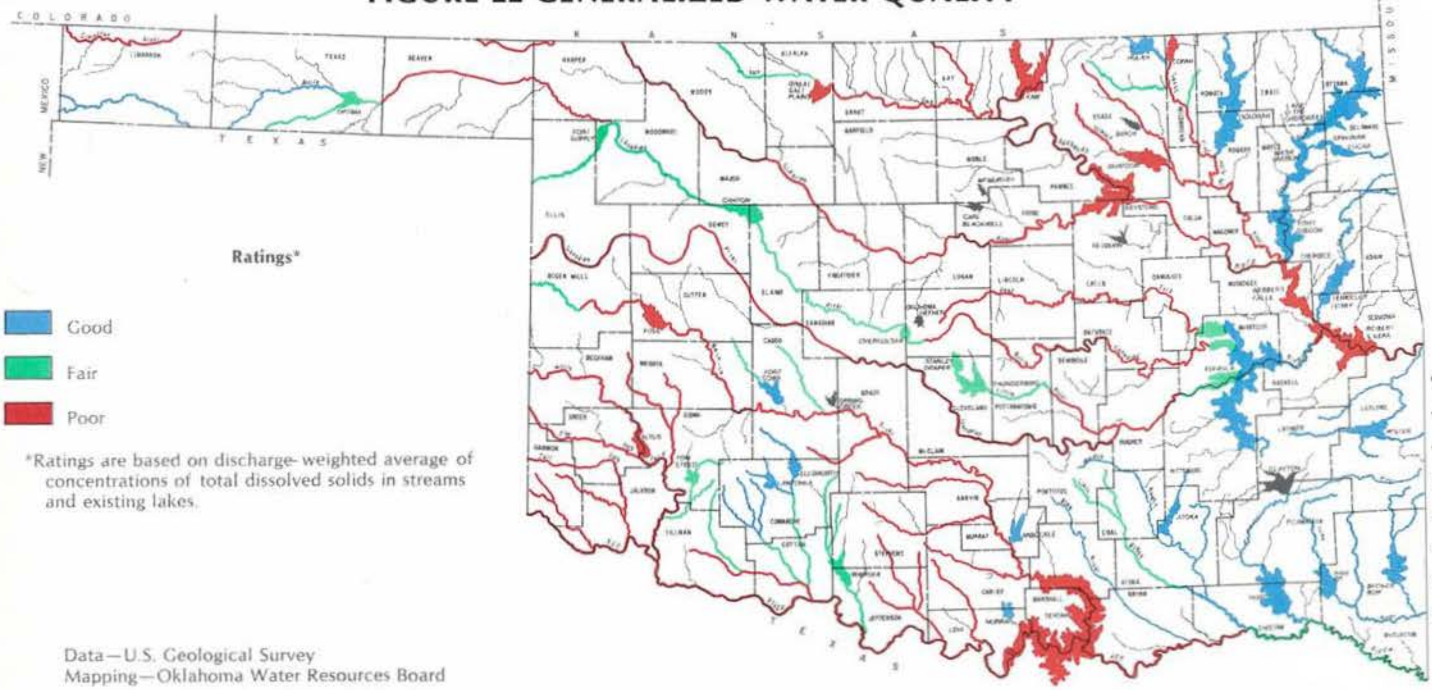
STREAM WATER QUALITY

Water quality of Oklahoma's streams is adversely affected by natural and man-made pollution. In the west, natural salt springs and salt flats emit into local streams large quantities of chlorides that are subsequently carried downstream, polluting other major streams as they go. In populous central and eastern Oklahoma, municipal and industrial effluents degrade many streams, restricting their beneficial uses. However, many of the streams in eastern Oklahoma are of excellent quality, consistently providing pure, fresh water in large quantities.

A discussion of the quality of water rests primarily on the type and amount of materials dissolved in any given water resources. The characteristics of these dissolved materials depend on such factors as geology, flow characteristics of streams and man's activities. Water

FIGURE 21 AVERAGE DISCHARGE OF PRINCIPAL RIVERS

FIGURE 22 GENERALIZED WATER QUALITY



falling as rain contains minute amounts of dissolved materials, but as this water moves over and through rock and soil, more materials are brought into solution. Man-made pollution also places soluable material in water, further degrading its quality.

Water of the Arkansas River Basin in the western and central portions of the state is highly mineralized and nutrient-rich. The Salt Fork and Cimarron River Basins are highly mineralized by natural chloride emission zones in their upper basins. The amount of chloride concentration is so great in some reaches of the Cimarron that the salt level often exceeds that of sea water. The Cimarron also contains high levels of gypsum, which contribute to the river's poor water quality.

The North Canadian, Deep Fork and Canadian Rivers are also nutrient-rich and highly mineralized. Municipal and industrial discharges in central Oklahoma have degraded these rivers in recent years, however, the water quality improves in the lower reaches, as the assimilative capacity of the streams increases.

Northeastern Oklahoma offers both good quality and poor quality streams. The Grand (Neosho) and Illinois Rivers are of excellent quality from their origin to their confluence with the Arkansas River. However, the Verdigris and Caney Rivers are rated poor due to high total dissolved solids from natural and man-made sources. Because of its degraded western tributaries, the main stem of the Arkansas is also of poor quality.

The general water quality of the Red River Basin is poor from the Texas Panhandle to Lake Texoma due to high mineral and nutrient levels. Natural salt plains in the lower Texas Panhandle, similar to those of northwestern Oklahoma, emit high levels of chlorides into the Red River making it unfit for beneficial use. The Salt Fork and North Fork drainage basins in Oklahoma also add chlorides to the Red, raising its total dissolved solids to undesirable levels. The highly nutrified East Cache Creek and moderately nutrified Mud Creek flow into the Red in Cotton and Jefferson Counties, respectively, further polluting the river. The Washita River, the major tributary of the Red, is a turbid, hard water stream, increasing in turbidity and hardness in its flow downstream. From its headwaters to Lake Texoma, the river is highly mineralized with sulfates and chlorides.

Once the Red River flows from Lake Texoma, the quality of its water improves significantly with the addition of the high quality waters of Muddy Boggy and Clear Boggy Creeks and the Blue and Kiamichi Rivers in southeastern Oklahoma. The Blue River is low in mineralization and nutrification, while Muddy Boggy and Clear Boggy Creeks are turbid, soft water streams. The Kiamichi River is a high quality stream with low to moderate turbidity, soft water and low mineralization.

Figure 22 illustrates the chemical water quality in major reservoirs (existing or under construction), as well as the general quality range of the state's major rivers and tributary streams, in terms of the discharge-weighted average of concentrations of total dissolved solids. A discharge-weighted average represents the average concentration of dissolved solids in all flows of a stream over an extended period. Such averages provide a valid measure of the quality of the water which will be impounded in proposed and potential reservoirs. Data upon which Figure 22 is based were collected by the U.S. Geological Survey in cooperation with the Oklahoma Water Resources Board and other state and federal agencies. Water quality analyses data for selected USGS monitoring stations and locations of the stations are shown in Appendix B, Figure 4 and 5 , respectively.

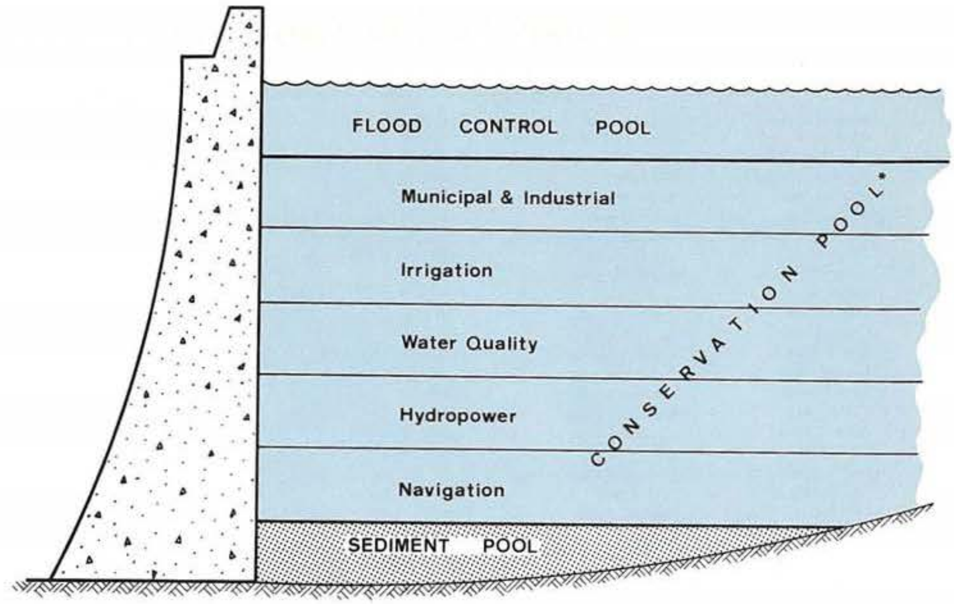


FIGURE 23 STORAGE SPACE IN A TYPICAL MULTIPURPOSE RESERVOIR

STREAM WATER DEVELOPMENT

Over the past three decades, Oklahoma has developed an impressive system of man-made lakes, developed through the efforts of the Corps of Engineers, Bureau of Reclamation, Soil Conservation Service, Grand River Dam Authority and several state agencies and cities. In the 1920's there were only three major lakes in Oklahoma. During the 1930's and 1940's, 12 more were completed, however, during the past 30 years, 25 major lakes have been completed, and four more are currently under construction. Construction is scheduled to begin on two additional lakes in 1980, and five others are authorized by Congress. The McClellan-Kerr Arkansas River Navigation System, the largest civil works project ever undertaken by the Corps of Engineers, was extended to north of Tulsa in the 1970's, opening the way for extensive commercial and industrial development along the entire waterway.

More stream water development has occurred in the eastern portion of the state than in the west, where the drier climate has afforded limited opportunities. In many areas of the state there are restrictions on further development due to the unavailability of water for appropriation and/or poor water quality.

Most major lakes in Oklahoma have been designated as multipurpose projects, allocating storage space for flood control and conservation purposes such as municipal and industrial water supply, irrigation water supply, water quality control, recreation, fish and wildlife propagation, navigation and hydropower uses. Figure 24 presents pertinent data on the major developed and authorized water resources development projects in Oklahoma.

Figure 23 illustrates in cross section the storage space in a typical multipurpose reservoir. Most large reservoirs contain space for sedimentation storage, which continually fills throughout the life of the project as silt from the stream is deposited in the lake, thereby reducing the lake's yield. Above the sedimentation storage lies conservation storage, and above that, storage for flood control.

Flood Control

Severe thunderstorms moving across the state each year cause flooding problems throughout Oklahoma. Since cities and towns and productive agricultural bottomland must be assured protection against flooding, most federal reservoirs include flood control as a major purpose. Federal agencies design a reservoir's flood control pool to accommodate the most severe potential flood, based upon the drainage area and historical data. The flood control pool is usually designed to contain the 50-year or 100-year flood of record and, in some cases, the 500-year flood. Oklahoma has almost 14 million acre-feet of flood control storage in major existing lakes and those under construction.

Municipal and Industrial

Municipal and industrial water supply storage in a federal reservoir is purchased by the water user through a repayment contract with the construction agency, i.e., the Soil Conservation Service, Corps of Engineers or Bureau of Reclamation. Such a contract entitles the user to withdraw water directly from the lake or divert water downstream after requesting a release. Municipal and industrial storage amounts to approximately 85 percent of the total water supply storage in Oklahoma's developed reservoirs.

