CHAPTER V
PLANNING REGION ANALYSES

The scope and magnitude of the Oklahoma Comprehensive Water Plan defy considering the entire state as a single unit for the purpose of meaningful long-range water planning, yet Oklahoma's 77 counties represent fragments too small for the preparation of any plan of a comprehensive nature. Therefore, at the inception of the Board's work on Oklahoma's Comprehensive Water Plan, the state was divided into the eight planning regions shown in Figure 34 . The counties grouped in each region exhibit certain common characteristics, including homogeneity of climate, geography, hydrology, economics and demography, that meld them into functional planning units.

At the same time, the multi-county regions are unique in their water-related characteristics, varying one from another in their water resources and requirements. Planning on a regional basis permits the evaluation of these unique characteristics in the design of appropriate local water development plans.

The ground water and stream water resources of each region were inventoried to determine existing and potential water resource development capabilities. Water requirements were projected in order to forecast municipal, industrial, utility (power) and irrigation needs of each region. Projected water requirements were then compared with the local water development potential, and a local development plan based on potential development was formulated.

This chapter contains an analysis of each of the eight planning regions, including proposed Regional Plans of Development and costs for their implementation.

The proposed Regional Plans of Development offer a means of meeting all or part of the regions' projected water requirements through the year 2040. The plans have been prepared to optimize the potential water resources development within each region. In several regions, sufficient local supplies have not been identified for development capable of meeting future needs, therefore, these regions will require water from outside the local area if they are not to suffer from expected water deficits.

Cost estimates for the proposed Regional Plans of Development are shown in Figure 35 . Based upon January 1978 price levels, the total cost of regional development could approach $3 billion. Estimates were prepared with assistance from the Bureau of Reclamation, Corps of Engineers and Soil Conservation Service. The costs are not of a final nature, but rather should be used to comprehend the financial requirements necessary to implement the local plans.

A benefit analysis has not been prepared for any of the proposed projects. Additional studies would be required on each proposed project to determine their economic feasibility under federal guidelines, as well as the amount of state or local contributions that might be necessary.

The plans proposed should be considered a flexible guide for each reigon, subject to change; not as a hard and fast blueprint for action. Alternative projects within each region would be appropriate so long as they are compatible with the overall policies and guidelines of the Oklahoma Comprehensive Water Plan.

FIGURE 34 PLANNING REGIONS

FIGURE 35 SUMMARY OF COSTS[1] PROPOSED REGIONAL PLANS OF DEVELOPMENT (In $1,000)

REGION	CONSTRUCTION COST	AVERAGE ANNUAL OMR&E[3]	TOTAL AVERAGE ANNUAL EQUIVALENT COST[4]
Southeast[2]	$ 289,800	$ 4,010	$ 15,335
Central	123,370	935	9,225
South Central	321,915	1,845	21,528
Southwest	270,130	1,740	17,115
East Central[2]	243,820	4,642	18,540
Northeast[2]	374,940	14,484	41,320
North Central	839,080	4,925	66,210
Northwest	288,830	1,544	19,825
TOTAL	$2,751,885	$34,125	$209,098

[1]Based on January 1978 prices.

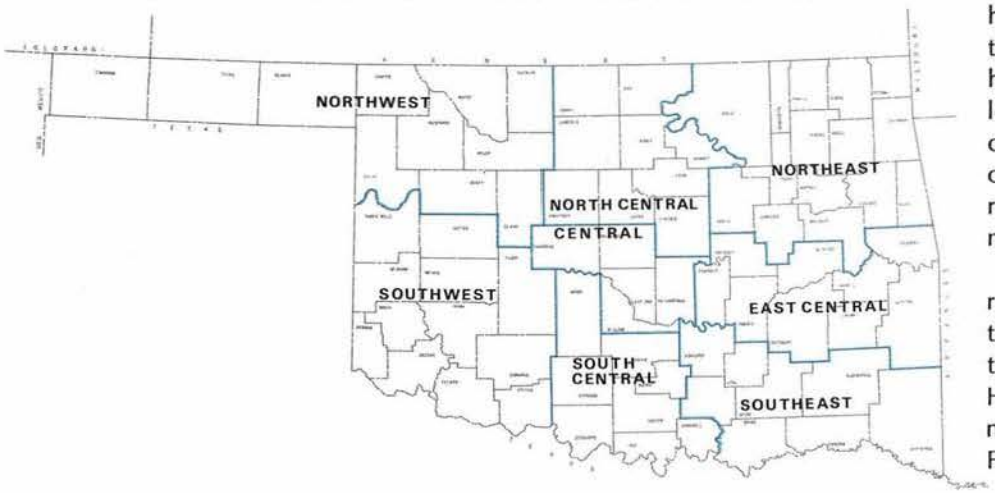
[2]Mitigation/compensation costs not completed for these regions at this time.

[3]Energy costs computed at a 30-mil power rate.

[4]Includes interest and amortization, as well as average annual OMR&E.

SOUTHEAST PLANNING REGION

The 8-county Southeast Planning Region covers 7,919 square miles, encompassing Atoka, Bryan, Choctaw, Coal, Johnston, McCurtain, Pontotoc and Pushmataha Counties.



The mining of coal in the 1870's and the first drilling for oil near the City of Atoka mark the earliest development of natural mineral resources in the state. Vast timber and water resources also distinguish this region.

The northern part of the region is characterized by rugged hills and mountains, smoothing the gently rolling plains, then leveling to the alluvial plain where it meets the Red River in the south. Elevations range from over 2,500 feet in the north to approximately 300 feet in the southeast. The region is drained by the Red River and its tributaries: the Blue, Kiamichi, Mountain Fork and Little Rivers; and Clear Boggy Creek.

Population statistics compiled in 1977 show this 8-county region at 144,000, an increase of 10 percent since 1970. This rise is equivalent to the 7-year increase for the state as a whole, demonstrating the healthy growth of the area. During the same period, per capita personal income (before taxes) increased from $2,040 to $4,100. The region is further characterized by a high percentage of employment in the sectors of wholesale and retail trade, manufacturing and construction.

Population in the Southeast Planning Region consists of 62 percent rural and 38 percent urban residents. Major population centers include Poteau, Idabel, Durant and Hugo.

The economic condition of the region is strong with opportunities available in a number of dependable fields. An occupational potential inventory in 1978 shows clerical, sales and service fields to be highly promising. With an abundance of natural resources and a growing population, the economic outlook for this area is bright.

The southeast region lies in a moist, subhumid climate where annual precipitation and evaporation levels are virtually equal. Although precipitation is normally distributed evenly throughout the year, droughts of short duration are fairly frequent during the 8-month growing season. In summer, under the influence of prevailing southerly winds bearing moisture from the Gulf of Mexico, a favorable atmosphere for thunderstorms exists. Occasionally, westerly or northerly winds introduce hotter and drier air. During the winter months winds over the region can alternate between tropical and polar air masses, bringing sudden drops in temperature.

As shown in Figure 8 , average annual precipitation ranges from 40 inches in the west to 56 inches in the east, with the heaviest rainfall occurring in northern McCurtain County over the Little River and Kiamichi River watersheds. The region receives approximately six inches of snowfall annually. The average lake evaporation east to west across the region varies from 48 to 56 inches, as shown in Figure 9 . This amount is low in comparision to that of western Oklahoma, and is due to the lack of sustained high velocity winds during the hot summer months. High rainfall and low evaporation rates present a climate favorable to the construction of reservoirs, as evidenced by the region's many lakes and impoundment structures.

Mean annual temperature in the region ranges from 62° F in the north to 64° F in the south. The maximum temperature recorded was 118° at Hugo in August 1936, and the minimum, -22° at Smithville in February 1951.

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, averages 240 days.

The large amounts of precipitation and runoff in this region foster frequent damaging floods such as those recorded on the Kiamichi near Belzoni in October 1915, with a maximum discharge of 72,000 cfs; on Little River near Wright City in 1951, with a 78,200 cfs discharge; and on Mountain Fork River near Eagleton in 1969, with a maximum discharge of 101,000 cfs.

Twice within an 11-month period, on December 10, 1971 and again on October 31, 1972, Glover Creek and Little River overran their banks and caused devastating floods. The gaging station at Glover, Oklahoma recorded discharge rates of 98,000 cfs and 86,300 cfs respectively for these floods, and according to local residents, the 1971 flood inundated 60,000 acres of land, causing damages in excess of $17.5 million. The 1972 flood covered an estimated 30,000 to 40,000 acres and caused $12.6 million in damages in McCurtain County.

In 1973, moderate flooding occurred on the Red River and Blue River and on Clear Boggy and Muddy Boggy Creeks. Again in October and

November of 1974, these streams experienced serious flooding, with the Blue River at Blue rising almost 11 feet above flood stage and the Clear Boggy and Caney registering 4.6 feet of flooding. High flows from these and other tributaries of the Red combined with heavy rains areawide and caused flooding downstream around DeKalb, Texas which inflictd $115,000 in losses to soybeans, hay and cattle.

Following two dry years, during which Texoma Reservoir dropped as much as eight feet below normal pool elevation, heavy rainfalls returned in March of 1977, deluging the basin with 10 inches. As a result of a 6-inch rainfall in six hours, Blue River at Blue crested nearly 13 feet over flood stage, and 20 people fled their homes in Durant as flash flooding struck Mineral Bayou, a Blue River tributary.

Extensive work on watershed protection and flood prevention on the Boggy River has been accomplished by the Soil Conservation Service, and many additional sites are planned to further relieve flooding problems. The Corps of Engineers has reduced the severity of flooding by providing flood storages in the remainder of the Red River Basin below Denison Dam.

WATER RESOURCES

Stream Water

Stream Water is readily available in large quantities throughout the region. The high rate of precipitation and naturally rough, steep terrain lend themselves to the production of substantial amounts of water within comparatively small drainage areas. Through the efforts of the Corps of Engineers, Bureau of Reclamation, Soil Conservation Service and various state and local entities, numerous lakes have been planned and developed to make stream water available for beneficial uses. There are many potential reservoir sites available as the future beneficial needs of this region and the state increase.

Average annual runoff from precipitation and springs is about 15 inches, ranging from six inches in Pontotoc County to 20 inches in the northeast corner of McCurtain County, for a total originating within the region of six million acre-feet per year. Of this amount, 2,804,000 acre-feet flow into the Red River within Oklahoma.

The United States Geological Survey maintains nine gaging stations on streams in the southeast region. Metering devices compile stream data used in determining the amount of water available for storage at a given site and the effect of such impoundment structures on downstream flows.

A summary of stream flows at selected USGS gaging stations is included in Appendix B, Figure 2.

Red River (main stem) water quality is rendered inferior by a high total dissolved solids content, a result of natural salt pollution upstream. Water quality improves farther downstream as high quality stream flows from tributaries below Denison Dam enter the Red River. Municipal and industrial use of water from the Red River is restricted by quality limitations. Irrigation use is restricted in the upper reaches, but improved quality downstream makes the water usable for irrigation of certain crops.

The lower reaches of the Red are characterized as being moderately turbid, exhibiting high levels of iron and manganese. Dissolved oxygen depletions occur directly below Denison Dam during the warmest months, but downstream recovery is rather rapid.

The Little River is a high quality stream with low mineralization and enrichment. The stream has low turbidity and very soft water, and metals toxicity is not a problem.

Glover Creek has good water quality with nutrient and mineral indices indicating minimal mineralization and low nutrient levels. The stream exhibits very little turbidity of hardness, and dissolved oxygen remains at saturation levels throughout the year.

Mountain Fork River has no known point source discharges, so the insignificant pollution that exists is assumed to be attributable to nonpoint sources. It is a high quality stream with little mineralization and low nutrient levels. There has been no evidence of degradation trends to date, and toxic metals remain at very low levels throughout the stream's length.

Kiamichi River is a high quality stream with low to moderate turbidity, soft water and low mineralization. The river has generally low nutrient enrichment. Iron and manganese frequently exceed standards, but toxic metals are not present in elevated levels.

Clear Boggy Creek is a fairly turbid stream with dissolved oxygen usually remaining near saturation levels. Water quality is good with low mineralization and nutrient levels.

Muddy Boggy Creek is a very turbid stream with good water quality and exhibiting fair nutrient levels and low mineralization. The stream has very soft water, and its dissolved oxygen content consistently registers near saturation levels.

Blue River waters show very good quality, and mineralization and nutrient concentrations remain low. The river has hard water, and registers dissolved oxygen at levels close to saturation. The water is somewhat turbid most of the year in the lower reaches of the river.

Water quality analyses data for selected USGS monitoring stations and the station locations are shown in Appendix B, Figures 4 and 5.

STREAM WATER DEVELOPMENT

The Southeast Planning Region is more richly endowed with rainfall and good quality streams than any other part of the state, an advantage contributing to the region's extensive development of stream water resources. There are three existing federal lakes: Broken Bow, Hugo and Pine Creek; two additional federal lakes under construction: Clayton and McGee Creek; and one major municipal lake: Atoka. These lakes have a combined water supply storage capacity of 875,000 acre-feet for municipal and industrial purposes.

Major Reservoirs

Authorized purposes of the five federal projects include water supply, flood control, water quality control, recreation, fish and wildlife propagation and hydroelectric power generation.

Broken Bow Lake is located on the Mountain Fork River in McCurtain County, with the dam located about 10 miles north of the town of Broken Bow in the Kiamichi Mountains. The lake is a unit in the 7-reservoir system planned for flood control in the Little River watershed. The dam is the highest earthfill structure in Oklahoma, having a crest length of 2,820 feet and rising to a maximum height of 225 feet above the streambed.

There are 317,600 acre-feet of hydroelectric power generation storage, converted to energy by two 50,000 kw generating units.

Mountain Fork River exhibits water of excellent quality, making Broken Bow Lake water appropriate for any beneficial use. Since impoundment of the lake, the water supply storage has not been utilized other than for recreation and hydroelectric power generation purposes. The entire water supply yield of 196,000 acre-feet per year is available for appropriation.

Hugo Lake is located on the Kiamichi River about seven miles east of Hugo in Choctaw County. Along with Clayton Lake, under construction, and authorized Tuskahoma Lake, it comprises a 3-lake system proposed within the Kiamichi River Basin. Upon completion of Clayton and Tuskahoma Reservoirs upstream, conversion of flood control to water supply in Hugo Lake could raise the ultimate dependable yield of the reservoir to 302,800 acre-feet annually.

Water impounded in Hugo Lake is of high quality, classifying as suitable for municipal and industrial uses. The Cities of Hugo and Antlers are the only current users of this water. Western Farmers Electric Cooperative is currently building a new generating facility, and has contracts pending for storage in the lake. Water is available for additional appropriations.

Pine Creek Lake is located on Little River approximately five miles northwest of Wright City in McCurtain County.

The 70,500 acre-feet of conservation storage will supply a dependable yield of 134,400 acre-feet from the combined water supply and water quality control storages.

Water quality of Pine Creek Lake is excellent, suitable for any beneficial purpose. Presently the Weyerhaeuser Company is the only user, so some of the water supply yield remains available for appropriation.

Clayton Lake is located on Jackfork Creek, one of the main tributaries of the Kiamichi River, and lies 2½ miles north of Clayton and five miles northwest of Tuskahoma in Pushmataha and Latimer Counties. Construction of the embankment and outlet works was begun in September 1977, with an expected completion date in 1981. The project is approximately 60 percent complete.

Water quality is good except for the presence of iron, which from time to time exceeds the recommended limit of 0.3 ppm. Removal of iron in the amounts anticipated is neither difficult nor costly.

Before the Corps of Engineers could begin construction of Clayton Lake, contracts to repay the costs allocated for water supply storage in the lake had to be approved. Because no local water-using entity was capable of obligating the funds necessary to enter into the contract, the Oklahoma Water Conservation Storage Commission signed the required contract in 1974, facilitating construction of the lake development. The entire water supply yield of Clayton Lake is available for appropriation.

McGee Creek Reservoir is under construction on McGee Creek, a major tributary of the Muddy Boggy, about three miles north of Farris and 18 miles southeast of Atoka.

Dependable water supply yield from the reservoir will be 71,800 acre-feet of water of very good quality. Water rights encompassing this yield have been allocated as follows: 40,000 acre-feet to Oklahoma City; 8,000 acre-feet to the City of Atoka; 8,000 acre-feet to Atoka County; 4,000 acre-feet to the Southern Oklahoma Development Association;

FIGURE 36 STREAM WATER DEVELOPMENT

NAME OF SOURCE	STREAM	PURPOSE*	FLOOD CONTROL STORAGE ACRE FT.□	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
		EXISTING OR UNDER CONSTRUCTION			
Atoka Lake	North Boggy Creek	WS, R	0	123,500	1,224[1]
Broken Bow Lake	Mountain Fork River	WS, FC, P, R, FW, WQ	450,000	152,500[2]	196,000[2]
Clayton Lake+	Jack Fork Creek	WS, FC, R, FW	128,200	297,200	156,800
Hugo Lake	Kiamichi River	WS, FC, WQ, R, FW	809,100	121,500[3]	165,800[3]
McGee Creek Lake+	McGee Creek	WS, FC, R	86,000	109,800	31,800[4]
Pine Creek Lake	Little River	WS, FC, WQ, FW	388,100	70,500[5]	134,400[5]
SUBTOTAL			1,861,400	875,000	686,024

(Continued)

NAME OF SOURCE	STREAM	PURPOSE*	FLOOD CONTROL STORAGE ACRE FT.□	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
		AUTHORIZED			
Boswell Lake	Boggy Creek	WS, FC, R, FW	1,096,000	1,243,800	621,400
Hugo Lake ultimate development	Kiamichi River	WS, FC, WQ, R, FW	651,800	284,300	137,000[6]
Lukfata Lake	Glover Creek	WS, FC, R, FW	208,600	37,500[7]	59,400[7]
Tuskahoma Lake	Kiamichi River	WS, FC, R, FW	138,600	231,000	224,000
SUBTOTAL			2,095,000	1,796,600	1,041,800
TOTAL			3,956,400	2,671,600	1,727,824
		POTENTIAL			
				CONSERVATION STORAGE	
Ada	Sandy Creek	WS, R	0	115,000	23,500
Albany	Island Bayou	WS, FC, R	55,100	85,200	35,800
Broken Bow reregulation structure[8]	Mountain Fork River		—	—	289,000[8]
Buck Creek	Buck Creek	WS, FC, R	36,300	48,300	56,000
Caney Mountain	Little River	WS, FC, R	105,100	530,000	280,000
Chickasaw	Chickasaw Creek	WS, FC, R	22,000	36,000	17,900
Durant	Blue River	WS, FC, R	232,200	147,000	134,400
Finley	Cedar Creek	WS, FC, R	63,300	210,600	95,200
Kellond	Ten Mile Creek	WS, FC, R	43,300	133,000	56,000
Lukfata Modification	Glover Creek		—	—	175,800[9]
Parker	Muddy Boggy Creek	WS, FC, R	115,400	114,650	47,000
Ravia	Mill Creek	WS, R, FW	0	45,000	19,000
Tupelo	Clear Boggy Creek	WS, FC, R, FW, I	177,300	302,550	100,800
TOTAL			850,000	1,767,300	1,330,400
TOTAL YIELD					3,058,224

*WS-Municipal Water Supply, FC-Flood Control, WQ-Water Quality, P-Power, R-Recreation, FW-Fish and Wildlife, I-Irrigation, N-Navigation.

□Although flood control storages are shown for potential sites, further studies will be required to determine the amount of flood control storage than can be economically justified as a project purpose.

+ Under Construction

[1]Total yield of Atoka Lake is 65,000 acre-feet per year. The 1,224 acre-feet per year yield shown above is allocated to the southeast region. The other 63,776 acre-feet per year is allocated to Oklahoma City in the central region.

[2]Includes water quality control storage of 95,000 acre-feet which yields 123,200 acre-feet per year. Broken Bow Lake also has 317,600 acre-feet of hydroelectric power storage.

[3]Includes water quality control storage of 74,000 acre-feet which yields 100,800 acre-feet per year.

[4]Total yield of McGee Creek is 71,800 acre-feet per year. The 31,800 acre-feet per year yield shown above is allocated to the southeast region. The remaining 40,000 acre-feet per year is allocated to Oklahoma City in the central region.

[5]Includes water quality control storage of 21,100 acre-feet which yields 49,320 acre-feet per year.

[6]Potential additional yield after Clayton and Tuskamona are constructed.

[7]Yield at original authorized dam site includes 13,230 acre-feet for fishery mitigation and recreation which yields 22,400 acre-feet per year.

[8]This is the approximate yield that could be developed from hydropower releases from Broken Bow.

[9]Additional yield with modification at recently considered downstream dam site.

8,000 acre-feet for downstream releases; and 3,800 acre-feet reserved for future needs. Water allocated to Oklahoma City will be transported to Lake Stanley Draper via Lake Atoka through the existing Atoka pipeline.

Funding for the Bureau of Reclamation to begin land acquisition was approved by Congress for FY 1980. Completion time of the project is expected to be four to five years.

Major Municipal Lakes

Atoka Lake, on North Boggy Creek four miles north of the City of Atoka, serves as a major water supply source for Oklahoma City, the water being transported out of basin by a 60-inch pipeline to Lake Stanley Draper in southeast Oklahoma City. Built in 1964 by the City of Oklahoma City, the pipeline initially had a 60 mgd capacity, but a recent $10 million modification increased the capacity to 90 mgd to meet the city's escalating water needs. The lake also provides water supply to the City of Atoka.

Upon completion of McGee Creek Reservoir, Atoka Lake will receive water from that reservoir for subsequent further transfer via the existing pipeline to Oklahoma City. The water is of very good quality.

Soil Conservation Service Projects

The Soil Conservation Service has planned and engineered construction of a number of flood control structures in the Southeast Planning Region in conjunction with its watershed programs. Although primary emphasis in on protection of watershed drainage areas and reduction of floods in productive bottomlands, in recent years increased emphasis has been placed on multipurpose structures to provide storage for municipal, irrigation and recreation uses.

The City of Coalgate is presently using a Soil Conservation Service multipurpose flood control structure as a source of water supply. Potential SCS multipurpose sites are also being considered for development by the Cities of Durant and Antlers.

Authorized Development

There are three reservoirs authorized for construction by the Corps of Engineers in the southeast region.

Boswell Lake is authorized for construction on Boggy Creek, three miles west of Soper in Choctaw County. The project is authorized to include 1,096,000 acre-feet of flood control storage. Dependable water supply yield is estimated at 621,400 acre-feet per year.

The quality of water to be impounded in Boswell Lake is rated good and, although hard, it will be suitable for municipal and most industrial purposes.

Lukfata Lake is authorized for construction on Glover Creek, approximately 13½ miles north of Glover in McCurtain County. It will provide water of excellent quality.

In 1977 the Lukfata project was jeopardized by the discovery of the Leopard Darter, a fish species classified as a threatened species, and it was determined that the project would adversely affect the Darter's habitat. As a result, Congress withdrew construction funds and the project remains inactive.

Tuskahoma Lake is authorized for construction on the Kiamichi River in Pushmataha and LeFlore Counties. The dam site is located one mile south of the town of Albion. Water proposed for impoundment is of high quality and suitable for general municipal and industrial purposes.

Potential Development

The high rate of precipitation and the abundance of geographically suitable dam sites make the southeast region appropriate for extensive water resource development. Although a virtually unlimited number of potential dam sites exists, those listed in Figure offer the greatest potential for multipurpose development. The studies that provided the bases for their selection ranged in complexity from simple appraisals or preliminary local assessments to larger and more comprehensive feasibility level investigations.

STREAM WATER RIGHTS

As of February 20, 1979, there had been issued 560 vested stream water rights and permits for the appropriation of 812,820 acre-feet of water per year from the rivers, streams and lakes in the Southeast Planning Region. The totals by county and by use are shown in Figure 37 .

Ground Water

Several major ground water basins exist within the boundaries of the Southeast Planning Region. The rock units that comprise these major basins are the Arbuckle Group, sandstones of the Simpson Group, Antlers Sandstone and various alluvium and terrace deposits. The locations of these formations are shown in Figure 28 .

Ground water resources supply moderate quantities of water for domestic, municipal, industrial and irrigation uses.

Arbuckle Group (Cambrian-Ordovician) consists of broad areas of limestone and dolomite exposed over a 200-square mile area in southwestern Pontotoc and northwestern Johnston Counties. The several thousand feet of limestone and dolomite show high permeability resulting from fractures, joints and solution channels formed in the rocks, conditions causing the accumulation and circulation of large quantities of water. Depth to water ranges from 50 feet to more than 100 feet, but generally is less than 100 feet. Well yields are commonly 200 to 500 gpm and as great as 2,500 gpm.

Although hard and of the calcium bicarbonate type, the water is suitable for most purposes because of its low content of dissolved solids, consisting mainly of sulfates and chlorides.

Present development is sparse, but this basin offers a major potential source of water.

Simpson Group (Ordovician) is a series of sandstone beds totaling 300

FIGURE 37 STREAM WATER RIGHTS

COUNTY	MUNICIPAL		INDUSTRIAL		IRRIGATION		SECONDARY OIL RECOVERY		COMMERCIAL		RECREATION		TOTAL	
	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated
Atoka	9	186,188	2	12,000	38	9,556	—	—	—	—	2	216	51	207,960
Bryan	4	8,500	1	17	128	50,042	1	2,820	1	500	1	7,000	136	68,879
Choctaw	3	80,500	1	32,000	47	32,380	—	—	—	—	2	290	53	145,170
Coal	2	1,645	3	447	21	2,198	—	—	—	—	—	—	26	4,290
Johnston	3	2,746	3	55	58	62,405	—	—	1	25	1	1,845	66	67,076
McCurtain	7	51,464	5	95,703	80	34,125	—	—	2	16,025	3	370	97	197,687
Pontotoc	1	3,358	2	7,077	35	10,278	—	—	1	23	1	60	40	20,796
Pushmataha	5	7,825	—	—	82	16,816	—	—	—	—	4	3,681	91	28,322
Total	34	342,226	17	147,298	489	217,800	1	2,820	5	16,573	14	13,462	560	740,180

These tabulations reflect the total water rights issued by the Board as of a specific date and are not an accurate reflection of the actual amount of water presently being put to use, and are subject to reduction or cancellation from continued non-use. The data indicate prevalent trends of beneficial water use by county and region.

feet in thickness and cropping out in a 60-square mile area of northeastern Johnston County and smaller areas in central and southeastern Pontotoc County. The sandstone is fine grained and loosely cemented, yielding water freely to wells. Most wells are shallow, with an estimated depth to water of 400 feet. However, southwest of Ada, wells tap the sandstones at a depth of 1,600 feet. Yields are 125 to 500 gpm, averaging 200 gpm. Quality of water is potable in the outcrop area, but deteriorates downdip from the outcrop. Due to its small areal extent, this ground water basin is not as significant as the Arbuckle Group.

Antlers Sandstone (Cretaceous) is part of the large coastal plain deposits which crop out in the southern half of the region. The Antlers Aquifer, which consists of up to 900 feet of friable sandstone, silt, clay and shale, crops out in a 1,500-square mile area in parts of Atoka, Bryan, Choctaw, Johnston, McCurtain and Pushmataha Counties. It underlies about 3,500 square miles. Precipitation ranges from 34 to 50 inches per year across the outcrop area, which is receptive to high rates of infiltration. The average saturated thickness of the sand is 250 feet.

Aquifer tests indicate the average transmissivity is 1,480 feet per day and the average storage coefficient is 0.0005. High capacity wells tapping the aquifer commonly yield 100 to 500 gpm, with the maximum yield having been measured at 1,700 gpm. Little water is used from the aquifer because of the abundance of surface water in the area.

Actual recharge rates are estimated to be approximately six inches per year, representing about 15 percent of the average annual precipitation of 42 inches. The total annual recharge to the aquifer from precipitation is an estimated 480,000 acre-feet of water.

Water in the Antlers Aquifer in Oklahoma is discharged naturally through springs and seeps, evaporation, transpiration by plants, underflow out of Oklahoma to the south and southeast and, in the artesian portion of the reservoir, by upward movement of water through less permeable confining strata.

Water is discharged artificially by pumpage and by flowing artesian wells. In 1975 estimated ground water withdrawals from the aquifer totaled 7,000 acre-feet.

Water quality throughout the central and northern part of the aquifer is generally acceptable for municipal use. A few wells, however, yield water containing concentrations of iron and manganese exceeding the recommended limits. In general, water quality tends to degrade downdip. In some areas water in the upper part of the aquifer contains less than 1,000 mg/L dissolved solids, while water in the lower part contains somewhat more.

Water from the Antlers Aquifer varies in its chemical composition, usually being of the sodium bicarbonate type in the outcrop area, although in isolated areas immediately downdip, it may be of the calcium sulfate or calcium bicarbonate type. As the water moves further downdip, it changes to a sodium chloride type. Based on the analyses available, most of the wells yield water with a dissolved solids concentration of less than 500 mg/L.

GROUND WATER DEVELOPMENT

Ground water is an abundant natural resource in the region and present development could be greatly expanded. However, certain factors do present constraints: small areal extent of the basins (with the exception of the Antlers Sandstone); topography unfavorable to irrigation; lack of data concerning hydraulic characteristics of the basins; and lack of water quality information such as locations of fresh water/salt water interface zones.

Use of ground water for municipal, industrial and rural purposes can be expected to increase because southeastern Oklahoma is rapidly attracting industries that require moderate quantities of good quality water. Because large amounts of

precipitation fall in the area, demand for irrigation water will probably remain limited. Rural water usage may increase rapidly as industry develops, but rural wells will be widely spaced, pumping for short periods at rates of five to 10 gpm, and recharge from precipitation should nullify most of the effects of pumping.

Ground water development has occurred predominantly in two of the four major basins: the alluvium and terrace deposits and the Antlers Sandstone. Of the 221 municipal, industrial and irrigation wells in the region, 111 are in the alluvium and terrace deposits. The area most favorable for the development of wells is along the Red River, where wells commonly yield several hundred gallons per minute. The most productive sites are those in areas with the greatest saturated thickness and the coarsest material.

The Antlers Sandstone, second in importance of development, has 89 municipal, industrial and irrigation wells in parts of Atoka, Bryan, Choctaw, Johnston, McCurtain and Pushmataha Counties producing yields of a few gallons per minute to more than 650 gpm. The Arbuckle and Simpson Group ground water basins have experienced only sparce development, with 21 municipal, industrial and irrigation wells recorded, although well yields often exceed 200 gpm.

FIGURE 39 PRESENT AND PROJECTED WATER REQUIREMENTS (In 1,000 Af/Yr)

Use	Present	1990	2000	2010	2020	2030	2040
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

GROUND WATER RIGHTS

As of July 1979, a total of 115 ground water permits had been issued in the region for the appropriation of 53,907 acre-feet of water per year. These permits allocate ground water for municipal, industrial, irrigation, secondary oil recovery and commercial purposes.

Data from the ground water rights files of the Oklahoma Water Resources Board are shown in Figure 38 . Prior rights have not yet been determined for any county in the Southeast Planning Region.

PRESENT WATER USE AND FUTURE REQUIREMENTS

Current water requirements for the Southeast Planning Region are estimated to be 101,700 acre-feet per year with over half of this amount being used for industrial purposes. The primary industrial user is the Weyerhauser Company, a paper and pulp processing firm in McCurtain County which operates three plants employing 1,771 persons. Irrigation is the next largest user, with municipal use ranking third.

Municipal water projections, which include rural water needs, indicate that the southeast region will require 56,100 acre-feet annually by the year 2040, an increase of over two and one-half times the present use of 16,500 acre-feet. The Cities of Ada, Durant, Hugo and Idabel will probably consume most of this increase, as they are expected to lead the planning region to a total population growth of over 250,000 by the year 2040.

There are 49 rural water districts in the region serving an estimated 40,000 people. Increasing water demands of small towns and rural areas are expected to require expansion of existing systems and the formation of new districts. By the year

FIGURE 38 GROUND WATER RIGHTS

	MUNICIPAL		INDUSTRIAL		IRRIGATION		SECONDARY OIL RECOVERY		COMMERCIAL		RECREATION		TOTAL	
COUNTY	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated
Atoka	3	634	—	—	—	—	—	—	—	—	—	—	3	634
Bryan	7	4,579	—	—	24	5,088	—	—	1	50	1	10	33	9,727
Choctaw	4	3,440	1	1,240	4	1,300	—	—	—	—	1	60	10	9,020
Coal	2	95	—	—	1	500	—	—	1	160	—	—	4	755
Johnston	5	874	1	703	9	3,521	—	—	2	100	—	—	17	5,198
McCurtain	3	392	1	160	2	390	—	—	—	—	—	—	6	942
Pontotoc	5	12,318	3	7,425	30	5,170	2	2,600	1	20	—	—	41	27,533
Pushmataha	—	—	—	—	1	100	—	—	—	—	—	—	1	100
Total	29	22,332	6	10,708	71	17,869	2	2,600	5	330	2	70	115	53,909

These tabulations reflect the total water rights issued by the Board as of a specific date and are not an accurate reflection of the actual amount of water presently being put to use. The data indicate prevalent trends of beneficial water use by county and region.

2040, almost 70,000 citizens will be served by rural water districts in this planning region.

Industrial water requirements are presently 71,300 acre-feet annually. The region's abundance of water and other natural resources continue to attract new industries which could drive 2040 projected water demands up to 172,200 acre-feet annually. The largest industrial users in the region are firms involved in pulp and paper processing as well as meat processing and packaging.

Although there are no existing demands for water for power purposes, a steam powered electric generating plant is currently under construction near Hugo which will require water for cooling purposes. The 400 megawatt plant being built by Western Farmers Electric Cooperative is scheduled for completion by April, 1982. The plant will have a gross annual water usage of 8,400 acre-feet (7.5 mgd) of water from Hugo Lake with a discharge of 1,344 acre-feet per year (1.2 mgd) for a consumptive use of 7,056 acre-feet per year (6.3 mgd). Total cooling water for power generation in the region is projected to be 38,000 acre-feet annually by 2040.

A 1977 Irrigation Survey by the Oklahoma State University Cooperative Extension Service indicated there were 182 farms encompassing 21,488 irrigated acres in the region. Present estimated use is 13,900 acre-feet per year and projections indicate that 282,400 acres requiring 282,400 acre-feet of water may be irrigated by the year 2040. With the region's abundant rainfall, irrigation will only be used as a supplemental supply.