Irrigation

In eastern Oklahoma irrigation water supply comes primarily from natural precipitation, however in western Oklahoma, average annual precipitation does not supply adequate water, so irrigation farmers supplement rainfall with water from ground water sources, by direct diversion from streams or with water from irrigation storage in reservoirs. Since irrigation is generally confined to the

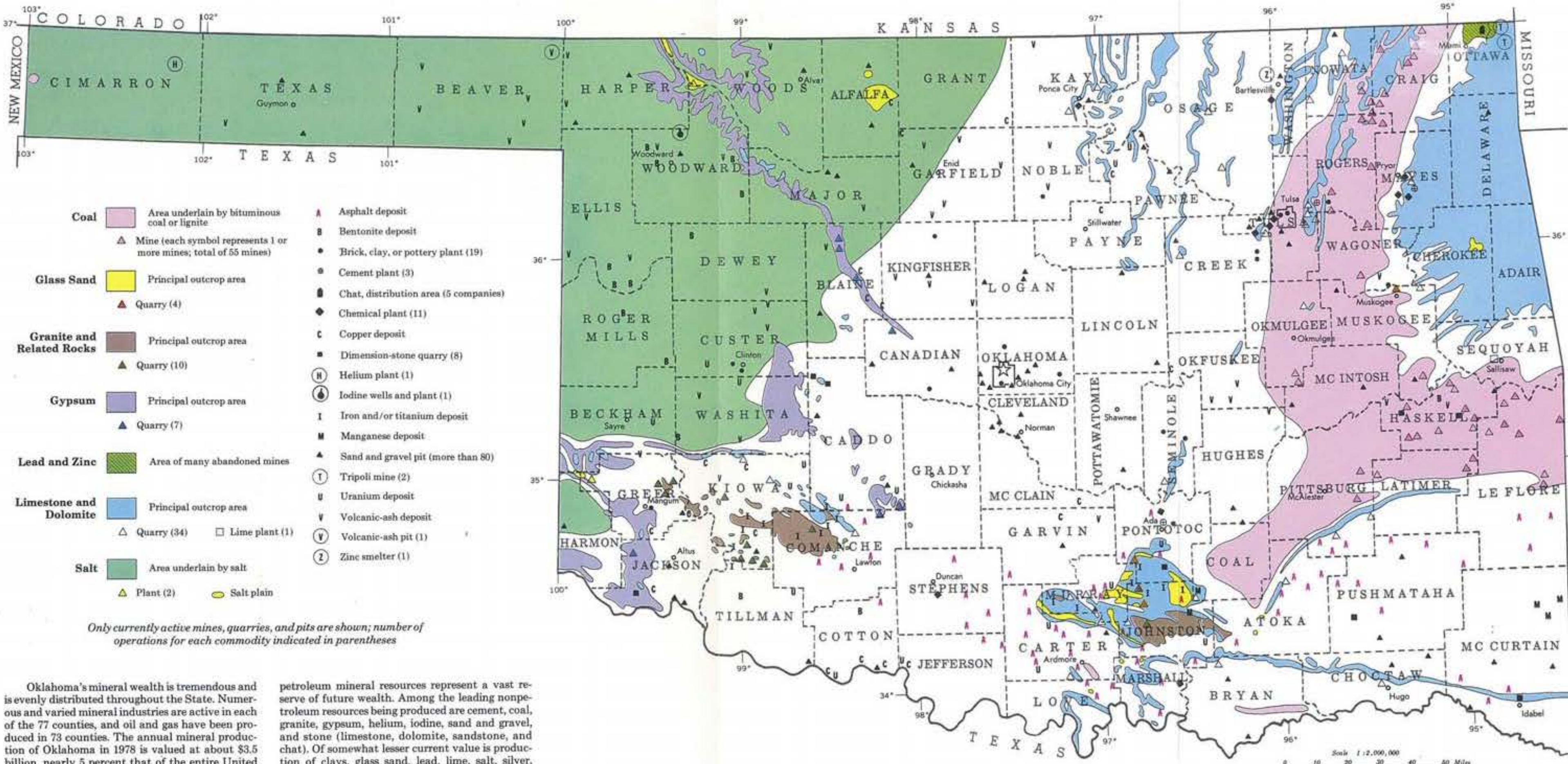
FIGURE 24 WATER RESOURCE DEVELOPMENT PROJECTS

NAME OF SOURCE	STREAM	PURPOSE*	FLOOD CONTROL STORAGE (AF)	WATER SUPPLY STORAGE (AF)	WATER SUPPLY YIELD (AF/YR)	CONSTRUCTION AGENCY□	DATE OF COMPLETION	
Altus Lake	North Fork of Red River	WS, FC, R, I	19,600	146,000	18,600	BR –	Dec	1948
Arbuckle Lake	Rock Creek	WS, FC, R, FW	36,400	62,600	22,700	BR –	Jan	1967
Arcadia Lake +	Deep Fork	WS, FC, R	70,700	27,380	12,100	COE	Oct	1984
Atoka Lake	North Boggy Creek	WS, R	0	123,500	65,000	City of Okla. City		1964
Birch Lake	Birch Creek	WS, FC, WQ, R, FW	39,000	15,200	6,700	COE	Mar	1977
Broken Bow Lake	Mountain Fork River	WS, FC, P, R, FW, WQ	450,000	152,500	196,000	COE	Apr	1970
Candy Lake +	Candy Creek	WS, FC, R, FW	31,260	43,100	8,620	COE	Jul	1982
Canton Lake	North Canadian River	WS, FC, I	267,800	107,000'	13,440	COE	Jul	1948
Lake Carl Blackwell	Stillwater Creek	WS, R	0	55,000	7,000	U.S. Dept. of Agric.		1948
Clayton Lake +	Jack Fork Creek	WS, FC, R, FW	128,200	297,200	156,800	COE	Oct	1981
Copan Lake +	Little Caney River	WS, FC, WQ, R, FW	184,300	33,600	21,300	COE	Oct	1981
Draper Lake	East Elm Creek	WS, R	0	100,000	86,000'	City of Okla. City		1962
Lake Ellsworth	East Cache Creek	WS, R	0	68,700	9,500	City of Lawton		1962
Eucha Lake	Spavinaw Creek	WS, R	0	79,600	84,000'	City of Tulsa		1952
Eufaula Lake	Canadian River	WS, FC, N, P	1,470,000	56,000	56,000	COE	Feb	1964
Fort Cobb Lake	Cobb Creek	WS, FC, R, I	63,330	78,350	13,300	BR –	Nov	1959
Fort Gibson Lake	Grand (Neosho) River	FC, P	919,200	0	0	COE	Sept	1953
Fort Supply Lake	Wolf Creek	WS, FC, R	86,800	400	220	COE	May	1942
Foss Lake	Washita River	WS, FC, R, I	180,400	203,700	18,000	BR –	Feb	1961
Grand Lake O'the Cherokees	Grand (Neosho) River	FC, P	525,000	0	0	GRDA –		1940
Great Salt Plains Lake	Salt Fork of Arkansas River	FC, R	240,000	0	0	COE	May	1941
Lake Hefner	Bluff Creek	WS, R	0	75,000	17,000	City of Okla. City		1943
Heyburn Lake	Polecat Creek	WS, FC, conservation	48,400	2,000	1,900	COE	Sept	1950
Hudson Lake	Butler Creek	FC, P	244,200	0	0	GRDA –		1964
Hugo Lake	Kiamichi River	WS, FC, WQ, R, FW	809,100	121,500	165,800	COE	Jan	1974
Hulah Lake	Caney River	WS, FC, low flow regulation	257,900	27,000	19,000	COE	Sept	1951
Kaw Lake	Arkansas River	WS, FC, WQ, R, FW	866,000	203,000	230,700	COE	May	1976
Keystone Lake	Arkansas River	WS, FC, P, FW	1,218,500	20,000	22,400	COE	Sept	1964
Lake Lawtonka	Cache Creek	WS, R	0	64,000	8,500	City of Lawton		1905
McAlester Lakes	Coal Creek	WS, FC, R	25,000	24,300	10,500	City of McAlester		1923
McGee Creek Lake +	McGee Creek	WS, FC, R	85,000	109,800	71,800	BR –	Oct	1985
Lake McMurtry	North Stillwater Creek	WS, FC, R	5,000	13,500	3,000	City of Stillwater		1971
Lake Murray	Tributary of Hickory Creek	R	0	0	0	State of Oklahoma		1937
Oologah Lake	Verdigris River	WS, FC, N	965,600	342,600	172,500	COE		1974
Optima Lake	North Canadian River	WS, FC, R, FW	71,800	76,200	5,400	COE	Sept	1978
Lake Overholser	North Canadian River	WS, R	0	17,000	5,000	City of Okla. City		1919
Pine Creek Lake	Little River	WS, FC, WQ, FW	388,100	70,500	134,400	COE	Jun	1969
Lake Ponca	Big and Little Turkey Creeks	WS, R	0	15,300	9,000	City of Ponca City		1935
Robert S. Kerr Lake	Main Stem Arkansas River	N, P, R	0	0	0	COE	Oct	1970
Shawnee Lakes	South Deer Creek	WS, R	0	34,000	4,400	City of Shawnee		1935
Skiatook Lake +	Hominy Creek	WS, FC, WQ, R, FW	182,300	304,800	85,100	COE	Oct	1982
Sooner Lake	Greasy Creek	P, FC, R	47,500	149,000	3,600	Okla. Gas & Elect.	Jul	1976
Spavinaw Lake	Spavinaw Creek	WS, R	0	30,600	–'	City of Tulsa		1924
Tenkiller Lake	Illinois River	FC, P, WS, R	576,700	25,400	17,900	COE	Jul	1953
Lake Texoma	Red River	WS, FC, P	2,669,000	22,100	23,700	COE	Jan	1944
Lake Thunderbird	Little River	WS, FC, R	76,600	105,900	21,700	BR –	Mar	1965
Tom Steed Lake	Otter Creek	WS, FC, R	19,500	88,160	16,000	BR –		1977
Waurika Lake	Beaver Creek	WS, FC, WQ, R, FW, I	131,900	170,200	44,800	COE	Aug	1977
Webbers Falls Lock & Dam	Arkansas River	N, P, R, FW	0	0	0	COE	Dec	1970
Wister Lake	Poteau River	WS, FC, R, FW	400,000	9,600	6,700	COE	Oct	1949
SUBTOTAL			13,801,090	3,771,290	1,894,280			

AUTHORIZED

				CONSERVATION STORAGE		
Boswell Lake	Boggy Creek	WS, FC, R, FW	1,096,000	1,243,800	621,400	COE
Lukfata Lake	Glover Creek	WS, FC, R, FW	208,600	37,500	59,400	COE
Sand Lake	Sand Creek	WS, FC, WQ, R, FW	51,700	35,000	13,450	COE
Shidler Lake	Salt Creek	WS, FC, R, FW	49,050	54,900	16,800	COE
Tuskahoma Lake	Kiamichi River	WS, FC, R, FW	138,600	231,000	223,900	COE
SUBTOTAL			1,543,950	1,602,200	934,950	
TOTAL			15,345,040		2,829,230	

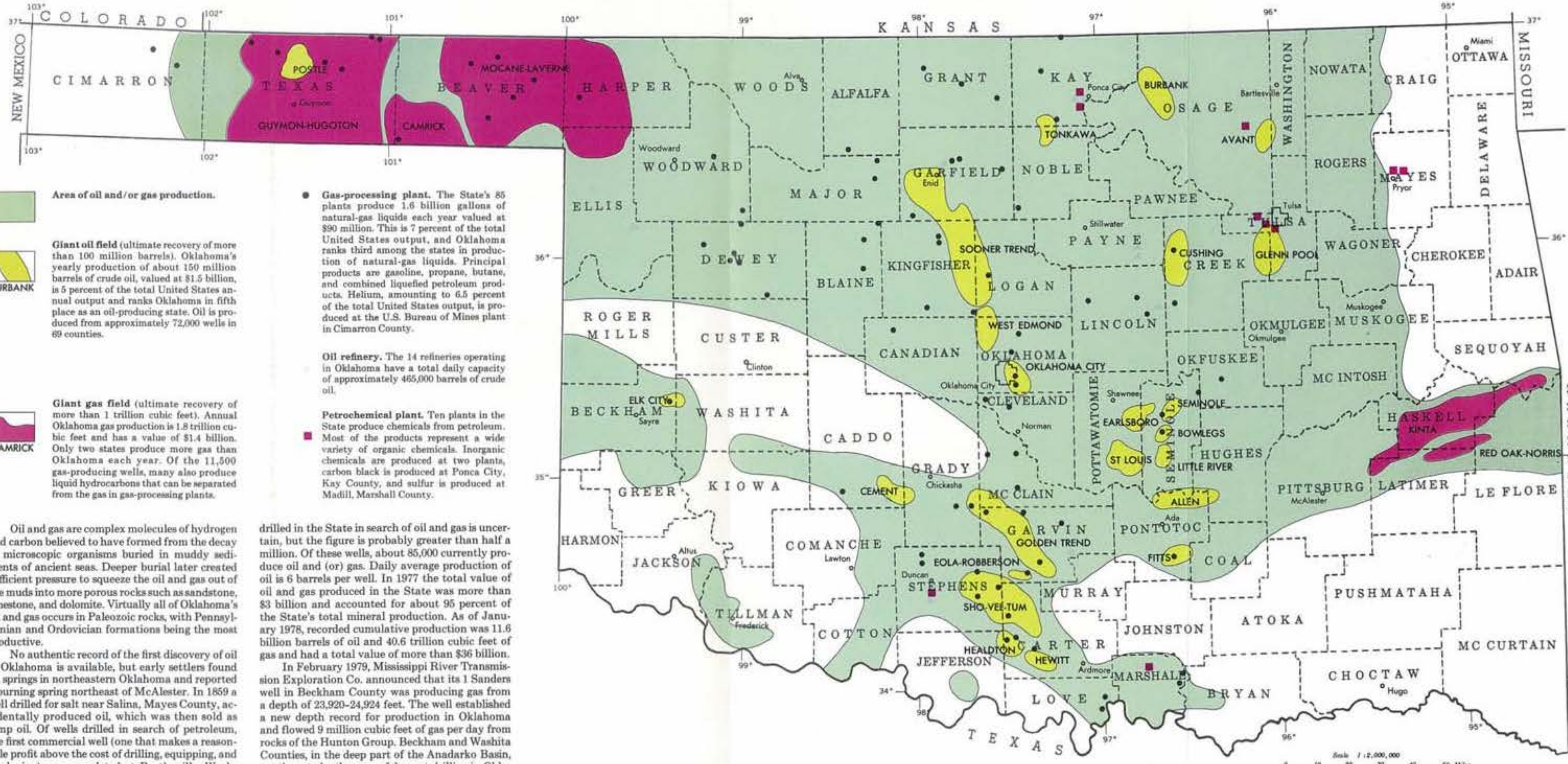
* WS-Municipal Water Supply, FC-Flood Control, WQ-Water Quality, P-Power, R-Recreation, FW-Fish and Wildlife, I-Irrigation, N-Navigation
+ Under Construction
□ BR-Bureau of Reclamation, COE-Corps of Engineers, GRDA-Grand River Dam Authority
– Lake Stanley Draper is a terminal storage reservoir for the existing pipeline from Atoka Lake and McGee Creek Lake (under construction). The 86,000 acre-feet per year yield shown is the capacity of the Atoka Pipeline (90 mgd) minus evaporation losses from Draper Lake. The 86,000 acre-feet per year yield is not included in the total.
± Combined yield of both lakes
÷ Includes irrigation storage



Only currently active mines, quarries, and pits are shown; number of operations for each commodity indicated in parentheses

Oklahoma's mineral wealth is tremendous and is evenly distributed throughout the State. Numerous and varied mineral industries are active in each of the 77 counties, and oil and gas have been produced in 73 counties. The annual mineral production of Oklahoma in 1978 is valued at about $3.5 billion, nearly 5 percent that of the entire United States, and the State is the fourth leading mineral producer in the nation. Total production since statehood (1907) is valued in excess of $47 billion. Oklahoma is well known as an oil state, and petroleum (including crude oil, natural gas, and natural-gas liquids) accounts for about 94 percent of the State's yearly mineral output. However, nonpetroleum mineral resources represent a vast reserve of future wealth. Among the leading nonpetroleum resources being produced are cement, coal, granite, gypsum, helium, iodine, sand and gravel, and stone (limestone, dolomite, sandstone, and chat). Of somewhat lesser current value is production of clays, glass sand, lead, lime, salt, silver, tripoli, volcanic ash, and zinc. Untapped resources include iron, manganese, titanium, and uranium. Oklahoma ranks first among the states in production of iodine, second in helium and tripoli, third in liquefied petroleum gas and natural gas, and fifth in crude oil and gypsum.

FIGURE 19 MINERAL RESOURCES



■ **Area of oil and/or gas production.**

BURBANK

Giant oil field (ultimate recovery of more than 100 million barrels). Oklahoma's yearly production of about 150 million barrels of crude oil, valued at $1.5 billion, is 5 percent of the total United States annual output and ranks Oklahoma in fifth place as an oil-producing state. Oil is produced from approximately 72,000 wells in 69 counties.

CAMRICK

Giant gas field (ultimate recovery of more than 1 trillion cubic feet). Annual Oklahoma gas production is 1.8 trillion cubic feet and has a value of $1.4 billion. Only two states produce more gas than Oklahoma each year. Of the 11,500 gas-producing wells, many also produce liquid hydrocarbons that can be separated from the gas in gas-processing plants.

● **Gas-processing plant.** The State's 85 plants produce 1.6 billion gallons of natural-gas liquids each year valued at $90 million. This is 7 percent of the total United States output, and Oklahoma ranks third among the states in production of natural-gas liquids. Principal products are gasoline, propane, butane, and combined liquefied petroleum products. Helium, amounting to 6.5 percent of the total United States output, is produced at the U.S. Bureau of Mines plant in Cimarron County.

Oil refinery. The 14 refineries operating in Oklahoma have a total daily capacity of approximately 465,000 barrels of crude oil.

■ **Petrochemical plant.** Ten plants in the State produce chemicals from petroleum. Most of the products represent a wide variety of organic chemicals. Inorganic chemicals are produced at two plants, carbon black is produced at Ponca City, Kay County, and sulfur is produced at Madill, Marshall County.

Oil and gas are complex molecules of hydrogen and carbon believed to have formed from the decay of microscopic organisms buried in muddy sediments of ancient seas. Deeper burial later created sufficient pressure to squeeze the oil and gas out of the muds into more porous rocks such as sandstone, limestone, and dolomite. Virtually all of Oklahoma's oil and gas occurs in Paleozoic rocks, with Pennsylvanian and Ordovician formations being the most productive.

No authentic record of the first discovery of oil in Oklahoma is available, but early settlers found oil springs in northeastern Oklahoma and reported a burning spring northeast of McAlester. In 1859 a well drilled for salt near Salina, Mayes County, accidentally produced oil, which was then sold as lamp oil. Of wells drilled in search of petroleum, the first commercial well (one that makes a reasonable profit above the cost of drilling, equipping, and producing) was completed at Bartlesville, Washington County, in about 1896. The earliest recorded production of oil in Oklahoma was 30 barrels in the year 1901.

Detailed data are available on oil and gas exploration in Oklahoma since 1933, but unfortunately records on the number of wells drilled during the boom years prior to that time are incomplete. Therefore, the total number of wells drilled in the State in search of oil and gas is uncertain, but the figure is probably greater than half a million. Of these wells, about 85,000 currently produce oil and (or) gas. Daily average production of oil is 6 barrels per well. In 1977 the total value of oil and gas produced in the State was more than $3 billion and accounted for about 95 percent of the State's total mineral production. As of January 1978, recorded cumulative production was 11.6 billion barrels of oil and 40.6 trillion cubic feet of gas and had a total value of more than $36 billion.

In February 1979, Mississippi River Transmission Exploration Co. announced that its 1 Sanders well in Beckham County was producing gas from a depth of 23,920–24,924 feet. The well established a new depth record for production in Oklahoma and flowed 9 million cubic feet of gas per day from rocks of the Hunton Group. Beckham and Washita Counties, in the deep part of the Anadarko Basin, continue to be the area of deepest drilling in Oklahoma, and other wells will probably be productive at depths greater than the current State record of 24,924 feet. Beckham County is also the location of the world's deepest borehole. In 1974 the Lone Star 1 Rogers was drilled to a total depth of 31,441 feet and thus claimed the depth record from a Washita County well, the Lone Star 1 Baden, which had been drilled to a total depth of 30,050 feet in 1972.

FIGURE 18 GENERALIZED OIL & GAS RESOURCES

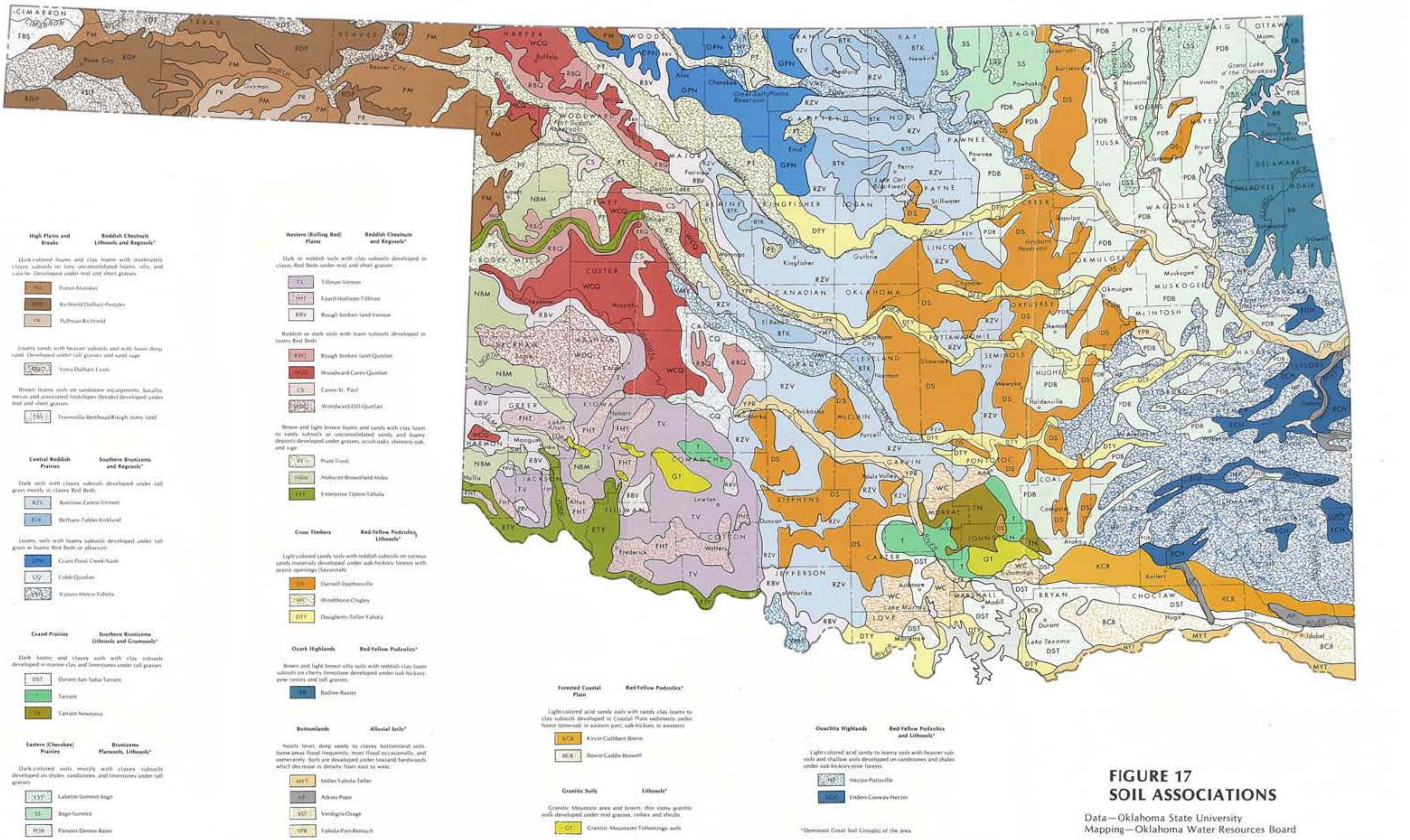


FIGURE 17
SOIL ASSOCIATIONS

Data—Oklahoma State University
Mapping—Oklahoma Water Resources Board

dry summer months, irrigation water supply is not required on as constant a basis as municipal and industrial waters. Fifteen percent of the state's total water supply storage in developed reservoirs is allocated for irrigation purposes, and is contracted for in the same manner as municipal and industrial storage. Traditionally, only the Bureau of Reclamation and the Soil Conservation Service have constructed reservoirs providing irrigation storage, however Canton and Waurika Lakes, constructed by the Corps of Engineers, contain some irrigation storage.

Water Quality Control

Water quality has become a concern of increasing importance to state and federal water authorities. In past years, Congress has recognized benefits derived from controlling water quality problems. As a result, if it is determined that downstream water quality would benefit from periodic reservoir releases, a reservoir may include water quality as an authorized purpose. Eight major Oklahoma reservoirs built or under construction are authorized for water quality purposes. Because pollutants have been reduced significantly by more stringent pollution control laws, not all the present water quality control storage is needed or utilized. The Oklahoma Water Resources Board has issued water rights for municipal and industrial use on a portion of the water quality control storage in these lakes, contingent upon Congress authorizing the conversion of the water quality control storage to water supply storage. Numerous reallocation studies by the Corps of Engineers are presently underway to determine if such reallocation is justified.