FIGURE 40 SURPLUS WATER AVAILABILITY (In 1,000 Af/Yr)

Source	Total Yield	Local Allocation	Potential Surplus
Atoka	65.0	1.2	63.8
Broken Bow	196.0	47.3	148.7
Hugo (Initial)	165.8	32.8[1]	133.0
Pine Creek	134.4	102.4[2]	32.0
Clayton	156.8	11.2	145.6
McGee Creek	71.8	7.0	64.8
Tuskahoma	224.0	2.2	221.8
Albany	35.8	32.5	3.3
Parker	47.0	15.5	31.5
Tupelo	100.8	67.5	33.3
Ground Water & SCS & Municipal Lakes	981.4	284.0	697.4
Subtotal	2178.8	603.6	1575.5
Other Potential Sources			
Hugo (Stage 2)	91.8	—	91.8
Hugo (Stage 3)	44.8	—	44.8
Boswell	621.4	—	621.4
Lukfata (Ultimate)	212.8	—	212.8
Kellond	56.0	—	56.0
Buck Creek	56.0	—	56.0
Finley	95.2	—	95.2
Caney Mountain	280.0	—	280.0
Durant	134.4	—	134.4
Ada	23.0	—	23.0
Ravia	19.0	—	19.0
Chickasaw	18.0	—	18.0
Broken Bow (Power Releases)	289.0	—	289.0
Subtotal	1941.4	—	1941.4
TOTAL	4120.0	603.6	3516.6

[1]Includes 14,560 acre-feet per year for downstream releases.

[2]Includes 40,320 acre-feet per year for water quality control and 33,600 acre-feet per year presently under contract.

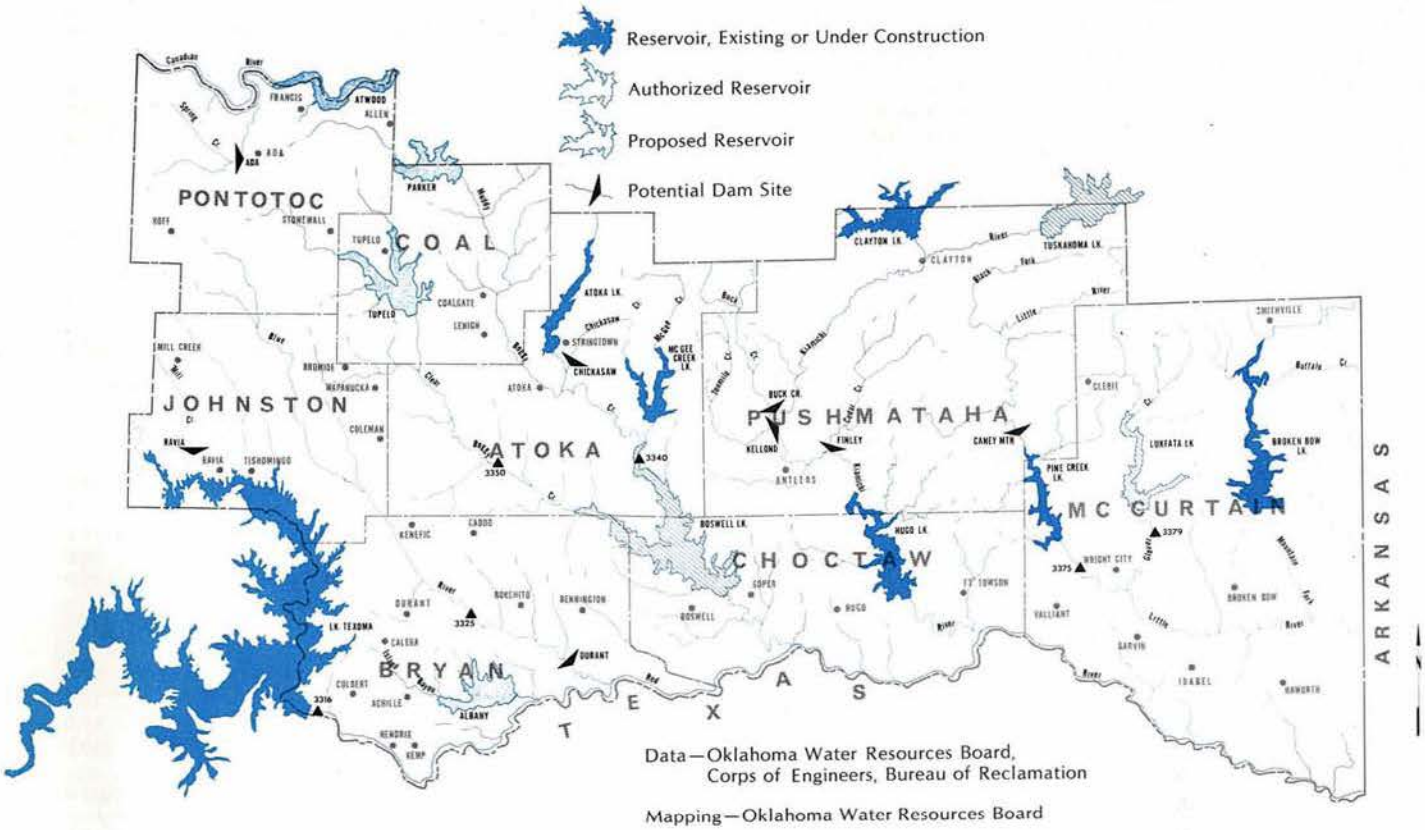
PROPOSED REGIONAL PLAN OF DEVELOPMENT

Abundant rainfall and runoff provide the Southeast Planning Region with the potential for extensive water resources development. Consequently, the 8-county area currently has three major reservoirs and two additional reservoirs under construction, making great amounts of good quality water available. However, much of the area suffers inadequate distribution problems which limit potential economic development and periodic flooding throughout the region endangers human lives and threatens property destruction. To meet the region's future water needs, efforts should be directed toward controlling the region's flood waters and developing local water supplies.

Existing ground and stream water sources can supply approximately 102,000 acre-feet per year and proposed local sources could provide the additional water to meet the region's projected 2040 water requirements with an annual surplus of approximately 1.6 million acre-feet. Other stream water sources not included in the local plan could provide an additional two million acre-feet, achieving a total potential annual surplus of over 3.5 million acre-feet. (See Figure 40.)

The Oklahoma Comprehensive Water Plan proposes a regional plan of development which includes utilization of existing sources, development of new reservoirs and increased usage of available ground water supplies, as well as construction of appropriate municipal, industrial and irrigation distribution facilities. (See Figure 41 .) Existing Broken Bow, Hugo and Pine Creek Lakes have excellent quality water available for beneficial use, however, water supply storage in these lakes is presently used only sparingly. With the construction of pertinent distribution facilities or trunk lines, these

FIGURE 41 PROPOSED PLAN OF DEVELOPMENT



lakes could supply most of the southeastern area's future water needs.

McGee Creek Reservoir, under construction in Atoka County, will not only provide water to the local area, but also supply water to central Oklahoma. Clayton Reservoir, also under construction, and Tuskahoma Lake, authorized for construction in Pushmataha and LeFlore Counties, would serve the region and also be a potential source of supply for areas outside.

Three proposed reservoirs, Albany, Parker and Tupelo, would be needed to supply water to the western part of the region. Albany and Parker would provide municipal and industrial water, while Tupelo would supply water for municipal, industrial and irrigation purposes. Increased ground water development could supply most of the region's irrigation demands, except in Coal County where Tupelo would be located. A total of 282,500 acres are projected to be irrigated requiring 282,500 acre-feet of water per year based on one acre-foot of water per acre.

Municipal and industrial transmission lines to Pushmataha and McCurtain Counties and irrigation distribution facilities from Tupelo Reservoir are included in the proposed Regional Plan of Development.

Figure 42 shows the region's eight counties, their planned sources of supply and projected 2040 wate demands. As indicated, the propose supplies would satisfy projecte demands.

Preliminary cost estimates fo development of the local plan ar shown in Figure 43. Total construc tion cost is estimated at almost $29 million, which includes the cost o storage in existing, authorized an proposed reservoirs, increase ground water development and ap propriate distribution facilities. An nual OMR&E costs are estimated a approximately $4 million, with tota average annual equivalent costs o $15.3 million.

FIGURE 42 SUPPLY AND DEMAND ANALYSIS
PROPOSED PLAN OF DEVELOPMENT
(In 1,000 Af/Yr)

Source	Atoka	Bryan	Choctaw	Coal	Johnston	McCurtain	Pontotoc	Pushmataha	Total
				COUNTY					
				Municipal and Industrial Component[1]					
Ground Water & SCS & Municipal Lakes	1.2	1.0	1.0	3.0	5.0	0.8	6.7	—	18.7
Broken Bow	—	—	—	—	—	47.3	—	—	47.3
Hugo	—	—	18.3	—	—	—	—	—	18.3
Pine Creek	—	—	—	—	—	62.0	—	—	62.0
Clayton	—	—	—	—	—	—	—	11.2	11.2
McGee Creek	7.0	—	—	—	—	—	—	—	7.0
Tuskahoma	—	—	—	—	—	—	—	2.2	2.2
Albany	—	32.5	—	—	—	—	—	—	32.5
Parker	—	—	—	15.5	—	—	—	—	15.5
Tupelo	—	—	—	—	—	—	50.3	—	50.3
Local Streams	—	—	—	—	—	1.2	—	—	1.2
M & I Supply	8.2	33.5	19.3	18.5	5.0	111.3	57.0	13.4	266.2
				Irrigation Component					
Ground Water	32.8	68.1	42.5	—	33.8	44.6	27.1	16.4	265.3
Tupelo	—	—	—	17.2	—	—	—	—	17.2
Irrigation Supply	32.8	68.1	42.5	17.2	33.8	44.6	27.1	16.4	282.5
TOTAL LOCAL SUPPLY	41.0	101.6	61.8	35.7	38.8	155.9	84.1	29.8	548.7
2040 DEMAND	41.0	101.6	61.8	35.7	38.8	155.9	84.1	29.8	548.7

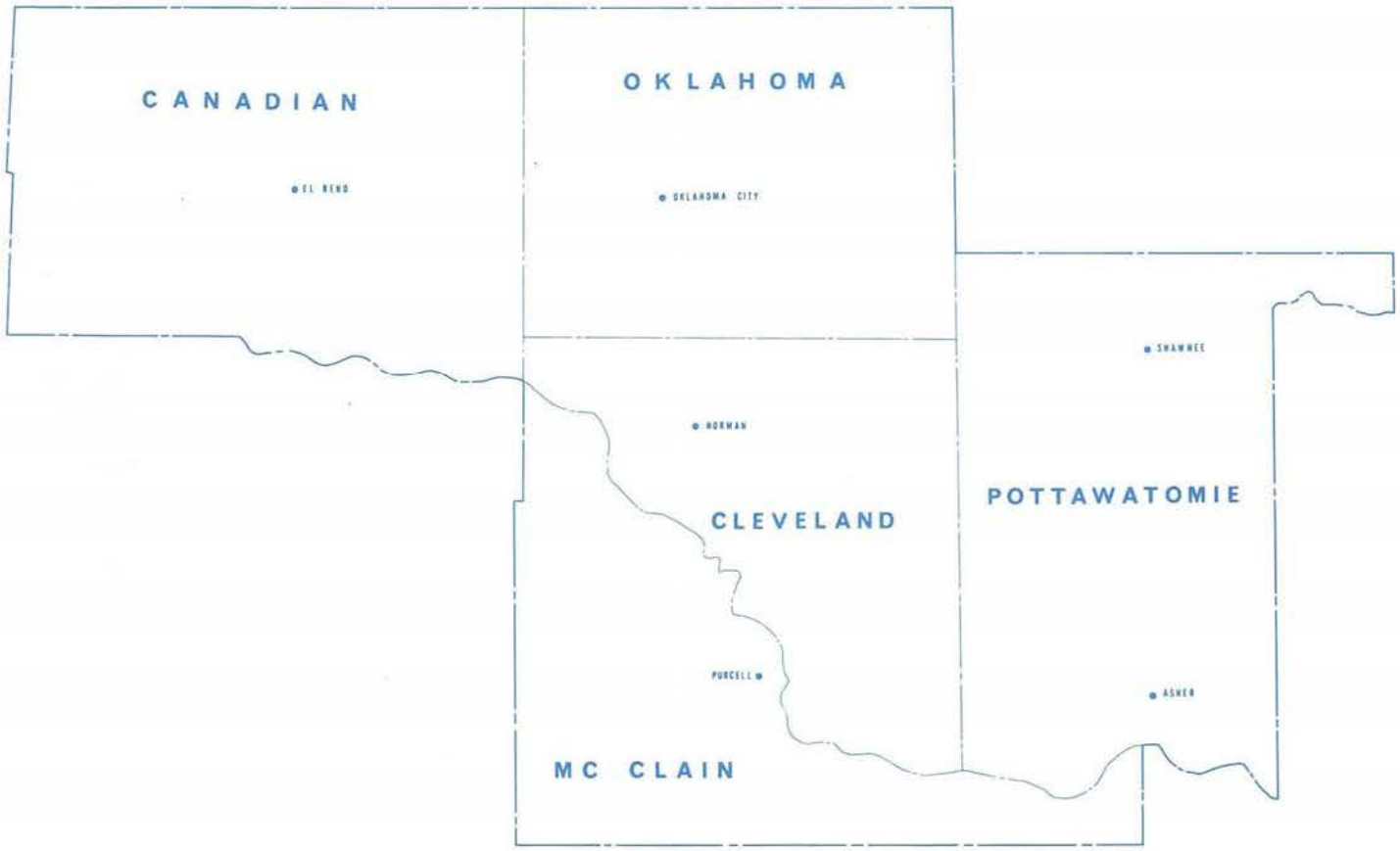
[1]Includes cooling water (power) demands.

FIGURE 43 SUMMARY OF COSTS[1]
PROPOSED PLAN OF DEVELOPMENT
(In $1,000)

FACILITY	CONSTRUCTION COST	AVERAGE ANNUAL OMR&E[2]	TOTAL AVERAGE ANNUAL EQUIVALENT COST[3]
M & I Water Supply System			
Water Supply Storage[4]	$112,300	$ 510	$ 5,670
Ground Water Development	100	20	25
Water Conveyance Facilities	10,100	375	875
Terminal Storage	9,700	160	710
Subtotal	$132,300	$ 1,065	$ 7,280
Irrigation System (Excluding Wells)			
Water Supply Storage	$12,400	$ 5	$ 80
Terminal Storage	4,000	70	365
Distribution System	37,200	200	1,465
Subtotal	$ 53,600	$ 275	$ 1,910
Irrigation Wells	$103,900	$ 2,670	$ 6,145
Subtotal	$103,900	$ 2,670	$ 6,145
TOTAL	$289,800	$ 4,010	$15,335

[1]Based on January 1978 prices levels and a 100-year period of analysis.
[2]Based on a 30-mil power rate.
[3]Includes interest and amortization as well as average annual OMR&E expenses.
[4]Based on 3 1/8 percent interest for Hugo Lake, 3 1/4 percent interest for Clayton and Tuskahoma Reservoirs, and 6 1/8 percent interest for McGee Creek Reservoir. Cost of McGee Creek is based on 28,000 acre-feet per year (39 percent of 71,800 total yield) and reflects allocated cost of total project.

CENTRAL PLANNING REGION



The Central Planning Region consists of Canadian, Cleveland, McClain, Oklahoma and Pottawatomie Counties, an area of 3,544 square miles. The region exhibits a sharp contrast in development, with open farmlands in the west and heavy urban and industrial growth in the center and eastern portions.

The terrain varies from red, sandy prairies in western areas to wide alluvial plains in the east. Elevations range from approximately 1,450 feet above mean sea level in western Canadian County to 1,000 feet in southeastern Pottawatomie County. Most of the region is drained by the North Canadian and (South) Canadian Rivers. Other major streams in the area are the Little River and upper reaches of the Deep Fork.

Population estimates for the year 1977 for the region showed a total of 768,500 in the 5-county area, compared to 699,092 in 1970; the 10 percent increase corresponding with the statewide average.

Between 1970 and 1977 per capita personal income rose from $3,209 to $5,795, while average annual covered employment increased from 167,526 to 264,397, with most of those employed in wholesale and retail trade, personal services and manufacturing.

Even though Oklahoma City's population is not presently growing as fast as in the past, the Oklahoma City metropolitan area's population is increasing rapidly due to the accelerated growth of suburbs such as Edmond, Moore, Yukon and Mustang. This growth has brought with it a greater demand for municipal and industrial water. Continued economic and social growth is anticipated, assuming the metropolitan Oklahoma City area is able to augment its available water supplies.

Industry plays an important role in the economy of this region, fostering associated water and air pollution problems. Measures to combat such environmental problems must be addressed in area planning if prosperity is to continue.

The Central Planning Region has a climate characterized by pronounced and rapid changes in the weather, but only gradual seasonal changes. Thunderstorms producing high rainfall intensities over limited areas frequently occur during the late spring and summer months. Fall and winter storms usually last longer, with lower intensities of precipitation over larger areas.

Prevailing winds across the region are generally southerly, with northerly winds dominant during January and February. Numerous spring and summer tornadoes throughout the area have caused it to be nicknamed "tornado alley."

Figure 9 shows average annual lake evaporation ranging from 65 inches in the northwest to 57 inches in the southeast, a rate greatly exceeding the average annual precipitation. High winds and hot temperatures combine to produce high losses on area lakes, so increased storage capacities are needed to compensate for these losses in order to obtain required yields. Mean annual temperatures are between 60° and 62°F throughout the region, with the highest temperature recorded at 116°F in Shawnee and the lowest -17°F in Oklahoma City. 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, is about 210 days.

As shown in Figure 8 , average annual precipitation varies from 28 inches in the northwest to 38 inches in the southeastern portion. May is the wettest month of the year, providing 15 percent of the year's total moisture, and spring is the wettest season, accounting for 33 percent of the annual total. Snowfall in the area averages approximately nine inches annually.

Most flooding in the central region is attributed to intense thunderstorms which cause flood waters to rise rapidly. Flooding frequently occurs in street underpasses and other low-lying metropolitan areas where city storm drains cannot accommodate such concentrations of water. Although these flood waters usually recede within a few hours, low areas along the engorged streams occasionally trap the excess waters for longer periods of time, inflicting severe damage to homes, streets or crops.

In May 1977, six to 8-inch rainfalls in three hours or less caused up to four feet of flooding along Little River at Tecumseh in the southeastern part of the region. Damages were estimated at approximately $2 million in the affected areas.

Serious flood and drainage problems exist along the Deep Fork Basin with major floods occurring on the average of twice each year. The Little River Basin experienced serious flooding problems until 1965, when Lake Thunderbird was completed by the Bureau of Reclamation.

The Corps of Engineers has made channel improvements along the North Canadian on its course through Oklahoma City, which have greatly decreased flooding in the metropolitan area. Smaller Soil Conservation Service watershed projects constructed under the Watershed Protection and Flood Prevention Act have also been effective in controlling flooding.

WATER RESOURCES

Stream Water

Extensive urbanization and industrialization of the Central Planning Region have directed the needs for water primarily to municipal and industrial uses, although limited irrigation does occur. Quality and quantity problems limit the amount of water available for beneficial uses, so Oklahoma City, the major water user in the area, has developed out-of-basin sources to supplement its supply of suitable water.

Average annual runoff from precipitation in the area ranges from two inches in the northwest to seven inches in the southeast, accounting for approximately 685,000 acre-feet of runoff each year. Discharge varies widely from this runoff as a result of diversions, consumption, regulation by storage and other factors. Low flows in the North Canadian and Deep Fork are dependent on Oklahoma City's sewage effluent.

A summary of streamflow records of the four U.S. Geological Survey gaging stations located within the region are presented in Appendix B, Figure 2 .

Inferior water quality in several major streams in this region restricts their use for most beneficial purposes. High mineral and nutrient contents render the natural flows of the (South) Canadian, North Canadian and Deep Fork Rivers only marginal for municipal and industrial use, however with the construction of a reservoir, such as Arcadia on the Deep Fork, the water quality is sufficiently improved for most beneficial uses. Upper Little River is of good quality and can be used for any beneficial purpose. Water quality analysis data for selected U.S.G.S. monitoring stations and the station locations are shown in Appendix B, Figures 4 and 5 .

The Canadian River in this region is generally of poor quality due to high nutrient and mineral levels. The significant degradation in quality below the Oklahoma City metropolitan area is caused by nutrient contributions from both point and nonpoint sources.

The North Canadian River is very turbid and of generally poor quality due to high nutrient and mineral levels. Oklahoma City's effluent greatly contributes to the North Canadian's poor water quality. However, the marked degree of degradation occurring at Harrah does improve further downstream.

The Upper Little River is a high quality stream with low mineralization, nutrification and turbidity. The water is very soft, and metal toxicity does not appear to be a problem. As development continues at the headwaters of the river, increased nutrification will contribute to an accelerated rate of euthrophication in Lake Thunderbird, which could potentially present a serious problem.

The Deep Fork River in the Central Planning Region exhibits fair water quality, with occasional high nutrient levels and moderate mineralization from point and nonpoint sources in the Oklahoma City metropolitan area. The water is hard and slightly alkaline, and becomes increasingly turbid as it flows downstream into Eufaula Lake.

In order to meet the national goals of fishable, swimmable waters by 1983, it is anticipated that Oklahoma City will need to subject its effluent to tertiary treatment. With such treatment, the water in these rivers could potentially be used for municipal and industrial purposes.

STREAM WATER DEVELOPMENT

Industrial contamination from upstream sources and urban runoff have rendered the quality of the water in the region poor for municipal use, so stream water development has been limited to a few reservoirs in which the water quality is suitable for most beneficial uses.

There are six major lakes existing in the central area; Draper, Hefner, Overholser, Thunderbird, Shawnee and Arcadia, providing a combined water supply yield of 146,200 acre-feet for municipal and industrial purposes.

Major Reservoirs

Lake Thunderbird, constructed by the Bureau of Reclamation, is the only federal lake in the region. It is located on Little River about eight miles east of Norman in Cleveland County. The quality of water in Thunderbird is excellent, making it suitable for all beneficial purposes. The Central Oklahoma Master Conservancy District has allocated 21,700 acre-feet of water from Thunderbird to supply the municipal and industrial needs of Norman, Midwest City and Del City. The lake is a major recreational area in central Oklahoma.

Modification of Lake Thunderbird to augment the water supply storage is currently under study by the Bureau of Reclamation. Through such modification, additional water could be impounded from out-of-basin sources to provide a greater yield to meet the future water needs of central Oklahoma.

Arcadia Lake was authorized in 1970 for construction by the Corps of Engineers for the purposes of water supply, flood control and recreation. The project is currently under construction on Deep Fork Creek in far northeast Oklahoma County. The full yield, 12,320 acre-feet, has been appropriated to the City of Edmond for municipal and industrial water supply purposes.

Funding was approved by Congress to allow the Corps of Engineers to begin acquiring land for the project in FY 1980. Completion is expected approximately five years following site acquisition.

Major Municipal Lakes

There are four major municipal lakes located in the central area, three supplying the Oklahoma City area and one supplying the City of Shawnee.

Lake Stanley Draper, located on East Elm Creek, was built by the City of Oklahoma City in 1962. Draper Lake is a terminal storage reservoir containing 100,000 acre-feet of water supply storage with an annual yield of 41,000 acre-feet provided by water pumped from Atoka Lake in southeastern Oklahoma. Water quality is excellent for any beneficial use and the lake is used for a variety of recreational activities.

Lake Hefner, built by the City of Oklahoma City on Bluff Creek in far northwest Oklahoma City, is made unique by its 1,155-acre drainage area, which is so small it aids little in its replenishment. Thus, the principal inflow is through diversion of water from the North Canadian River, often originating with releases from Canton Lake upstream flowing by gravity through the Bluff Creek canal to Lake Hefner. Water quality of the lake is fair, allowing its use for most beneficial purposes.

Lake Overholser, constructed by the City of Oklahoma City, is located on the North Canadian River. A channel along the east side of the lake allows poor quality water during periods of low flow to bypass the lake. The yield of Lake Overholser is also supplemented by Canton Lake releases. Because the water quality of the reservoir is fair, it may be used for most beneficial purposes including recreation.

Shawnee Lake, which is actually two separate lakes connected by a 10-foot deep canal near the two dams, was built by the City of Shawnee on South Deer Creek seven miles west of the city. The larger lake was built in 1935 with a storage capacity of 22,600 acre-feet and the smaller one in 1960 with 11,400 acre-feet of storage. Combined yield from the two lakes is 4,400 acre-feet.

Soil Conservation Service Projects

Numerous Soil Conservation Service flood control structures have been planned and constructed in the Central Planning Region. In addition to watershed protection and flood prevention, these lakes are used for municipal and irrigation water supply and recreational purposes. Multipurpose sites in the area provide excellent recreation facilities for the Cities of El Reno and Lindsey, and the City of Maysville utilizes a multipurpose structure for its water supply.

Of the 31 SCS watersheds in the area, 16 are completed or under con-

FIGURE 44 STREAM WATER DEVELOPMENT

NAME OF SOURCE	STREAM	PURPOSE*	FLOOD CONTROL STORAGE ACRE FT.	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
		EXISTING OR UNDER CONSTRUCTION			
Arcadia Lake+	Deep Fork Creek	WS, FC, R	70,700	27,380	12,100
Draper Lake	East Elm Creek	WS, R	0	100,000	86,000[1]
Lake Hefner	Bluff Creek	WS, R	0	75,000	17,000[2]
Lake Overholser	North Canadian River	WS, R	0	17,000	5,000[2]
Lake Thunderbird	Little River	WS, FC, R	76,600	105,900	21,700
Shawnee Lakes	South Deer Creek	WS, R	0	34,000	4,400
TOTAL			147,300	359,280	146,200
		POTENTIAL			
				CONSERVATION STORAGE	
West Elm[3]	West Elm Creek	WS, R	0	103,600	0[3]
TOTAL			0	103,600	0
TOTAL YIELD					146,200

*WS-Municipal Water Supply, FC-Flood Control, WQ-Water Quality, P-Power, R-Recreation, FW-Fish and Wildlife, I-Irrigation, N-Navigation.

+ Under Construction

[1]Draper Lake is a terminal storage lake for water pumped from Lake Atoka via Atoka pipeline. McGee Creek Reservoir, currently under construction, will also supply water to Draper Lake. The 86,000 acre-feet per year yield is the capacity of the Atoka pipeline (90 mgd) minus evaporation losses.

[2]Yields do not include releases made from Canton Reservoir.

[3]Proposed terminal storage reservoir and develops no local yield.

struction; four are planned; and 11 have potential for development. See Figure 26.

Authorized Development

There are no other authorized projects in the Central Planning Region.

Potential Development

The potential for additional major stream water development projects in the Central Planning Region is limited by the number of suitable dam sites available, water availability and water quality considerations. The West Elm Creek site has been studied as a potential terminal storage reservoir to hold water conveyed from outside sources and will develop no appreciable yield of its own.

Increasing population and vigorous industrial development may cause the Central Planning Region to face severe water shortages that could retard future economic development. Alternative water supply sources must be made available if healthy development is to continue.

STREAM WATER RIGHTS

As of February 20, 1979 there were 267 vested stream water rights and permits issued by the Oklahoma Water Resources Board for the appropriation of 224,443 acre-feet of water per year from rivers, streams and lakes in the Central Planning Region. Stream water rights and use are shown in Figure 45 .

Ground Water

Two major ground water basins are located in central Oklahoma: the Garber-Wellington Formation and alluvium and terrace deposits. See Figure 28.

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. Water table conditions exist in the outcrop area of the ground water basin and artesian conditions exist where the Garber-Wellington is overlain by the Hennessey Group. Reported yields from wells range from 70 to 475 gallons per minute (gpm), and average 250 gpm. Chemical analyses of water from the basin indicate that hardness is greater in the upper part of the Garber-Wellington than in the lower portion. Overall, water quality is very good and little if any treatment is required to meet federal and state drinking water standards.

Alluvium and terrace deposits (Quaternary) occur in all five counties along the Canadian and North Canadian Rivers and the Deep Fork arm of the North Canadian. The deposits consist of interfingering lentils of clay, sandy clay, sand and gravel laid down by ancient streams. The coarse sand gravel in lower parts yields water to wells freely, while the upper part is usually fine-grained and less permeable silt or clay with corresponding lower yields. Maximum thickness of the deposits is 90 feet, with an average of 50 feet. Well yields range from less than 100 gpm to as much as 600 gpm; averaging 200 gpm. Hardness is the principal water quality problem, with some samples containing concentrations of more than 500 mg/L. Generally, the water is a calcium magnesium bicarbonate type.

GROUND WATER DEVELOPMENT

Development in the ground water basins of the Central Planning Region is extensive, with withdrawals from the Garber-Wellington beginning prior to 1900. At present, this ground water basin is the principal source of water for municipal and industrial purposes for many of the satellite communities of Oklahoma City. Alluvium and terrace deposits of the North Canadian River supply water to the cities of El Reno, Okarche, Geary and Calumet, with numerous industries and irrigation farmers also using these sources.

The Garber-Wellington has been studied by both the U.S. Geological Survey and the Oklahoma Water Resources Board, with the Board concentrating its study on the area between the North Canadian River and the Canadian River, which includes southern Oklahoma County, all of Cleveland County and the western half of Pottawatomie County. Congress has appropriated $1 million for additional studies by the Environmental Protection Agency that are scheduled to begin soon. Additional development of both the Garber-Wellington and alluvium and terrace deposits ground water basins is probable.

FIGURE 45 STREAM WATER RIGHTS

	MUNICIPAL		INDUSTRIAL		IRRIGATION		SECONDARY OIL RECOVERY		COMMERCIAL		RECREATION		TOTAL	
COUNTY	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated
Canadian	—	—	1	6,400	29	6,331	—	—	1	220	5	7,479	36	20,430
Cleveland	3	2,560	—	—	18	4,797	—	—	1	160	2	218	24	7,735
McClain	2	930	—	—	56	9,340	—	—	1	67	—	—	59	10,337
Oklahoma	2	77,300	3	21,914	43	7,720	—	—	2	741	13	516	63	108,191
Pottawatomie	3	7,405	—	—	79	14,016	—	—	1	15	2	299	85	21,735
Total	10	88,195	4	28,314	225	42,204	—	—	6	1,203	22	8,512	267	168,428

FIGURE 46 GROUND WATER RIGHTS

COUNTY	MUNICIPAL # of app.	MUNICIPAL acre-feet allocated	INDUSTRIAL # of app.	INDUSTRIAL acre-feet allocated	IRRIGATION # of app.	IRRIGATION acre-feet allocated	SECONDARY OIL RECOVERY # of app.	SECONDARY OIL RECOVERY acre-feet allocated	COMMERCIAL # of app.	COMMERCIAL acre-feet allocated	RECREATION # of app.	RECREATION acre-feet allocated	TOTAL # of app.	TOTAL acre-feet allocated
Canadian	12	8,883	9	12,460	175	47,655	—	—	9	2,279	3	614	208	71,901
Cleveland	13	43,206	1	36	40	11,357	5	2,694	11	8,684	3	307	73	66,284
McClain	11	1,878	2	424	29	8,225	—	—	2	614	—	—	44	11,141
Oklahoma	48	104,258	24	14,404	50	12,673	—	—	18	4,760	2	46	142	136,141
Pottawatomie	7	2,384	1	1	34	8,527	—	—	5	255	1	4	48	11,171
Total	91	160,609	37	27,325	328	88,447	5	2,694	45	16,592	9	971	515	296,638

These tabulations reflect the total water rights issued by the Board as of a specific date and are not an accurate reflection of the actual amount of water presently being put to use. The data indicate prevalent trends of beneficial water use by county and region.

GROUND WATER RIGHTS

As of July 1979 there were 515 ground water permits issued by the Oklahoma Water Resources Board for the appropriation of 296,638 acre-feet of water per year in the area. See Figure 46. Prior ground water rights have not been determined in this region, however, prior rights hearings are scheduled to begin on the Garber-Wellington aquifer in 1980.

PRESENT WATER USE AND FUTURE REQUIREMENTS

The Central Planning Region's 1977 population of 768,500 is projected to rise to 1,550,500 by the year 2040. The current population utilizes an estimated 227,600 acre-feet of water per year for all purposes, with a projected requirement of 819,700 acre-feet annually by 2040. The largest present water usage in the region is for municipal purposes, with industrial use being the next largest. Although municipal and industrial water presently account for over 75 percent of total present water demands, projections indicate an increasingly larger percentage of total water will be used as cooling water for power generation purposes.

Municipal and rural water district water consumption is presently 113,700 acre-feet annually. Due primarily to the anticipated future growth of the Oklahoma City metropolitan area, the Central Planning Region is projected to need 351,600 acre-feet annually for municipal purposes by the year 2040. There are presently 11 rural water systems serving 10,000 customers in the 5-county region, and as the rural areas develop, by 2040 an additional 20,000 people will require service from such districts.

Industries in the region currently use 55,600 acre-feet of water per year. The largest industrial use is in processing and packaging and automobile production. Future water use for industrial purposes is projected to be 272,600 acre-feet annually by 2040, with 54,880 acre-feet of such demand expected to be met by recycled wastewater.

Present utility demand for water is 18,500 acre-feet each year, however, the rapidly escalating demand for electricity in urban centers will cause utility cooling water demands to reach 120,400 acre-feet by 2040. Oklahoma Gas and Electric Company operates three generating plants in this region with a total net capability of 1,558 megawatts.

Most of the water used for irrigation purposes in the Central Planning Region is consumed in Canadian County, which accounts for 16,920 acres of the total 24,640 irrigated acres in the region. The estimated water use for irrigation is 39,800 acre-feet of water per year, primarily supplied from ground water pumped from alluvium and terrace deposits of the Canadian and North Canadian Rivers. Annual irrigation water requirements for a projected 50,000 acres are anticipated to be 75,100 acre-feet by 2040.

PROPOSED REGIONAL PLAN OF DEVELOPMENT

The Central Planning Region, the most populous region in the state, is expected to continue its rapid growth of recent years, particularly in Oklahoma City's suburban areas. Many of these suburbs purchase water from Oklahoma City, however, during summer months when water usage is highest, Oklahoma City often is forced to reduce its sale of water in order to meet local demands. Such seasonal demands have often precipitated temporary shortages requiring voluntary or involuntary rationing. Development of additional reservoir sites in the region is virtually precluded by poor water quality induced by natural and man-made pollutants.

Existing sources can supply 208,300 acre-feet per year from ground water, SCS and municipal lakes, and major reservoirs. Potential

FIGURE 47 PRESENT AND PROJECTED WATER REQUIREMENTS (In 1,000 Af/Yr)

Use	Present	1990	2000	2010	2020	2030	2040
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

local development and reuse of waste water could provide an additional 124,400 acre-feet per year, but as shown in Figure 48 , the central region could still experience a deficit of 487,000 acre-feet per year by 2040, which would have to be met from sources outside the region.