Recreation

Recreation as an authorized project purpose attracts visitors for boating, skiing and fishing. Since recreation is considered incidental to water supply, storage for recreational water is normally not contracted for. Fluctuations in lake levels resulting from regular reservoir operations can adversely affect recreational opportunities. However, since there is no contract to maintain levels for recreational purposes, no guarantee of recreational privileges can be provided. If it were determined worthwhile to maintain lake levels for these purposes, the beneficiaries would have to pay for that storage allocation.

Fish and Wildlife

Fish and wildlife are dependent on the quality of the environment, and many species are sensitive to the changes caused by development of water and related land resources. Although water is essential to the survival of fish and wildlife, the quantity and quality required by different species vary enormously. Reservoirs are authorized for fish and wildlife purposes in order to preserve and enhance an area's environmental resources, and are usually achieved through periodic releases to maintain minimum downstream flows. However, in some streams, particularly those of western Oklahoma, base flows are frequently zero, making minimum flows an unattainable goal. In any case, consideration of fish and wildlife resources is appropriate in the operation of all reservoirs.

Navigation

Completion of the McClellan-Kerr Arkansas River Navigation System by the Corps of Engineers in 1970 brought vigorous industrial growth along the channel, spurring economic activity in surrounding areas and increasing the commerce opportunities for all of Oklahoma.

The 448-mile navigation channel extends from near the mouth of the Arkansas River to the Port of Catoosa northeast of Tulsa. The system is composed of a series of 17 locks and dams, including five in Oklahoma. See Figure 25. The channel's 9-foot depth is maintained by periodic dredging. Major commodities transported on the system include bauxite, iron and steel, chemicals and chemical fertilizers, petroleum products, coal, sand and gravel, crushed stone, soybeans, wheat and other grains. Total tonnage has increased each year, achieving a record of approximately 10.2 million tons in 1978.

Only one reservoir in Oklahoma, Oologah Lake on the Verdigris River, contains navigation storage for release when necessary to maintain channel flows. However, hydroelectric power storage in several other reservoirs on the Arkansas River serves the additional purpose of providing navigation flow requirements.

Hydroelectric Power

There are 11 existing hydroelectric projects in Oklahoma with a total power storage of 5,103,600 acre-feet of water. Operation of a reservoir's power pool causes dramatic fluctuations in lake levels because of the great quantities of water that must pass through the generating turbines at one time. The power produced is marketed by the Grand River Dam Authority and/or the Southwest Power Administration. Figure 27 provides significant information on the existing hydroelectric projects in Oklahoma.

Soil Conservation Service

Upstream Watershed Program

As part of its upstream watershed program, the Soil Conservation Service has constructed thousands of flood control structures throughout the state, funded under four different Congressional authorizations.

The first watershed program was authorized in 1944 for the protection of 11 watersheds in the United States, including the Washita River in Oklahoma and Texas. A similar program initiated in 1953 provided for the installation of works on 60 pilot watersheds, among them Double Creek in Oklahoma. The Watershed Protection and Flood Control Act of 1954, along with its amendments, provides federal assistance in the installation of works of improvement on watersheds no larger than 250,000 acres, a maximum of 12,500 acre-feet of flood storage, and a total capacity for all purposes not to exceed 25,000 acre-feet in any one structure.

FIGURE 27 EXISTING HYDROELECTRIC PROJECTS

PROJECT	STREAM	POWER STORAGE AF	INSTALLED CAPACITY in Okla.	AVERAGE ANNUAL GENERATION in Okla.	WATER USE (AF/YR)
Pensacola (Grand Lake)	Grand (Neosho)	544,200	86.4	311,000	3,507,000
Markham Ferry	Grand (Neosho)	200,300	108.0	190,000	4,544,000
Salina[1]	Chimney Rock Hollow	11,700	260.0	540,000	N/A
Keystone	Arkansas	310,500	70.0	228,000	3,134,000
Ft. Gibson	Grand (Neosho)	53,700	45.0	190,500	3,738,000
Webbers Falls	Arkansas	30,000	60.0	213,300	1,332,000
Robert S. Kerr	Arkansas	79,500	110.0	459,000	13,009,000
Tenkiller Ferry	Illinois	345,600	34.0	95,100	880,000
Eufaula	Canadian	1,481,000	90.0	260,300	3,735,000
Broken Bow	Mountain Fork	317,100	100.0	44,500	841,000
Denison	Red	1,730,000	70.0[2]	244,000	2,953,000
TOTAL		5,103,600	1,033.4	2,775,700	37,673,000

[1]Pump-back project designed to receive water during off-peak period then generate during peak periods.

[2]35,000 KW used in Oklahoma—35,000 KW used in Texas.

N/A — Not available

The fourth watershed progam, authorized by the Food and Agriculture Act of 1962, empowers the Secretary of Agriculture to provide technical assistance to sponsors of Resource Conservation and Development Projects. Financial assistance is provided under the Soil Conservation Act. Recent legislation has awarded the Secretary authority to include recreation and wildlife improvements in Resource Conservation and Development Projects providing for the conservation, development and use of water and related land resources through a small watershed approach.

As shown in Figure 26 , 125 watersheds covering 11,556,300 acres are presently under development in the state, with 55 percent of this area protected by existing structures. Of the 2,558 structures planned, 1,908 are complete or under construction. Combined storage capacity in lakes existing or planned is approximately three million acre-feet. As of November 1979, the Soil Conservation Service has received applications for additional watersheds bringing the total to approximately 17 million acres.

In recent years increased emphasis has been placed on the development of multipurpose lakes constructed for floodwater detention. In addition to widespread recreational use of sediment pools of watershed structures, many local sponsors have added storage for municipal, irrigation, recreation and fish and wildlife purposes.

Multipurpose lakes foster economic growth in cities, towns and rural areas by providing dependable water supplies and recreational areas attractive to tourists and residents. Landowners in the watersheds, now secure against flood threats, have developed and intensified their farming and ranching operations, and also are utilizing these sites as sources of irrigation water.

Multipurpose lakes with municipal water supply storage capacities of 160,000 acre-feet are presently being utilized by cities and towns in Oklahoma. Structures with a water supply storage capacity of 50,000 acre-feet remain in planning stages. Multipurpose sites which have been identified for potential use as municipal water supply sources are shown in Figure 26 .

Ground Water

Ground water, one of Oklahoma's most valuable resources, is available in almost every part of the state. Ground water is water that has percolated downward from the surface, filling voids or open spaces in rocks. Below a certain level, the voids are completely saturated with water. This is called the zone of saturation.

A rock formation or group of formations that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs is termed a ground water basin. The amount of water available to wells depends on the saturated thickness, areal extent and specific yield. The amount of water that can be pumped perennially without depletion of the ground water in storage depends on the amount of recharge from precipitation.

Ground water in Oklahoma is found in a variety of rock formations. Sand, gravel, limestone, dolomite, sandstone and gypsum are the major water-bearing formations. These range in age from Cambrian and Ordovician, represented by the Arbuckle Group, to Quaternary stream-laid deposits.

Twelve major ground water basins occur in Oklahoma with an estimated 320 million acre-feet of fresh water in storage, half of which is estimated to be recoverable. Less significant amounts are available in at least 150 minor basins. See Figure 28 . Ground water supplies 61 percent of the total water reported used in Oklahoma, providing for over 80 percent of the state's irrigation and meeting the municipal needs of approximately 300 towns and cities.

Due to the lack of available stream water, ground water development is greatest in the western part of the state, where it is extensively used for irrigation, municipal and industrial purposes. Development is not as widespread in central and eastern Oklahoma, although great potential exists for further use if supplies remain unpolluted.

MAJOR GROUND WATER BASINS

Alluvium and terrace deposits (Quaternary) consist of unconsolidated clay, silt, sand and gravel which interfinger and were deposited by streams in an irregular pattern. The alluvium underlies the bottomlands along the stream, while the terrace deposits are topographically higher and usually adjacent to the alluvium.

Thickness of the deposits ranges from 40 feet in southwestern Oklahoma to a maximum of 170 feet along the Cimarron River. In some deposits, the maximum saturated thickness is greater than 100 feet, but the average is 25 to 30 feet. Well yields commonly average 100 to 300 gallons per minute (gpm), but can be as high as 1,000 gallons per minute. Water quality is generally affected by nearby streams flowing along the deposits. Some quality problems are hardness and high sulfate and chloride concentrations. Where water quality is good, the water is used for domestic, irrigation, industrial and municipal supplies.

Ogallala Formation (Tertiary) consists of interbedded sand, siltstone, clay, lenses of gravel, thin limestone and caliche. The Ogallala covers an area of about 10,000 square miles, including all of Beaver, Texas and Cimarron Counties and parts of Harper, Woods, Ellis, Woodward, Roger Mills, Beckham and Dewey Counties. Total thickness ranges from zero to more than 700 feet, due to the irregular surface on which the Ogallala was deposited. Average thickness in the Panhandle is 300 feet.

The Ogallala is the major source of water in the Oklahoma Panhandle with over 2,000 irrigation wells drilled in the area. Most of the wells yield from 500 to 1,000 gallons per minute, averaging approximately 700 gallons per minute. The water is generally of a calcium magnesium bicarbonate type, containing between 200 and 500 mg/L of dissolved solids and, although hard, it is suitable for most uses.

In the southwest, the Ogallala is partly eroded and it also thins toward the east. In these areas yields can be as high as 800 gallons per minute, but due to thinning and erosion of the ground water basin, they are usually about 200 gallons per minute. Water quality is good with low dissolved solids content and, except for hardness, the water is suitable for most uses.

Ground water in the Ogallala is being used at a rate greatly exceeding that of recharge. As the water table is lowered by pumping and the saturated thickness is reduced, the yields of the wells decline. Depletion of the aquifer is expected to exert serious economic pressures on the area in the future.

Antlers Sand (Cretaceous) is part of the larger coastal plain deposits that crop out in a 10-mile wide belt in parts of Atoka, Bryan, Choctaw, Johnston, McCurtain and Pushmataha Counties. The unit is a fine-grained sand interbedded with clay, unconsolidated and friable.

FIGURE 29 TOTAL GROUND WATER ESTIMATED RECOVERABLE FROM STORAGE

GROUND WATER BASIN	WATER IN STORAGE (1000 AF)	ESTIMATED[1] RECOVERABLE (PERCENT)	ESTIMATED[2] TOTAL AVAILABLE WATER (1000 AF)
Alluvium and terrace deposits	18,400	60	11,000
Ogallala Formation	76,000	60	46,000
Antlers Sand	70,000	40	28,000
Elk City Sandstone	1,400	40	1,000
Rush Springs Sandstone	31,200	50	16,000
Dog Creek Shale and Blaine Gypsum	600	50	300
Garber-Wellington Formation	52,000	50	26,000
Oscar Formation	8,900	40	4,000
Vamoosa Formation	36,000	40	14,000
Simpson Group	3,300	40	1,000
Arbuckle Group	15,000	50	8,000
Roubidoux	7,200	40	3,000
STATEWIDE TOTAL	320,000		159,000

[1]Based on quality, economic, legal and technological constraints.

[2]Will not equate because of rounding off.

The Antlers Sand ranges in thickness from 180 feet in the west to more than 880 feet in the southeast. Water occurs under water table conditions, with well yields ranging from five to 50 gallons per minute for water table wells to 50 to 650 gallons per minute for artesian wells. An average yield for wells completed in the ground water basin is 100 to 150 gallons per minute.

The quality of the water is good in the outcrop areas, suitable for industrial, municipal and irrigation use. Downdip from the outcrop the quality of the water deteriorates. Dissolved solids range from 130 to 1,240 mg/L, hardness from 8 to 850 mg/L, sodium from 1 to 350 mg/L and bicarbonate from 10 to 580 mg/L.

Due to the availability of surface water in the area, water from the Antlers Sand is not being utilized extensively at the present time.

Rush Springs Sandstone (Permian) is an extensive ground water basin outcropping over approximately 1,900 square miles in Caddo, Custer, Washita and small parts of Comanche, Dewey and Grady Counties. It is a fine-grained, crossbedded sandstone, containing irregular silty lenses. Thickness ranges from less than 200 feet in the south to about 330 feet in the northern part of the region. Depth below land surface to water ranges from zero to 150 feet. Wells yield as much as 1,000 gallons per minute and average about 400 gallons per minute. Most of the water is suitable for domestic, municipal, irrigation and industrial use.

Dissolved solids concentration in 39 samples ranged from 179 to 2270 mg/L, with the median concentration at 296 mg/L. Seventy-five percent of the wells sampled showed less than 450 mg/L dissolved solids, which is within the recommended (500 mg/L) level for drinking water. Median hardness is 179 mg/L.