The Oklahoma Comprehensive Water Plan proposes a Regional Plan of Development to meet a portion of the region's future water needs. This plan, utilizing resources within the region, includes increased use of ground water, new SCS and municipal lakes and reuse of wastewater effluent. Ground water sources could yield an additional 46,600 acre-feet per year, and SCS and municipal lakes could annually provide 22,800 acre-feet. (See Figure 50 .) Extensive municipal and industrial development in the central region makes available large quantities of wastewater. An estimated 54,900 acre-feet of such effluent per year could be reused for industrial, cooling water (power) and irrigation purposes.

A total of 24,000 acres could be irrigated from the proposed development, based on 1.5 acre-feet of water per acre. Figure 48 shows the five counties in the Central Planning Region, their proposed supplies and 2040 water demands, and indicates that all counties will experience future water shortages of varying degrees.

FIGURE 48 SUPPLY AND DEMAND ANALYSIS PROPOSED PLAN OF DEVELOPMENT (In 1,000 Af/Yr)

Source	Canadian	Cleveland	McClain	Oklahoma	Pottawatomie	Total
			Municipal and Industrial Component[1]			
Ground Water & SCS & Municipal Lakes	25.4	21.5	19.1	—	17.6	83.6
Overholser & Hefner	—	—	—	22.0	—	22.0
Shawnee Lakes	—	—	—	—	4.4	4.4
Stanley Draper	—	—	—	86.0	—	86.0
Thunderbird	—	21.7	—	—	—	21.7
Arcadia	—	—	—	12.1	—	12.1
Wastewater Reuse	—	4.6	—	23.2	—	27.8
M & I Supply	25.4	47.8	19.1	143.3	22.0	257.6
			Irrigation Component			
Ground Water & SCS Lakes	12.6	—	13.4	6.5	15.5	48.0
Wastewater Reuse	20.0	7.1	—	—	—	27.1
Irrigation Supply	32.6	7.1	13.4	6.5	15.5	75.1
TOTAL LOCAL SUPPLY	58.0	54.9	32.5	149.8	37.5	332.7
2040 DEMAND	106.0	145.3	68.6	435.4	64.4	819.7
NET DEFICIT	48.0	90.4	36.1	285.6	26.9	487.0

[1]Includes cooling water (power) demands.

The construction cost of the local proposed development is estimated at $123.4 million, with an average annual equivalent cost of approximately $9.2 million. This cost includes $12.1 million for development of new ground water sources, $6.7 million for new SCS structures, $53.7 million for construction of Arcadia Reservoir in northeastern Oklahoma County, and $51 million for the region's allocated cost of McGee Creek Reservoir in Atoka County. Although Arcadia and McGee Creek are under construction and considered existing supplies, their costs have been included in the local plan in order to more accurately reflect future costs of development. Arcadia, with an average annual equivalent cost of almost $4 million, will serve the Edmond area.

The cost shown for Arcadia includes a gravity flow conduit from the dam to a water treatment facility near the reservoir.

The cost for McGee Creek includes the allocated cost of a pipeline and pumping plant to carry water from McGee Creek to Atoka Lake, where it will connect with the existing pipeline to central Oklahoma for eventual diversion from Lake Stanley Draper. The average annual equivalent cost of the McGee Creek project assigned to the Central Planning Region is estimated at $3.7 million.

FIGURE 49 SUMMARY OF COSTS[1] PROPOSED PLAN OF DEVELOPMENT (In $1,000)

FACILITY	CONSTRUCTION COST	AVERAGE ANNUAL OMR&E[2]	TOTAL AVERAGE ANNUAL EQUIVALENT COSTS
SCS Lakes	$ 6,700	$ 5	$ 355
Ground Water Development	12,100	200	1,200
Major Reservoirs			
Arcadia	53,700	410	3,970
McGee Creek[1]	50,870	320	3,700
TOTAL	$123,370	$935	$9,225

[1]Based on January 1978 prices.
[2]Reflects cost of total project allocated to central region based upon 40,000 acre-feet per year of water (56 percent of 71,800 total yield). Does not indicate the amount of reimbursable cost.

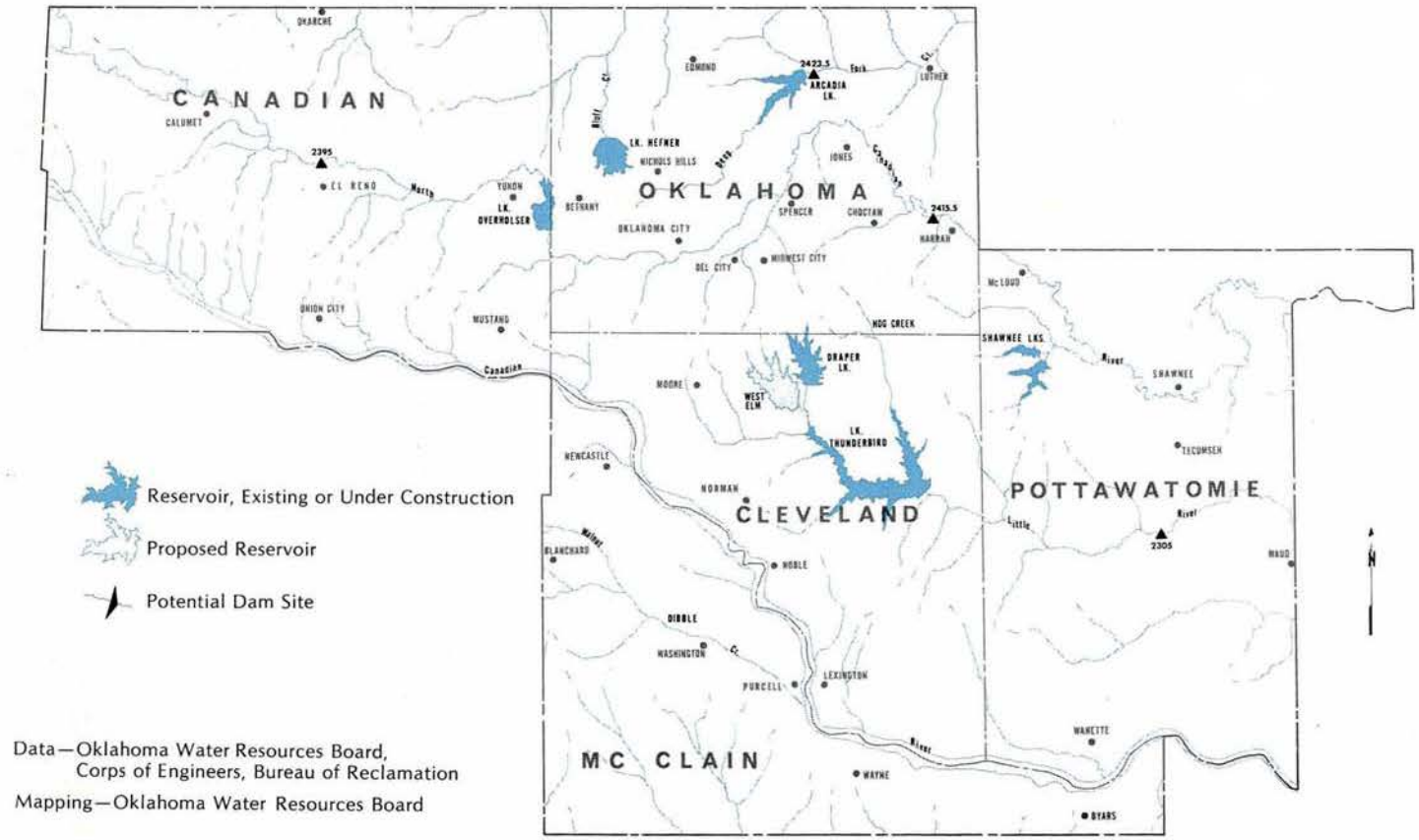


FIGURE 50 PROPOSED PLAN OF DEVELOPMENT

SOUTH CENTRAL PLANNING REGION

also applicable to allocations made on the main stem of the Washita and its tributaries above Pauls Valley, such restrictions specifying that water can be captured or diverted only during periods of high flow or during certain periods of the year. Average annual runoff ranges from three inches in Grady County to seven in Marshall County, as shown in Figure 20 . The average annual runoff originating from the six main stream basins is estimated at 1,500,000 acre-feet per year.

The U.S. Geological Survey maintains 10 continuous streamflow gaging stations on seven of the major creeks and streams in the region. Most of the region's streams eventually enter Lake Texoma, where their combined annual flow for a 49-year period averages 3,400,000 acre-feet.

In parts of the region, water quality is extremely poor, due to excessive amounts of dissolved minerals from natural and man-made sources. Poor quality restricts the use of the water for municipal and industrial purposes and often, even for irrigation. High flows from storm runoff are generally of better quality, thus making these waters available for irrigation if suitable sites can be constructed to capture and store the water. The better quality water required for municipal water use precludes water supply development on some streams. Water quality analysis data for selected U.S. Geological Survey monitoring stations and the station locations are shown in Appendix B, Figure 4 and 5 .

The Red River forms the southern border of this planning region and in this region is highly mineralized, primarily from high concentrations of chlorides from natural sources upstream. Iron and manganese concentrations frequently exceed maximum recommended limits. Limits for chromium, silver, copper and zinc have occasionally been exceeded. Nutrient enrichment on the Red River is highest below Beaver Creek, which has shown recent degradation in water quality and contributes the highest nutrient levels of any tributary to the Red River in the area. This is attributed to extremely high nutrient levels in the Cow Creek tributary to Beaver Creek. Pesticide monitoring in the Red River Basin shows the presence of chlorinated hydrocarbon pesticides and their byproducts in fish tissue and sediment. The high chloride content of the Red River renders this water unsuitable for most beneficial uses, except where some salt-tolerant crops are irrigated from the river using special irrigation management techniques.

The Washita River dominates the northern and eastern portion of this planning region. The lower Washita is highly mineralized due to gypsum outcroppings in its upper drainage basin, and increases in turbidity and hardness as it flows downstream. However, its tributary streams are of sufficient quality to significantly improve the river's overall quality as it flows toward the Red River. The quality of the water ranges from fair to poor with some water quality problems arising from high concentrations of iron, manganese, silver, pH, copper, chromium and mercury.

The Canadian River forms a portion of the region's northern boundary and its water is highly mineralized, exhibits high nutrient levels and often exceeds limits for turbidity and pH. Dissolved oxygen remains at saturation levels. Iron and manganese are present from natural nonpoint sources, and the waters of the Canadian occasionally violate standards for chromium and lead.

STREAM WATER DEVELOPMENT

As shown in Figure 51 , there are lakes (existing and under construction) in this region that provide a total of 2,863,200 acre-feet of flood control storage and 107,700 acre-feet of water supply storage. Of the four major reservoirs in the area, one is maintained by the State of Oklahoma, one by the Bureau of Reclamation and two by the Corps of Engineers. The Soil Conservation Service has four multipurpose sites being utilized as municipal water supplies and recreational facilities. There are also five city lakes and three recreational lakes in the area.

Major Reservoirs

Arbuckle Lake was completed by the Bureau of Reclamation in 1967 for the purposes of water supply, flood control, recreation, and fish and wildlife. The dam is located on Rock Creek, a tributary to the Washita River, in Murray County about six miles southwest of Sulphur.

Water impounded in Arbuckle Lake is of high quality, classified as suitable for all beneficial uses. The Arbuckle Master Conservancy District which provides water to the Cities of Ardmore, Davis, Sulphur, Wynnewood and Dougherty and the Southern Oklahoma Water Cooperative have been allocated the total water supply yield of the reservoir.

Lake Murray, located on a tributary to Hickory Creek in Love County, was completed by the State of Oklahoma in 1937, built primarily as a park lake for recreation. Its surface area is 5,728 acres with a conservation storage capacity of 153,250 acre-feet. Lake Murray is a major recreational attraction in southern Oklahoma. The lake contains no water supply storage.

Lake Texoma (Denison Dam), located on the Red River in Marshall County and the Washita River in Bryan County, is the second largest lake in Oklahoma. The lake, completed by the Corps in 1944, encompasses 143,300 acres of surface area, authorized for the purposes of flood control, water supply, hydroelectric power, regulating flows of the Red River and improving navigation.

The project contains 2,669,000 acre-feet of flood control storage and 1,673,000 acre-feet of power storage. The power plant has two generating units with a capacity of 70,000 kilowatts and the potential for installation of two additional units. Flood damages prevented by the project through December 1978 were estimated at $40,608,000, while power generation averages 244 million kilowatt hours annually.

Texoma has a dependable water supply yield of 23,700 acre-feet per year, however, due to natural salt pollution upstream, the quality of water is poor and the water is not being beneficially used except for emergency supplies. The quality of the water near the dam makes it usable with proper treatment for most beneficial purposes some of the time, while the water quality on the Washita arm is suitable most of the time. Studies by the Corps of Engineers are presently underway to determine the amount of good quality water that can be developed from Lake Texoma. The authorized chloride control project on the Red River would eventually clean up the river's waters and make them usable for most purposes. It should be noted that any future water supply that becomes available must be divided equally between Oklahoma and

FIGURE 51 STREAM WATER DEVELOPMENT

NAME OF SOURCE	STREAM	PURPOSE*	FLOOD CONTROL STORAGE ACRE FT.□	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
		EXISTING OR UNDER CONSTRUCTION			
Arbuckle Lake	Rock Creek	WS, FC, R	36,400	62,600	22,700
Ardmore City Lake	Tributary of Caddo Creek	WS, R	0	2,300	550
Ardmore Mountain Lake	Tributary of Caddo Creek	WS, R	0	4,650	2,800
Ardmore SCS Site 18	Tributary of Caddo Creek	WS, R	1,600	2,600	700
Ardmore SCS Side 13	Tributary of Caddo Creek	WS, FC, R	4,400	4,550	1,950
Clear Creek Lake	Tributary of Wildhorse Creek	WS, R	0	6,000	0[1]
Duncan Lake	Tributary of Wildhorse Creek	WS, R	0	10,000	2,050[1]
Lake Fuqua	Black Bear Creek	WS, FC, R	8,500	17,600	0[1]
Lake Humphreys	Tributary of Wildhorse Creek	WS, R	11,900	10,700	2,750
Lake Murray	Tributary of Hickory Creek	R	0	0	0[2]
Pauls Valley Lake	Washington Creek	WS, R	0	8,500	4,000
Lake Texoma	Red River	WS, FC, P	2,669,000	22,100	11,850[3]
Waurika Lake	Beaver Creek	WS, FC, WQ, R, FW, I	131,900	170,200	16,200[4]
TOTAL			2,863,000	321,800	65,550
		POTENTIAL			
				CONSERVATION STORAGE	
Courtney	Mud Creek	WS, R	120,000	261,000	53,000
Gainesville	Red River	WS, P, R, FW, I	0	1,816,600	400,000[5]
Purdy	Rush Creek	WS, FC, R	45,000	140,000	20,000
TOTAL			165,000	2,217,600	473,000
TOTAL YIELD					538,550

*WS-Municipal Water Supply, FC-Flood Control, WQ-Water Quality, P-Power, R-Recreation, FW-Fish and Wildlife, I-Irrigation, N-Navigation.

□Although flood control storages are shown for potential sites, further studies will be required to determine the amount of flood control storage than can be economically justified as a project purpose.

[1]The combined yield of Clear Creek Lake, Lake Fuqua and Lake Duncan equals 2,050 acre-feet per year.

[2]Lake Murray has a conservation storage of 153,250 acre-feet. The lake has no water supply storage.

[3]Lake Texoma is an interstate lake and all plans for utilization are subject to compact agreements between the States of Oklahoma and Texas. Existing water supply storage will yield 23,700 acre-feet per year. Under the terms of the Red River Compact, Oklahoma has a right to one-half of the water supply yield of the reservoir (11,850 acre-feet per year). A restudy of the project is currently underway to determine the feasibility of providing additional water supply storage. Preliminary studies indicate water supply storage yielding 101,000 acre-feet per year for municipal, industrial and irrigation use and the addition of two hydro-power generation units may be economically justified. Water quality is unsuitable for most beneficial uses.

[4]Waurika Lake will yield 44,800 acre-feet per year. This yield includes irrigation storage to provide 5,040 acre-feet per year. Approximately 40.0% (18,400 acre-feet per year) of the yield is allocated to the South Central Region. The other 60.0% (26,400 acre-feet per year) is allocated to the Southwest Region.

[5]Gainesville Dam site is located on an interstate stream. Plans for utilization are subject to compact agreements between the States of Oklahoma and Texas. Yield shown is amount allocated to Oklahoma based on 80% dependability for irrigation purposes.

Texas under the terms of the Red River Compact.

Recreational facilities at Texoma are among the best in the state, attracting approximately 11,125,000 visitors to the area in 1976.

Waurika Lake on Beaver Creek in Jefferson County is one of the newest lakes in Oklahoma, with impoundment occurring in 1977. Onsite construction by the Corps began in July 1971, and completion of the water conveyance facilities is scheduled for 1980. Waurika was built for the purposes of flood control, irrigation, water supply, water quality, fish and wildlife propagation and recreation.

The Waurika project is unique in that the Corps was authorized to develop conveyance facilities as a part of the project. Local interests will repay all construction costs attributable to the water supply features of the project and operate and maintain the facilities. Water rights have been granted to the Waurika Master Conservancy District, which will furnish water to the Cities of Lawton, Duncan, Waurika, Temple and Comanche.

Major Municipal Lakes

Lake Fuqua is located on Black Bear Creek in Stephens County. Constructed in 1961, it is a water supply reservoir for the City of Duncan, providing 8,500 acre-feet of flood control storage and 17,600 acre-feet of water supply storage.

In addition to Lake Fuqua, the City of Duncan also receives municipal and industrial water supply from Clear Creek Lake, Duncan Lake and Lake Humphreys. The combined yield from these four lakes is 4,800 acre-feet per year.

Ardmore City Lake was constructed in 1903 by the City of Ardmore for the purposes of water supply and recreation. The lake contains 2,300 acre-feet of storage, yielding 550 acre-feet per year. The City also utilizes Ardmore Mountain Lake, constructed in 1922 and 1923, which provides an additional 2,800 acre-feet of water supply annually. Both lakes are located on tributaries to Caddo Creek in Carter County.

Pauls Valley Lake, on Washington Creek in Garvin County, was constructed in 1955 by the City of Pauls Valley for the purposes of water supply and recreation. The lake supplies 4,000 acre-feet per year from 8,500 acre-feet of storage.

Soil Conservation Service Projects

Numerous mutlipurpose SCS sites have been planned or constructed, providing municipal and irrigation water and excellent recreation facilities. The Cities of Ardmore, Chickasha, Duncan, Elmore City, Lindsay, Marlow and Maysville utilize these multipurpose lakes for municipal water supplies and recreation.

The Washita River Watershed, which covers most of the 8-county area, is the only major river drainage area in the state in which all the watersheds are developed or under construction. Of the 46 watersheds in the South Central Planning Region, 36 are complete or under construction, nine are planned and one has potential for development. For locations of these watersheds and multipurpose sites, see Figure 26 .

Authorized Development

There are no other authorized projects in the South Central Planning Region.

Potential Development

Additional sources of stream water supplies for use in the South Central Planning Region are potentially available through the development of two large multipurpose reservoir sites listed in Figure 51 . Although no feasibility-level studies have been conducted, preliminary investigations have indicated potential for their future development.

STREAM WATER RIGHTS

As of February 20, 1979 there had been a total of 555 vested stream water rights and permits issued for the appropriation of 625,843 acre-feet of water per year from rivers, streams and lakes in the region. The tabulation by counties and use is shown in Figure 52 .

Ground Water

Five major ground water basins are located in the South Central Planing Region: the Arbuckle Group, Simpson Group, Oscar Formation, Rush Springs Sandstone, Antlers Sandstone and alluvium and terrace deposits. See Figure 28 . Ground water resources serve the need of most rural homes and smaller towns

FIGURE 52 STREAM WATER RIGHTS

	MUNICIPAL		INDUSTRIAL		IRRIGATION		SECONDARY OIL RECOVERY		COMMERCIAL		RECREATION		TOTAL	
COUNTY	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated
Carter	7	29,056	1	4,680	34	22,051	—	—	2	12,660	3	500	47	68,947
Garvin	8	14,381	2	4,506	91	21,067	—	—	—	—	2	340	103	40,294
Grady	6	35,124	—	—	182	29,106	—	—	—	—	2	520	109	64,750
Jefferson	7	38,976	—	—	46	14,551	—	—	—	—	1	200	54	53,727
Love	—	—	1	5	19	4,628	—	—	1	3,100	—	—	21	7,733
Marshall	3	2,442	1	1,000	27	10,735	3	790	3	303	3	710	40	15,980
Murray	5	32,800	5	34,621	29	41,361	—	—	1	350	6	33,043	46	142,175
Stephens	4	7,414	4	816	42	106,126	1	75	—	—	3	1,782	54	116,213
Total	40	160,193	14	45,628	470	249,625	4	865	7	16,413	20	37,095	555	509,819

and communities, as well as irrigation farmers in the region.

Arbuckle Group (Cambrian-Ordovician) is limestone and dolomite, 5,000 to 6,000 feet thick. Relatively high permeability results from fractures, joints and solution channels in the limestone. In eastern Murray County, the ground water basin is known to produce large quantities of water. Yields of 200 to 500 gpm are common and deeper tests have produced quantities in excess of 2,500 gpm. Although the water may be hard, total dissolved solids are generally low and the quality is good. Well development is sparse at the present time.

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. Wells yield 100 to 200 gpm commonly. Water from sandstones is of poor quality at Sulphur, but elsewhere it is usually potable.

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. Well yields range from 60 gpm to as much as 400 gpm, but more commonly 150 to 180 gpm are reported. Ardmore, Healdton, Ringling and Duncan are presently using or have used wells in the Oscar Formation for their municipal supplies. 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.

Rush Springs Sandstone (Permian) crops out in southwestern Grady and northern Stephens Counties, where it is approximately 280 feet thick. It is generally composed of fine-grained, even to highly cross-bedded sandstone. Wells in the formation yield 10 to 300 gpm. In a few areas, however, there is sufficient saturated thickness to provide water in quantities adequate for municipal supplies. The Rush Springs Sandstone provides moderate amounts of water to the Cities of Rush Springs and Marlow.

Antlers Sandstone consists of as much as 900 feet of friable sandstone, silt, clay and shale. The ground water basin outcrops over an extensive area in Marshall and Love Counties and a small part of Carter County. Well yields range from 50 gpm to as high as 650 gpm and water quality is good in the outcrop area, but deteriorates downdip. The average saturated thickness of the sand is 250 feet.

Alluvium and terrace deposits (Quaternary) were laid down by streams and rivers and consist of poorly sorted interfingering lentils of clay, sand and gravel. The terrace is topographically higher than the alluvium, but hydrologically they constitute a single unit. The ground water basin provides favorable quantities of water in areas adjacent to the Washita and Red Rivers.

Wells yield a maximum of 400 gpm near Lindsay, 1,000 gpm near Pauls Valley and 200 gpm near Wynnewood and Davis, in areas of maximum saturated thickness and coarsest gravel. Most wells yield smaller supplies of 20 to 100 gpm, owing to fine-grain sediments in the alluvial fill. Overall water quality is good, although water is better in the terrace than in the alluvium. The terrace deposits generally receive less water from the adjacent bedrock and are not affected by influent seepage of river water, which may be mineralized.

GROUND WATER DEVELOPMENT

Development of ground water resources in the South Central Planning Region is limited by low yields, small areal extent of its basins and lack of information concerning water quality, recharge, drawdown, static water level and transmissivity. However, wells in the Oscar Formation provide water supplies to Ardmore, Healdton, Ringling and Duncan; wells in the Rush Springs Sandstone supply Marlow and Rush Springs; and wells in the Simpson Group furnish water to Mill Creek and Bromide.

There is potential for further

FIGURE 53 GROUND WATER RIGHTS

	MUNICIPAL		INDUSTRIAL		IRRIGATION		SECONDARY OIL RECOVERY		COMMERCIAL		RECREATION		TOTAL	
COUNTY	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated
Carter	10	5,933	—	—	9	6,307	2	1,657	1	100	—	—	22	13,997
Garvin	7	10,875	14	11,186	67	14,458	3	518	—	—	—	—	91	37,037
Grady	8	8,833	3	850	107	24,230	—	—	—	—	—	—	118	33,913
Jefferson	4	2,465	—	—	22	5,517	—	—	—	—	—	—	26	7,982
Love	4	2,285	2	501	21	11,359	—	—	2	8,776	1	400	30	23,321
Marshall	1	40	—	—	5	2,785	—	—	7	2,204	—	—	13	5,029
Murray	1	8,900	3	7,412	10	6,486	—	—	—	—	—	—	14	22,798
Stephens	4	921	1	1	20	3,908	—	—	2	320	2	164	29	5,314
Total	39	40,252	23	19,950	261	75,050	5	2,175	12	11,400	3	564	343	149,391

These tabulations reflect the total water rights issued by the Board as of a specific date and are not an accurate reflection of the actual amount of water presently being put to use. The data indicate prevalent trends of beneficial water use by county and region.

development in isolated areas of good supply. Where it exists, ground water is generally of suitable quality for most purposes, however, some wells in the Oscar Formation in Carter County are threatened with brine pollution from oil field activities.

GROUND WATER RIGHTS

As of July 1979, there was a total of 343 ground water permits issued in the South Central Planning Region. These permits allocate fresh ground water for municipal, irrigation or industrial purposes. The tabulation of data from the Oklahoma Water Resources Board files is shown in Figure 53 .

PRESENT WATER USE AND FUTURE REQUIREMENTS

The South Central Planning Region currently uses an estimated 98,000 acre-feet annually to meet its total water needs; somewhat less than half of this is used for irrigation, with the remainder divided between municipal and industrial use including 1,000 acre-feet per year for cooling water purposes. Future projections indicate the demand for irrigation water will increase three-fold and municipal use will double by the year 2040. Industrial use is projected to increase only slightly during the entire planning period. Total annual water requirements for the region may reach 228,800 acre-feet by 2040.

The region's population is expected to increase from the 1977 figure of 180,500 to 303,900 by 2040, resulting in municipal water demands (including rural requirements) increasing from the present estimated use of 20,400 acre-feet per year to 37,800 acre-feet per year in 2040. Growing populations in Duncan, Ardmore, Chickasha and Pauls Valley will require most of this increase.

There are 48 rural water districts serving over 30,000 citizens in this region. The formation and expansion of rural systems have accelerated in recent years in response to growing rural water demands and it is anticipated that such growth will continue.

Present industrial water use in the area is 34,000 acre-feet per year, consumed largely by oil refineries and machine manufacturers. Industrial use currently is greater than municipal use, however, projections indicate that demand for industrial water will increase by only 6.6 percent, to 38,700 acre-feet annually, by 2040.

Cooling water requirements for power generation are expected to increase from the present figure of 1,000 acre-feet per year to 4,900 acre-feet per year. Oklahoma Gas and Electric Company currently operates one small plant in the region with a generating capacity of 75 megawatts. If additional plants are constructed in this area, it is assumed that water necessary for cooling purposes will be available from local streams.

Irrigation presently requires 42,600 acre-feet of water each year in the South Central Planning Region. In 1977 the Oklahoma State University Irrigation Survey showed 320 farms in the region irrigating 37,900 acres, with almost a third of these acres lying in Grady County. Projections indicate that by the year 2040, the area may need 147,400 acre-feet of water annually to irrigate 88,500 acres.

PROPOSED REGIONAL PLAN OF DEVELOPMENT

The South Central Planning Region has experienced limited water development due to water quality constraints and nominal rainfall levels. Inadequate distribution also plagues much of the region, as many areas are not served by any water system. The lack of available water supplies has hindered potential agriculture and agribusiness activities.

Existing water resources in the area — ground water, SCS lakes and Arbuckle and Waurika Reservoirs — can supply 90,000 acre-feet annually. However, due to depletion and quality problems, ground water supplies are projected to decline in the future, thus requiring a portion of the proposed surface water development as a replacement supply. Use of existing supplies by the year 2040 is projected to be 73,400 acre-feet per year. Potential local sources could provide an additional 119,900 acre-feet per year, but as shown in Figure 55 , even if total proposed local development occurred, by 2040 this region would still face an annual deficit of approximately 35,500 acre-feet which would have to be supplied by sources outside the region.

The Oklahoma Comprehensive Water Plan proposes a Regional Plan of Development which could meet part of the region's future water needs. See Figure 56 . It includes expansion of distribution facilities at the two exiting reservoirs and construction of two major reservoirs with appropriate municipal, industrial and irrigation distribution facilities capable of supplying 52,000 acre-feet of water per year. In addition, new SCS structures are proposed within the region which would supply 67,900 acre-feet per year of water for increased irrigation.

Approximately 58,000 acres could be irrigated from the proposed development by the year 2040, based upon 1.5 acre-feet of water per acre.

FIGURE 54 PRESENT AND PROJECTED WATER REQUIREMENTS (In 1,000 Af/Yr)

Use	Present	1990	2000	2010	2020	2030	2040
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

FIGURE 55 SUPPLY AND DEMAND ANALYSIS PROPOSED PLAN OF DEVELOPMENT (In 1,000 Af/Yr)

Source	Carter	Garvin	Grady	Jefferson	Love	Marshall	Murray	Stephens	Total
	COUNTY								
	Municipal and Industrial Component[1]								
Ground Water & SCS & Municipal Lakes	5.0	4.0	1.7	—	2.0	0.7	2.7	5.0	21.1
Arbuckle	11.0	5.1	—	—	—	—	6.6	—	22.7
Waurika	—	—	—	1.3	—	—	—	12.1	13.4
Courtney	11.3	2.7	—	—	—	1.3	—	—	15.3
M & I Supply	27.3	11.8	1.7	1.3	2.0	2.0	9.3	17.1	72.5
	Irrigation Component								
Ground Water & SCS Lakes	9.1	12.1	19.6	7.4	11.6	2.9	6.1	10.3	79.1
Waurika	—	—	—	5.0	—	—	—	—	5.0
Courtney	—	4.9	—	7.5	4.3	—	—	—	16.7
Purdy	—	20.0	—	—	—	—	—	—	20.0
Irrigation Supply	9.1	37.0	19.6	19.9	15.9	2.9	6.1	10.3	120.8
TOTAL LOCAL SUPPLY	36.4	48.8	21.3	21.2	17.9	4.9	15.4	27.4	193.3
2040 DEMAND	36.4	48.8	56.8	21.1	17.9	4.9	15.4	27.4	228.8
NET DEFICIT	—	—	35.5	—	—	—	—	—	35.5

[1]Includes cooling water (power) demands.

FIGURE 56 PROPOSED PLAN OF DEVELOPMENT

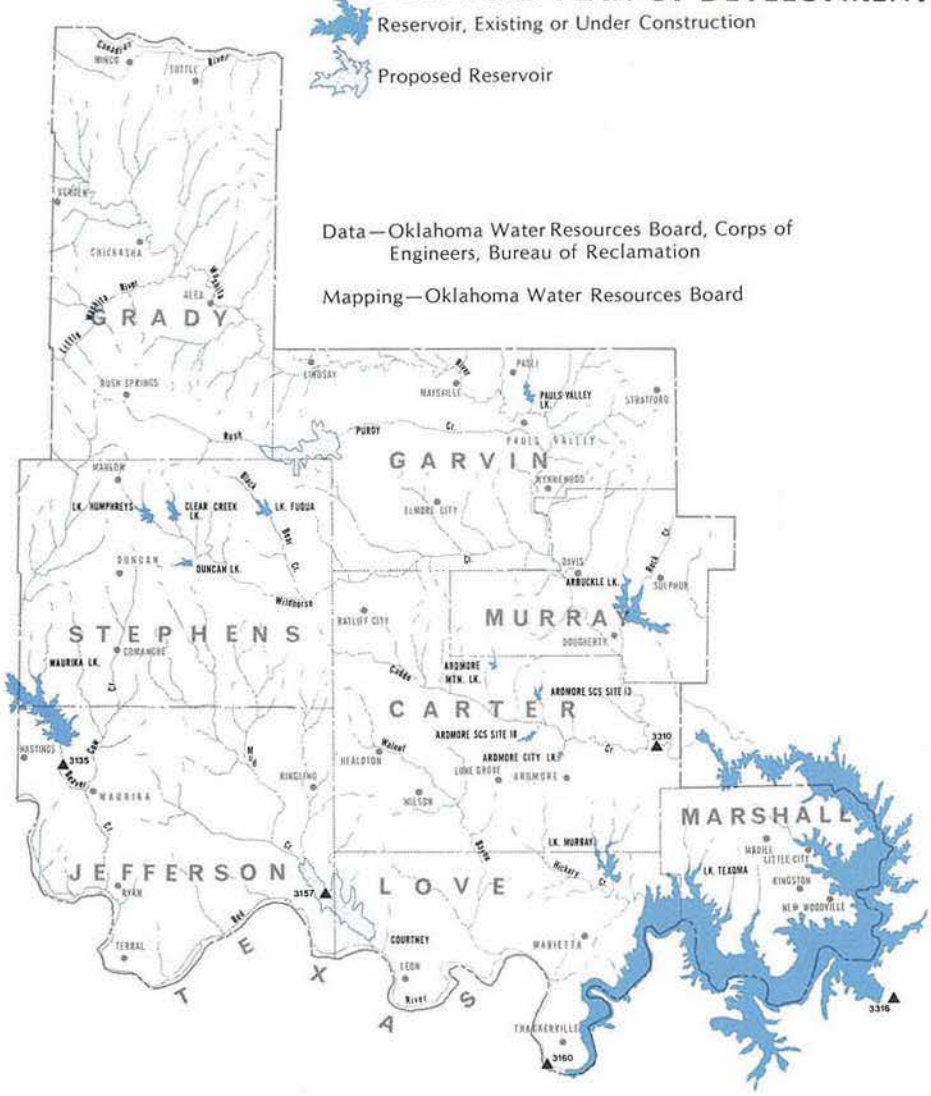


Figure 55 shows the region's eight counties and their proposed sources and projected demands for the year 2040. It should be noted that the regional deficit of 35,500 acre-feet per year is a result of the lack of adequate water sources in the Grady County area.