Elk City Sandstone (Permian) occurs in western Washita and eastern Beckham Counties. It is similar to the Rush Springs ground water basin in being a fine-grained sandstone with little or no shale; however, it is of smaller areal extent and considerably thinner. Well yields range from 60 to 200 gallons per minute with water suitable in quality for most purposes.

Dog Creek Shale and Blaine Gypsum (Permian) occur in Harmon and parts of Jackson, Greer and Beckham Counties. The ground water basin consists of interbedded shale, gypsum, anhydrite, dolomite and limestone, which are characterized in places by solution channels and zones of secondary porosity. The yields from wells tapping the Dog Creek Shale and Blaine Gypsum range from less than 10 to as much as 2,000 gallons per minute. For a well to yield enough water for irrigation, it must tap a water-filled solution cavity.

Water levels in the ground water basin respond rapidly to infiltration of precipitation and also to the effects of pumping. Due to the erratic nature of solution channels and cavities, it is difficult to predict yields or estimate amounts in storage. Water quality is poor because of hardess and very high calcium sulfateconcentrations.Locally, in southeastern and northwestern Harmon County, the water has a high sodium chloride content. The water, although suitable for irrigation, is not drinkable.

Garber-Wellington Formation (Permian) consists of two formations: the Garber Sandstone and the Wellington Formation. The two units were deposited under similar conditions, both containing lenticular beds of sandstone alternating with shale, and are considered a single water-bearing unit.

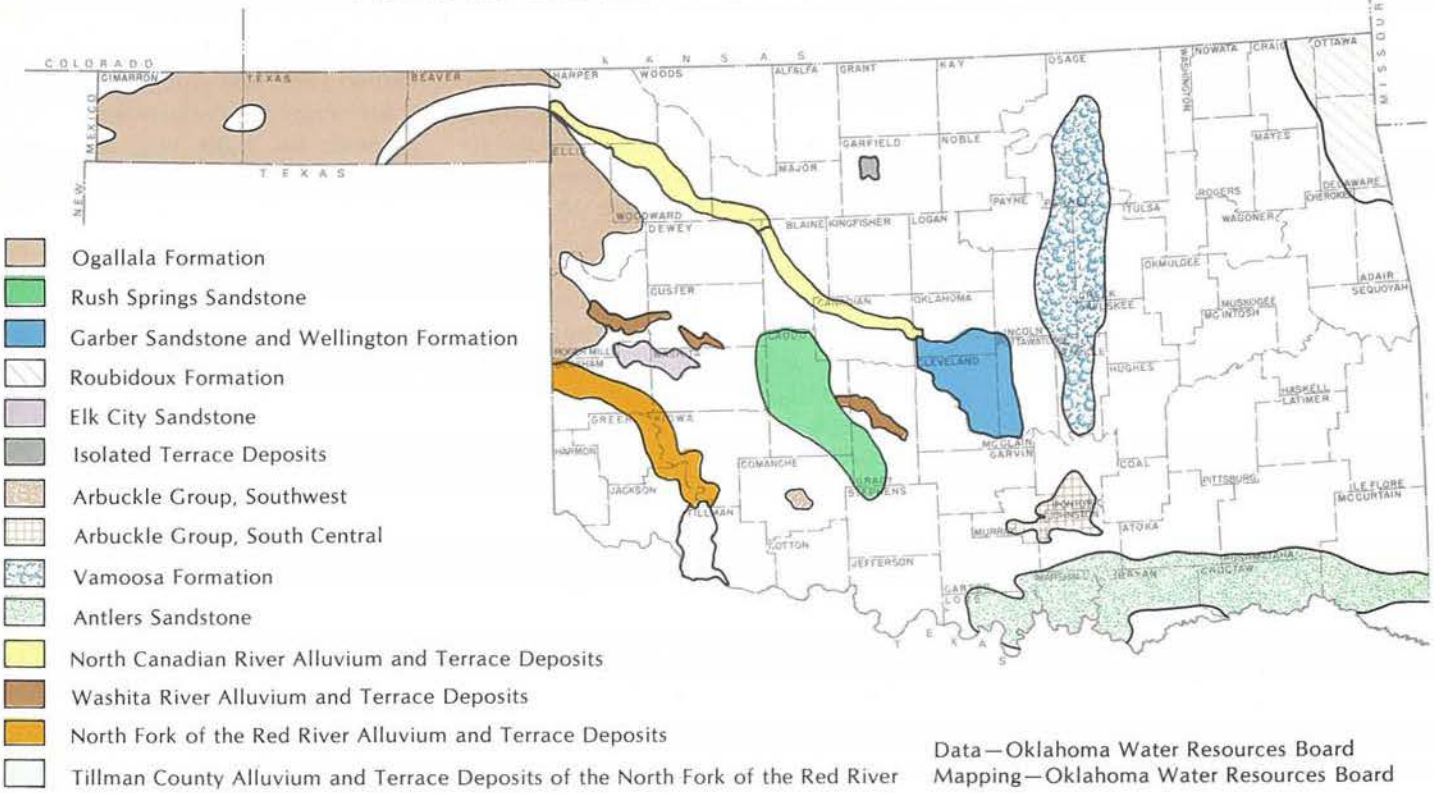
The total thickness of the combined formations is 800 to 1,000 feet. Depth to water varies from 100 feet or less in areas of outcrop to 350 feet in structural depressions such as that at Midwest City. Well yields range from 150 to 450 gallons per minute and average 250 gallons per minute. In Logan County, the formation is shaly with wells exhibiting yields of 10 gallons per minute or less near Guthrie. Natural recharge to the basin over the entire outcrop area is estimated at 130,000 acre-feet annually. Presently, the rate of natural recharge exceeds total discharge from the basin, as evidenced by static annual water levels. Pumpage cannot be estimated at this time, due to insufficient data, but will be determined following prior rights hearings.

The Garber-Wellington yields large amounts of good quality water for municipal, irrigation and industrial uses and exhibits potential for additional development to help meet central Oklahoma's future water needs.

Oscar Formation (Pennsylvanian) consists of interbedded shale, sandstone and limestone conglomerate with lithology varying from place to place. The formation is 300 to 400 feet thick and occurs in western Stephens, southwestern Garvin, southwestern Carter and eastern Jefferson Counties. Depth to water is generally 100 feet below the surface, and well yields range from 60 gallons per minute to as much as 400 gallons per minute, with 150 to 180 gallons per minute the common reported yield. Water quality is considered suitable for most purposes. The ground water basin is of major importance locally, but its potential over a broad area is unknown, due to lack of information and sparse well development.

Vamoosa Formation (Upper Pennsylvanian) is composed of 125 to 1,000 feet of interbedded sandstone, shale and conglomerate with proportions of shale increasing northward. The Vamoosa outcrops in Seminole, Okfuskee, Pottawatomie, Osage, Creek, Pawnee, Payne and Lincoln Counties and supplies water for municipal uses and secondary oil recovery operations. The most productive wells are in the Seminole area, where wells produce up to 500 gallons per minute. Yields decline northward, decreasing from 250 gallons per minute to 10 to 20 gallons per minute. Although water quality is generally good, brine infiltration and hardness present problems. Studies

FIGURE 30 GROUND WATER BASIN STUDIES



Data—Oklahoma Water Resources Board
Mapping—Oklahoma Water Resources Board

show the Vamoosa exhibits the potential for supplying large quantities of water to help meet the area's future water requirements if properly developed and managed.

Simpson Group (Ordovician) consists of fine-grained, loosely cemented and friable sandstones. The ground water basin crops out in an area of about 40 square miles in southwestern Murray and northeastern Carter Counties with wells commonly yielding 100 to 200 gallons per minute. Water from the sandstones is of poor quality at Sulphur, but elsewhere in the region, it is usually drinkable.

Arbuckle Group (Cambrian-Ordovician), underlying parts of Murray, Pontotoc, Johnston and Comanche Counties, is limestone and dolomite, 5,000 to 6,000 feet thick. Relatively high permeability results from fractures, joints and solution channels in the limestone. This ground water basin produces large quantities of water, with wells in the area commonly yielding 200 to 500 gallons per minute. Although the water may be hard, total dissolved solids are generally low and the quality is good, except for some areas in Comanche County, where high fluoride levels have been recorded. Well development in this aquifer is sparse at the present time.

Roubidoux (Upper Cambrian-Lower Ordovician) consists mainly of sandy and cherty dolomite. The Roubidoux basin in this discussion includes the Roubidoux, Gasconade and Eminence-Potosi Formations, of which the Roubidoux Formation is the principal water-bearing unit. The Roubidoux does not outcrop on the surface, but is deeply buried beneath Ottawa and Delaware Counties and small parts of Craig and Adair Counties at depths of 450 to 1,700 feet. The artesian or confined water is under sufficient pressure to cause it to rise above the surface. With pumpage over a long period, the artesian head has declined, and presently the water is some wells is being lifted more than 500 feet to the surface. Yields are as much as 1,000 gallons per minute, but average 200 gallons per minute. Although the water is hard, it has a low total mineral content. In Ottawa County the water quality is suitable for most purposes and is characterized as a calcium bicarbonate type, but it changes to a sodium chloride type farther west, and thus becomes unusable.

GROUND WATER BASIN STUDIES

In order to fulfill the requirements of the Oklahoma Ground Water Law (1972), the Board must determine the maximum annual yield of ground water in each ground water basin or subbasin through the establishment of prior rights and completion of hydrologic surveys of the major basins and subbasins. (See Chapter II, "Oklahoma Water Law and its Adminstration.")

The determination of maximum annual yield is based on the total land overlying the basin or subbasin, amount of fresh ground water available for use, rates of recharge and discharge, and the possibility of natural pollution. The maximum annual yield is based upon a minimum basin life of 20 years from July 1, 1973, the effective date of the Ground Water Act.

Equal proportionate shares are allotted to overlying land owners according to the amount of ground water determined available by estimate of the maximum annual yield, assuming a basin life of 20 years. Any individual permitted to use ground water prior to July 1, 1973 is given the opportunity to establish a prior right.

The Oklahoma Water Resources Board, in cooperation with the U.S. Geological Survey, Oklahoma Geological Survey, Oklahoma State University and the U.S. Department of Agriculture (Agricultural Research Service), has completed or is currently participating in studies of the ground water basins shown in Figure 30 .

Ogallala Formation, a cooperative study by the Oklahoma Water Resources Board and U.S. Geological Survey, produced a hydrologic atlas and data on geohydrology and subsurface geology, as well as determination of maximum annual yield, equal proportionate share and prior rights for the Panhandle counties underlain by the aquifer. Board approval of maximum annual yield and equal proportionate shares in this area is scheduled for 1980.

The Board also cooperates with the U.S. Geological Survey in the Regional Aquifer Study Analysis (RASA) to gather data for a 5-year computer model study on the entire Ogallala area in northwestern Oklahoma which has an expected completion date in 1984.

North Fork of the Red River alluvium and terrace deposits, a joint project of the Oklahoma Water Resources Board, Oklahoma State University and the Agricultural Research Service, accomplished hydrologic and computer model studies and determinations of maximum annual yield, equal proportionate share and prior rights for that portion of the aquifer in Tillman County which were approved by the Board in 1978. A computer model study to determine maximum annual yield and equal proportionate share has been completed and prior rights determined for alluvium and terrace deposits in the remaining area in Kiowa, Jackson, Greer and Beckham Counties. Approval of maximum annual yield and equal proportionate share in these areas is planned for 1980.

Rush Springs Sandstone, a project of the Oklahoma Water Resources Board, produced a hydrologic atlas. Determinations of prior rights, maximum annual yield and equal proportionate share are scheduled for 1980.

Garber Sandstone and Wellington Formation. The Oklahoma Water Resources Board completed a hydrologic atlas on the southern half in 1979 to complement studies on the northern portion of the aquifer completed by the U. S. Geological Survey and the Bureau of Reclamation in 1977. Prior rights determinations are planned for 1980.

Washita River alluvium and terrace deposits (from the Texas line in Roger Mills County to Alex, Oklahoma in Grady County). A computer model study by Oklahoma State University in cooperation with the Oklahoma Water Resources Board begun in 1979, with an expected completion date in 1981, will determine maximum annual yield and equal proportionate share. Determination of prior rights is planned for 1980, with approval of maximum annual yield and equal proportionate share scheduled for 1981.

North Canadian River alluvium and terrace deposits (Harper-Beaver County line to Canton Dam). Studies by the U.S. Geological Survey in cooperation with the Oklahoma Water Resources Board determined maximum annual yield, equal proportionate share and prior rights. Approval of maximum annual yield and equal proportionate share is planned for 1980.

(Canton Dam to Oklahoma City Area). Studies by the U.S. Geological Survey and Oklahoma Water Resources Board begun in January 1980, will determine maximum annual yield, equal proportionate share and prior rights. Studies of this segment are scheduled for completion in 1982.

Elk City Sandstone. A computer model study begun in 1979 under the auspices of Oklahoma Water Resources Board and Oklahoma State University and scheduled for completion in 1980, will determine maximum annual yield and equal proportionate share. Prior rights determinations are planned for 1980, and approval of maximum annual yield and equal proportionate share is expected in 1981.

Isolated terrace deposits (Garfield County). A computer model study begun in 1979 by the Oklahoma Water Resources Board and Oklahoma State University to determine maximum annual yield and equal proportionate share is scheduled for completion in 1980, along with determination of prior rights. Approval of maximum annual yield and equal proportionate share is planned for 1981.

Arbuckle Group (southwest) was the subject of a joint study by U.S. Geological Survey and Oklahoma Geological Survey, who completed geologic, ground water availability and water quality data for the Wichita Mountain region in southwestern Oklahoma in 1978.

Arbuckle Group (south central). An inventory of wells and springs in this aquifer was completed by the U.S. Geological Survey and Oklahoma Geological Survey, with water quality samples and geophysical logs collected on selected wells. Data collection, utilizing a network of observation wells, rain gauges and stream gaging stations, is scheduled for completion in 1980.

Vamoosa Formation is under study by the U.S. Geological Survey and Oklahoma Geological Survey, who have produced geologic and hydrologic data analyses and published hydrologic data in 1977. The final report on the aquifer prepared by study participants is scheduled for review and publication in 1980.

Antlers Sandstone. A cooperative study by the U.S. Geological Survey and Oklahoma Geological Survey has produced data on geology, water quality, well locations and water table levels which have been plotted on maps. Hydrologic data was published in

1978, and the report is to be completed in 1980.

Roubidoux Formation is currently under study by the U.S. Geological Survey and Oklahoma Geological Survey. This investigation, scheduled for completion in late 1982, will produce data on water quality, thickness and distribution of water zones and hydraulic characteristics.

PRESENT WATER USE AND FUTURE REQUIREMENTS

Sharp escalations in population, industrial development, and irrigated agriculture, along with increased affluency and higher standards of living have placed heavy demands on the state's available water resources. Projections by the Oklahoma Employment Security Commission (OESC) forecast a population of 4.4 million by the year 2040 and over six million by the year 2090.

Since Oklahoma's water resources are not inexhaustible, planning for the optimal use of all potential supplies is imperative in order to assure all parts of the state adequate water.

Analysis of Oklahoma's historical population data indicates a trend toward greater concentrations in the urban areas. Industries, attracted by larger populations and available labor forces, typically locate in those areas, thereby placing even heavier demands on water supplies. Increased industrial activity in turn attracts more people, further increasing municipal water requirements, which then leads to greater demand for electrical power cooling water to supply such induced requirements.

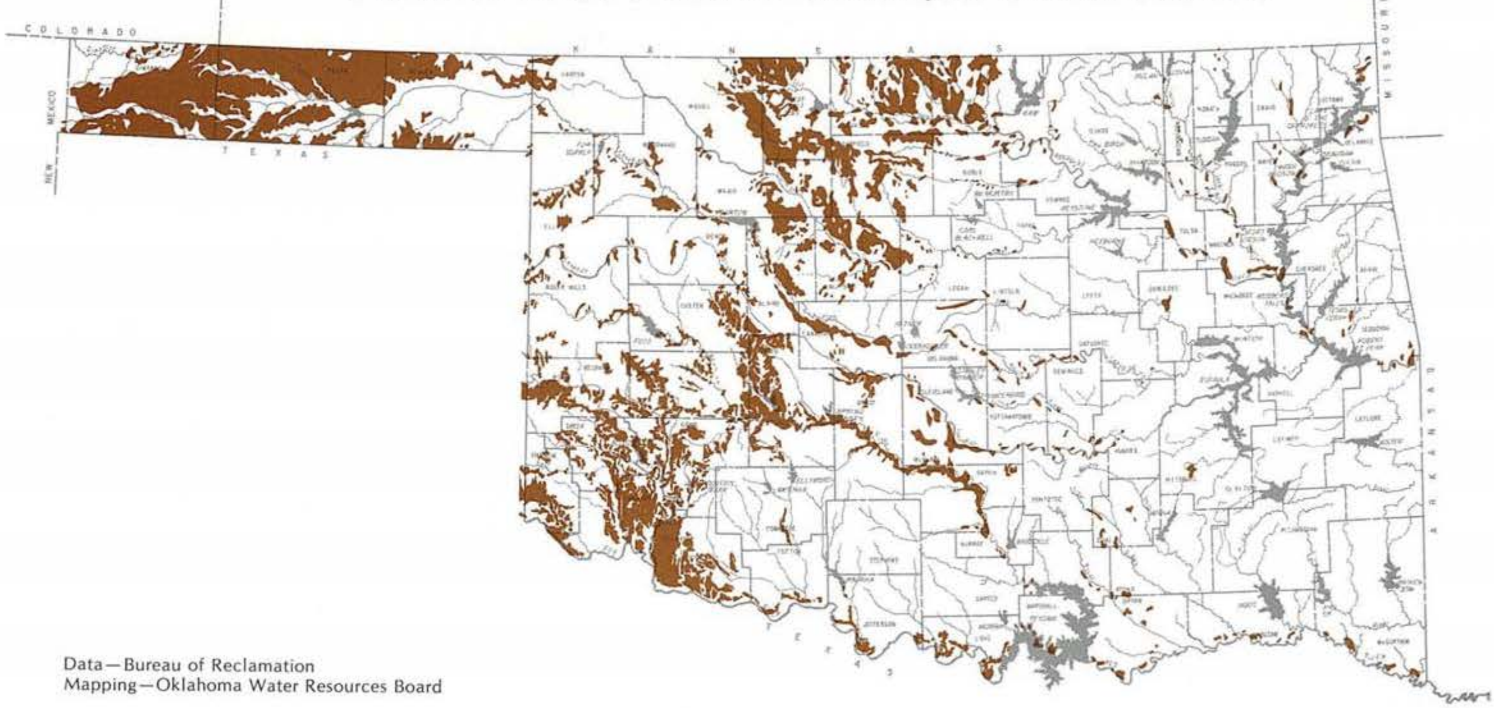
Current municipal water use in the state is estimated at 402,200 acre-feet per year; industrial use at 388,300 acre-feet; and use of cooling water for power generation at 110,900 acre-feet, totaling over 900,000 acre-feet annually. See Figure 31.

FIGURE 31
STATEWIDE PRESENT AND PROJECTED WATER REQUIREMENTS
(In 1,000 Af/Yr)

PLANNING REGION	Use	Present	1990	2000	2010	2020	2030	2040
SOUTHEAST	Municipal	16.5	21.0	24.4	29.1	32.3	37.4	56.1
	Industrial	71.3	88.7	103.6	119.8	137.4	154.9	172.2
	Power	—	10.7	16.2	21.6	27.1	32.6	38.0
	Irrigation	13.9	46.9	94.3	141.1	188.2	235.5	282.4
	Total	101.7	167.3	238.5	311.6	385.0	460.4	548.7
CENTRAL	Municipal	113.7	167.2	191.8	228.0	264.1	324.5	351.6
	Industrial	55.6	88.8	119.2	149.5	179.9	226.3	272.6
	Power	18.5	39.5	59.6	79.6	99.7	110.1	120.4
	Irrigation	39.8	43.3	49.6	56.0	62.4	68.7	75.1
	Total	227.6	338.8	420.2	513.1	606.1	729.6	819.7
SOUTH CENTRAL	Municipal	20.4	24.7	27.3	30.8	34.3	36.0	37.8
	Industrial	34.0	34.5	35.4	36.5	37.6	38.1	38.7
	Power	1.0	1.8	2.9	3.6	4.2	4.5	4.9
	Irrigation	42.6	69.5	87.8	107.7	127.5	137.4	147.4
	Total	98.0	130.5	153.4	178.6	203.6	216.0	228.8
SOUTHWEST	Municipal	36.0	45.2	52.0	56.7	61.5	63.9	66.2
	Industrial	50.6	55.7	61.7	63.9	66.2	67.3	68.4
	Power	5.6	14.8	23.0	28.4	33.7	36.4	39.1
	Irrigation	504.4	576.4	631.3	827.4	1,023.0	1,121.0	1,219.1
	Total	596.6	692.1	768.0	976.4	1,184.4	1,288.6	1,392.8
EAST CENTRAL	Municipal	33.8	42.0	47.9	54.7	58.7	66.1	70.8
	Industrial	9.3	10.9	11.5	12.3	12.9	13.3	16.9
	Power	20.8	66.7	103.7	140.7	177.7	204.2	230.8
	Irrigation	9.5	29.3	32.7	36.0	39.4	42.9	46.6
	Total	73.4	148.9	195.8	243.7	288.7	326.5	365.1
NORTHEAST	Municipal	119.4	179.2	219.4	248.5	278.6	309.0	349.0
	Industrial	104.9	140.1	158.6	172.8	177.9	183.1	187.5
	Power	57.0	146.1	197.0	241.4	285.6	311.7	338.9
	Irrigation	26.0	51.0	60.4	70.3	80.0	87.9	95.6
	Total	307.3	516.4	635.4	733.0	822.1	891.7	971.0
NORTH CENTRAL	Municipal	45.6	58.1	67.4	77.3	85.5	93.9	101.6
	Industrial	47.6	48.9	49.4	51.5	53.0	54.1	59.3
	Power	4.6	42.9	66.7	90.6	114.4	138.3	162.1
	Irrigation	28.6	82.8	133.5	179.4	238.2	282.3	336.9
	Total	126.4	232.7	317.0	398.8	491.1	568.6	659.9
NORTHWEST	Municipal	16.8	19.1	20.6	22.9	24.4	26.0	27.6
	Industrial	15.0	15.2	15.3	15.9	16.3	16.3	17.8
	Power	3.4	5.6	8.7	11.9	15.0	18.2	21.3
	Irrigation	850.0	1,077.6	1,205.4	1,377.8	1,557.0	1,724.4	1,886.8
	Total	885.2	1,117.5	1,250.0	1,428.5	1,612.7	1,784.9	1,953.5
STATEWIDE TOTAL	Municipal	402.2	556.5	650.8	748.0	839.4	956.8	1,060.7
	Industrial	388.3	482.8	554.7	622.2	681.2	753.4	833.4
	Power	110.9	328.1	477.8	617.8	757.4	856.0	955.5
	Irrigation	1,514.8	1,976.8	2,295.0	2,795.7	3,315.7	3,700.1	4,089.9
	Total	2,416.2	3,344.2	3,978.3	4,783.7	5,593.7	6,266.3	6,939.5

The early economy of Oklahoma revolved around agriculture as settlers gravitated to the state's favorable climate, soil and abundant lands. Today agriculture remains the leading economic activity, and agribusiness has evolved to complement traditional farming and ranching activities. Approximately 895,000 acres were devoted to irrigated agriculture in 1977, as shown in Figure 13, with approximately 1.6

FIGURE 32 LANDS SUITABLE FOR PROJECT-TYPE IRRIGATION



Data—Bureau of Reclamation
Mapping—Oklahoma Water Resources Board

million acre-feet of water per year being used for irrigation. Western Oklahoma accounts for over 80 percent of this total, primarily utilizing ground water pumped from the Ogallala Formation and alluvium and terrace deposits. An exception is the Altus-Lugert Irrigation District in Jackson County which utilizes surface water from Altus Reservoir, a Bureau of Reclamation project, for the irrigation of appoximately 47,000 acres. The potential for increased irrigation development is excellent in western Oklahoma, primarily due to soil suitability.

Figure 32 indicates the general extent of lands in the state suitable for potential long-term, project-type irrigation development. Approximately 4.7 million acres have been given this classification, based on land classification studies conducted by the Bureau of Reclamation. Irrigation suitability land classifications are conducted for the prupose of establishing the extent and degree of suitability of lands for sustained irrigation farming, and serve as a basis for selecting lands to be included in federal irrigation projects. This designation assumes all suitable soil types and takes into account slope, present land use and other physical and economic factors. Although other areas present potential, those in Figure 32 seem most likely to offer sufficient repayment capacities to justify irrigation costs.