Figure 57 shows the estimated total cost of development which includes construction costs of $322 million and average annual equivalent cost of $22 million. The cost of water supply storage in new SCS structures is estimated to be $22.6 million, with an average annual equivalent cost of $1.2 million. Cost estimates of distribution systems from these SCS structures are not included, but should be addressed in future planning efforts.

The construction cost of major reservoir development and appropriate distribution facilities is estimated at $300 million. This includes construction costs of the proposed Courtney and Purdy Reservoirs, along with appropriate municipal, industrial and irrigation distribution facilities. The cost also includes municipal and industrial distribution facilities from Arbuckle and irrigation distribution facilities from Waurika and appropriate mitigation/compensation costs. The irrigation distribution cost shown is the cost of delivering water to members of the Jefferson County Irrigation District #1. Annual operation, maintenance, replacement and energy (OMR&E) costs are $1.8 million for major reservoirs, with average annual equivalent cost of around $20 million. Additional studies on each of the two proposed reservoirs would be necessary to determine their economic feasibility under federal guidelines, as well as the amount of state or local contributions which would be necessary.

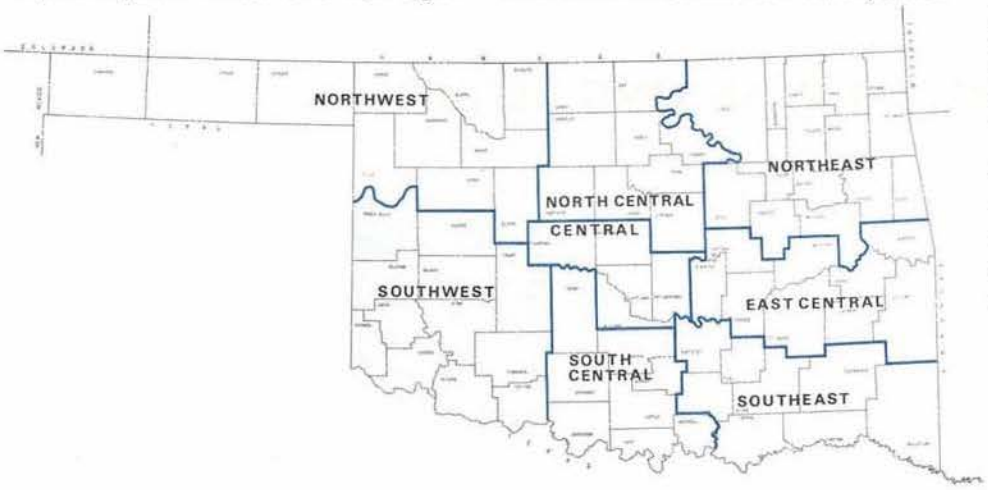
FIGURE 57 SUMMARY OF COSTS[1] PROPOSED PLAN OF DEVELOPMENT (In $1,000)

FACILITY	CONSTRUCTION COST	AVERAGE ANNUAL OMR&E[2]	TOTAL AVERAGE ANNUAL EQUIVALENT COST[3]
SCS Lakes	$ 22,600	$ 10	$ 1,220
Major Reservoirs			
Arbuckle			
M & I Distribution	23,350	330	2,020
Subtotal	$ 23,350	330	$ 2,020
Waurika			
Irrigation Storage	$ 75	$ —[4]	$ 3[5]
Irrigation Distribution	6,450	60	490
Mitigation/Compensation	590	25	65
Subtotal	$ 7,115	$ 85	$ 558
Courtney			
Dam & Reservoir	$ 48,570	$ 50	$ 3,020
Irrigation Distribution	24,020	310	1,680
M & I Distribution	98,390	680	6,480
Mitigation/Compensation	9,130	25	630
Subtotal	$180,110	$1,065	$11,810
Purdy			
Dam & Reservoir	$ 59,730	$ 40	$ 3,860
Irrigation Distribution	28,660	290	2,010
Mitigation/Compensation	350	25	50
Subtotal	$ 88,740	$ 355	$ 5,920
TOTAL	$321,915	$1,845	$21,528

[1]Based on January 1978 prices.
[2]Energy costs computed at a 30-mil power rate.
[3]Includes interest and amortization as well as average annual OMR&E expenses.
[4]Less than $500 per year.
[5]Interest computed at 3.436 percent.

SOUTHWEST PLANNING REGION

The Southwest Planning Region consists of Beckham, Caddo, Comanche, Cotton, Greer, Custer, Harmon, Jackson, Kiowa, Roger Mills, Tillman and Washita Counties and covers 11,996 square miles. The rich agricultural lands of the region's western plains support more acres of irrigation than any area of similar size in the state. The Wichita Mountains in the east rise 1,000 to 1,100 feet above the general elevation. Major streams are the Red River and its tributaries in the south, the Washita River in the north and Cache Creek near Lawton.



The region's population was estimated at 284,500 in 1977, a six percent increase over 1970 figures. This growth at a rate slightly below the state average is attributed to the steady migration of young adults from rural areas to more attractive industrial employment opportunities in larger cities. Further migration from the region's farms and ranches has been prompted by decreased agricultural production, a result of recent droughts and depressed crop prices.

The largest cities in the region are Lawton, Altus, Anadarko, Frederick and Hobart. The distribution of population is 66 percent urban and 34 percent rural.

Average covered employment increased from 27,887 in 1970 to 44,186 in 1977, while per capita personal income rose from $2,859 to $5,470 during the same period. Wholesale and retail trade and service industries exhibited the highest rates of employment, however, these are closely related to agricultural activity in the region. If agricultural production continues its current downtrend, the general economic climate is expected to follow. A change in economic direction can be expected only if additional water can be made available to stimulate agricultural activity.

The region's location near the center of the southern Great Plains is responsible for its warm continental climate of mild winters and long, hot summers. Seasonal weather characteristics are generally well defined and changes between seasons occur gradually, marked only occasionally by rapid change. Spring is the wettest season, with peak rainfall measured over the region in May.

The length of the growing season averages approximately 188 days in the northwest and 230 days in the southeastern portion of the region. Strong winds and high temperatures cause the state's highest losses to evaporation, averaging 64 inches annually. See Figure 9 . Mean annual temperature ranges from 59° in the north to 65°F in the south. Annual average precipitation varies from 22 inches in the west to 32 inches in the east, and this variability, along with high evaporation rates, accounts for the region's tendency toward frequent and prolonged droughts, the destructive effect of which have been somewhat mitigated by increased irrigation. The region's annual snowfall accumulation averages 19 inches.

Despite relatively low annual precipitation, severe flooding occurs more than once each year. Flood damages have been significantly reduced through the construction of many flood control watershed projects. The Corps of Engineers regulates flood control storage in the lakes constructed in the region by the Bureau of Reclamation.

Climatic conditions which foster the water problems in this region limit the development of additional major water supply reservoirs and will force dependence on alternative sources as water demands continue to increase.

WATER RESOURCES

Stream Water

All major streams in the Southwest Planning region, except the Washita River, enter the main stem of the Red River, with their combined flow over a 14-year period averaging 555,000 acre-feet per year at the U.S. Geological Survey gaging station at Burkburnett, Texas. Flood control storage in Bureau of Reclamation lakes and Soil Conservation Service flood control structures on the Washita River have significantly decreased damage to property and crops formerly inflicted by the unchecked river.

In contrast, small rainfall amounts and high evaporation rates have caused all major streams in the region to record zero flow at certain times. Two rivers, the Salt Fork and North Fork of the Red, have registered no flow at some time during each year of record. A summary of streamflows recorded at the USGS gaging stations within the region is presented in Appendix B, Figure 2 .

Average annual runoff from precipitation ranges from one inch in the west to 3.5 inches in the southeastern corner, totaling almost 1.3 million acre-feet of water per year. See Figure 20.

With few exceptions, the stream water in the Southwest Planning Region is too highly mineralized for municipal or industrial use, and in many cases, unusable even for irriga-

tion. Natural pollutants such as gypsum, chloride and sodium restrict the beneficial uses of available stream water. Water quality analyses data for selected U.S. Geological Survey monitoring stations and the station locations are shown in Appendix B, Figures 4 and 5 .

The Red River marking the southern boundary of the region is a moderately to extremely turbid stream with hard, heavily mineralized water traceable to all the tributaries. High chloride concentrations from salt seeps and springs in the upper part of the river basin in Texas and Oklahoma make the waters of the Red River generally unsuitable for most purposes. Biomagnification and the accumulation of toxic metals and persistent pesticides in the sediment also present problems. Nutrient enrichment is highest below the mouth of Cache Creek, although monitoring in the tributaries shows that marked improvement has occurred in East Cache Creek, primarily due to the City of Lawton's advanced wastewater treatment facilities.

The Elm Fork of the North Fork of the Red River is contaminated by chlorides originating in natural salt seeps and springs near the Texas-Oklahoma border, which make the water unusable for most beneficial purposes. The flows of the North Fork below the mouth of Elm Fork and the Salt Fork of the Red are also unusable due to high chloride concentrations.

FIGURE 58 STREAM WATER DEVELOPMENT

NAME OF SOURCE	STREAM	PURPOSE*	FLOOD CONTROL STORAGE ACRE FT.□	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
		EXISTING OR UNDER CONSTRUCTION			
Altus Lake	North Fork of Red River	WS, FC, R, I	19,600	146,000[1]	16,800
Clinton Lake	Turkey Creek	WS, R	0	4,400	1,700
Lake Ellsworth	East Cache Creek	WS, R	0	68,700	9,500
Fort Cobb Lake	Cobb Creek	WS, FC, R, I	63,300	78,350[1]	13,300
Foss Lake	Washita River	WS, FC, R, I	180,400	203,700[2]	18,000[2]
Lake Lawtonka	Medicine Creek	WS, R	0	64,000	8,500
Tom Steed Lake	Otter Creek	WS, FC, R	19,500	88,160	16,000
TOTAL			282,800	653,310	83,800
		POTENTIAL			
				CONSERVATION STORAGE	
Altus Lake Modification	North Fork of Red River	WS, FC, R, I	196,000	204,600	8,200[3]
Carnegie Diversion Dam[4]	Washita River	WS	0	0	50,000
Cookietown	Deep Red Run	WS, FC, R, I	78,250	230,200	34,700
Faxon Diversion Dam[5]	West Cache Creek	WS	0	0	10,700
Mangum	Salt Fork of Red River	WS, FC, R	60,000	162,200	15,000
Port	Elk Creek	WS, FC, R	47,700	68,000	14,000
Rainy Mountain	Rainy Mountain Creek	WS, FC, R	66,500	60,000	6,000
Snyder	Deep Red Run Creek	WS, FC, R	11,800	95,000	0
Verden	Spring Creek	WS, R	0	40,000	7,500
Weatherford	Deer Creek	WS, FC, R	44,000	62,500	12,000
TOTAL			504,250	922,500	158,100
TOTAL YIELD					241,900

*WS—Municipal Water Supply, FC—Flood Control, WQ—Water Quality, P—Power, R—Recreation, FW—Fish and Wildlife, I—Irrigation, N—Navigation

□Although flood control storages are shown for potential sites, further studies will be required to determine the amount of flood control storage that can be economically justified as a project purpose.

[1]This includes irrigation storage.

[2]The quality of water from Foss Lake is too mineralized for municipal and industrial use. A 3 MGD (3,360 AF/YR) electrodialysis treatment plant is now in operation. This plant is designed for a maximum output of 4 MGD (4,480 AF/YR). The water supply storage listed above also includes irrigation storage.

[3]Additional yield from modification of Altus Dam.

[4]Diversion dam used in conjunction with Foss Reservoir.

[5]Diversion dam used in conjunction with Cookietown Reservoir.

The Washita River and most of its tributaries contain large concentrations of gypsum, and at times carry dissolved mineral concentrations exceeding 2,000 mg/L. Because area soils will accept the Washita River's high sulfate load, its waters are suitable for irrigation, but do not meet public health drinking water standards on a dependable basis.

The Cache Creek basin exhibits the highest quality water in this region, making water impounded on Cache Creek suitable for most beneficial uses.

Limited quanitites of good quality water severely restrict development of additional water supply storage facilities in this area, so outside sources to fulfill its future water requirements must be considered.

STREAM WATER DEVELOPMENT

The Southwest Planning Region has seven existing reservoirs which provide flood control, municipal water supply, irrigation and recreation for the 12 counties.

Lake Altus, a Bureau of Reclamation project on the North Fork of the Red River, was completed in 1948. The lake contains 146,000 acre-feet of municipal and irrigation water supply storage and 19,600 acre-feet of flood control storage. The major user of lake water is the Altus-Lugert Irrigation District which supplies water to the Bureau's 45,000-acre W.C. Austin Irrigation Project. The City of Altus also obtains part of its water supply from Lake Altus.

Water quality is fair in the North Fork of the Red River above Altus Dam, so the lake's water can be beneficially used for municipal, industrial or irrigation purposes.

Foss Lake, located on the Washita River, was completed by the Bureau of Reclamation in 1961 and authorized for irrigation, flood control, municipal water supply, fish and wildlife, and recreation. The lake contains 180,400 acre-feet of flood control storage, along with 203,700 acre-feet of storage for water supply, including irrigation storage.

Although requiring desalination prior to municipal and industrial uses, with conventional treatment water in Foss is of sufficient quality for irrigation. Many farmers irrigate successfully along the Washita River downstream from Foss. A desalination facility utilizing the electrodialysis process is currently producing one mgd (1,120 acre-feet per year) of water. The plant has an existing capacity of three mgd (3,360 acre-feet per year) and can be modified to produce four mgd (4,480 acre-feet per year). The Foss Reservoir Master Conservancy District supplies the Cities of Clinton, Cordell, Hobart and Bessie with water from Foss.

Fort Cobb Reservoir on Cobb Creek, a tributary of the Washita River, was completed by the Bureau of Reclamation in 1959. The project was authorized for irrigation, flood control, municipal water supply, fish and wildlife propagation, and recreation. The reservoir provides 63,300 acre-feet of flood control storage and 78,350 acre-feet of water supply storages including irrigation storage.

Although the water is high in sulfates, it is rated fair in quality for municipal and industrial purposes and good for irrigation purposes. The reservoir's water supply storage is allocated to the Fort Cobb Master Conservancy District which supplies municipal and industrial water to Western Farmers Electric Cooperative and the Cities of Anadarko and Chickasha.

Major Municipal Lakes

Lake Lawtonka, the original water supply lake constructed by the City of Lawton in 1905, impounds the waters of Medicine Creek. The lake has 64,000 acre-feet of water supply storage, with an annual yield of 8,500 acre-feet.

Quality is excellent, so the water is used for municipal and industrial supplies and recreation.

Lake Ellsworth, completed by the City of Lawton in 1962 to provide additional water supply, is located on East Cache Creek 10 miles north of Lawton. The lake contains 68,700 acre-feet of storage, providing an annual yield of 9,500 acre-feet.

Water quality is excellent, making it suitable for all beneficial purposes. In addition to supplying municipal and industrial water, the lake also provides recreational opportunities.

Soil Conservation Service Projects

The Sandstone Creek watershed project in Roger Mills County is the first completed upland stream detention program in the nation, and is one of numerous projects engineered and constructed by the Soil Conservation Service. There are 54 SCS watersheds in this 12-county region, 41 of them complete or under construction; 13 in planning stages.

In addition to retaining flood waters, these reservoirs are used for irrigation, domestic supplies and recreation. The Cities of Elk City, Sentinel, Cheyenne, Frederick and Clinton utilize Soil Conservation Service multipurpose sites for water supply and recreational purposes. For locations of watersheds and multipurpose structures, see Figure 26 .

Authorized Development

There are no authorized projects in the Southwest Planning Region.

Potential Development

Although there are numerous geographically suitable dam sites available in the Southwest Planning Region, limited water availability and poor water quality limit the potential for additional large stream water development projects. The sites listed in Figure 58 offer the greatest potential for multipurpose development.

STREAM WATER RIGHTS

As of February 20, 1979, a total of 1,227 vested stream water rights and permits had been issued for the appropriation of 634,409 acre-feet of water per year from rivers, streams and lakes in the region. See Figure 59.

Ground Water

Six major ground water basins

FIGURE 59 STREAM WATER RIGHTS

COUNTY	MUNICIPAL		INDUSTRIAL		IRRIGATION		SECONDARY OIL RECOVERY		COMMERCIAL		RECREATION		TOTAL	
	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated
Beckham	1	2,583	—	—	53	11,542	—	—	—	—	2	20	56	14,145
Caddo	3	30,340	2	3,428	289	32,966	—	—	—	—	3	14,834	297	81,568
Comanche	4	56,600	3	8,442	60	11,462	—	—	1	210	1	13	69	76,727
Cotton	9	3,183	—	—	74	14,598	—	—	—	—	—	—	83	17,781
Custer	9	34,000	—	—	110	13,606	—	—	1	89	7	36,900	127	84,595
Greer	—	—	1	100	15	1,962	—	—	1	4	—	—	17	2,066
Harmon	—	—	—	—	11	1,266	—	—	—	—	1	250	12	1,516
Jackson	2	4,961	1	72	124	108,873	—	—	—	—	—	—	127	113,906
Kiowa	6	59,680	—	—	81	14,440	—	—	—	—	—	—	87	74,120
Roger Mills	2	500	—	—	91	9,244	—	—	—	—	1	50	94	9,794
Tillman	3	7,300	—	—	48	7,981	—	—	—	—	—	—	51	15,281
Washita	3	5,603	1	56	196	29,197	—	—	1	740	1	1,680	202	37,276
TOTAL	42	204,750	8	12,098	1,152	257,137	—	—	4	1,043	16	53,747	1,222	528,775

varying in extent and storage potential exist in the Southwest Planning Region: the Arbuckle Group, Dog Creek Shale and Blaine Gypsum, Rush Springs Sandstone, Ogallala Formation and alluvium and terrace deposits. See Figure 28 . Ground water serves the needs of most rural homes, towns and communities in the southwest region.

Arbuckle Group (Cambrian-Ordovician in age) consists predominantly of carbonate rocks (limestone and dolomite) which outcrop in Comanche, Caddo and Kiowa Counties. The ground water basin provides water to wells in the vicinity of Lawton, Cache and Indiahoma. The Arbuckle Group, approximately 6,000 feet in thickness, has high porosity locally, and wells yield 25 to 500 gpm. Where permeabilities are high, water may be suitable for industrial use; however, before it is utilized as a public water supply, quality should be checked for excessive concentrations of fluoride.

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, characterized in places by solution channels and zones of secondary porosity. Well yields range from less than 10 to as much as 2,000 gpm.

Water levels in the ground water basin respond rapidly to infiltration or precipitation and 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 hardness and very high calcium sulfate concentrations. In southeastern and northwestern Harmon County, the water has a high sodium chloride content. The water, although suitable for irrigation, is not potable.

Rush Springs Sandstone (Permian) outcrops in the Southwest Planning Region in Custer, Washita and Caddo Counties and in a small portion of Comanche County. The aquifer is much more productive in this planning region than in the neighboring South Central Planning Region, where yields are markedly lower and supplies are spotty. It is a fine-grained, cross-bedded sandstone containing irregular silty lenses. Total thickness ranges from less than 200 feet in the south to about 330 feet in the northern part of the region. Depth to water below land surface ranges from zero to 150 feet. Wells yield as much as 1,000 gpm and average about 400 gpm. Most of the water is suitable for domestic, municipal, irrigation and industrial use, however, the water in some portions of Caddo County is very hard with high concentrations of dissolved solids.

The area of heaviest development is in northwestern Caddo County around Sickles, where wells have registered water level declines from 10 to 45 feet over the past 20 years. In adjacent areas, the wells have shown declines of five to 20 feet. In contrast, a few wells in northeast Washita County have risen an average of 31 feet.

The development of ground water from the aquifer has not yet caused critical declines on a widespread basis because of some great localized thickness, but overdevelopment and overpumping in some areas threaten to drop well levels critically low.

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 differs in being smaller and considerably thinner. Well yields range from 60 to 200 gpm. Water quality is generally suitable for most purposes.

Ogallala Formation (Tertiary) consists of unconsolidated deposits of interbedded sand, siltstone, clay, lenses of gravel, thin limestone and caliche. The Ogallala was deposited on an eroded land surface, so its thickness varies greatly. The proportions of the different rock types comprising the Ogallala change significantly from place to place, but sand

generally predominates. In the southwest region, the Ogallala occurs in western Roger Mills and Beckham Counties, where it is partly eroded and thins to the east. Yields can be as much as 800 gpm, but because of thinning and erosion, yields are more commonly about 200 gpm. Water quality is good, with low dissolved solids content, and except for hardness, the water is suitable for most uses.

Alluvium and terrace deposits (Quaternary) are interfingering lentils of clay, sandy clay, sand and gravel laid down by streams and rivers. The deposits provide water in the areas adjacent to the Washita River and North Fork of the Red River. The terrace deposits in Tillman County are a source of large quantities of ground water used for municipal, domestic and irrigation purposes.

As a result of increasing irrigation development, ground water supplies are being depleted. Because of the extensive drawdowns in the water table and saline encroachment problems, in November 1968 the Oklahoma Water Resources Board declared Tillman County to be a critical ground water area. In two areas (southwest of Tipton and west of Frederick) overall water levels have declined as much as 19 feet, leaving as little as 12 to 15 feet of saturated thickness. To achieve optimum development, a balance between average annual pumpage and average annual recharge must be established and maintained in the basin.

As required by the Oklahoma Ground Water Act (1972), the maximum annual yield and equal proportionate share of the alluvium and terrace deposits of the North Fork of the Red River in Tillman County have been determined. A computer simulation of all prior appropriative and subsequent allocated pumping rates in relation to the effective date of the Ground Water Act calculates the maximum annual yeild to be 70,000 acre-feet per year. This allows for each landowner overlying the basin to receive an annual proportionate share of the maximum annual yield of 1.0 acre-feet per acre.

GROUND WATER DEVELOPMENT

Present development of ground water is extensive, with overdevelopment occurring in some areas. Well development has increased greatly over the past 10 to 20 years, with ground water supplying domestic, municipal and irrigation needs in the region. Aquifers in the region provide municipal water supplies to Binger, Carnegie, Cement, Fort Cobb, Gracemont, Hinton, Hydro, Lookeba, Weatherford, Clinton, Cordell, Canute, Dill City, Frederick, Tipton, Davidson and Manitou.

Since the area is semiarid and annual rainfall averages only 27 inches, pumpage rates exceed recharge and the ground water is being mined. Well development in the Tillman Terrace deposits has increased from 80 irrigation wells in 1952 to about 570 in 1974, resulting in water level declines up to 20 feet between 1953 and 1972 around Tipton and Frederick. Marked water level declines have also occurred in the Rush Springs Sandstone of Caddo County, where the Sickles area reported declines of 11 to 40 feet between 1956 and 1974. The Dog Creek Shale and Blaine Gypsum may also be overdeveloped, with wells pumping more water than is recharged annually from rainfall. Declining water levels, higher pumping costs, lower well yields and saline water encroachment occur in areas where the aquifers are being overdrafted.

GROUND WATER RIGHTS

As of July 1979, there were 2,895 ground water permits issued in the Southwest Planning Region for the appropriation of 687,180 acre-feet of water. See Figure 60 . Prior rights have been determined on Beckham, Greer, Jackson, Kiowa and Tillman Counties.

PRESENT WATER USE AND FUTURE REQUIREMENTS

The Southwest Planning Region

FIGURE 60 GROUND WATER RIGHTS

	MUNICIPAL		INDUSTRIAL		IRRIGATION		SECONDARY OIL RECOVERY		COMMERCIAL		RECREATION		TOTAL	
COUNTY	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated
Beckham	11	8,824	1	350	108	28,719	—	—	—	—	—	—	120	37,893
Caddo	21	8,349	10	7,976	888	174,427	1	235	—	—	2	120	922	191,107
Comanche	10	2,085	2	435	41	9,043	—	—	4	1,853	—	—	57	13,416
Cotton	6	3,940	—	—	22	6,004	—	—	—	—	—	—	28	9,944
Custer	8	7,593	1	191	153	33,722	—	—	1	134	—	—	163	41,640
Greer	14	10,305	—	—	151	31,296	—	—	1	403	—	—	166	42,004
Harmon	5	5,204	—	—	362	85,905	—	—	—	—	—	—	367	91,109
Jackson	6	1,225	3	538	222	57,742	1	658	2	321	1	12	235	60,496
Kiowa	9	3,953	1	200	108	18,954	—	—	2	646	1	20	121	23,773
Roger Mills	5	682	—	—	118	26,962	—	—	—	—	—	—	123	27,644
Tillman	20	6,005	—	—	387	83,920	—	—	—	—	—	—	407	89,925
Washita	16	19,071	2	111	167	37,117	—	—	1	1,930	—	—	186	58,229
TOTAL	131	77,236	20	9,801	2,727	593,811	2	893	11	5,287	4	152	2,895	687,180

These tabulations reflect the total water rights issued by the Board as of a specific date and are not an accurate reflection of the actual amount of water presently being put to use. The data indicate prevalent trends of beneficial water use by county and region.

FIGURE 61 PRESENT AND PROJECTED WATER REQUIREMENTS (In 1,000 Af/Yr)

Use	Present	1990	2000	2010	2020	2030	2040
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	1023.0	1121.0	1219.1
Total	596.6	692.1	768.0	976.4	1184.4	1288.6	1392.8

is currently estimated to utilize 596,600 acre-feet of water annually to meet the area's total water needs, with irrigation requiring 85 percent of that total. Since total water requirements are expected to continue to increase, the area is projected to require 1,392,800 acre-feet per year by the year 2040.

Population estimates for 1977 show 284,500 residents in the 12-county area, which is expected to increase to 391,800 by the year 2040. Municipal water use should also increase from the estimated 36,000 acre-feet presently used to 66,200 acre-feet annually. The Cities of Lawton and Altus will probably consume most of this increase.

Rural water needs in this area, which are included in the municipal projections, are currently being met by 46 rural water districts which rely almost exclusively on ground water as a water supply source. Future rural water needs are expected to rise significantly and depleting ground water aquifers and deteriorating water quality are expected to force many of these rural water districts to seek alternative water supply sources.

Industrial water use, currently at 50,600 acre-feet per year, is projected to rise to 68,400 acre-feet by the year 2040. The largest industrial water users in the area are a tire manufacturer and various film processing companies.

Current utility requirements in the Southwest Planning Region are estimated to be 5,600 acre-feet annually. Public Service Company of Oklahoma operates two generating plants in the region with a total capacity of over 500 megawatts, and Western Farmers Electric Cooperative operates a plant with a

FIGURE 62 SUPPLY AND DEMAND ANALYSIS PROPOSED PLAN OF DEVELOPMENT (In 1,000 Af/Yr)

Source	Beckham	Caddo	Comanche	Cotton	Custer	Greer	Harmon	Jackson	Kiowa	Roger Mills	Tillman	Washita	Total
					Municipal and Industrial Component[1]								
Ground Water & SCS & Municipal Lakes	2.8	2.2	1.9	0.3	1.6	2.5	2.0	0.6	—	0.8	2.8	1.8	19.3
Altus	—	—	—	—	—	—	—	—	—	—	—	—	—
Ellsworth	—	—	9.5	—	—	—	—	—	—	—	—	—	9.5
Fort Cobb	—	4.1	—	—	—	—	—	—	—	—	—	—	4.1
Foss	—	—	—	—	1.2	—	—	—	1.0	—	—	1.2	3.4
Lawtonka	—	—	8.5	—	—	—	—	—	—	—	—	—	8.5
Tom Steed	—	—	—	—	—	—	—	8.0	—	—	2.0	—	10.0
Waurika	—	—	23.8	2.6	—	—	—	—	—	—	—	—	26.4
Cookietown	—	—	5.1	—	—	—	—	—	—	—	1.6	—	6.7
Hydro	—	—	—	—	—	—	—	—	—	—	—	—	—
Weatherford	—	—	—	—	12.0	—	—	—	—	—	—	—	12.0
M & I Supply	2.8	6.3	48.8	2.9	14.8	2.5	2.0	8.6	1.0	0.8	6.4	3.0	99.9
					Irrigation Component								
Ground Water & SCS Lakes	15.2	97.8	14.0	14.4	12.6	15.6	43.2	28.8	24.8	20.8	40.8	26.6	354.6
Altus	—	—	—	—	—	—	—	25.0	—	—	—	—	25.0
Fort Cobb	—	9.2	—	—	—	—	—	—	—	—	—	—	9.2
Foss	—	—	—	—	7.4	—	—	—	3.8	—	—	3.4	14.6
Tom Steed	—	—	—	—	—	—	—	6.0	—	—	—	—	6.0
Cookietown	—	—	—	15.0	—	—	—	—	—	—	25.4	—	40.4
Hydro	—	44.2	—	—	—	—	—	—	—	—	—	—	44.2
Irrigation Supply	15.2	151.2	14.0	29.4	20.0	15.6	43.2	59.8	28.6	20.8	66.2	30.0	494.0
TOTAL LOCAL SUPPLY	18.0	157.5	62.8	32.3	34.8	18.1	45.2	68.4	29.6	21.6	72.6	33.0	593.9
2040 DEMAND	23.0	209.3	73.4	32.3	45.4	62.5	105.2	297.2	154.8	21.6	297.2	70.9	1,392.8
NET DEFICIT	5.0	51.8	10.6	—	10.6	44.4	60.0	228.8	125.2	—	224.6	37.9	798.9

[1]Includes cooling water (power) demands.

capacity of 374 megawatts. Water needs for power generation are projected to increase to 39,100 acre-feet annually by the year 2040.

Present irrigation water needs are estimated at 504,400 acre-feet of water annually used in the irrigation of 274,531 acres on 2,929 farms producing alfalfa, peanuts, cotton and grain sorghum. Projections for the year 2040 show a potential for 609,550 acres being irrigated, requiring 1,219,100 acre-feet of water annually.

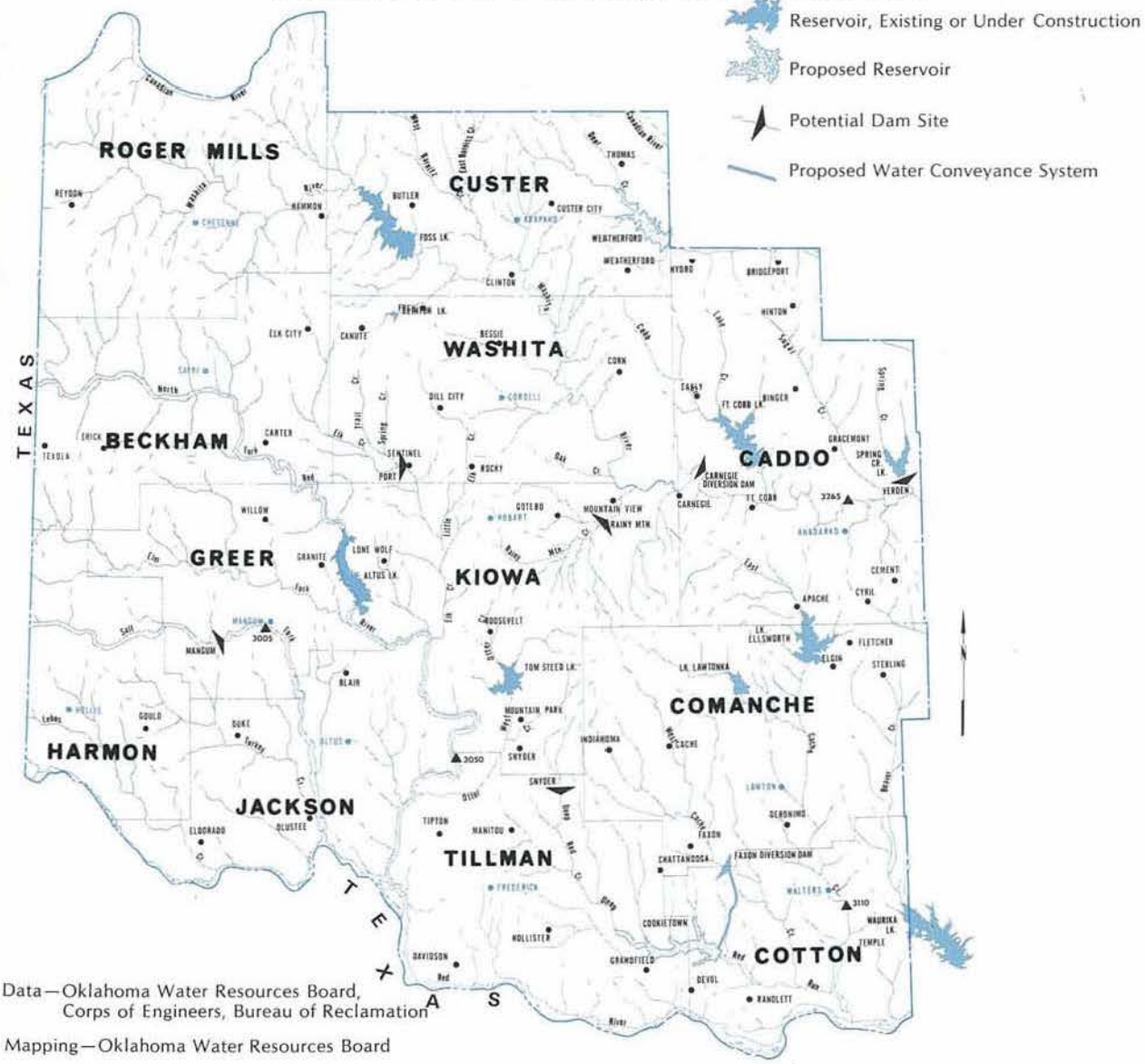
PROPOSED REGIONAL PLAN OF DEVELOPMENT

Chloride and sulfate concentrations in the water of the Southwest Planning Region and inadequate rainfall have limited stream water development and forced reliance on ground water resources. However, depletion and pollution of ground water in this region are placing a strain on future development, making it an unreliable source of a long-term water supply. Inadequate distribution is also a major problem in the region, and many rural areas remain unserved by a water system.

Existing supplies in the region can annually provide 590,000 acre-feet from ground water, SCS and municipal lekes, and major reservoirs. However, declining ground water supplies are expected to limit future use of existing sources to 400,100 acre-feet annually by the year 2040, thus requiring surface water replacement. Potential source sin the area could supply and additional 193,800 acre-feet per year, but the region would still suffer a future deficit of almost 800,000 acre-feet per year which must be supplied from sources outside the region. (See Figure 62 .)

The Oklahoma Comprehensive Water Plan proposes a Regional Plan of Development to meet a portion of the region's future water needs. (See Figure 63 .) This plan would utilize the local water resources and include the construction of three new reservoirs — Cookietown, Hydro and Weatherford — with municipal, industrial and irrigation distribution

FIGURE 63 PROPOSED PLAN OF DEVELOPMENT



Data—Oklahoma Water Resources Board, Corps of Engineers, Bureau of Reclamation

Mapping—Oklahoma Water Resources Board

facilities. These three reservoirs could provide an additional 103,300 acre-feet per year and planned SCS structures could augment local water supplies with 90,500 acre-feet per year. A total of 247,000 acres would be irrigated by 2040, based on 2.0 acre-feet of water per acre.

Figure 62 shows the 12 counties in the region, their proposed sources and projected 2040 water demands. Even after development of local proposed sources, 10 of the 12 counties would face a deficit.

The estimated total construction cost of local development for the region is approximately $270.2 million, with an average annual equivalent cost of $17.2 million. (See Figure 64 .) New SCS development is estimated to cost $36 million, a cost representing the local cost for water supply storage in an SCS multipurpose project. Costs for distribution facilities from SCS lakes are not included here, but should be addressed in future planning.

The cost of development for the three proposed reservoirs is estimated at $234.2 million, which includes the cost of the three reservoirs, construction of Faxon Diversion Dam, municipal and industrial distribution facilities from Cookietown and Weatherford, irrigation distribution facilities from Cookietown and Hydro and mitigation/compensation costs. Annual OMR&E costs for these facilities are estimated at $1.7 million, with an average annual equivalent cost of $15.9 million. Additional feasibility studies would be necessary to determine each reservoir's economic feasibility under federal criteria, and the portion of state or local cost that could be required.

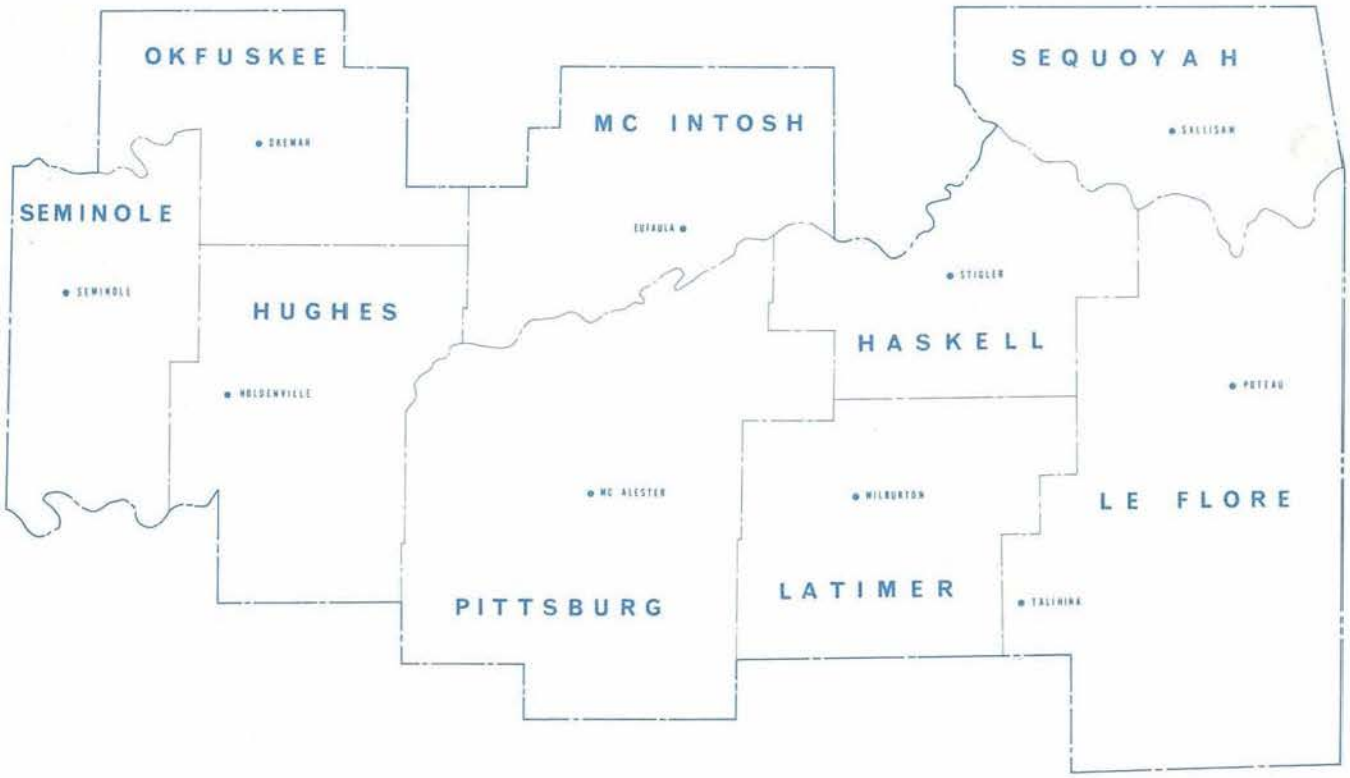
In order to develop a sufficient amount of water from Cookietown Reservoir, a diversion dam would be necessary on West Cache Creek near Faxon in Comanche County. This diversion dam would be connected to Cookietown via a gravity flow canal, allowing a diversion of 47,100 acre-feet per year.

FIGURE 64 SUMMARY OF COSTS[1] PROPOSED PLAN OF DEVELOPMENT (In $1,000)

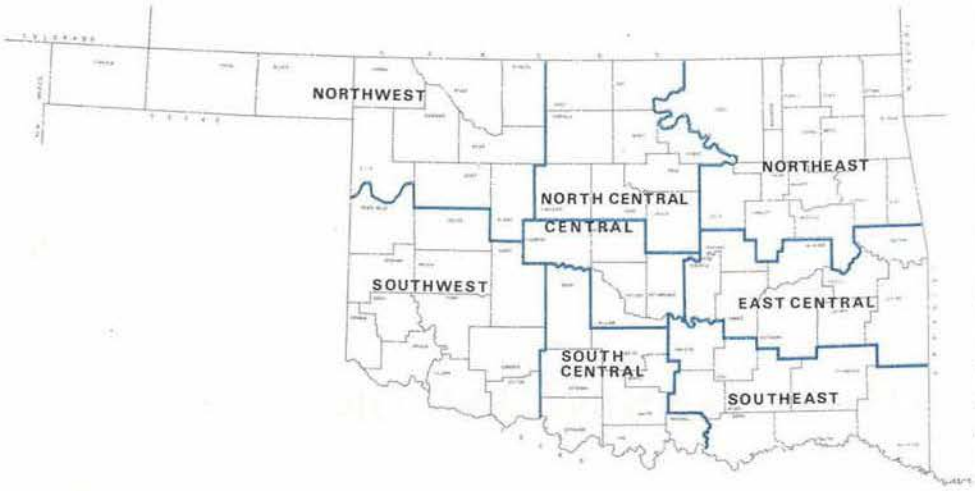
FACILITY	CONSTRUCTION COST	AVERAGE ANNUAL OMR&E[2]	TOTAL AVERAGE ANNUAL EQUIVALENT COST[3]
SCS Lakes	$ 35,990	$ 20	$ 1,230
Major Reservoirs			
Cookietown			
Dam & Reservoir	$ 62,700	$ 50	$ 4,750
Irrigation Distribution	43,430	570	2,450
M & I Distribution	5,260	90	280
Mitigation/Compensation	11,450	25	780
Subtotal	$122,840	735	$ 8,260
Hydro[4]			
Dam & Reservoir	$ —	$ —	$ —
Irrigation Distribution	47,520	620	3,250
Mitigation/Compensation	—	—	—
Subtotal	$ 47,520	$ 620	$ 3,250
Weatherford			
Dam & Reservoir	$ 33,870	$ 30	$ 2,210
M & I Distribution	11,870	280	690
Mitigation/Compensation	1,540	25	130
Subtotal	$ 47,280	$ 335	$ 3,030
Faxon Diversion Dam[5]	$ 16,500	$ 30	$ 1,345
Subtotal	$ 16,500	$ 30	$ 1,345
TOTAL	$270,130	$1,740	$17,115

[1]Based on January 1978 prices.
[2]Energy costs computed at a 30-mil power rate.
[3]Includes interest and amortization as well as average annual OMR&E expenses.
[4]Dam and reservoir and mitigation/compensation costs for Hydro are included in the costs of local development for the Northwest Planning Region.
[5]Mitigation/compensation have not been determined for Faxon Diversion Dam at this time.

EAST CENTRAL PLANNING REGION



The East Central Planning Region consists of Haskell, Hughes, Latimer, LeFlore, McIntosh, Okfuskee, Pittsburg, Seminole and Sequoyah Counties and covers 7,829 square miles. A portion of the rugged, forest-covered Kiamichi Mountains lies in its southeastern part, the wide alluvial plains of the Arkansas and Canadian Rivers dominate the central portion, and the foothills of the Ozarks cross its northern areas. The elevation ranges from 2,700 feet above mean sea level in the mountainous southeast to 900 feet in the rolling western plains.



Most of the region is drained by the Arkansas, (South) Canadian and North Canadian Rivers. Other streams in the region are the Poteau River, Gaines Creek, lower reaches of the Deep Fork River and the headwaters of the Kiamichi River.

The 1977 population estimate of 190,600 residents for the 12 counties of the East Central Planning Region shows an increase of 10 percent over the 1970 figure of 172,734, which increase is almost identical to the 9.8 percent state average.

Per capita personal income rose from $2,293 in 1970 to $4,258 in 1977, and average annual covered employment rose from 16,983 to 27,024. In spite of this substantial increase in employment, the region's unemployment rate remains very high, registering by far the highest in the state at almost 10 percent during 1974 to 1978. Major industries in the area are wholesale and retail trade, manufacturing and services.

Although the region's vast natural resources present it with a potential for unlimited growth, there has been a net decrease in the number of manufacturing firms conducting business in the region. Development of the region's indigenous resources must be awarded top priority if east central Oklahoma is to experience further social and economic progress.

The region has a warm, moist climate with gradual changes. Spring and autumn months are usually mild with warm days and cool nights, and summers are long and hot. Winters are mild and long periods of cold are uncommon.

Annual lake evaporation is approximately equal to annual precipitation. Evaporation rates vary from 56 inches in the west to 48 inches in the east, very low in comparison to other parts of the state, which is attributable to lower summer temperatures and lesser wind velocities. See Figure 9 . Mean annual temperatures vary from 51° to 62°F across the region, as also shown in Figure 7. These characteristics present the region with conditions ideal for the development of reservoirs and storage facilities, as evidenced by the number of lakes in this area.

The length of the growing season averages 212 days. As shown in Figure 8 , average annual precipitation varies from 37 inches in the northwest to 56 inches in southern LeFlore County, with most rainfall associated with frequent spring thunderstorms. Snowfall in the region averages eight inches annually.

Stream water development in the East Central Region has significantly decreased the extent of flooding and flood damage, however, rapid storm runoff from mountainous drainage areas often causes floods of short duration. Flooding most frequently occurs on the smaller tributaries in the region. The Poteau River and Fourche Maline Creek occasionally share moderate flooding problems. In March 1973 their lower reaches experienced minor secondary crests, and in November and December of the same year high waters damaged roads and bridges. Such activity is typical of flood problems experienced in the spring and fall seasons of most wet years.

The Soil Conservation Service has planned or constructed many watersheds throughout the region, including the Poteau River, Fourche Maline, Sans Bois, Wewoka, Coal, Brushy and Peaceable Creeks.

WATER RESOURCES

Stream Water

Abundant rainfall over the East Central Planning Region provides an adequate quantity of water, but quality factors in some streams restrict their use for certain purposes. Despite these restrictions, a bountiful water supply exists for potential development.

The average annual runoff from precipitation ranges from five inches in the northwest to 20 inches in the southeast corner, generating a total of approximately 4,885,000 acre-feet per year. The mountainous terrain encourages rapid accumulation of rainfall, often producing severe, short-

duration flooding. This runoff, plus the flows originating outside the region, constitute a tremendous amount of water flowing through the East Central Planning Region.

A summary of stream flows as recorded at the USGS gaging stations in the region is presented in Appendix B, Figure 2 .

In parts of east central Oklahoma, quality considerations restrict the use of water for beneficial purposes. Waters of the Canadian River above Eufaula Reservoir and the Arkansas River do not meet accepted standards for municipal or domestic use. Natural pollutants and man-made wastes containing organic material and nutrients discharged into these streams degrade water quality. Excessive amounts of dissolved minerals, along with oil brine and sewage effluent, contribute to a high degree of eutrophication of some of the region's reservoir water.

Along with some substandard water, the region possesses an abun-

FIGURE 65 STREAM WATER DEVELOPMENT

NAME OF SOURCE	STREAM	PURPOSE*	FLOOD CONTROL STORAGE ACRE FT.□	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
		EXISTING OR UNDER CONSTRUCTION			
Eufaula Lake	Canadian River	WS, FC, N, P	1,470,000	56,000	56,000
Robert S. Kerr Lake	Main Stem Arkansas	N, P, R	0	0	0
McAlester Lakes[1]	Coal Creek	WS, FC, R	25,000[1]	24,300[1]	10,500[1]
Tenkiller Lake[2]	Illinois River	WS, FC, P, R	576,700[2]	25,400[2]	17,900[2]
Wister Lake	Poteau River	WS, FC, R, FW	400,000	9,600	6,700
TOTAL			2,471,700	115,300	91,100
		POTENTIAL			
				CONSERVATION STORAGE	
Atwood	Canadian	WS, R	—	—	44,800[3]
Brazil	Brazil Creek	WS, FC, R	108,000	190,000	87,400
Higgins	Gaines Creek	WS, R	—	195,000	68,400
Peaceable	Peaceable Creek	WS, R	—	—	33,600[3]
Sasakwa	Little River	WS, FC, R	150,000	600,000	135,500
Tenkiller Power and Inactive Storage	Illinois River	WS, FC, R	—	—	392,100[4]
Vian Creek[5]	Vian Creek	WS, R	—	200,000	—[5]
Weleetka	North Canadian River	WS, R	—	—	35,800[3]
Wetumka	Wewoka Creek	WS, FC, R	36,700	70,000	23,900
Wister Lake Modification	Poteau River	WS, FC, R, FW	400,000	835,000[6]	462,600[6]
TOTAL			694,700	2,090,000	1,284,100
TOTAL YIELD					1,375,200

*WS-Municipal Water Supply, FC-Flood Control, WQ-Water Quality, P-Power, R-Recreation, FW-Fish and Wildlife, I-Irrigation, N-Navigation.

□Although flood control storages are shown for potential sites, further studies will be required to determine the amount of flood control storage that can be economically justified as a project purpose.

[1]The city of McAlester utilizes three lakes for their water supply. The above storages and yields represent the total of the three.

[2]A restudy is currently underway to consider the modification of the existing lake and/or its operation to meet future resource needs of the area.

[3]Storage requirements have not been developed. The yields were based on approximately 60% of the average annual stream flow in the drainage area.

[4]Additional estimated yield that can be developed by converting the hydropower and inactive storage to water supply storage.

[5]Regulating storage reservoir to regulate surplus flows diverted from the Arkansas River.

[6]Additional water supply yield of 462,600 acre-feet per year is based on first, second, and third stage modifications or ultimate development. First stage modification will yield 151,200 acre-feet per year.

dant supply of good quality water which is suitable for most beneficial purposes. Tributary streams of the Arkansas and Canadian Rivers are of good quality, and water in the Poteau River and its tributaries is excellent. Water in Eufaula and Wister Reservoirs is of fair and excellent quality, respectively. Water quality analyses data for selected USGS monitoring stations and the station locations are shown in Appendix B, Figures 4 and 5.

The Arkansas River is the major recipient of the region's runoff from its greater tributaries, the Canadian, Poteau and Illinois Rivers. Waters, via the Arkansas, leave the state on the region's eastern border at Fort Smith, Arkansas. In this region the Arkansas River is a moderately to highly turbid stream with very hard water. The river has relatively low mineralization levels and does not exhibit a toxic metals problem. Nutrient levels are increasing in places, but dissolved oxygen levels remain near saturation most of the time.

The Poteau River drains the southeastern portion of the region with approximately 1,300 of its 1,800 square mile drainage area lying inside the regional boundaries. Levels of nutrients and minerals decrease from the headwaters to Lake Wister, with slight elevations in nutrients observed at stations downstream from the dam.

The Canadian River joins the flow of the Arkansas River in the Robert S. Kerr Reservoir. The segment of the river downstream from Lake Eufaula is of high quality with low enrichment, low mineralization and little evidence of toxic metals. The segment above Lake Eufaula is characterized by elevated phosphorus levels and high solids, primarily chlorides. Lead sometimes exceeds water quality standards in this segment, but no other toxic metals are present in significant concentrations.

The North Canadian River has poor nutrient quality and although less mineralized in this region than in its upstream portions, it is still of poorer quality than other rivers in the area.

STREAM WATER DEVELOPMENT

The East Central Planning Region has experienced extensive development of stream water resources as evidenced by Lake Eufaula and the McClellan-Kerr Navigation System. There are currently four major reservoirs built and maintained by the Corps of Engineers and one group of municipal lakes in the area.

Major Reservoirs

Eufaula Lake, a key unit in the comprehensive development of the Arkansas River Basin, was completed by the Corps in December 1964, authorized for the purposes of flood control, water supply, hydroelectric power and navigation (sediment control). It is the largest lake in the state and the 15th largest man-made lake in the United States, with 143,700 acres of surface area and 600 miles of irregular shoreline. Eufaula is located in McIntosh, Pittsburg, Haskell and Latimer Counties and also extends into Muskogee and Okmulgee Counties in the Northeast Planning Region.

The project supplies 1,470,000 acre-feet of flood control storage and 56,000 acre-feet per year of water supply. The hydroelectric power plant, with three penstocks providing water for three 30,000 kilowatt generating units, has an estimated annual energy output of 317 million kilowatt hours.

Water quality in Eufaula is fair, and is suitable for municipal and industrial use with proper treatment. Natural pollution is contributed by gypsum deposits in the western part of the watershed along with man-made pollution from industrial sources, primarily as a result of past petroleum activities. In recent years, as oil fields upstream from Eufaula have neared depletion, a marked decrease in local chloride concentrations has been noted. It is anticipated that the quality of water in Eufaula will continue to improve.

Current use of Eufaula Reservoir water is limited to numerous small cities and towns, and a substantial amount of water remains available for appropriation.

Robert S. Kerr Reservoir was begun in April 1964 as part of the McClellan-Kerr Navigation System on the Arkansas River, and the lock and dam became operational in December of 1970. The impoundment was authorized for the purposes of navigation, hydroelectric power and recreation. The navigation lock is a single-lift Ohio River type, with culvert and port filling system. The lock chamber is 110 feet wide by 600 feet long and has a maximum litt of 48 feet. The power house is an integral structure with four 27,500 kilowatt units capable of developing a total capacity of 110,000 kilowatts.

The reservoir contains no storage for flood control or water supply, since it is operated as a run-of-the-river project for hydroelectric power generation and navigation.

Tenkiller Lake, located on the Illinois River in Sequoyah County, was completed in July 1953 by the U.S. Army Corps of Engineers. Authorized purposes of the project include flood control and hydroelectric power. The power plant has two 17,000 kilowatt units and is operated remotely from the Fort Gibson power plant. Total flood control storage in the lake is 576,700 acre-feet and the power drawdown is 371,000 acre-feet. There is interim water supply storage of 25,400 acre-feet in the power pool, however, the project is not specifically authorized for that purpose.

The Corps is currently restudying Tenkiller in order to determine the feasibility of adding additional purposes, such as water supply and recreation. Many local towns need water and the excellent quality of water in Tenkiller would make it a viable source. The completion of this restudy is scheduled for 1982.

Wister Lake, located on Poteau River in LeFlore County, was constructed by the U.S. Army Corps of Engineers between 1946 and 1949 for the purposes of flood control and conservation. The lake contains 400,000 acre-feet of flood control storage and 27,100 acre-feet of water

FIGURE 66 STREAM WATER RIGHTS

COUNTY	MUNICIPAL		INDUSTRIAL		IRRIGATION		SECONDARY OIL RECOVERY		COMMERCIAL		RECREATION		TOTAL	
	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated
Haskell	4	3,133	5	3,822	6	970	—	—	2	75	—	—	17	8,000
Hughes	2	3,593	—	—	111	20,265	—	—	1	743	—	—	114	24,601
Latimer	4	5,165	—	—	15	1,999	—	—	—	—	5	2,764	24	9,928
LeFlore	7	26,725	4	254	54	19,934	—	—	—	—	4	447	69	46,360
McIntosh	7	4,039	—	—	2	298	—	—	9	1,225	—	—	18	5,592
Okfuskee	2	8,724	1	161,280	21	9,470	—	—	—	—	1	56	25	179,530
Pittsburg	9	15,213	2	34,200	21	9,252	—	—	13	398	—	—	45	59,063
Seminole	4	4,244	2	35,000	25	5,464	—	—	—	—	3	340	34	45,048
Sequoyah	14	76,227	4	30,970	32	12,330	—	—	8	5,344	4	5,041	62	129,912
Total	53	147,063	18	265,526	287	79,982	—	—	33	7,815	17	8,648	408	509,034

in the conservation pool, which yields 6,700 acre-feet per year for water supply.

The Corps has considered future modifications of the Wister project, the first of which would yield 151,200 acre-feet per year, with the second stage or ultimate modification providing over 473,000 acre-feet of water supply each year.

The existing water supply is currently being utilized by the Cities of Heavener and Poteau and the Poteau Valley Improvement Authority.

Major Municipal Lakes

Lake McAlester is located on Bull Creek about five miles northwest of McAlester in Pittsburg County. The lake was constructed in 1923 and serves as the water supply for McAlester, providing 11,470 acre-feet of storage.

McAlester has two other city lakes, Talawanda Number One and Number Two, which also provide water supply to the area. The combined water supply yield from all three lakes is 10,500 acre-feet per year.

Soil Conservation Service Projects

The Soil Conservation Service has planned and engineered construction of numerous flood control structures in the East Central Planning Region for the purpose of watershed protection and flood prevention. Of the 36 SCS watersheds in this region, 13 are complete or under construction, 12 are planned and 11 have potential for development.

In recent years increased emphasis has been placed on multiple uses of these flood retarding structures. In addition to widespread recreation use, many local sponsors have added water storage for municipal purposes. These structures provide water supply to the Cities of Wilburton, Sallisaw and Talihina. See Figure 26 .

Authorized Development

There are no other authorized projects in the East Central Planning Region.

Potential Development

The subhumid climate, along with the large drainage area of the streams in the region, contribute such a large volume of water that it is virtually impossible to provide adequate storage to develop the full potential of the streams. The sites listed in Figure 65 offer attractive potential for multipurpose development.

STREAM WATER RIGHTS

As of Feburary 20, 1979 there are 408 vested stream water rights and permits issued for the appropriation of 459,034 acre-feet of water per year from rivers, streams and lakes in the region. See Figure 66 .

Ground Water

Ground water is available in the East Central Planning Region from two major ground water basins, the Vamoosa Formation and alluvium deposits. Wells in these basins provide water for domestic, municipal, industrial and irrigation purposes. See Figure 28 .

Vamoosa (Pennsylvanian) underlies an area of approximately 600 square miles, including all or parts of the Barnsdall, Hilltop, Tallant, and Vamoosa Formations and the Ada and Vanoss Groups. It is a complex sequence of fine- to very fine-grained sandstone, siltstone, shale and conglomerate interbedded with very thin limestone. Cumulative thicknesses of water-bearing sandstones are greatest south of the Cimarron River, where they reach a maximum of 550 feet in the vicinity of Seminole. North of the Cimarron River, the average cumulative thicknesses of the sandstones are about 100 feet, but locally may be as great as 200 feet.

The quality of water in the Vamoosa is generally suitable for municipal, domestic and stock use. The water in most of the area is of the sodium bicarbonate type, but water from wells which penetrate to near the base of potable water is commonly of the sodium chloride type. Laboratory and field data indicate that both surface and ground water

FIGURE 67 GROUND WATER RIGHTS

COUNTY	MUNICIPAL # of app.	MUNICIPAL acre-feet allocated	INDUSTRIAL # of app.	INDUSTRIAL acre-feet allocated	IRRIGATION # of app.	IRRIGATION acre-feet allocated	SECONDARY OIL RECOVERY # of app.	SECONDARY OIL RECOVERY acre-feet allocated	COMMERCIAL # of app.	COMMERCIAL acre-feet allocated	RECREATION # of app.	RECREATION acre-feet allocated	TOTAL # of app.	TOTAL acre-feet allocated
Haskell	1	242	—	—	1	640	—	—	—	—	—	—	2	882
Hughes	3	5,930	—	—	23	8,102	1	360	—	—	—	—	27	14,392
Latimer	—	—	—	—	1	134	—	—	—	—	—	—	1	134
LeFlore	1	31	—	—	7	1,420	—	—	1	160	—	—	9	1,611
McIntosh	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Okfuskee	1	1,000	—	—	5	2,260	1	7,043	2	1,833	—	—	9	12,136
Pittsburg	—	—	—	—	5	967	—	—	—	—	—	—	5	967
Seminole	7	7,072	2	1,525	10	2,812	1	990	4	41	—	—	24	12,440
Sequoyah	—	—	—	—	18	7,492	—	—	1	80	—	—	19	7,572
Total	13	14,275	2	1,525	70	23,827	3	8,393	8	2,114		0	96	50,134

These tabulations reflect the total water rights issued by the Board as of a specific date and are not an accurate reflection of the actual amount of water presently being put to use. The data indicate prevalent trends of beneficial water use by county and region.

have been degraded locally by sodium chloride brines.

Alluvium deposits (Quaternary) occur along the Arkansas and Canadian Rivers and are composed of silts, clay, sand and gravel. The total thickness averages 42 feet, and the average saturated thickness is approximately 25 feet. Reported well yields range from 200 to 1,000 gpm. Yields of at least 200 gpm can be obtained in most areas. Although the water is predominantly of a calcium, magnesium bicarbonate type, variable in dissolved solids content and hard, it is suitable for irrigation, domestic, stock and some industrial purposes.

GROUND WATER DEVELOPMENT

Due the the availability of stream water, ground water development in the East Central Planning Region has been limited. Development of the alluvium deposits is limited to those of the Arkansas and Canadian Rivers. Most of the existing development in the Vamoosa occurs in Seminole and Okfuskee Counties. The cities of Konawa, Maud, Seminole, Boley and Paden, as well as a rural water district near Bowlegs, utilize water from the Vamoosa.

Detailed and accurate ground water information is meager, and considerable work is needed to assess the potential development of the region's ground water basins.

GROUND WATER RIGHTS

As of July 1979, there were 96 ground water permits issued for the appropriation of 50,134 acre-feet of water annually within the region. See Figure 67 . Prior rights have not as yet been determined in any county in the region.

PRESENT WATER USE AND FUTURE REQUIREMENTS

The East Central Planning Region is presently using an estimated 73,400 acre-feet of water annually to meet the area's total water demands. Municipal and power uses consume the greatest amount of water, with irrigation the next largest use. Projections indicate that by the year 2040 the region will require 365,100 acre-feet per year to fulfill its water needs, with a dramatic increase in water for cooling purposes expected.

The population of the east Central Region is expected to increase from 190,600 in 1977 to 280,300 by the year 2040, an increase resulting in municipal and rural water needs rising from the present 33,800 acre-feet per year to 70,800 acre-feet annually by 2040. The majority of this increase will be due to the expected growth of the Cities of McAlester, Poteau and Seminole.

Rural water needs in the region are currently being met by 60 rural water districts supplying water to almost 60,000 people. Future needs will be met by expanded rural water systems and water districts.

Industrial water use in the region is currently 9,300 acre-feet per year, with the largest users being clothing manufacturers and oil and gas refineries. Future projections for industrial water needs indicate the region will require 16,900 acre-feet annually by the year 2040.

Use of cooling water for power generation in the area is now 20,800 acre-feet annually. Oklahoma Gas

FIGURE 68 PRESENT AND PROJECTED WATER REQUIREMENTS (In 1,000 Af/Yr)

Use	Present	1990	2000	2010	2020	2030	2040
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

and Electric Company's largest generating plant, with a capacity of 1,562 megawatts, is located in this planning region. Projections indicate a substantial increase in the demand for cooling water in the future, rising to 230,800 acre-feet annually, a sevenfold increase, by 2040.

The Oklahoma State University 1977 Irrigation Survey indicated that the 9-county region contained 25,465 irrigated acres on 172 farms. It is estimated that 9,500 acre-feet of water is presently used for irrigation, with almost half of the total irrigated acreage being located in Hughes County. Projections indicate 47,600 acres will be irrigated by 2040 requiring 46,600 acre-feet of water annually.

PROPOSED REGIONAL PLAN OF DEVELOPMENT

Abundant rainfall and runoff ideally suit the East Central Planning Region to further water resource development. Although a few of the region's major streams have been developed, many potential sources remain. Many local residents are served by inadequate distribution facilities which often are tapped into poor quality sources. To meet future water requirements, east central Oklahoma must rely on new sources and the expanded use of existing supplies.

Existing sources within the region can supply 70,400 acre-feet per year from ground water, SCS and municipal lakes, and federal reservoirs. Potential sources could provide enough water to meet the region's 2040 projected need of 365,000 acre-feet per year, with an annual excess over 880,000 acre-feet. (See Figure 72.) The addition of other potential sources not included in the regional plan could increase the annual surplus to approximately 1.4 million acre-feet.

As part of the Oklahoma Comprehensive Water Plan, a Regional Plan of Development is proposed to meet the 2040 water needs of the East Central region. This plan utilized sources within the region and proposes construction of several major reservoirs, increased ground water development, increased usage of existing supplies and construction of appropriate municipal, industrial and irrigation distribution facilities. (See Figure 70.)

Four new reservoirs — Atwood, Sasakwa, Weleetka and Wetumka — would be constructed in the region. The existing Wister Lake would be modified to increase its dependable yield, present use from Eufaula would be increased and use from Tenkiller Lake would be increased, contingent upon reallocation of hydropower

FIGURE 69 SUPPLY AND DEMAND ANALYSIS PROPOSED PLAN OF DEVELOPMENT (In 1,000 Af/Yr)

Source	Haskell	Hughes	Latimer	LeFlore	McIntosh	Okfuskee	Pittsburg	Seminole	Sequoyah	Total
					Municipal and Industrial Component[1]					
Ground Water & SCS & Municipal Lakes[2]	1.2	4.4	1.1	4.1	0.7	2.7	12.0	13.7	4.3	44.2
Eufaula	—	—	—	—	4.6	—	5.3	—	—	9.9
Tenkiller	—	—	—	—	—	—	—	—	22.6	22.6
Tuskahoma	—	—	—	0.7	—	—	—	—	—	0.7
Atwood	—	—	—	—	—	—	—	44.8	—	44.8
Sasakwa	—	—	—	—	—	—	—	134.6	—	134.6
Weleetka	—	—	—	—	—	7.8	—	28.0	—	35.8
Welty	—	—	—	—	—	3.2	—	—	—	3.2
Wetumka	—	0.9	—	—	—	0.8	—	14.2	—	15.9
Wister (Modification)	3.8	—	5.5	9.7	—	—	—	—	—	19.0
M & I Supply	5.0	5.3	6.6	14.5	5.3	14.5	17.3	235.3	26.9	330.7
					Irrigation Component					
Ground Water & SCS Lakes	1.5	6.8	2.8	6.4	1.1	2.9	6.3	2.6	5.2	35.6
Eufaula	0.9	—	—	—	—	—	—	—	—	0.9
Tenkiller	—	—	—	—	—	—	—	—	3.8	3.8
Sasakwa	—	—	—	—	—	—	—	0.9	—	0.9
Welty	—	—	—	—	—	1.2	—	—	—	1.2
Wetumka	—	5.2	—	—	—	—	—	—	—	5.2
Irrigation Supply	2.4	12.0	2.8	6.4	1.1	4.1	6.3	3.5	9.0	47.6
TOTAL LOCAL SUPPLY	7.4	17.3	9.4	20.9	6.4	18.6	23.6	238.8	35.9	378.3
2040 DEMAND	5.8	17.2	8.7	21.6[3]	6.2	18.7	21.5	238.8	26.6	365.1

[1]Includes cooling water (power) demands.

[2]Includes present municipal use from federal reservoirs.

[3]Remaining supply (700 acre-feet per year) provided by adjacent county.

storage to water supply storage. Tenkiller is presenty authorized to provide 17,920 acre-feet per year, and reallocation by Congress would be required to supply additional water for municipal, industrial and irrigation purposes. New ground water development could provide an additional 11,000 acre-feet per year to the region. A small portion of the region's supply would be provided by two reservoirs outside the region, yet close enough to serve demand centers more economically than sources within the region. These are the authorized Tuskahoma Reservoir in the Southeast Planning Region and the proposed Welty Reservoir in the Northeast region. Total supply from all existing, authorized and proposed sources would be 1.4 million acre-feet per year. A total of 47,600 acres are projected to be irrigated, based on one acre-foot of water per acre.