The recent and rapid growth of irrigated agriculture has placed a severe strain on ground water supplies, especially those of the Ogallala aquifer. Oklahoma's economy will face severe economic consequences if additional water supplies are not made available to assure continued agricultural stability.

Methodology

The methodology used in estimating Oklahoma's future water requirements was developed by the Oklahoma Comprehensive Water Planning Committee composed of representatives of the Oklahoma Water Resources Board, Bureau of Reclamation, Corps of Engineers, Soil Conservation Service, the U.S. Geological Survey and other agencies. Water requirement projections for the counties of Creek, Osage and Tulsa were derived from the Tulsa Urban Study currently underway by the Corps of Engineers. These projections were developed from data provided by INCOG and the Corps, reflecting a detailed analysis of the water situation in the Tulsa area. The methodology used to derive the projections is slightly modified from that used in the Oklahoma Comprehensive Water Plan, but it was believed these projections indicated the most accurate future water demands for that area. These projections should not be interpreted as quotas or goals, but simply as forecasts based on the best information presently available. As variations from these assumptions become evident, such changes will become part of future planning efforts and subsequent revisions of this Plan.

POPULATION PROJECTIONS

Population projections utilized in the development of the Plan were provided by the Oklahoma Employment Security Commission (OESC). By combining projected births, survival of the base year population and migration of the population, the projections were derived to the year 2040.

MUNICIPAL AND DOMESTIC USE

Increasing per capita use rates (gallons per person per day) were applied to the population forecasts to determine the total municipal, domestic and rural water use projections. Historical trends were used to project increases in per capita use rates.

INDUSTRIAL REQUIREMENTS

The economic data which provided a basis for the industrial water requirement projections are disaggregates of the United States Water Resources Council's regional forecasts. Employment rates presented in these forecasts were multiplied by appropriate population projections to arrive at Oklahoma's portion of future employment by industrial activity according to Standard Industrial Classifications. Appropriate industrial water use coefficients for the Standard Industrial Classifications were applied to the employment projections to arrive at a total industrial water requirement. The industrial water requirement forecast was then disaggregated to arrive at individual county projections by applying the ratios of projected county population to the total state population forecasts. Since the paper and pulp industry is relatively new in the region, little data existed on which to base projected water use, so industrial requirements for the Southeast Planning Region were increased further to allow for future growth in this water-intensive industry.

To account for future water conservation measures in Oklahoma's urban areas, it was anticipated that 15 percent of the year 2040's return flows could be recovered, but lack of public acceptance almost precludes large-scale reuse for municipal purposes. However, considering the high costs of waste treatment, it is anticipated that by the year 2040, reuse could provide about seven percent of the projected industrial, cooling water and irrigation requirements of Oklahoma's urban centers. Therefore, wastewater reuse is shown as a source of supply in the Central Planning Region and Tulsa County in the Northeast Planning Region.

IRRIGATION REQUIREMENTS

Projections of soils suitable for irrigation were developed through the joint effort of the Bureau of Reclamation and Soil Conservation Service. Although methods of the Bureau of Reclamation and the Soil Conservation Service differ slightly, both consider soil types, slopes and methods of irrigation (present and future) among other factors.

In areas where sufficient water is available, projections were on a straight-line basis. In areas requiring import water, it was assumed that such water would be available sometime between 2000 and 2040, and expected increases in irrigation were made for that period. In areas of concentrated ground water development, it was assumed that irrigation would continue to increase and that the ground water would continue to be mined. It was also assumed that import water would come into use before the ground water was depleted and thereafter the amount of ground water used for irrigation would not exceed the annual recharge. Land projected for irrigation from SCS detention structures and farm ponds was also included in these projections.

Irrigation water requirements were determined by subtracting the consumptive water use for a general cropping pattern in each region from the effective precipitation, as well as allowing for losses occurring between sources of supply and the farm. It was determined that two acre-feet of water per land acre in the Northwest and Southwest Planning Regions, 1.5 acre-feet per acre in the North Central, Central and South Central Planning Regions, and 1.0 acre-feet per acre in the Northeast, East Central and Southeast Planning Regions would be required at supply sources in each region.

The potential for reuse of wastewater for irrigation was assumed to be feasible in the central Oklahoma area. Therefore, a portion of the irrigation water requirements is proposed to be met by this source.

POWER

Consumptive water use by utilities for power generation was computed at a rate of 2.5 acre-feet of water per million kilowatt hours (MKWH) of energy generated. Energy requirement estimates through the year 2040 were supplied by "Oklahoma's Energy Needs for the Future, An Interim Report."[1] As suggested in "1970 National Power Survey,"[2] the 2040 energy estimate was obtained by linear projection of 1985 and 1990 energy estimates as specified in "Oklahoma's Energy Needs for the Future." The consumptive use rate of 2.5 acre-feet of water per MKWH was applied to the projected energy requirement to determine total utility water requirements. Future power generation facilities were assumed to be developed in areas where existing facilities are presently located. Thus, utility water requirements are shown on a regional basis, rather than by individual county.

OTHER USES

In addition to the requirements previously mentioned, other water uses such as recreation, fish and wildlife enhancement, low flow augmentation, navigation and water quality control are recognized. Water for these purposes is not a consumptive use, so it is therefore reusable. Thus, it was assumed that these future requirements can be fulfilled by potential reservoir development planned to meet the consumptive needs previously discussed.

PROJECTED WATER REQUIREMENTS

Present water use and estimated water use projections to the year 2040 are summarized by planning region in Figure 31. The Oklahoma Comprehensive Water Plan has been developed to meet projected needs from 1990 to 2040, a 50-year planing period. Such a long period subjects forecasts to many uncertainties. However, when planning for water needs, it is necessary to assess demands as far into the future as feasible in order to maximize the return on the tremendous investment required for water development projects.

A recent study by the Bureau of Water and Environmental Resources Research (BWERR) at the University of Oklahoma developed four computer models capable of forecasting future water requirements for Oklahoma. These models -- one each for municipal and domestic usage, industrial, irrigation and total water demands -- are stepwise multiple regression models which utilize population, gross state product, precipitation, nonagricultural employment, total employment, bituminous coal and lignite production, per capita income, acres irrigated and land on farms as independent variables.

Projections available from these models for the years 1990 to 2040 correspond closely with projections by the Planning Committee during the initial forecasting periods. However, in the latter forecasts, the BWERR projections are substantially less than those used as a basis for the Oklahoma Comprehensive Water Plan, indicating that BWERR projections do not anticipate a growth rate as high as that assumed by the Planning Committee. If BWERR projections prove to be more accurate, the Plan simply would achieve the additional benefit of providing guidance in water planning beyond the year 2040.

WATER-RELATED PROBLEMS

Flooding

The Arkansas River Basin and the Red River Basin inflicted an estimated $167 million in flood damages on the state between 1955 and 1975, with the majority of that attibutable to the Arkansas. Immense property losses occurrd in the severe floods recorded in April through June of 1957, and in June of 1965.

Some floods occur gradually, as when prolonged steady rainfall saturates a river or stream basin until almost all of it runs off, creating a greater volume of water than the natural channels and drainage structures can carry. Others are a result of sudden, heavy rains occurring in a short time, with Oklahoma experiencing more flooding of the latter type. In either case, floods are considered a problem only when they result in widespread damage to agriculture and structures, or when the normal activities of man are seriously interrupted.

Flood damages generally are assessed within the categories of agriculture, rural, urban and transportation. Agricultural damages result in loss of crops and livestock; rural damages in erosion and destruction of fences and buildings; urban damages in loss of houses and commercial properties; transportation losses in damaged highways and bridges; and rescue and clean-up costs.

Recognizing the adverse consequences of flooding, the Soil Conservation Service and the Corps of Engineers have sought and received federal statutory authority to construct flood control and prevention structures in areas where flooding presents a threat. Under Public Law 566, the Watershed Protection and Flood Prevention Act, the Soil Conservation Service has constructed hundreds of small impoundment structures on streams throughout the state, which also serve a secondary purpose of providing a water supply source for many Oklahoma communities.

The Corps of Engineers, under the provisions of various flood control acts passed by Congress, has decreased the incidence of damaging floods through construction of extensive reservoir storage, primarily in eastern Oklahoma. The Corps is also responsible for regulating the flood control portion of reservoir projects constructed by the Bureau of Reclamation and the Grand River Dam Authority. The combined programs of the Soil Conservation Service and the Corps produce an estimated annual benefit of $180 million to the state.

Man's encroachment on a stream's natural floodplain is responsible for many flooding problems. As land has become more scarce and expensive, cities and towns have gradually encroached on flood-prone areas. Each year damages from floods cause severe economic consequences, particularly for those individual property owners, businesses and local governments which are not adequately insured.

Recognizing these dangers, the Federal Government, through the Federal Emegency Management Agency (FEMA), offers a subsidized insurance program which requires any participating local, county or state government to adopt FEMA's floodplain management criteria which limits additional development in designated floodplain areas.

Of the 466 Oklahoma communities identified as containing flood-prone areas as of December 31, 1978, 275 were participating in the federal flood insurance program. Sixteen counties in Oklahoma have been mapped and identified as containing flood-prone areas. However, 15 of the 16 lack the proper authority to participate in the flood insurance program. In case of a damaging flood, cities or counties cannot qualify for federal disaster assistance unless they are participants in the National Flood Insurance Program. Many Oklahoma communities are ineligible for the subsidized insurance program due to the absence of state floodplain legislation, and therefore remain vulnerable to the heavy financial losses associated with floods.

Drought

Like other southern Great Plains states, Oklahoma has scorched under extended droughts on an approximately 20-year cycle. Notable among them were the dry years that occurred at the end of the century, again in 1910 and 1919, the dust bowl years of the 1930's, and more recently the prolonged drought of the 1950's and 1960's. Although the drought of the 1930's was the longest in Oklahoma's history, that of the 1950's was more widespread and ranked among the most destructive of the past 400 years.

An analysis of drought conditions in Oklahoma from 1931 to 1971 indicates that drought occurred somewhere in the state 51 percent of the time; more frequently in the Panhandle, and less frequently in northeast and south central areas. Eastern Oklahoma experienced short periods of drought, while the Panhandle averaged longer dry periods; again emphasizing the variability of weather in eastern Oklahoma and the normal shortage of rainfall in the west.

Drought inflicts extensive damage to agriculture, as crops burn up and livestock die from thirst. Municipalities also are adversely affected, often forced to resort to rationing programs as water supplies dwindle. Water-intensive industries often experience reduced production during water shortages, and hydroelectric power generation can be substantially cut back resulting in power shortages. Decreases in navigation storage accompanying prolonged periods of drought would necessarily have an impact on navigation on the McClellan-Kerr naviagtion system.

Although prevention of droughts is impossible, measures such as weather modification can somewhat mitigate its effect. Weather modification has evolved into a viable water resource augmentation technique. However, due to the unresolved legal and political questions surrounding weather modification, as well as its limited applicablity, in this Plan it is considered as only a supplemental water source.

Upstream flood control projects such as those constructed throughout Oklahoma by the Soil Conservation Service allow the storage of water during high flows for use during dry periods. In addition to providing many communities with their sole dependable source of water, these structures also provide water for other drought caused needs.

Erosion and Sedimentation

Natural erosion and sedimentation adversely affect the quantity and quality of lakes and streams, cause the depletion of productive soils, and the deterioration of waters through the buildup of silt. When eroding soil contains residues from fertilizers or human and animal wastes, the streams and lakes become nutrient-enriched, thus enhancing eutrophication. High nutrient levels, especially nitrogen and phosphorus, result in accelerated growth of algae and other microscopic plant life, choking lakes and streams and decreasing their capacity to hold water.

Since sedimentation affects the yield of a reservoir by encroaching on conservation storage, buildup must be considered in the design of the reservoir and sediment storage provided. Periodic sediment surveys are necessary to determine the rate of accumulation, and if it exceeds design limits, might be accommodated by reallocating the remaining storage.

Sediment movement can be controlled through agronomic and mechanical practices which can typically reduce the amount of sediment reaching the reservoirs between 28 and 73 percent. Sediment yield can be reduced up to 90 percent by converting poorly suited cropland to continuous vegetation. In addition, flood-retarding structures have decreased sediment yields as much as 48 to 61 percent.