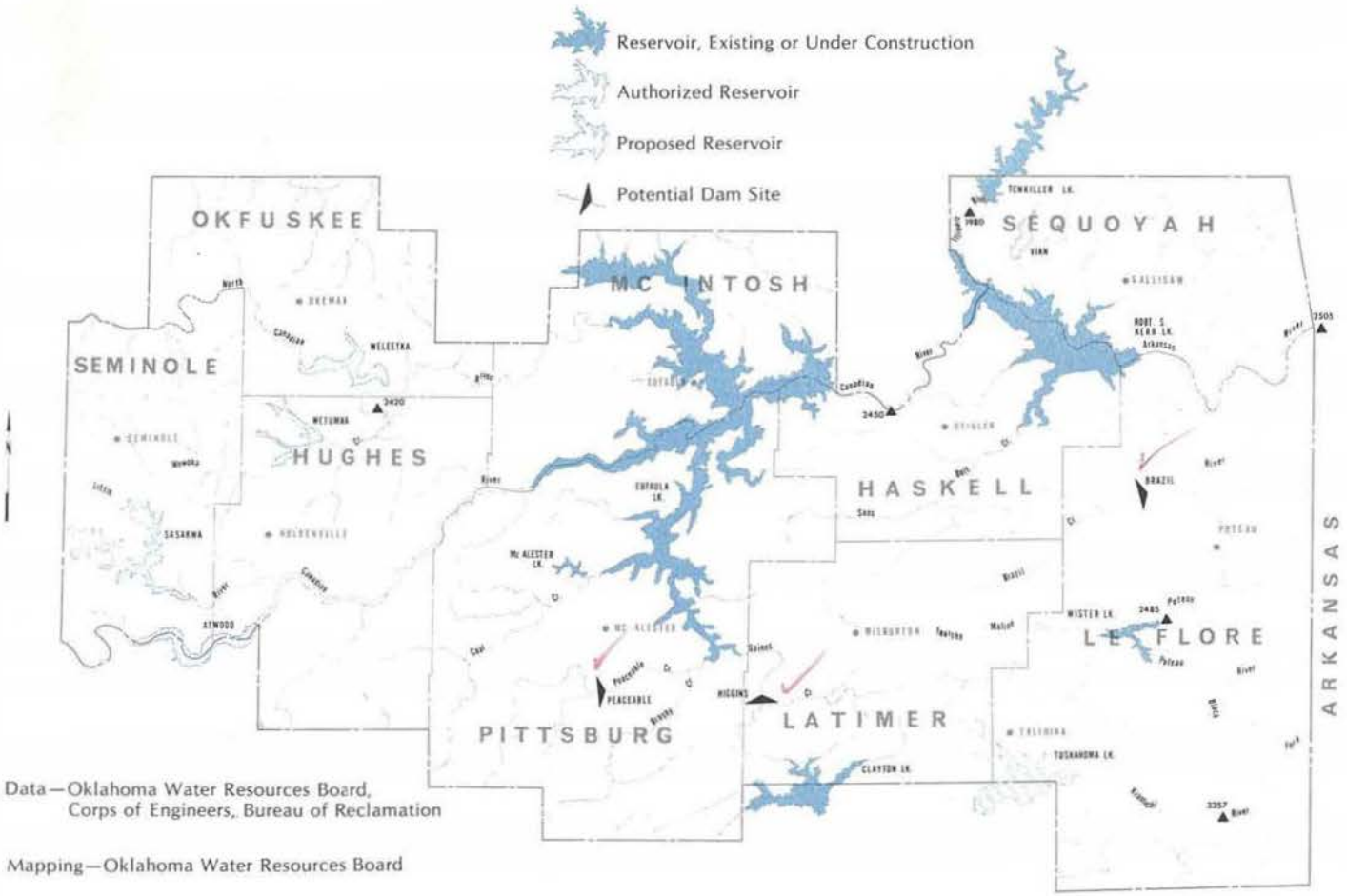
Figure 69 shows the region's nine counties, their proposed sources and projected 2040 water requirements. Total supply would slightly exceed demand due to sources in this region serving adjacent counties in a neighboring planning region. LeFlore County would receive a small portion of its total supply from an adjacent county within the region.

As shown in Figure 71, the total construction cost of all proposed development is estimated to be over $240 million, with an average annual equivalent cost of $18.5 million.

The construction cost of the municipal and industrial water supply system is estimated at slightly more than $200 million, including $149 million for storage, $1.5 million for limited ground water development and $56 million for water conveyance facilities. The annual OMR&E costs for this system are approximately $4.4 million, with an average annual equivalent cost of approximately $16 million.

The irrigation system construction cost is estimated at $37.7 million, including $11.9 million for irrigation storage in potential SCS lakes and existing and proposed major reservoirs, and $25.8 million for distribution facilities from the reservoirs. The annual OMR&E and average annual equivalent costs are $222,000 and $2.8 million, respectively. Distribution costs from SCS lakes are not included, but should be addressed in future planning.

FIGURE 70 PROPOSED PLAN OF DEVELOPMENT



Data—Oklahoma Water Resources Board, Corps of Engineers, Bureau of Reclamation

Mapping—Oklahoma Water Resources Board

FIGURE 71 SUMMARY OF COSTS[1] PROPOSED PLAN OF DEVELOPMENT (In $1,000)

FACILITY	CONSTRUCTION COST	AVERAGE ANNUAL OMR&E[2]	TOTAL AVERAGE ANNUAL EQUIVALENT COST[3]
M & I Water Supply System			
Water Supply Storage	$149,000	$ 460	$ 8,290
Ground Water Development	1,450	170	240
Water Conveyance Facilities	55,700	3,790	7,180
Subtotal	$206,150	$4,420	$15,710
Irrigation Water Supply System			
Water Supply Storage[4]	$ 11,870	$ 12	$ 905
Distribution Facilities	25,800	210	1,925
Subtotal	$ 37,670	$ 222	$ 2,830
TOTAL	$243,820	$4,642	$18,540

[1]Based on January 1978 prices.

[2]Energy costs computed at a 30-mil power rate.

[3]Includes interest and amortization as well as annual OMR&E expenses.

[4]Includes $4,470,000 in construction cost for irrigation storage in potential SCS lakes, $2,000 annual OMR&E and $340,000 total average annual equivalent cost.

FIGURE 72 SURPLUS WATER AVAILABILITY (In 1,000 Af/Yr)

Source	Total Yield	Local Allocation	Potential Surplus
Eufaula	56.0	12.3	43.7
Tenkiller	410.1[1]	214.8[2]	195.2
Tuskahoma	0.7[3]	0.7	—
Atwood	44.8	44.8	—
Sasakwa	135.5	135.5	—
Weleetka	35.8	35.8	—
Welty	4.4[4]	4.4	—
Wetumka	23.9	21.1	2.8
Wister (Modification)	151.2	19.0	132.2
Ground Water & SCS & Municipal Lakes	578.8	63.1	515.7
Subtotal	1441.1	551.5[5]	889.6
Other Potential Sources			
Brazil	87.4	—	87.4
Brushy	9.0	—	9.0
Higgins	68.4	—	68.4
Peaceable	33.6	—	33.6
Wister Modification (Phases 2 & 3)	318.1	—	318.1
Subtotal	516.5	—	516.5
TOTAL	1957.6	551.5	1406.1

[1]Estimated yield from reallocation of hydropower storage to water supply storage.

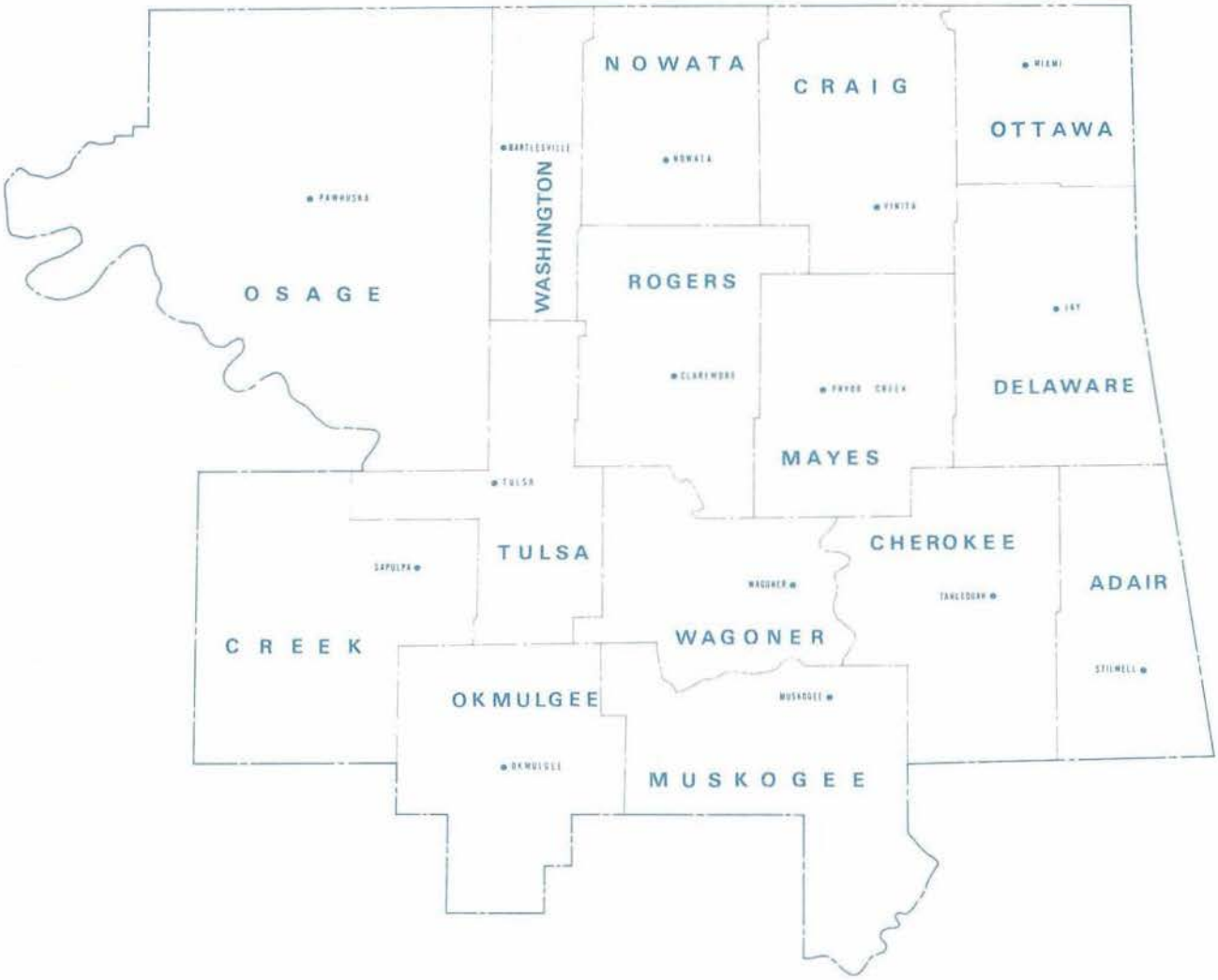
[2]186,500 acre-feet per year of local allocation is for the Northeast Planning Region (28,300 acre-feet per year is allocated to east central region.)

[3]Reflects allocated yield to east central region.

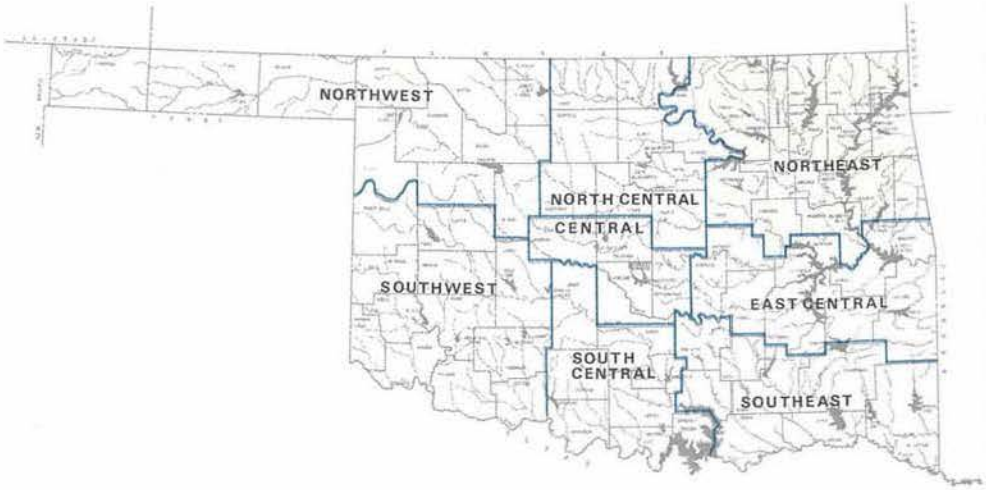
[4]Yield depends on surface water available from Arkansas River.

[5]Includes 186,500 acre-feet per year allocation to northeast region.

NORTHEAST PLANNING REGION



Bordered by Kansas on the north and Arkansas and Missouri on the east, the Northeast Planning Region is composed of 15 counties — Adair, Cherokee, Craig, Creek, Delaware, Mayes, Muskogee, Nowata, Okmulgee, Osage, Ottawa, Rogers, Tulsa, Wagoner and Washington. The eastern counties are distinguished by densely forested mountains, the southern counties by wide alluvial plains along the banks of the Arkansas River, and the northwestern portion by low rolling hills. Elevations range from 1,750 feet above mean sea level in Adair County to 400 feet near the Arkansas River. The region covers 11,794 square miles and is drained by the Arkansas, Caney, Verdigris, Deep Fork, Illinois and Grand (Neosho) Rivers.



The Northeast Planning Region experienced an increase in population from 798,389 in 1970 to 877,800 in 1977, very close to the 10 percent rate of increase registered by the entire state. During the same period per capita personal income rose from $2,910 to $5,596, while average covered employment increased from 105,377 to 287,282; these escalations reflecting the strong economic base of the region. Rapid industrial growth has permitted the region to develop richly in terms of human and natural resources. Wholesale and retail trade, oil and gas activities, manufacturing, services and construction contribute to the economic vitality of these 15 counties.

The Northeast Planning Region appears to have a promising economic future due to its abundant supply of oil, gas, water, land and people. Unemployment rates for the region have been moderate over the last few years, declining to 4.4 percent in 1978. A strong labor force should continue to provide the human resources necessary to develop the area's vast natural resources and promote overall social and economic development.

The moist climate in the region varies from humid in the east to subhumid in the west. Spring and fall months are mild with warm days and pleasant nights, and summers are long and usually moderate. Winters are comparatively mild, but on occasion, brief periods of extremely cold weather have been recorded. Average annual lake evaporation slightly exceeds precipitation, ranging from 56 inches in the west to 46 inches in the extreme northeastern corner. Strong southerly winds contribute significantly to this evaporation rate. Mean annual temperatures vary from 59° in the eastern portion to 61° F in the west.

The length of the growing season averages 195 days. As shown in Figure 8 , average annual precipitation measures approximately 34 inches in the extreme west to 44 inches in Adair County. Maximum precipitation occurs in the late spring and early summer, with May being the wettest month of the year. Average annual snowfall amounts to slightly over eight inches in the region.

In May 1943, some areas of the Neosho and Arkansas River basins received up to 16 inches of rain in a 2-day period, causing the Arkansas to rise six feet over flood stage at Muskogee. In some areas the water rose 40 feet, covering 2-story buildings and drowning 23 people. The same waters destroyed 90 percent of the area's crops. Clean water and food supplies were scarce, and typhoid posed a threat in many communities. In 1972 severe flooding on the Spring River in the northeast corner resulted in heavy damages. Again in 1973 rainfall amounts over five inches caused the Neosho River to rise one to eight feet above flood stage, inundating several thousand acres of land. In the fall of 1974 heavy rains caused waters to rise 10 to 14 feet above flood stage on Bird Creek, Black Bear Creek, Polecat Creek and Little Caney River and resulted in the loss of two lives and $10 million in damages. Severe flooding of the "150-year frequency" occurred on Pryor Creek in September 1975, when 8.5 inches of rain damaged 30 homes and caused $300,000 in property losses. Mingo, Fred and Joe Creeks rose 19.5 feet above flood stage in May 1976, when 11-inch rains were recorded. This "150-year" flood destroyed 255 houses and 100 mobile homes and inflicted damage to another 290 mobile homes, 30 businesses and 416 apartment units. The 1976 flood caused three deaths and an estimated $12 million in damages in the area.

The Corps of Engineers and the Soil Conservation Service contribute to control of main stem flooding by providing storage in reservoirs throughout the region. In the future, adequate floodplain zoning practices could prove an effective and inexpensive means to assist in the control of flooding.

WATER RESOURCES

Stream Water

Abundant rainfall and naturally accommodating terrain have fostered

the construction of many impoundment structures and produced excellent water supplies and recreational facilities for northeast Oklahoma residents and tourists.

Stream water is of high quality, with the exceptions of some of the region's western streams and the main stem of the Arkansas and its tributaries near Tulsa, where natural and man-made pollutants have somewhat degraded the waters. For water quality analysis data at selected USGS monitoring stations, and for locations of these stations, see Appendix B, Figures 4 and 5 .

Average annual runoff ranges from five inches in the northwest corner to 13 inches in the southeast corner, each year producing approximately 5,445,000 acre-feet of runoff providing vast amounts of water surplus to local requirements. A summary of streamflow records from USGS gaging stations within the region is presented in Appendix B, Figure 2 .

The Arkansas River drainage basin encompasses a large portion of this planning region. In general, the Arkansas' water from Tulsa upstream to the mouth of the Salt Fork fails to meet criteria for municipal or domestic use because of high dissolved mineral content from natural sources upstream and/or improper waste disposal. The quality improves significantly by dilution from intervening runoff as it flows downstream from Keystone Dam. Water quality violations have been noted frequently in the waters around the heavily populated Tulsa area. At Muskogee the quality is suitable for municipal raw water supplies approximately 65 percent of the time.

Grand (Neosho) River exhibits good quality water from Kansas to Fort Gibson Reservoir. Turbidity levels are moderately high in the headwaters, but low below the impoundments, and the water ranges from generally hard to slightly alkaline.

The Caney River and Portions of the Verdigris River and some of their tributaries do not meet accepted water quality standards because of occasional high concentrations of dissolved minerals, however impoundments on these streams will provide raw water of acceptable quality for most purposes. The Verdigris has relatively high quality water in the upper reaches, but quality decreases downstream due to contributions from inferior tributaries such as Bird Creek and the Caney River.

The Bird Creek drainage area includes the northern part of the Tulsa metropolitan area. Water quality problems are attributed to sewage effluent and stormwater runoff which contribute fertilizer, animal feces, certain metals and turbidity. Water running off city streets adds oil, grease, asbestos and lead. Polecat and Snake Creeks exhibit problem pollutants such as biochemicals, suspended and dissolved solids, nutrients, some metals and high pH.

The Deep Fork River in this planning region is very turbid and hard, but dissolved oxygen remains near saturation levels and no toxic metals violations have been noted. Because of higher quality flood flows, impounded water of the Deep Fork should produce raw water acceptable for most purposes.

The Illinois River Basin has very good water which is suitable for most purposes. The Illinois, combined with the Grand (Neosho) River, produces an average of nearly six million acre-feet of usable water annually.

Pryor Creek is the recipient of many industrial discharges and has recently exhibited water quality problems in areas where no water quality violations had been previously observed. Recent discovery of the contaminant polychlorinated biphenyls (PCBs) in bottom-feeding fish and sediments precipitated an intensive investigation which is still underway. Since no continuous water quality

FIGURE 73 STREAM WATER DEVELOPMENT

NAME OF SOURCE	STREAM	PURPOSE*	FLOOD CONTROL STORAGE ACRE FT.□	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
		EXISTING OR UNDER CONSTRUCTION			
Birch Lake	Birch Creek	WS, FC, WQ, R, FW	39,000	15,200[1]	6,700[1]
Candy Lake+	Candy Creek	WS, FC, R, FW	31,260	43,100	8,620
Copan Lake+	Little Caney River	WS, FC, WQ, R, FW	184,300	33,600[2]	21,300[2]
Eucha Lake	Spavinaw Creek	WS, R	0	79,600	84,000[3]
Fort Gibson Lake	Grand (Neosho) River	FC, P	919,200	0	0
Grand Lake[4]	Grand (Neosho) River	FC, P	525,000	0	0
Heyburn Lake	Polecat Creek	WS, FC, Conservation	48,400	2,000	1,900
Hudson Lake[4]	Grand (Neosho) River	FC, P	244,200	0	0
Hulah Lake	Caney River	WS, FC, low-flow regulation	257,900	27,500[5]	19,000[5]
Oologah Lake	Verdigris River	WS, FC, N	965,600	342,600	172,500
Skiatook Lake	Hominy Creek	WS, FC, WQ, R, FW	182,300	304,800[6]	85,100[6]
Spavinaw Lake	Spavinaw Creek	WS, R	0	30,600	0[3]
Webber's Falls Lock & Dam	Arkansas River	N,P,R,FW	0	0	0
SUBTOTAL			3,397,160	878,500	399,120

(Continued)

NAME OF SOURCE	STREAM	PURPOSE*	FLOOD CONTROL STORAGE ACRE FT.□	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
		AUTHORIZED			
Sand Lake	Sand Creek	WS, FC, WQ, R, FW	51,700	35,000[7]	13,450[7]
Shidler Lake	Salt Creek	WS, FC, R, FW	49,050	54,900	16,800[8]
SUBTOTAL			100,750	89,900	30,250
TOTAL			3,497,910	968,400	429,370
		POTENTIAL		Conservation Storage	
Big Creek	Big Creek	WS, R	—	—	32,500[9]
Boynton[10]	Cloud Creek	WS, R	—	—	104,800[14]
Chelsea	Pryor Creek	WS, R	—	—	21,300[9]
Eldon[11]	Barren Fork Creek	WS, R	0	280,000	157,900
Fort Gibson Power and Inactive Storage	Grand (Neosho) River	WS, FC, P, R	—	—	223,800[12]
Grand Lake Power and Inactive Storage	Grand (Neosho) River	WS, FC, P	—	—	203,300[13]
Heyburn modification	Polecat Creek	WS, FC, R	70,500	101,500	18,800[14]
Peggs	Spring Creek	WS, R	0	88,000	20,000
Salina	Salina Creek	WS, R	0	73,000	16,000
Sid	Spavinaw Creek	WS, R	0	95,000	20,000
Tahlequah[11]	Illinois River	WS, FC, R	200,000	1,500,000	350,000
Welty[15]	Deep Fork River	WS, R, FW	0	800,000	49,300[1]
TOTAL			270,500	2,937,500	1,217,700
TOTAL YIELD					1,647,070

*WS-Municipal Water Supply, FC-Flood Control, WQ-Water Quality, P-Power, R-Recreation, FW-Fish and Wildlife, I-Irrigation, N-Navigation.

□Although flood control storages are shown for potential sites, further studies will be required to determine the amount of flood control storage that can be economically justified as a project purpose.

+Under Construction.

[1]Includes water quality control storage of 7,600 acre-feet which yields 3,350 acre-feet per year.

[2]Includes water quality control storage of 26,100 acre-feet which yields 17,920 acre-feet per year.

[3]Combined yield of both lakes.

[4]The water of these lakes are under the jurisdiction of the Grand River Dam Authority.

[5]This includes low-flow regulation storage of 7,100 acre-feet which yields 5,040 acre-feet per year.

[6]Includes water quality control storage of 240,000 acre-feet which yields 69,440 acre-feet per year.

[7]Includes water quality control storage of 12,200 acre-feet which yields 4,704 acre-feet per year.

[8]Includes yield of 1,456 acre-feet per year for fish and wildlife releases.

[9]Storage requirements have not been developed. The yields were based on approximately 60% of the average annual streamflow in the drainage area.

[10]Offstream storage reservoir. Yield is developed from surplus flows diverted from the Arkansas River.

[11]These potential sites are located on scenic rivers designated by the State Legislature. The Scenic Rivers Act prohibits the construction of an improvement on a scenic river except as specifically authorized by the Legislature.

[12]Yield that can be developed by converting a portion of the hydro-power storage and inactive storage in Fort Gibson Lake to water supply storage.

[13]Yield that can be developed by converting a portion of the hydro-power storage and inactive storage in Grand Lake to water supply storage.

[14]Additional yield with modification.

[15]Regulating storage reservoir to regulate surplus flows diverted from the Canadian and Arkansas Rivers. The yield of the reservoir can supply 28,100 acre-feet per year of which 23,700 acre-feet per year and 4,400 acre-feet per year is proposed for the Northeast Planning Region and East Central Planning Region respectively.

monitoring stations previously existed on this creek, extremely limited historical data are available.

STREAM WATER DEVELOPMENT

Due to an abundance of good quality water, the Northeast Planning Region has experienced extensive stream water development. Of the 13 major reservoirs existing or under construction, nine are under the jurisdiction of the Corps of Engineers; two are regulated by the Grand River Dam Authority; and two belong to the City of Tulsa.

Major Reservoirs

Birch Lake on Birch Creek in Osage County was completed by the Corps of Engineers in March 1977 for the purposes of flood control, water supply, water quality control, recreation and fish and wildlife. The lake contains 39,000 acre-feet of flood control storage and 15,200 acre-feet of water supply and water quality control storage. The water supply and water quality control storage will yield 6,700 acre-feet annually. Since the water is of excellent quality, it is available for any beneficial use.

The City of Barnsdall has an appropriative right to the water supply yield of the lake and has a contract pending with the Corps to repay the cost of storage.

Candy Lake, located on Candy Creek in Osage County, begun by the Corps of Engineers in 1976 and scheduled for completion in 1982, is authorized for flood control, water supply and recreation. The completed reservoir will provide 8,620 acre-feet of water supply annually to local cities, towns and rural water districts, along with 31,260 acre-feet of flood control storage.

The quality of Candy Lake water is anticipated to be excellent and appropriate for any beneficial use. The lake will provide an abundance of recreational opportunities for residents and tourists in northeastern Oklahoma. Water rights to the yield of the lake have been granted to the Cities of Ocheleta and Owasso and Washington County Rural Water District #3.

Copan Lake, under construction by the Corps of Engineers on Little Caney River in northern Washington County, is authorized for water supply, flood control, water quality control, recreation and fish and wildlife propagation. Scheduled for completion in October 1981, it will provide 184,300 acre-feet of flood control storage and 33,600 acre-feet of water supply and water quality control storage. Dependable annual yield from the reservoir will be 21,300 acre-feet. Water rights to the full water supply yield of the lake are held by the City of Copan and Public Service Company of Oklahoma.

Fort Gibson Lake, on the Grand (Neosho) River, was completed by the Corps of Engineers in 1953, authorized for flood control and hydroelectric power generation. The reservoir provides 919,200 acre-feet of flood control storage. The hydroelectric power plant has four generators with a capacity of 11,250 kilowatts each, with potential for the installation of two additional units.

The Corps recently has been considering adding more power units and/or providing for water supply in the lake. As planning studies continue, the feasibility of these and other alternatives will be assessed.

Heyburn Lake on Polecat Creek southwest of Sapulpa, was completed by the Corps of Engineers in 1950 for the purposes of flood control and conservation storage. The lake provides 48,410 acre-feet of flood control storage. Two thousand acre-feet of water supply storage in the lake will yield 1,900 acre-feet annually. Water rights have been appropriated to Creek County Rural Water District #1, which sells water to Rural Water District #2 to supply Glenpool and Kiefer, and to Rural Water District #3.

Water quality of Heyburn is excellent and the lake is a reliable source of water.

Hulah Lake on the Caney River in far north Osage County, was completed by the Corps of Engineers in 1951 for the authorized purposes of flood control, water supply, low flow regulation and other conservation purposes. The lake contains 257,900 acre-feet of flood control storage and provides 30,300 acre-feet of conservation storage. Hulah Lake's water supply yield of nearly 14,000 acre-feet makes municipal and industrial water available to the local area. The City of Bartlesville and the Hulah Rural Water District have water rights to the lake.

Present water quality of Hulah Lake is excellent, however surveillance of oil field operations and control over waste discharges must continue in order to prevent pollution.

Oologah Lake was built by the Corps in two phases, with the first phase completed in 1963 and the second in 1974. The project, located on the Verdigris River in northern Rogers County, was authorized for flood control, water supply and navigation. Flood control storage in the project is 965,600 acre-feet, with 342,600 acre-feet allocated for water supply, 168,000 acre-feet for navigation and 33,500 acre-feet for 50 years' sediment. Water supply yield from the project is 172,500 acre-feet. The City of Tulsa holds a majority of the water rights for municipal and industrial uses. Other water rights holders include Collinsville, Chelsea, Public Service Company, Nowata Rural Water District #1 and Rogers County Rural Water Districts #1 and #2. Water quality of Oologah is fair and the water must be treated to make it suitable for municipal use.

Skiatook Lake on Hominy Creek near the City of Skiatook was begun by the Corps of Engineers in 1974 for the purposes of flood control, water supply, water quality control, recreation and fish and wildlife. Scheduled for completion in 1982, the flood control storage in Skiatook Lake will be 182,300 acre-feet, with conservation storage of 319,400 acre-feet. The lake contains water supply storage for 15,680 acre-feet of water supply yield and 69,440 acre-feet yield from water quality control storage. The water supply storage yield of the lake has been fully appropriated to the Cities of Skiatook and Sand Springs, Sperry-

Avant-Ramona and Washington County Rural Water District #3. Water rights have also been issued to the City of Sapulpa, Public Service Company and Rogers County Rural Water District #4 from the water quality control storage. The use of this water is contingent upon Congressional reallocation of the water quality control storage to water supply storage.

The quality of water in Skiatook Lake will meet drinking water standards except during periods of low inflows.

Webbers Falls Dam and Lock is an integral component of the McClellan-Kerr Navigation System on the Arkansas River. Begun in 1955, the project was completed in 1970 for the purposes of navigation and hydroelectric power generation, which began in July 1973 and developed a total capacity of 60,000 kilowatts from three units. Average potential power generating capacity is 213,300,000 kwh per year.

Grand Lake o' the Cherokees on the Grand (Neosho) River in far northeastern Oklahoma was constructed by, and remains under the jurisdiction of, the Grand River Dam Authority for the purposes of flood control, hydroelectric power and recreation. Completed in 1940, the huge reservoir spans three counties and is a major recreational attraction. Flood control storage contains 525,000 acre-feet, along with 1,192,000 acre-feet of power storage.

Wash Hudson Lake (Markham Ferry Reservoir) on the Grand (Neosho) River, was completed by the Grand River Dam Authority in 1964. Authorized purposes of the project are flood control and hydroelectric power. The lake contains 244,200 acre-feet of flood control storage and 200,300 acre-feet of run-of-the-river water for power production. Lake Hudson is operated by the GRDA in conjunction with Grand Lake upstream and Fort Gibson Lake downstream for power production.

Major Municipal Lakes

There are two major municipal lakes in the Northeast Planning Region, both built and maintained by the City of Tulsa.

Spavinaw Lake, on Spavinaw Creek, the smaller of Tulsa's two municipal lakes, has a conservation storage capacity of 30,600 acre-feet. Completed in 1924, Spavinaw was the first major transbasin water supply facility constructed in Oklahoma.

Eucha Lake was constructed in 1952 as a municipal water supply reservoir on Spavinaw Creek in Delaware County to augment the storage of Spavinaw Lake, which is located three miles downstream from Eucha. Conservation storage is 79,600 acre-feet with a maximum combined yield of 112,000 acre-feet from Eucha and Spavinaw. The excellent quality water is transported to Tulsa via two pipelines.

Soil Conservation Service Projects

The Soil Conservation Service has 39 watershed projects in this 15-county region designed for the purpose of providing watershed protection and flood prevention as well as providing municipal and industrial water. Local residents and tourists utilize these lakes for recreation, and the Cities of Stilwell and Okmulgee use them for the storage of supplemental water supplies.

Thirteen of the projects are complete or under construction, 17 are planned and the remaining nine have a potential for development. Multipurpose sites are designated as potential municipal water sources for the towns of Foraker, Grainola, Ramona, Bristow, Dewey and Wann.

Authorized Development

There are two water resource projects in the Northeast Planning Region, Sand and Shidler Lakes, authorized for construction by the Corps of Engineers. Upon their completion the lakes will provide a total annual water supply yield of approximately 24,000 acre-feet.

Sand Lake will be located on Sand Creek in Osage County nine miles west of Bartlesville and is authorized for flood control, water supply, water quality, recreation and fish and wildlife. Conservation storage in the lake will be 35,000 acre-feet, with flood control storage of 51,700 acre-feet. The conservation storage will provide a dependable 13,450 acre-feet per year. The City of Bartlesville has the water rights to the yield from the reservoir. The quality of water would be satisfactory for municipal and industrial use after normal treatment.

Shidler Lake was authorized for the purposes of flood control, water supply, recreation and low flow augmentation. The dam will be located on Salt Creek in far southwestern Osage County. The lake is expected to provide 49,050 acre-feet of flood control storage and 15,344 acre-feet per year of dependable water supply yield.

Preconstruction planning has been completed, and the Corps awaits Congressional funding for construction. Water impounded by the project would be of fair quality, suitable for most beneficial uses.

Potential Development

Although numerous reservoirs have been developed utilizing the most suitable dam sites, the favorable climate and topography of the Northeast Planning Region create almost unlimited potential for further development, with those sites listed in Figure 73 considered the most promising. A large portion of the existing reservoir development is authorized for hydroelectic power generation, but the increasing demand for municipal and industrial water supplies may in the future justify the conversion of a portion of the hydroelectric power storage to municipal and industrial storage. The potential water supply development from hydroelectric power conversion in existing reservoirs is shown in the same figure.

STREAM WATER RIGHTS

As of February 20, 1979 there had been issued 592 vested stream water rights and permits for the appropriation of 774,504 acre-feet of water per year in the region. See Figure 74 .

FIGURE 74 STREAM WATER RIGHTS

COUNTY	MUNICIPAL		INDUSTRIAL		IRRIGATION		SECONDARY OIL RECOVERY		COMMERCIAL		RECREATION		TOTAL	
	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated
Adair	6	13,850	3	6,611	115	22,597	—	—	1	16	2	1,060	127	44,134
Cherokee	8	34,831	1	420	41	8,833	—	—	32	1,341	8	1,347	90	46,772
Craig	1	3,620	—	—	—	—	—	—	—	—	—	—	1	3,620
Creek	10	35,800	1	7,511	8	4,167	1	565	2	1,250	—	—	22	49,293
Delaware	1	2,000	—	—	13	2,806	—	—	1	850	—	—	15	5,656
Mayes	3	2,382	—	—	2	160	—	—	—	—	—	—	5	2,542
Muskogee	4	37,620	5	144,581	27	8,664	—	—	—	—	—	—	36	190,865
Nowata	5	6,856	1	27,922	5	886	5	1,140	—	—	—	—	16	36,804
Okmulgee	6	24,168	—	—	7	2,694	3	4,010	—	—	—	—	16	30,872
Osage	26	93,059	4	31,025	39	12,112	3	3,740	4	278	3	440	79	140,654
Ottawa	—	—	—	—	2	280	—	—	—	—	—	—	2	280
Rogers	14	28,552	8	40,644	36	12,213	2	505	10	6,900	2	650	72	89,464
Tulsa	2	7,112	3	26,800	19	1,459	3	2,915	3	178	1	780	31	39,244
Wagoner	7	27,097	1	1,378	22	10,374	1	272	1	40	1	83	33	39,244
Washington	6	42,979	—	—	36	10,812	2	582	1	450	2	237	47	55,060
Total	99	359,926	27	286,892	372	98,057	20	13,729	55	11,303	19	4,597	592	774,504

Ground Water

Major ground water basins in the region are the Roubidoux and Vamoosa Formations and alluvium deposits. See Figure 28 .

Because of their insignificant yields, the Noxie Sandstone, Keokuk and Reeds Springs Formations are considered of minor importance and are not included in this discussion.

See Figure 29 for estimated total water in storage and amounts recoverable from ground water basins in the Northeast Planning Region.

Roubidoux (Upper Cambrian-Lower Ordovician) consists mainly of sandy and cherty dolomite. The Roubidoux basin is generally considered to include the Roubidoux, Gasconade and Eminence-Potosi Formations, of which the Roubidoux is the principal water-bearing unit. It does not outcrop at the surface, but is buried at depths of 450 to 1,700 feet beneath Ottawa and Delaware Counties, and under small parts of Craig and Adair Counties. The artesian or confined water is under sufficient pressure to cause it to rise above the surface. With pumpage over time, the artesian head has declined, requiring the water to be lifted more than 500 feet to the surface in some wells. Yields are as great as 1,000 gpm and average 200 gpm. Although the water is hard, it has a low total mineral content. The water quality in Ottawa County is of a calcium bicarbonate type and suitable for most purposes, but farther west, it changes to sodium chloride and becomes unusable.

Vamoosa Formation (Upper Pennsylvanian) outcrops in a band four to nine miles wide across Osage and Creek Counties. It is composed of interbedded sandstone, shale and conglomerate, with the proportion of shale increasing northward. The formation ranges from about 300 to more than 630 feet thick. The large amount of shale in northern portions of the Vamoosa limits well yields to about 60 gpm, and a major water quality problem is brine infiltration from oilfield operations.

Alluvium deposits (Quaternary) are stream-laid deposits of interfingering sand, silt and clay. The most productive deposits lie along the Arkansas River in a band ranging in width from one to six miles. Near Tulsa, the alluvium is about 30 feet thick, while downstream around Webbers Falls, thickness is approximately 55 feet. Yields range from 20 to 400 gpm, with wells penetrating the sand layers having the greatest yield. Variations in yield depend on well depth as well as size and method of well construction. Water in the alluvium is classified as hard to very hard, with dissolved solids content in excess of 500 mg/L in some places. The water is generally of a sodium or calcium bicarbonate type.

GROUND WATER DEVELOPMENT

The Roubidoux is the most significant aquifer in the Northeast Planning Region, yielding great amounts of ground water to the cities, towns and industries along northern Oklahoma's Missouri and Arkansas borders. It provides municipal supplies to Miami, Afton, Fairland, Bluejacket, Welch, Picher, Quapaw and Commerce, as well as water to extensive mining operations and other industries in the area.

Recharge to the Roubidoux aquifer is in Missouri, and structural features such as faults obstruct the flow of the recharge, resulting in increasing drawdowns in pumped wells. Large drawdowns and declining water levels have made it necessary to lower pumps or deepen wells to attain adequate yields. Although a large amount of water is available in the aquifer, its cost is driven progressively higher by increased pumping lifts.

The alluvium and terrace deposits along the Arkansas River yield large amounts of water, especially in Muskogee, Tulsa, Wagoner and

Osage Counties. Potential exists for expanded development.

The Vamoosa aquifer is a potential source of large amounts of water, however the areas that exhibit the greatest potential are not located near the cities and towns which require large quantities of water. The Cities of Oilton, Bristow and Drumright utilize ground water from the Vamoosa for municipal and industrial supplies. Compared to the amount of water in storage and the annual rate of recharge, the amount of water withdrawn for municipal and irrigation use is insignificant.

GROUND WATER RIGHTS

As of July 1979, 187 ground water permits had been issued in the region, allocating fresh ground water for municipal, industrial, irrigation and other beneficial uses. See Figure 76 .

PRESENT WATER USE AND FUTURE REQUIREMENTS

The Northeast Planning Region is currently using an estimated 307,300 acre-feet of water annually. Municipal use consumes the greatest amount of water, with industrial needs a close second. Irrigation and power needs require significantly smaller amounts as indicated in Figure 75 . Projections indicate that the area will require a total of 971,000 acre-feet per year by 2040 with the majority of the increase to meet additional municipal and power needs.

FIGURE 75 PRESENT AND PROJECTED WATER REQUIREMENTS (In 1,000 Af/Yr)

Use	Present	1990	2000	2010	2020	2030	2040
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

Population figures in 1977 revealed that 877,800 citizens resided in the Northeast Planning Region, and projections indicate that 1,664,200 persons may reside in the 15-county region by the year 2040. As a result of this increase, municipal water demands, which include rural water needs, are expected to grow from the present 119,400 acre-feet per year to 349,000 acre-feet per year. The Cities of Muskogee, Tulsa, Broken Arrow, Bartlesville and Sapulpa are expected to experience the greatest population growth and hence, the largest increases in demand.

One hundred nine rural water districts presently serve the region and obtain their water supplies from both ground water basins and area streams. Projections indicate that rural needs will increase substantially in the future.

Industrial uses currently demand 104,900 acre-feet per year, a figure projected to rise to 187,500 acre-feet annually by 2040. The largest industrial water users are oil and gas refineries and coal mining operations, both water-intensive industries. It is anticipated that 33,600 acre-feet per year of this demand can be met by recycled wastewater.

Utility water requirements in the area are presently 57,000 acre-feet per year. Oklahoma Gas and Electric Company operates two plants in the area with a net generating capacity of

FIGURE 76 GROUND WATER RIGHTS

	MUNICIPAL		INDUSTRIAL		IRRIGATION		SECONDARY OIL RECOVERY		COMMERCIAL		RECREATION		TOTAL	
COUNTY	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated
Adair	1	320	—	—	3	633	—	—	3	3	—	—	7	956
Cherokee	—	—	—	—	3	144	—	—	2	2	—	—	5	146
Craig	2	70	1	56	—	—	—	—	—	—	—	—	3	126
Creek	3	1,724	7	3,227	2	206	10	1,996	—	—	—	—	22	7,153
Delaware	3	176	—	—	1	200	—	—	2	1123	—	—	6	1,499
Mayes	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Muskogee	1	500	2	382	16	5,890	—	—	1	80	—	—	20	6,852
Nowata	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Okmulgee	—	—	—	—	—	—	2	2,914	—	—	—	—	2	2,914
Osage	5	5,512	2	12,275	30	10,915	3	738	3	47	—	—	43	29,487
Ottawa	25	16,195	2	1,191	4	750	—	—	—	—	—	—	31	18,136
Rogers	—	—	—	—	—	—	1	56	—	—	—	—	1	56
Tulsa	3	1,273	2	821	19	3,632	1	14,100	3	750	—	—	28	20,576
Wagoner	—	—	—	—	19	4,426	—	—	—	—	—	—	19	4,426
Washington	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Total	43	25,770	16	17,952	97	26,796	17	19,804	19	2,005		0	187	92,327

These tabulations reflect the total water rights issued by the Board as of a specific date and are not an accurate reflection of the actual amount of water presently being put to use. The data indicate prevalent trends of beneficial water use by county and region.

1,279 megawatts, and an additional plant is under construction. Public Service Company of Oklahoma operates three plants with a combined capacity of 2,770 megawatts. In addition, the Grand River Dam Authority has one existing plant and one under construction, with the total capacity of the two plants being 540 megawatts. It is projected that the demand for water for cooling purposes will increase to 338,900 acre-feet per year.

Present irrigation water needs are 26,000 acre-feet per year for the irrigation of 24,555 acres on 194 farms. Projections indicate that the area will be irrigating 95,600 acres by 2040, requiring 95,600 acre-feet of water annually. Due to abundant rainfall in this area, irrigation water is normally utilized only as a supplemental water supply.

PROPOSED REGIONAL PLAN OF DEVELOPMENT

The Northeast Planning Region experiences generous rainfall and runoff, which present the area with excellent potential for water resources development. The region has many existing major reservoirs and smaller lakes which provide good quality water. However, the area continues to suffer from inadequate distribution facilities, with many people not served by a dependable water system, and flooding remains a frequent problem. Although progress has been made in harnessing the region's raging waters, many areas still need additional flood control and increased amounts of improved quality water.

Existing ground and surface water supplies in the area can provide 302,000 acre-feet per year. Proposed development could supply the additional water to meet 2040 requirements and, as Figure 77 shows, still have a potential surplus in excess of 1.3 million acre-feet per year. With the addition of other potential sources not considered in the plan, a total annual surplus of over two million acre-feet could be developed.

As a part of the Oklahoma Comprehensive Water Plan, it is proposed that the region expand the use of existing sources and develop additional local sources to meet projected water needs. See Figure 80 . Existing reservoirs such as Grand, Fort Gibson and Tenkiller would require a reallocation of hydropower and inactive storage to water supply storage. Existing law requires the Grand River Dam Authority to provide future water supplies to cities and towns in the Grand (Neosho) River Basin. The use of Fort Gibson and Tenkiller Lakes would require Congressional authorization for reallocation to water supply storage. The small amounts of water supply storage presently available in Tenkiller would have to be greatly expanded.

Proposed reservoirs include Welty and Sid Lakes, with Welty also serving the East Central Planning Region. Additional ground water development and new SCS lakes are also proposed to supply additional quantities of water.

Figure 79 shows the 15 counties, planned supplies and projected 2040 water demands. As indicated, supplies would equal or exceed demands in all counties. A total of 95,600 acres is projected to be irrigated based upon one acre-foot of water per acre.

Preliminary cost estimates for the proposed development are shown in Figure 78 . Total construction cost is estimated at $375 million, with an average annual equivalent cost of $41

FIGURE 77 SURPLUS WATER AVAILABILITY (In 1,000 Af/Yr)

Source	Total Yield	Local Allocation	Potential Surplus
Birch	6.7	6.7	—
Candy	8.6	6.5	2.1
Copan	15.0	15.0	—
Eufaula	3.7[1]	3.7	—
Fort Gibson	223.8	107.0	116.8
Grand	203.3	83.6	119.7
Hulah	19.0	19.0	—
Oologah	172.8	172.8	—
Skiatook	73.9	73.0	0.9
Spavinaw[2]	84.0	84.0	—
Tenkiller[1]	186.5	186.5	—
Sand	13.4	13.4	—
Shidler	15.3	2.1	13.2
Sid	20.0	4.0	16.0
Welty	49.3	23.7	25.6
Ground Water & SCS & Municipal Lakes[3]	1234.2	173.0	1061.2
Subtotal	2329.5	974.0	1355.5
Other Potential Sources			
Heyburn (Modification)	20.7	—	20.7
Big Creek	32.5	—	32.5
Boynton	104.8	—	104.8
Chelsea	21.3	—	21.3
Eldon	157.9	—	157.9
Greasy	10.1	—	10.1
Peggs	20.0	—	20.0
Salina	16.0	—	16.0
Tahlequah	350.0	—	350.0
Subtotal	733.3	—	733.3
TOTAL	3062.8	974.0	2088.8

[1]Reflects allocated yield to Northeast Planning Region.

[2]Includes yield of Eucha Lake.

[3]Includes 28,000 acre-feet per year from wastewater reuse and existing municipal sources, with the exception of existing supplies from major reservoirs, which are included in the local allocation for each existing reservoir listed, and with the exception of Spavinaw Lake (listed separately).

million. Costs of the municipal and industrial water supply system are estimated at approximately $363 million for storage and conveyance facilities. Annual OMR&E costs are $14 million for storage facilities and $40 million for conveyance facilities.

The cost for developing irrigation sources is estimated at $12 million, with an annual OMR&E cost of $94,000 and a total average annual equivalent cost of $960,000. These costs include storage in SCS lakes and new ground water development. The cost of distribution facilities is not included here, but should be addressed in future planning.

FIGURE 78 SUMMARY OF COSTS[1] PROPOSED PLAN OF DEVELOPMENT (In $1,000)

FACILITY	CONSTRUCTION COST	AVERAGE ANNUAL OMR&E[2]	TOTAL AVERAGE ANNUAL EQUIVALENT COST[3]
M & I Water Supply System			
Water Supply Storage	$121,000	$ 3,810	$12,880
Water Conveyance Facilities	242,000	10,580	27,480
Subtotal	$363,000	$14,390	$40,360
Irrigation System			
Water Supply Storage[4]	$ 8,570	$ 4	$ 650
Ground Water Development	3,370	90	310
Subtotal	$ 11,940	$ 94	$ 960
TOTAL	$374,940	$14,484	$41,320

[1]Based on January 1978 prices.
[2]Energy costs computed at a 30-mil power rate.
[3]Includes interest and amortization as well as average annual OMR&E expenses.
[4]Estimated cost of irrigation storage in an SCS multipurpose lake.

FIGURE 79 SUPPLY AND DEMAND ANALYSIS PROPOSED PLAN OF DEVELOPMENT (In 1,000 Af/Yr)

Source	COUNTY Adair	Cherokee	Craig	Creek	Delaware	Mayes	Muskogee	Nowata	Okmulgee	Osage	Ottawa	Rogers	Tulsa	Wagoner	Washington	Total Supply
Municipal and Industrial Component[1]																
Ground Water & SCS & Municipal Lakes[2]	–	–	–	2.2	0.1	–	11.4	2.0[3]	8.8	5.0	–	6.7	153.8[3]	–	11.2	201.2
Birch	–	–	–	–	–	–	–	–	–	1.9	–	4.8	–	–	–	6.7
Candy	–	–	–	–	–	–	–	–	–	–	–	5.2	–	–	1.3	6.5
Copan	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15.0	15.0
Eufaula	–	–	–	–	–	–	1.3	–	2.4	–	–	–	–	–	–	3.7
Fort Gibson	–	0.2	–	–	–	–	4.4	–	–	–	–	–	86.5	15.9	–	107.0
Grand	–	–	5.7	–	4.6	35.2	–	–	–	–	15.0	–	16.8	6.3	–	83.6
Hulah	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7.7	7.7
Oologah	–	–	–	–	–	–	–	3.5	–	–	–	77.4	54.5	–	–	135.4
Skiatook	–	–	–	10.3	–	–	–	–	–	2.6	–	6.7	53.4	–	–	73.0
Tenkiller	11.9	11.5	–	–	–	–	163.1	–	–	–	–	–	–	–	–	186.5
Sand	–	–	–	–	–	–	–	–	–	1.8	–	0.2	–	–	11.4	13.4
Shidler	–	–	–	–	–	–	–	–	–	2.1	–	–	–	–	–	2.1
Sid	–	–	–	–	4.0	–	–	–	–	–	–	–	–	–	–	4.0
Welty	–	–	–	9.4	–	–	–	–	14.3	–	–	–	–	–	–	23.7
Adjacent County[4]	–	–	–	–	–	–	8.2	–	0.5	–	–	–	–	0.2	–	8.9
M & I Supply	11.9	11.7	5.7	21.9	8.7	35.2	188.4	5.5	26.0	13.4	15.0	101.0	365.0	22.4	46.6	878.4
Irrigation Component																
Ground Water & SCS Lakes	8.3	6.8	4.6	5.6	2.7	3.5	21.3	2.7	1.8	18.2	1.6	2.4	5.6	6.1	4.4	95.6
Irrigation Supply	8.3	6.8	4.6	5.6	2.7	3.5	21.3	2.7	1.8	18.2	1.6	2.4	5.6	6.1	4.4	95.6
TOTAL LOCAL SUPPLY	20.2	18.5	10.3	27.5	11.4	38.7	209.7	8.2	27.8	31.6	16.6	103.4	370.6	28.5	51.0	974.0
2040 DEMAND	20.2	18.5	10.3	26.4	11.3	37.6	209.7	8.2	27.8	31.6	16.2	103.3	370.4	28.5	51.0	971.0

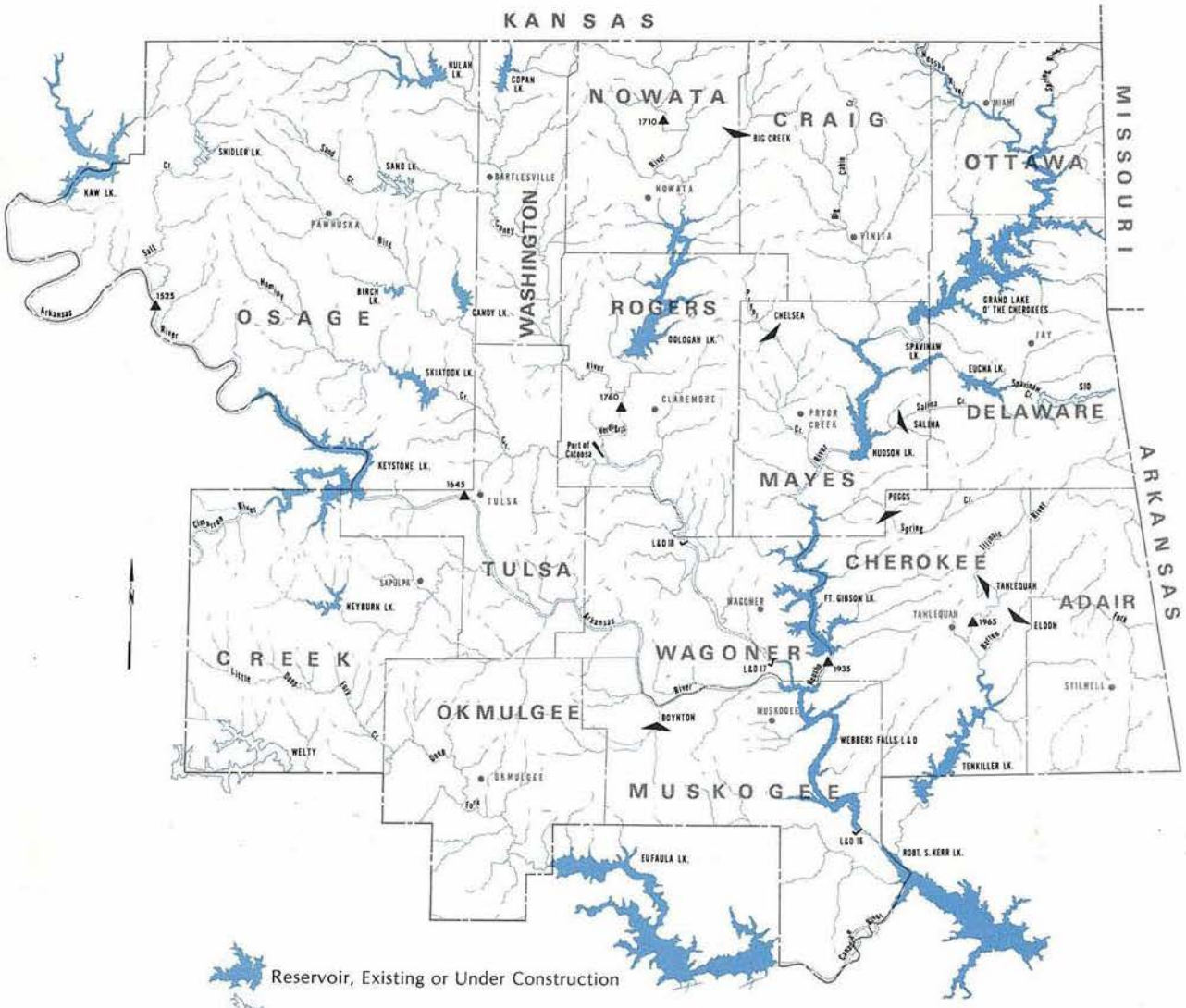
[1]Includes cooling water (power) demands.

[2]Includes present use from existing federal reservoirs.

[3]Includes 84,000 acre-feet per year from Spavinaw and Eucha Lakes, 28,000 acre-feet per year from wastewater reuse and 37,400 acre-feet per year from Oologah Reservoir.

[4]Source of supply from a county in the East Central Planning Region.

[5]Provided by Coffeyville, Kansas.

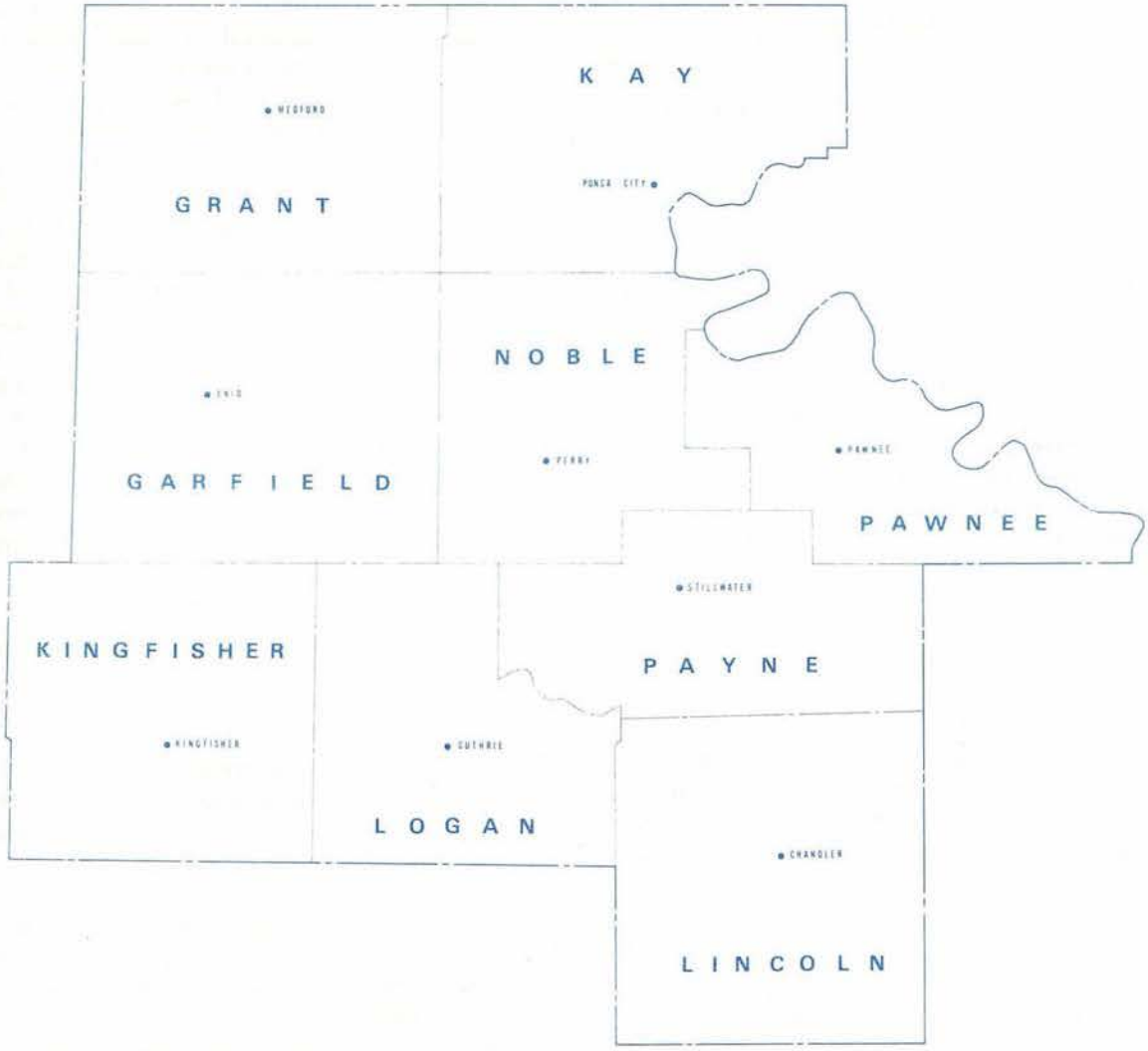


Data—Oklahoma Water Resources Board,
Corps of Engineers, Bureau of Reclamation

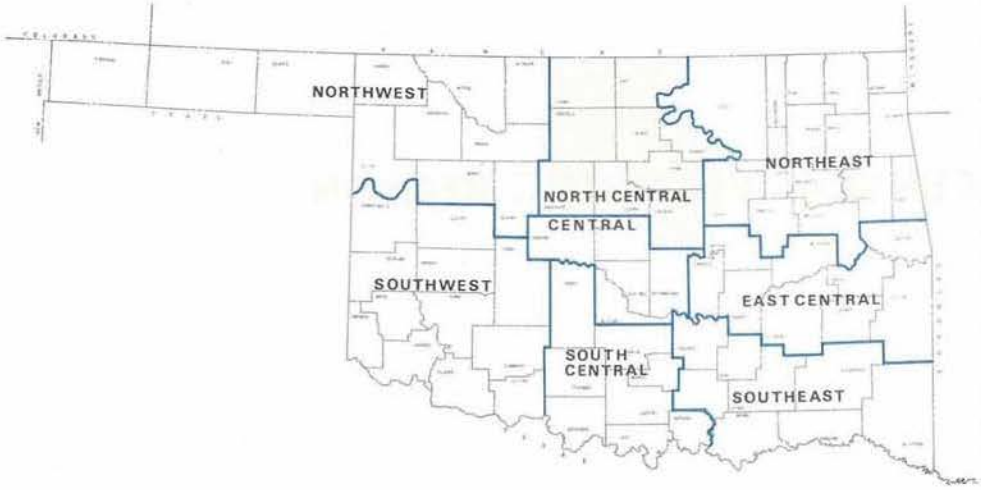
Mapping—Oklahoma Water Resources Board

FIGURE 80 PROPOSED PLAN OF DEVELOPMENT

NORTH CENTRAL PLANNING REGION



The North Central Planning Region covers 7,689 square miles and includes the counties of Garfield, Grant, Kay, Kingfisher, Lincoln, Logan, Noble, Pawnee and Payne.



The region rolls from bare, low sandhills in the west to scrub oak-spattered hills in the center to rough, densely forested hills in the east. Elevations range from 1,100 feet above mean sea level in Grant County to 850 feet in Lincoln County. The Cimarron, Chikaskia, Salt Fork of the Arkansas and the Arkansas Rivers drain the region.

Agriculture is the leading industry, with approximately half of the region's total area either in pastureland for grazing beef and dairy cattle or in cropland for the cultivation of wheat and other grains. All of the North Central Planning Region lies in the southern part of the midwest's wheat belt. Agriculture flourishes in the region, but frequent droughts inflict severe damage to crops. Dependable sources of water must be developed to insure the continued growth and prosperity of the agricultural economy. Oil and gas production is active in all nine counties, but the greatest production is from two giant oil fields, Tonkawa in Kay and Noble Counties and Sooner Trend in Garfield, Kingfisher and Logan Counties.

The population of the 9-county region has increased from 235,292 in 1970 to 262,800 in 1977, a 12 percent rise. During that same period, per capita personal income rose from $3,229 to $5,877 and the average covered employment increased from 37,783 to 66,942. Such increases reflect the region's rapid industrial growth in recent years, with 21 new manufacturing firms locating in the area between 1974 and 1978. Major industry types include wholesale and retail trade, manufacturing and personal services. Growth is most apparent in the area's three largest cities, Enid, Stillwater and Ponca City, which have grown at an average rate of 17 percent since 1970. Since the labor force has grown at a slower rate than that of the general population, the region's unemployment rate has remained among the lowest in the state.

The climate of the North Central Planning Region is moist and subhumid. Average annual lake evaporation greatly exceeds annual precipitation, ranging from 61 inches in the west to 55 inches in the east. See Figure 9 . Mean annual temperatures vary little across the region, from 60° to 61°F. as shown in Figure 7 . The length of the growing season averages approximately 205 days. Annual precipitation ranges from 28 inches in the west to 36 inches in the extreme eastern portion of the region as shown in Figure 8 . Maximum precipitation occurs in the spring and fall, and May is the wettest month of the year. Seventy-five percent of the annual precipitation falls during the 205-day growing season, and thunderstorms often accompanied by high winds and hail occur frequently over the region. Snowfall averages 14 inches annually.

The most severe flooding in the region is the result of sudden, concentrated areas of heavy precipitation that occur over the basin in a short time. In October 1973 a record-breaking 15.68-inch rainfall in a 24-hour period in the Enid area caused severe damage. Seventy-five percent of this amount fell in four hours, with total precipitation exceeding 20 inches reported at some stations. Devastating flooding occurred on the Salt Fork at Tonkawa, where several hundred motorists were stranded when a section of Interstate Highway 35 washed out. Other areas affected by the same storm were Ponca City and Ralston on the Arkansas River, Blackwell on the Chikaskia, and Waynoka, Dover, Guthrie and Perkins on the Cimarron. Tributaries to these streams which overflowed their banks included Skeleton, Black Bear and Red Rock Creeks, and especially Turkey Creek which heavily damaged Dover. Damage estimates reached $30 million in losses to property and agriculture.

In 1974 the Chikaskia again rose to seven feet above flood stage, forcing the evacuation of families from their homes in Blackwell. Black Bear Creek, Deep Fork Creek and other area streams rose 10 to 14 feet over flood stage and disaster relief funds were requested in several of the region's counties. In May 1975, 200 people were driven from their homes by four inches of rain that caused the Cimarron south of Stillwater to rise 3.7 feet. The Soil Conservation Service continues its program of watershed protection and flood prevention with projects planned or under construction in major problem areas of the North Central Planning Region.

WATER RESOURCES

Stream Water

The major streams in the North Central Planning Region are the Cimarron, Salt Fork of the Arkansas

and Arkansas Rivers with a combined drainage area of 7,689 square miles.

Average annual runoff from precipitation ranges from about two inches in western Garfield County to five inches along the eastern edge of Pawnee County. See Figure 20 . Approximately 5,000,000 acre-feet of water leaves the North Central Planning Region annually through the Arkansas River. The U.S. Geological Survey maintains 10 streamflow gaging stations in this region which provide data for determining the amount of water available for storage at particular sites and the effects of impoundment structures on downstream flows. See Appendix B, Figure 2 .

Water of the major streams in the region is generally of poor quality and unsuitable for many beneficial purposes. Good quality water in this planning region is confined to the tributaries of the major streams, such as the Chikaskia River tributary of the Salt Fork. For water quality analysis data at selected U.S. Geological Survey monitoring stations and locations of these stations, see Appendix B, Figures 4 and 5 .

The Cimarron River, which flows through Kingfisher, Logan and Payne Counties, has poor water quality due to high nutrient levels contributed by Cottonwood and Skeleton Creeks and heavy mineralization. The poor mineral quality is primarily due to natural chloride pollution in its upper reaches. The river water is very hard with moderate to high turbidity and pH levels sometimes in excess of water quality standards. Dissolved oxygen remains at or near saturation levels, and iron, manganese, lead, silver, cadmium and arsenic are present in elevated concentrations.

Cottonwood Creek, a tributary of the Cimarron River, has poor quality water due to high nutrient levels, high concentrations of iron and manganese and moderate levels of mineralization. It is a moderately turbid stream and dissolved oxygen concentrations decrease to near septic conditions during warm weather. These problems are the result of urban runoff and numerous sewage treatment plants discharging to tributary streams, especially Deer and Chisholm Creeks. However, completion of tertiary sewage treatment plants presently under construction and planned in the area, waters impounded on Cottonwood Creek will be suitable for municipal and industrial uses with appropriate treatment.

The Salt Fork of the Arkansas River draining northern portions of the region has very poor quality water. The water is extremely hard and very high in pH, often exceeding the Oklahoma water quality standards, however dissolved oxygen remains near saturation levels. The stream is moderately turbid, and chromium, lead and mercury levels occasionally violate standards.

The Deep Fork River in Logan and Lincoln Counties of this planning region contains turbid, hard water, although dissolved oxygen remains near saturation levels and no toxic metals have been noted recently.

The Chikaskia River, a tributary of the Salt Fork, has good water quality with low nutrient and mineral levels and dissolved oxygen remaining near saturation levels throughout the year. The river has hard water, moderate turbidity and the pH sometimes exceeds water quality standards.

The Arkansas River forms part of the eastern boundary of the North Central Planning Region. The river enters the state in Kay County and has poor water quality due to heavy nutrient loading and high mineralization. The nutrient quality improves, but due to elevated chloride concentrations, the mineral quality degrades significantly below its confluence with the Salt Fork. The stream has hard water and turbidity is moderately high in the headwaters-to-Ralston segment, but becomes much less turbid downstream. The river is slightly alkaline with high pH, but dissolved oxygen remains near saturation levels. Iron and manganese frequently exceed recommended limits, and of the toxic metals, chromium sometimes exceeds limits in the upper reaches.

STREAM WATER DEVELOPMENT

The North Central Planning Region has experienced limited surface water development because of poor stream water quality. There are two existing major reservoirs constructed by the Corps of Engineers and three major municipal lakes in the region.

Major Reservoirs

Kaw Reservoir, located on the main stem of the Arkansas River, was completed in May 1976. Authorized purposes of the project include flood control, water supply, water quality, recreation and fish and wildlife. Provisions for possible future development of hydroelectric power have been included in Kaw Dam, however installation of power facilities has not yet been authorized. Flood control storage is over 860,000 acre-feet, with a water supply and water quality storage capacity of 203,000 acre-feet. Water supply yield, including water quality storage, is 230,700 acre-feet per year. Oklahoma Gas and Electric Company is allocated approximately 40,000 acre-feet of water for cooling purposes at the company's generating plant downstream. Kaw City and the Kaw Reservoir Authority consisting of the member cities of Enid, Stillwater, Perkins, Yale, Perry, Tonkawa, Ponca City, Blackwell, Braman, Shidler, Morrison and Billings also have allocations of storage in the reservoir. The Kaw Reservoir Authority is seeking funding to finance a regional distribution system from Kaw to the member cities. If such efforts are successful, the regional system will be the largest such system in the state.

Water quality of the reservoir is fair and considered suitable for most beneficial purposes.

Keystone Lake, also located on the main stem of the Arkansas River, was completed in 1965, and authorized for flood control, water supply, hydroelectric power, navigation and fish and wildlife. The project contains 1,218,500 acre-feet of flood control

storage, along with 330,500 acre-feet of power storage. Water supply storage of 20,000 acre-feet provides a yield of 22,400 acre-feet annually. Two 35,000-kilowatt power generation units at the lake produce an average of 228 million kilowatt hours of energy each year. Public Service Company is allocated storage and utilizes water for cooling purposes at their plant in Tulsa.

Water quality of Keystone is poor due to the confluence of the Salt Fork and the Arkansas River upstream and the entrance of the Cimarron River at the southwest corner of the lake. Although poor quality restricts the use of water for most beneficial uses, the lake is an important recreational facility for area residents and tourists.

Major Municipal Lakes

Lake Carl Blackwell, on Stillwater Creek in Payne County, was built by the U.S. Department of Agriculture, and is owned and operated by Oklahoma State University. The university uses water and sells water to the City of Stillwater for municipal and industrial purposes. The lake contains 55,000 acre-feet of water supply storage with a yield of 7,000 acre-feet per year.

In addition to providing water supply to Stillwater, the lake plays a significant role in the research and educational mission of the university. Since its completion in 1937, Lake Carl Blackwell has also offered abundant recreational opportunities to residents of the area.