Acute erosion problems have developed downstream from reservoirs generating hydroelectric power, such as those areas below Keystone Dam on the Arkansas River and Denison Dam on the Red River. These wide riverbeds consist of sand deposits and other soils which are highly susceptible to erosion. Natural stream-flows undercut the riverbanks causing caving of the banks and loss of valuable bottomland, with high streamflows resulting from flooding or generated hydropower releases greatly accelerating this process and carrying large quantities of soil, sand and silt downstream as suspended sediment.

Bank caving and erosion have caused the loss of valuable agricultural lands and crops, damaged pipelines, power lines, roads, bridges and buildings and adversely affected urban and industrial growth.

The Corps of Engineers has studied a number of methods to reduce bank caving, including low-water dams to retard downstream sediment movement, dredging channels to prevent normal flows from meandering, using stell-jetty lines and dikes, and installing stone-fill dikes and revetments.

While many of these methods are effective in controlling erosion, they are often so costly when compared to the benefits that they are not economically justified under federal criteria. Thus local interests or the state are required to provide their own means of reducing erosion.

Drainage

Problems associated with the drainage of excess water exist on approximately 5.2 million acres in Oklahoma. Drainage is the removal of excess water from the plant root zone or from surface areas where normal precipitation, seepage or excess irrigation water keeps the soil too wet for economical agricultural production. The slope of the land, permeability of the soil, depth to the water table and amount of soil aeration are the primary factors affecting drainage. The purpose of drainage is fourfold: to provide increased crop yields, to improve machinery efficiency, to achieve higher crop quality and to provide better machinery adaptability. Drainage measures include land forming to eliminate pockets, depressions and intervals; and subsurface tile drains to carry excess water to deeper channels of water courses, among others.

Water Quality Degradation

The quality of Oklahoma's stream and ground water resources has emerged in recent years as a consideration of equal importance to that of quantity. Water quality is influenced by geology, climate, rural and urban development, wastewater treatment and disposal practices, storage in and diversions from lakes, and other practices applied to the operation of reservoirs. With increased discharges of wastes by municipalities, industries, and agriculture, further degradation of the waters can be expected unless adequate quality management policies are adopted.

MAN-MADE POLLUTION

Industrial development and population growth are primarily responsible for the dramatic increases in man-made pollution in recent years. Industrial discharges in excess of permit allowances burden surface waters with more than their assimilative capacities, and brine releases from oil and gas production contribute to the pollution of both stream and ground waters. New oil fields or wells may produce little or no brine, but fields nearing depletion may yield up to 100 barrels of salt water per barrel of oil.

Water-intensive coal mining operations in eastern Oklahoma produce great quantities of polluted water as a by-product. Improper disposal of this water presents serious pollution potential to the area's streams and lakes.

Municipalities often contribute damaging effluents through inadequate sewage treatment procedures. Some financially strapped smaller cities which cannot afford adequate treatment of their effluents frequently discharge excessive amounts of sulfates, sodium and other harmful elements into the state's waters. Additional treatment, primarily of a tertiary nature, will reduce such pollution but the reuse of effluent as a downstream water supply will remain a socially questionable practice.

Nonpoint sources of pollution from agricultural and urban runoff are increasing rapidly and remain difficult to identify and control. The ongoing 208 Waste Treatment Management Program will continue to investigate means of reducing or eliminating nonpoint source pollution.

Equally as endangered as surface waters are the state's fresh ground water aquifers. Oil and gas exploration activities throughout the state have adversely affected ground water supplies, while nitrate and flouride contamination threatens western Oklahoma's ground water basins. Pollution of ground water sources is particularly critical in those western areas where no alternative surface water sources are available.

Despite major strides in strengthening and enforcing Oklahoma's Water Quality Standards which determine municipal and industrial discharge limits, efforts to reduce man-made pollution of the state's stream and ground water resources must continue if the state's future water needs are to be met.

NATURAL POLLUTION

Natural mineral pollution in areas of western Oklahoma severely degrade the quality of water in the Arkansas and Red River Basins. These minerals, primarily chlorides and sulfates, often render the water of the rivers unusable for municipal, industrial, or irrigation purposes.

Streams severely degraded by chlorides include the Cimarron, Salt Fork of the Arkansas and the Arkansas River in northwestern Oklahoma; and the North Fork, Salt Fork, Elm Fork, and Prairie Dog Town Fork of the Red and the Red River in southwestern Oklahoma. The Canadian and Washita Rivers in west central Oklahoma are also polluted by sulfates originating from gypsum outcrops in their drainage areas.

Oklahoma's natural pollution problem is attributed to chlorides emitted from springs and salt flats. Fifteen such natural chloride emission areas have been identified in Texas, Kansas and Oklahoma; 10 of these in the Red River Basin, and five in the Arkansas River Basin. The extent and magnitude of the pollution problem is illustrated by the 11,900 tons of salt per day which enter Keystone Lake via the Arkansas and Cimarron Rivers and the estimated 5,400 tons per day which enter Lake Texoma on Red River.

Five of the emission zones have been identified in Oklahoma; four of them in northwestern Oklahoma in the Arkansas River Basin, and one in the Red River Basin in the southwestern corner of the state. (See Figure 25 for source locations in Oklahoma.) The four sources in the Arkansas River Basin emit an estimated 7,600 tons of chlorides per day into local streams, often raising the salt concentrations higher than that of sea water. The single southwestern source emits approximately 840 tons per day into the Red River Basin.

Extensive studies of the salinity problem by the U.S. Army Corps of Engineers have shown that the natural chloride pollution could be substantially reduced by implementing control measures at principal brine emission areas in Oklahoma and out of state.

Ground Water Depletion

Natural recharge to the underlying rock formations from precipitation and/or seepage along stream beds is very low in western Oklahoma, where ground water serves as the chief water supply source. To economically develop the agricultural resources of western areas, more water must be pumped out of the ground than is naturally flowing back into underground storage. Such mining or overdrafting of the ground water supplies threatens to deplete these vital resources within the forseeable future.

During the 1930's, few irrigation wells existed in western Oklahoma, but in the 1950's, the introduction of center pivot irrigation equipment brought extensive ground water development. The surge in irrigated agriculture resulted in declines in the water table of five to 10 feet per year. As the water table declined, the amount of saturated water-bearing rock also declined, and well yields dropped. In the Panhandle, wells that had yielded as much a 1,000 gallons per minute now produce only 500 to 800 gallons per minute. The decrease in well capactiy was accompanied by greater depth to water. Water encountered at 250 feet below the surface 20 years ago now requires drilling to a depth of 350 feet or more.

To pump water from greater depths requires more fuel, and as energy costs soar, many farmers and cattlemen are unable to afford irrigation's rising costs. Although water may be available at greater depths, technological and economic restraints may prevent its use, and the aquifer can be considered effectively depleted.

Short-term alternatives to depletion include additional conservation practices and management of ground water supplies. Wells smaller in diameter and spaced at proper intervals can slow water level declines. More efficient use of water through drip irrigation, limits on annual water use by well owners and the coordination of water application with rainfall can also prolong the life of an aquifer.

Although these measures may provide a temporary solution to the problem of ground water depletion, alternative water sources will eventually be needed to supplement western Oklahoma's declining reserves.

Stream Water Availability

Due to the limitations on stream water availability imposed by lack of precipitation and runoff as well as those presented by poor water quality, there are many areas where the demand for water has reached or surpassed a stream system's capacity for supplying it.

The Oklahoma Water Resources Board has determined that all the stream water in an 8.5 million acre area illustrated in Figure 3 has been fully appropriated. Because additional development could unduly interfere with existing allocations, only minimal development of additional stream water in this area is presently possible. However, the Board continually reviews stream water permits for compliance with state law, and such review could free some water for appropriation in areas that were previously fully appropriated.

Restrictions are applicable to allocations of stream water in an additional three million acres of the state including areas on three of the state's designated scenic rivers, Big and Little Lee Creeks and the upper reaches of the Illinois River including Flint Creek. These limits are based on minimum flow criteria, and were adopted in response to increased water demands in northeastern Oklahoma to protect the rivers' scenic nature.

Reservoirs are considered fully appropriated when the Oklahoma Water Resources Board has issued water right permits equal to the yield of the reservoir. In order to protect the yield of the reservoir, applications for water rights in the drainage area above the lake can be denied or restricted. Water rights above the reservoir are issued only when it is determined that water is available in

FIGURE 33 WATER LEVEL HYDROGRAPH
Well in NW ¼ NW ¼ Sec 9-T2N-R1 SE, Texas Co.

excess of the quantity necessary to maintain the reservoir yield.

Inadequate Municipal and Rural Water Systems

Approximately 200 communities across the state -- mostly small towns and rural water districts -- face serious water supply problems fostered by inadequate supplies and/or poor water quality. Lack of adequate supplies, mineralized water, inadequate treatment and storage facilities and aged and deteriorating distribution systems make it impossible for these communities to maintain, much less improve, their economic viability.

A July 1977 survey indicated that some form of mandatory or voluntary water rationing was necessary in 37 communities serving 196,000 Oklahomans. Storage, treatment plants and collection systems could not keep pace with user demands, thus necessitating water rationing. Problems were so critical in some communities that sufficient fire protection was not available to the residents.

Sixty public water systems presently utilize water with chemical constituents exceeding the maximum allowable level prescribed by Oklahoma's Primary Drinking Water Standards. Concentrations of nitrate, flouride and selenium present in a majority of the systems cannot be removed by conventional treatment, but rather, require expensive treatment facilities beyond the means of small or intermediate-size cities. Many of these systems have been placed on compliance schedules to correct the violations, and will be forced to obtain new sources of supply. (See Appendix A for analyses of water supplies of rural water districts and municipalities listed by planning region.)

Current municipal indebtedness, low per capita incomes and inadequate population bases make it impossible for some communities to finance the improvements and expansions to their water supply systems required by federal and state legislation. Many lack the administrative or technical skills to perform the necessary planning and to secure financial and legal guidance.

Although there are several federal assitance programs available, low funding levels have limited participation. State assistance has recently been made available through the passage of Title 82, O.S. 1979, Section 1085.31 et seq. (Senate Bill 215 of the First Session of the 37th Legislature), which authorized the Oklahoma Water Resources Board to provide financial aid to qualified cities, towns and rural water districts. Chapter VIII describes in detail the funding program available through the Oklahoma Water Resources Board.

Dam Safety

The federal legislation authorizing dam safety inspections was passed in response to the Buffalo Creek (West Virginia) dam failure in February 1972 which released flood waters that killed 125 people. Although the National Dam Safety Act was signed into law in August 1972, federal funds for its implementation were not approved until 1977, when the collapse of Teton Dam in Idaho and Toccoa Dam in Georgia again focused the attention of Congress and the public on dam safety.

Funds were made available to the states to inventory and determine hazard categories for all nonfederal dams and to conduct safety inspections of all high-hazard dams. The legislation mandated the inspection of every dam 25 feet or more in height, or with a capacity to impound 50 acre-feet or more of water.

The classification of dams by hazard potential has nothing to do with the dam's structural integrity, but with the degree of development downstream that could be adversely affected if the dam broke. It also serves to determine the priority for inspections; those appearing to possess greater hazard potential being inspected first.

As the state agency responsible for dam safety, the Oklahoma Water Resources Board is conducting an inventory which is expected to locate an estimated 4,000 dams in the state by completion of the program in 1980. Most dams in Oklahoma are earth-fill dams designed by a state-of-the-art method at the time of construction, with a potential for seepage and failure under abnormal conditions. Reductions in dam failure and mitigation of the consequences, as measured in life and property, are the major objectives of the Oklahoma Water Resources Board's dam safety program.

Once a dam is determined to have a high hazard potential, an inspection is required. Each inspection report contains recommendations for redesign or rebuilding, maintenance and operation, and the dam owner is required to comply with all major recommendations. To date, inventories have been performed on 1,819 structures, 112 of which were found to require corrective measures to insure the safety of those living downstream.

Although Oklahoma has not experienced a serious dam failure, the state is subject to torrential rains that can cause flooding and stress on its dams. A recent study by the National Weather Service showed that the 12-hour maximum precipitation for 10 square miles varies from 30 to 36 inches in the state. The most recent such rain occurred at Enid in 1973, when the National Weather Service measured 15.68 inches of rain in 13 hours.

An inventory of dams is never complete; new dams are built and old ones demolished. Nor is an inspection program of high-hazard dams ever finished; low-hazard dams become high-hazard and vice versa. Since present federal funding for the inventory is scheduled to end in 1980, and in 1981 for the inspection program, the question of continued funding for the state's dam safety program is crucial. If Congress fails to renew the programs through additional appropriations, the state will be required to underwrite the programs in order to insure the safety of thousands of nonfederal dams in Oklahoma.