Lake McMurtry is located on North Stillwater Creek, north of Lake Carl Blackwell. Owned by the City of Stillwater, the lake has 5,000 acre-feet of flood control storage as well as 13,500 acre-feet of water supply storage, with a dependable yield of 3,000 acre-feet annually. McMurtry also provides recreational opportunities complementing those of Lake Carl Blackwell.

Lake Ponca was completed in 1935 on Big and Little Turkey Creeks approximately three miles north of Ponca City. The city maintains a park

FIGURE 81 STREAM WATER DEVELOPMENT

NAME OF SOURCE	STREAM	PURPOSE*	FLOOD CONTROL STORAGE ACRE FT.□	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
		EXISTING OR UNDER CONSTRUCTION			
Lake Carl Blackwell	Stillwater Creek	WS, R	0	55,000	7,000
Kaw Lake	Arkansas River	WS, FC, WQ, R, FW	866,000	203,000[1]	230,700[1]
Keystone Lake	Arkansas River	WS, FC, P, FW	1,218,500	20,000	22,400
Lake McMurtry	North Stillwater Creek	WS, FC, R	5,000	13,500	3,000
Lake Ponca	Big and Little Turkey Creeks	WS, R	0	15,300	9,000
Sooner Lake[2]	Greasy Creek	P, FC, R	47,500	149,000[2]	3,600[2]
TOTAL			2,137,000	455,800	275,700
		POTENTIAL			
				CONSERVATION STORAGE	
Hennessey	Turkey Creek	WS, R, FW, I	0	173,000	18,800
Hunnewell	Chikaskia River	WS, FC, R, I	112,000	473,400	54,700
Lela	Black Bear Creek	WS, FC, R	84,000	199,200	48,400
Otoe	Red Rock Creek	WS, FC, R, I	142,000	403,300	46,000
Seward	Cottonwood Creek	WS, FC, R	51,000	128,200	21,700
Sheridan	Skeleton Creek	WS, FC, R, I	91,000	195,500	24,000
TOTAL			480,000	1,572,600	213,600
TOTAL YIELD					489,300

*WS-Municipal Water Supply, FC-Flood Control, WQ-Water Quality, P-Power, R-Recreation, FW-Fish and Wildlife, I-Irrigation.

□Although flood control storages are shown for potential sites, further studies will be required to determine the amount of flood control storage that can be economically justified as a project purpose.

[1]Includes water quality control storage of 31,800 acre-feet which yields 43,680 acre-feet per year.

[2]Provides existing and ultimate cooling water requirements for Oklahoma Gas and Electric Company's electric generation station. The conservation storage includes 128,000 acre-feet of inactive storage utilized as a heat sink for cooling purposes. The 3,600 acre-feet per year yield listed is developed locally from the Greasy Creek Drainage area. An additional yield of approximately 40,000 acre-feet per year is developed from releases of storage provided in Kaw Lake.

with recreational facilities around the lake.

Dependable yield from the lake is 9,000 acre-feet of water annually. The City of Ponca mixes this lake water with ground water to supply the city's needs.

Soil Conservation Service Projects

The Soil Conservation Service has planned and engineered the construction of numerous flood control structures for watershed protection and flood prevention throughout the North Central Planning Region. Of the 38 small watersheds in the region, 16 are complete or under construction, 13 are planned and nine have potential for development.

With increased emphasis on multipurpose projects, seven such projects were developed in this planning region. In addition to widespread recreational use, many local sponsors such as Perry, Stroud, Stillwater, Meeker, Sparks, Lucien and Langston have added water storage for municipal purposes. Similar structures combining the purposes of recreation and municipal water supply are planned for the Cities of Chandler, Wellston, Prague, Pawnee, Morrison and Glencoe.

Authorized Development

There are no authorized projects in the North Central Planning Region.

Potential Development

Because of constraints imposed by poor water quality of the major rivers in the North Central Planning Region, potential for additional stream water development is generally limited to sites located on tributary streams. An exception is the Hunnewell site located on the Chikaskia River, which would offer good quality water. The potential Seward site on Cottonwood Creek is presently undergoing feasibility-level investigations to determine its suitability as a future water supply source for the City of Guthrie. In addition, those sites listed in Figure 81 offer the greatest potential for development.

STREAM WATER RIGHTS

As of February 20, 1979 there had been issued a total of 321 vested stream water rights and permits for the appropriation of 392,298 acre-feet of water per year from rivers, streams and lakes in the region. The tabulation by county and use is shown in Figure 82 .

Ground Water

The Vamoosa Formation, Garber-Wellington Formation and alluvium and terrace deposits are the three major ground water basins in the North Central Planning Region. See Figure 28. Ground water is the source of water for most of the area's rural homes, many municipalities and extensive irrigated agriculture. See Figure 29 for estimated total water in storage and amounts recoverable from ground water basins.

Vamoosa Formation (Pennsylvanian) outcrops in Pawnee County and in eastern Payne and Lincoln Counties. It ranges in thickness from 300 to 400 feet and consists of interbedded sandstone, shale and conglomerate, with the amount of sandstone decreasing northward. The rock types in the Vamoosa differ in color and grain sizes, varying from fine to extremely coarse in clastic rocks. The sandstone of the aquifer yields about 100 gpm. Chemical quality of the water ranges widely, but generally has a high concentration of sodium bicarbonate.

Garber-Wellington Formation (Permian) consists of two rock units, the Garber Sandstone and the Wellington Formation, deposited under similar conditions and considered a single water-bearing zone. Both contain lenticular beds of red, fine-grained sandstone alternating with shale. The formation is approximately 300 feet thick near the Oklahoma -Logan County Line. In Logan County it is shaly and has low permeability, with wells yielding 10 gpm or less near Guthrie. Generally, the water is suitable for most purposes, but in some areas it is hard and high in sulfate, chloride, flouride and nitrate

FIGURE 82 STREAM WATER RIGHTS

	MUNICIPAL		INDUSTRIAL		IRRIGATION		SECONDARY OIL RECOVERY		COMMERCIAL		RECREATION		TOTAL	
COUNTY	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated
Garfield	3	160	2	251	36	3,597	—	—	1	80	—	—	42	4,088
Grant	—	—	—	—	9	1,460	—	—	—	—	1	15	10	1,475
Kay	10	107,282	3	94,000	31	5,867	—	—	1	90	1	1	46	207,240
Kingfisher	—	—	1	60	26	9,102	—	—	1	76	1	145	29	9,383
Lincoln	8	7,057	—	—	23	4,819	—	—	1	55	2	45	34	11,976
Logan	6	39,109	6	1,991	48	8,045	—	—	1	136	2	45	63	49,326
Noble	5	2,940	—	—	22	2,264	—	—	1	30	—	—	28	5,234
Pawnee	9	9,521	2	6,828	11	1,972	1	5	4	620	—	—	27	18,944
Payne	5	62,497	2	3,752	32	5,739	—	—	1	100	2	12,544	42	84,632
Total	46	228,566	16	106,880	238	42,865	1	5	11	1,187	9	12,795	321	392,298

FIGURE 83 GROUND WATER RIGHTS

COUNTY	MUNICIPAL		INDUSTRIAL		IRRIGATION		SECONDARY OIL RECOVERY		COMMERCIAL		RECREATION		TOTAL	
	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated
Garfield	44	21,276	3	592	13	2,038	—	—	2	124	—	—	62	24,000
Grant	12	26,205	—	—	48	13,254	—	—	—	—	—	—	60	39,459
Kay	9	47,808	5	8,197	29	8,154	2	1,648	1	74	—	—	46	65,881
Kingfisher	20	6,661	5	17,253	162	44,186	2	2,300	—	—	—	—	189	70,400
Lincoln	10	3,987	1	161	9	1,297	1	1,175	2	151	—	—	23	6,771
Logan	5	1,417	1	1,150	21	6,056	1	2,000	3	917	—	—	31	11,540
Noble	6	587	—	—	10	4,016	1	188	—	—	—	—	17	4,791
Pawnee	4	1,800	—	—	4	1,360	1	211	1	298	—	—	10	3,669
Payne	10	1,289	4	5,952	22	10,354	3	658	3	202	—	—	42	18,455
Total	120	111,030	19	33,305	318	90,715	11	8,180	12	1,766		0	480	244,996

These tabulations reflect the total water rights issued by the Board as of a specific date and are not an accurate reflection of the actual amount of water presently being put to use. The data indicate prevalent trends of beneficial water use by county and region.

concentrations. Dissolved solids range from 100 to 1,000 mg/L.

Alluvium and terrace deposits (Quaternary) are found in all of the region's nine counties, mainly along the Salt Fork of the Arkansas River across Grant and Kay Counties. Minor extensions reach in to Pawnee County and along the Cimarron River across Kingfisher County into Logan County. The deposits were stream-laid in an irregular pattern and consist of unconsolidated clay, silt, sand and gravel which interfinger.

The alluvium and terrace deposits along the Salt Fork reach a maximum thickness of about 60 feet, while similar deposits along the Cimarron attain a thickness of 120 feet. Maximum saturated thickness for the Salt Fork and the Cimarron deposits are 35 and 50 feet, respectively. Well yields from the alluvium of the Salt Fork average 400 to 500 gpm, while yields from the terrace are approximately 100 to 200 gpm. Well yields along the Cimarron range from 1,000 gpm to less than 50 gpm, averaging 100 to 300 gpm.

The water of the Cimarron alluvium is of poor quality due to high chloride and sulfate concentrations introduced upstream. Water quality of the Cimarron terrace deposits is generally suitable for most purposes, except in some areas where salt water encroachment has made the water unfit for domestic use. The water is hard and is of a calcium magnesium bicarbonate type. Dissolved solids average 350 mg/L. Water from the alluvium of the Salt Fork is poor, due to high sulfate and chloride concentrations, while that of the terrace deposits is suitable for most purposes and chemically similar to ground water of the Cimarron terrace.

GROUND WATER DEVELOPMENT

Only a small part of the water stored in the Garber-Wellington Formation is presently being utilized. The most productive portion of the basin is south of the Cimarron River to the Oklahoma County line. Although a few small towns and rural homes north of the Cimarron utilize water from the aquifer, low yields and the threat of salt water intrusion limit development in the lower portion of the basin. Potential exists for greater development, but the number of wells, their spacing and pumping rates will require management in order to prevent saline intrusion which could significantly reduce the supplies of fresh ground water.

Terrace deposits along the Cimarron River provide municipal and industrial water to the Cities of Enid and Hennessey, as well as ground water for irrigation. Some small communities and rural water districts utilize water from wells in the terrace of the Salt Fork of the Arkansas River. The terrace and alluvium deposits in the North Central Planning Region are only slightly developed and have the potential for the development of large capacity wells.

The Vamoosa Formation is the most important aquifer in this planning region and has the greatest potential for further development. As well as the Cities of Cushing, Stroud and Prague, many smaller towns and industries obtain water from the aquifer. The most favorable area for development appears to be the southeast corner of Payne County and Northeast Lincoln County, due to the water being of questionable quality in other areas.

GROUND WATER RIGHTS

As of July 1979, there was a total of 480 ground water permits issued, allocating fresh ground water for municipal, irrigation or industrial use. See Figure 83 .

PRESENT WATER USE AND FUTURE REQUIREMENTS

The population of the North Central Planning Region was estimated at 262,800 in 1977, and is projected to increase to 412,100 by the year 2040. Present annual water use is estimated at 126,400 acre-feet and is projected to increase by 2040 to 659,900 acre-feet. Municipal and industrial uses are currently the

largest water use categories, however, irrigation is anticipated to consume over half the total water requirements by the year 2040.

Municipal water uses, which include rural domestic water needs, are presently estimated to be 45,600 acre-feet per year, but an increasing population is expected to push municipal water requirements to 101,600 acre-feet anually by 2040. The majority of this increase is due to expected growth of the Cities of Enid, Stillwater and Ponca City.

Rural water needs are currently being met by 53 rural water districts serving almost 35,000 customers. Future rural growth will require expansion of existing systems and creation of new ones to satisfy the water needs of the numerous small towns and rural areas in the region.

Industrial water use in the North Central Planning Region is presently 47,600 acre-feet per year. Oil and gas refineries, along with iron and steel manufacturers and machinery production companies, are the largest industrial water users. Industrial water needs are projected to rise to 59,300 acre-feet annually by 2040.

Water for the generation of power presently amounts to 4,600 acre-feet annually in this planning region. Oklahoma Gas and Electric Company operates one small generating plant at Enid with a net generating capacity of 48 megawatts, and has a second under construction near Red Rock, Oklahoma. This plant will initially consist of two 510-megawatt generating units, and is designed to ultimately accommodate additional units with a potential capactiy of 4,500 megawatts, Water from Kaw Lake will be released and diverted downstream into Sooner Lake to provide cooling water for the fossil fueled power plant.

Irrigation water use is presently 28,600 acre-feet per year and is projected to rise to 336,900 acre-feet annually by 2040. The Oklahoma State University 1977 Irrigation Survey showed 17,552 irrigated acres in the region, with almost 80 percent of this being in Kingfisher County, where wheat and pasture grasses are primary irrigated crops. By 2040, the 9-county region is projected to contain 224,600 irrigated acres.

FIGURE 84 PRESENT AND PROJECTED WATER REQUIREMENTS (In 1,000 Af/Yr)

Use	Present	1990	2000	2010	2020	2030	2040
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

PROPOSED REGIONAL PLAN OF DEVELOPMENT

Much of the water in the North Central Planning Region is of inferior quality due to high natural chloride concentrations in upper reaches of its streams. Poor water quality has restricted stream water development and forced reliance on ground water resources. Although Kaw Reservoir in Kay County was completed in 1976, little of its total yield is presently utilized.

Existing water resources — ground water, SCS lakes and Kaw Reservoir — can supply 242,300 acre-feet annually and potential local sources could provide an additional 319,400 acre-feet per year. However, as Figure 85 indicated, even at ultimate proposed development, by the year 2040 this region would still face an annual deficit of 98,200 acre-feet which will have to be met by sources outside the region.

The Oklahoma Comprehensive Water Plan proposes a plan to meet a portion of the region's future water needs which includes the construction of five new reservoirs to provide north central Oklahoma with an additional 210,900 acre-feet of water per year. See Figure 86 . These are: Hennessey, Hunnewell, Lela, Otoe and Seward. Seward would annually provide Logan County with 14,500 acre-feet of water for municipal and industrial use. Hennessey would yield 18,400 acre-feet per year to Kingfisher County, primarily for irrigation. Hunnewell, on the Chickaskia River, would be supplemented with an average 39,600 acre-feet of water per year received from Kaw Reservoir via a diversion canal, increasing its total annual yield to 72,600 acre-feet. Grant County would receive all of this amount, most of which would be used for irrigation purposes. Lela Reservoir would provide Payne and Pawnee Counties with 38,200 acre-feet per year for municipal and industrial purposes. Finally, the yield of Otoe Reservoir would be supplemented from the Arkansas River by a diversion channel located above the Salt Fork-main stem confluence in order to ensure good quality water. Otoe would yield 64,200 acre-feet per year primarily for irrigation purposes.

Additional ground water and SCS structures could provide 108,500 acre-feet per year, primarily for irrigation purposes. Ground water is projected as a major source of supply only in Lincoln County.

Based upon 1.5 acre-feet of water per acre, 182,000 acres are projected to be irrigated by the year 2040. Figure 85 shows the nine counties in the region, their proposed supplies and projected demands in 2040. The overall regional deficit is a result of the lack of adequate water sources in the Garfield County area.

In addition to new source development, pertinent irrigation and municipal and industrial distribution facilities are proposed in the Regional Plan of Development. Also included is a water distribution system from Kaw Reservoir proposed by the Kaw Reservoir Authority to serve several

FIGURE 85 SUPPLY AND DEMAND ANALYSIS PROPOSED PLAN OF DEVELOPMENT (In 1,000 Af/Yr)

Source	Garfield	Grant	Kay	Kingfisher	Lincoln	Logan	Noble	Pawnee	Payne	Total
				Municipal and Industrial Component[1]						
Ground Water & SCS & Municipal Lakes[2]	11.2	1.5	9.0	3.6	12.1	0.9	0.4	0.1	11.0	49.8
Kaw	—	—	139.8	—	—	—	40.0	—	—	179.8
Hennessey	—	—	—	1.9	—	—	—	—	—	1.9
Hunnewell	—	1.5	—	—	—	—	—	—	—	1.5
Lela	—	—	—	—	—	—	—	6.1	32.1	38.2
Otoe	—	—	—	—	—	—	3.0	—	—	3.0
Seward	—	—	—	—	—	14.5	—	—	—	14.5
M & I Supply	11.2	3.0	148.8	5.5	12.1	15.4	43.4	6.2	43.1	288.7
					Irrigation Component					
Ground Water & SCS Lakes	15.6	16.5	14.7	15.3	17.4	13.5	13.2	4.5	13.5	124.2
Hennessey	—	—	—	16.5	—	—	—	—	—	16.5
Hunnewell	—	71.1	—	—	—	—	—	—	—	7.1
Otoe	—	—	54.3	—	—	—	6.9	—	—	61.2
Irrigation Supply	15.6	87.6	69.0	31.8	17.4	13.5	20.1	4.5	13.5	273.0
TOTAL LOCAL SUPPLY	26.8	90.6	217.8	37.3	29.5	28.9	63.5	20.7	56.6	561.7
2040 DEMAND	125.0	90.6	217.8	37.3	29.5	28.9	63.5	10.7	56.6	659.9
NET DEFICIT	98.2	—	—	—	—	—	—	—	—	98.2

[1]Includes cooling water (power) demands.

FIGURE 86 PROPOSED PLAN OF DEVELOPMENT

Data—Oklahoma Water Resources Board, Corps of Engineers, Bureau of Reclamation

Mapping—Oklahoma Water Resources Board

local communities with municipal and industrial water.

Figure 87 presents the total construction cost of all proposed facilities, estimated at $840 million, with an average annual equivalent cost of $66 million. The construction cost of new SCS lakes is estimated to be $32.4 million, with an average annual equivalent cost of $1.2 million. This cost includes local water supply storage for irrigation purposes, but excludes distribution facilities. New ground water development is estimated to cost $1.6 million, with $300,000 of average annual equivalent costs. The $805 million construction cost for major reservoirs includes five dams and reservoirs, appropriate distribution facilities, mitigation/compensation costs and the Kaw Reservoir Authority water supply system. Also included are the conveyance channels from Kaw to Hunnewell and from the Arkansas River to Otoe. Annual OMR&E cost is $4.7 million, with average annual equivalent cost of $64.7 million. Each proposed reservoir would require additonal studies to determine its feasibility according to federal criteria and the amount of state or local contributions which could be necessary.

Cost estimates for the Kaw Reservoir water supply system are just over $80 million, which included cost of distribution and storage. The costs for this regional water supply system could be considerably lower than those for the independent facilities proposed by some local cities and towns, and such development would be more consistent with the Regional Plan of Development proposed herein.

FIGURE 87 SUMMARY OF COSTS[1] PROPOSED PLAN OF DEVELOPMENT (In $1,000)

FACILITY	CONSTRUCTION COST	AVERAGE ANNUAL OMR&E[2]	TOTAL AVERAGE ANNUAL EQUIVALENT COST[3]
SCS Lakes	$ 32,375	$ 15	$ 1,200
Ground Water Development	1,600	200	300
Kaw Reservoir			
M & I Distribution	$ 80,000	$ 500	$ 5,310
Subtotal	$ 80,000	$ 500	$ 5,310
Hennessey			
Dam & Reservoir	$ 42,700	$ 40	$ 3,200
Irrigation Distribution	23,650	270	1,860
M & I Distribution	3,940	50	300
Mitigation/Compensation	3,325	25	250
Subtotal	$ 73,615	$ 385	$ 5,610
Hunnewell			
Dam & Reservoir	$ 81,600	$ 50	$ 5,700
Conveyance from Kaw	27,990	380	1,700
Irrigation Distribution	101,910	1,270	7,970
M & I Distribution	7,300	50	510
Mitigation/Compensation	20,700	25	1,400
Subtotal	$239,500	$1,725	$17,280
Lela			
Dam & Reservoir	$ 61,560	$ 40	$ 4,300
M & I Distribution	43,950	670	3,670
Mitigation/Compensation	8,500	25	5,880
Subtotal	$114,010	$ 735	$13,850
Otoe			
Dam & Reservoir	$108,000	$ 50	$ 8,000
Conveyance from Arkansas River	15,140	240	1,000
Irrigation Distribution	87,720	710	6,860
M & I Distribution	22,440	160	1,760
Mitigation/Compensation	16,200	25	1,100
Subtotal	$249,500	$1,185	$18,720
Seward[4]			
Dam & Reservoir	$ 38,900	$ 40	$ 3,100
M & I Distribution	9,580	140	840
Subtotal	$ 48,480	$ 180	$ 3,940
TOTAL	$839,080	$4,925	$66,210

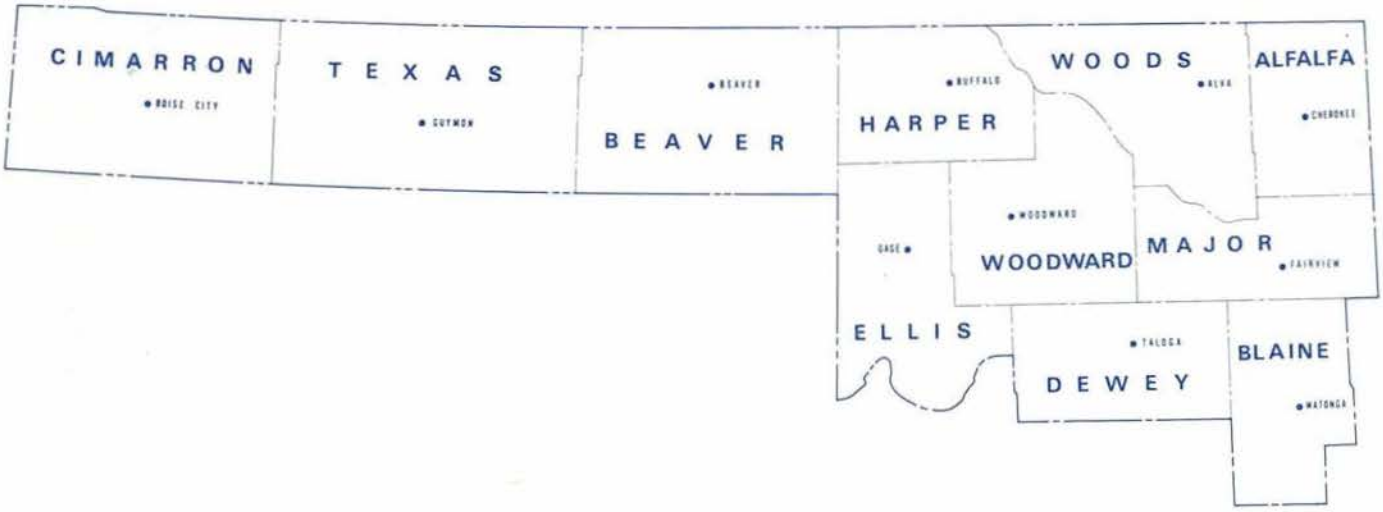
[1]Based on January 1978 prices.

[2]Energy costs computed at a 30-mil power rate.

[3]Includes interest and amortization as well as annual OMR&E expenses.

[4]Preliminary studies indicate no mitigation/compensation necessary for Seward, however, final determination is not completed.

NORTHWEST PLANNING REGION



The Northwest Planning Region, composed of Alfalfa, Beaver, Blaine, Cimarron, Dewey, Ellis, Harper, Major, Texas, Woods and Woodward Counties, covers 14,339 square miles.

Drought has become a way of life in these counties which register the state's lowest rainfall measurements. The three Panhandle counties—Cimarron, Texas and Beaver—are flat, while the remainder of the region is rough and marked by high sand hills and deep erosion.

The region supports the most extensive agricultural activities in the state, its bountiful feed and grain crops and fed cattle industry thriving on lands irrigated from the giant Ogallala aquifer and terrace and alluvium deposits. The Ogallala and other ground water deposits provide good quality water for irrigation. Future water shortages, along with escalated pumping and energy costs, could cause the pumping of ground water for the irrigation of marginally profitable crops to become economically infeasible. Unless a dependable new water supply is developed, farmers will have to revert to dryland farming, a measure which would substantially reduce crop yields and stifle agricultural production.

The 1977 population of the 11-county region was estimated at 102,000, a 5.5 percent increase over the 1970 figure of 96,719. During that same period, per capita personal income rose from $3,861 to $6,226, and average annual covered employment increased from 11,063 to 21,282. The slow population growth reflects, at least in part, the region's harsh climate and geographic conditions. However, the area's per capita income ranks highest among those of the state's eight planning regions. The region's unemployment rate historically has been the lowest in the state, averaging just above two percent between 1974 and 1978. This low rate probably is partially attributable to involvement in agricultural activities from which heavy capital investment and tradition make withdrawal difficult, even during economically troubled times. Major industries are agriculture, wholesale and retail trade and personal services. The largest cities in the Northwest Planning Region are Woodward, Guymon and Alva.

The widespread development and prosperity of the region are credited to irrigation with water from the Ogallala aquifer, a vast underground basin of water underlying nine of the 11 counties. However, minimal rainfall and runoff contribute little recharge to the Ogallala, causing it to be pumped at a much faster rate than it can refill and resulting in ground water mining. Alternative water supplies must be made available if the region is to continue its current economic progress.

The climate ranges from semiarid in the Panhandle to subhumid in the remainder of the region. As shown in Figure 8 , the average annual precipitation varies from 16 inches in the Panhandle to 28 inches in eastern Major and Blaine Counties, with most of it occurring in the spring, and May being the wettest month of the year. Thunderstorms dominate the rainfall pattern during the growing season, often producing high winds and damaging hailstorms. Although tornados seldom occur in the Panhandle, they cause frequent damage to the remainder of the area, particularly in Woodward, Dewey and Blaine Counties. The region receives almost 18 inches of snowfall in an average year.

Average annual lake evaporation ranges from 56 inches in the west to 64 inches in the southwest corner, and evaporation losses greatly in excess of precipitation create critical and persistent water problems. High winds and hot temperatures cause this exceptionally high evaporation rate, and since evaporation is a major consideration in reservoir design, additional water storage must be allowed in order to maintain dependable water supply yields.

Mean annual temperatures vary from 57° in the Panhandle to 61°F in the eastern part of the region, as shown in Figure 7 . The length of the growing season averages about 170 days in the west to 250 days in the southeastern counties. The northwest region has been scourged by long and disastrous droughts since the Dust Bowl days of the 1930's. The worst years of the decade were 1933, 1934 and 1936, while in stark contrast, the beginning and end of the period were relatively humid. The 1950's were marked by another period of severe drought, even longer and more widespread than that of the 1930's. Flooding is uncommon in the region, but when it does occur, four large flood control reservoirs built by the Corps of Engineers (Optima, Canton, Fort Supply and Great Salt Plains) and a few smaller SCS structures should prevent widespread damage. As a result of flooding, agriculture suffers the greatest damage, while urban property registers less severe losses.

WATER RESOURCES

Stream Water

Major streams in the Northwest Planning Region are the Salt Fork of the Arkansas River; the Cimarron River, which enters the state from eastern New Mexico; the Canadian, which enters from Texas; and the North Canadian (Beaver River), which enters from the west side of the Oklahoma Panhandle. Available stream water is of insufficient quantity and inadequate quality to provide significant amounts of water to the area.

Average annual runoff ranges from 0.2 inches in the western Panhandle to two inches in the eastern fringe of this region. Total average annual runoff originating in this region is estimated at 820,000 acre-feet. A summary of streamflow records at U.S. Geological Survey gaging stations in the region is presented in Appendix B, Figure 2 .

The beneficial use of all the major streams in the Northwest Planning Region is restricted by poor water quality, causing most local water to be unacceptable under public health standards for municipal or domestic use. Streams contain excessive amounts of salt and other dissolved minerals brought into solution as the water moves through the basin. Water quality analyses data for selected U.S. Geological Survey monitoring stations and the station locations are shown in Appendix B, Figures 4 and 5

The Cimarron River is of fair quality on entry from New Mexico in Cimarron County and re-entry further east. Quality of the river on its third entry at the Harper-Woods County line is degraded by salt sources in Kansas and local sources which often raise the river's salt content higher than that of sea water. A slight decrease in mineralization occurs downstream from Waynoka. Cimarron water is very hard with moderate to high turbidity, pH in excess of standards and some toxic metals problems, but dissolved oxygen remains at or near saturation levels throughout the year.

The Salt Fork of the Arkansas River passes through the Great Salt Plains and is highly mineralized and chemically unsuitable for most beneficial uses. The water of a number of northern tributaries of the Salt Fork is of good or fair quality and suitable for municipal and domestic use. Dissolved oxygen usually remains near saturation levels.

The North Canadian River has generally poor quality water in the Northwest Planning Region due to elevated levels of nitrogen and phosphorus in the upper portions and increased mineralization by sulfates and chlorides downstream, preventing its use for most municipal and domestic purposes. High sodium and dissolved mineral content in the water of the North Canadian downstream from Palo Duro Creek causes fair to poor quality for irrigation purposes, but tributaries in this reach that drain the Ogallala ground water formation exhibit water of good quality. Upstream from Palo Duro Creek water is of good quality and suitable for most uses.

The (South) Canadian River in this planning region has hard, highly mineralized water. Nutrient levels are high where the river enters Oklahoma from Texas, but improve in the river's flow through the region. Turbidity standards for warm water streams are occasionally violated and pH sometimes exceeds standards, but dissolved oxygen remains at or near saturation levels most of the year.

STREAM WATER DEVELOPMENT

Poor water quality and adverse climatological conditions have limited reservoir development in the region. Of the four major reservoirs, Canton, Fort Supply and Optima Lakes supply water for municipal and industrial uses, while Great Salt Plains Lake serves mainly as a flood control structure.

Major Reservoirs

Canton Lake on the North Canadian River was completed in May 1948. Authorized purposes of the project include flood control, water supply and irrigation. Irrigation storage in the lake has yet to be utilized for that purpose. By yearly contract Oklahoma City leases storage in Canton to supplement its supply, pending development of irrigation features. Water quality of the reservoir is rated poor, registering high in total dissolved solids, chlorides and sulfates.

Fort Supply Lake, located on Wolf Creek, was completed in 1942 for the purposes of providing 86,800 acre-feet for flood control and 13,900 acre-feet for conservation storage. Major water users from this storage are Western State Hospital and the City of Fort Supply. The water quality of the lake is acceptable except during periods of low flow.

In recent years, the Corps of Engineers has considered raising the dam at Fort Supply to provide additional water supply storage for the area. Contingent upon this modification, the Oklahoma Water Resources Board has appropriated 6,722 acre-feet to the City of Woodward for municipal use.

The Great Salt Plains Lake was completed in 1941, authorized for flood control and other conservation purposes. Storage allocated for flood control is 240,000 acre-feet. There is no water supply storage authorized in the project. The quality of the lake's water is very poor, degraded by natural chloride emissions upstream from the lake.

The Great Salt Plains National Wildlife Refuge, a critical habitat for migrating whooping cranes, occupies 31,174 acres of the project lands.

Optima Reservoir, among the earliest authorized for construction (1936), was begun in 1966 and final impoundment occurred in September 1978. Project purposes include flood control, water supply, recreation, and fish and wildlife propagation, with a dependable water supply yield of 5,400 acre-feet per year. Water quality tests show the water to be relatively hard with low chloride content, making it suitable for most municipal and industrial uses.

This good source of quality water is in high demand by towns in the Panhandle. Many more applica-

tions for water from Optima Reservoir have been made than the yield can satisfy, so the needs of each applicant will be examined closely to assure the best possible use of water available.

Soil Conservation Service Projects

The Soil Conservation Service has planned and engineered construction of numerous flood control structures on 31 watersheds in the Northwest Planning Region for the purpose of watershed protection and flood prevention. Five watersheds are complete or under construction, 14 are planned and 12 have potential for development.

As secondary benefits, Laverne and other towns adjacent to these watershed structures use them for recreational purposes. For locations of SCS watersheds, see Figure 26 .

Authorized Development

There are no other authorized projects in the Northwest Planning Region.

Potential Development

The potential for additional stream water development in the Northwest Planning Region is restricted due to water quality considerations and availability of stream water. Minimal amounts of additional good quality stream water are available because of existing stream water rights and uses. Reservoir sites that have been investigated and show potential for future development are listed in Figure 88 .

STREAM WATER RIGHTS

As of Feburary 20, 1979, there had been issued 172 vested stream water rights and permits for the appropriation of 55,164 acre-feet of water per year from rivers, streams and lakes in the Northwest Planning Region. The totals by county and by use are shown in Figure 89 .

FIGURE 88 STREAM WATER DEVELOPMENT

NAME OF SOURCE	STREAM	PURPOSE*	FLOOD CONTROL STORAGE ACRE FT.□	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
		EXISTING OR UNDER CONSTRUCTION			
Canton Lake	North Canadian River	WS, FC, I	267,800	107,000[1]	13,440[1]
Fort Supply Lake	Wolf Creek	WS, FC, R	86,800	400	220
Great Salt Plains Lake	Salt Fork of Arkansas River	FC, R	240,000	0[2]	0[2]
Optima Lake	North Canadian River	WS, FC, R, FW	71,800	76,200	5,400
TOTAL			666,400	183,600	19,060
		POTENTIAL			
				CONSERVATION STORAGE	
Alva	Salt Fork of Arkansas River	WS, FC, R, FW, I	110,700	455,000	42,900
Boise City	Cimarron River	WS, FC, R, FW, I	15,500	450,000	0[3]
Cestos	Kizer Creek	WS, R, FW, I	0	80,400	0[3]
Englewood	Cimarron River	WS, FC, R, FW, I	595,000	252,000	71,200
Fort Supply Modification	Wolf Creek	WS, FC, R, FW	86,800	113,600	18,580[4]
Goodwell	North Canadian River	WS, FC, R, FW, I	62,000	400,000	4,000[3]
Hydro	Canadian River	WS, R, FW, FC	300,000	670,300	110,000
Slapout	North Canadian River	WS, FC, R, FW	137,000	249,000	18,800[3]
TOTAL			1,307,000	2,670,300	265,480
TOTAL YIELD					284,540

*WS-Municipal Water Supply, FC-Flood Control, WQ-Water Quality, P-Power, R-Recreation, FW-Fish and Wildlife, I-Irrigation, N-Navigation.

□Although flood control storages are shown for potential sites, further studies will be required to determine the amount of flood control storage than can be economically justified as a project purpose.

[1]This figure includes irrigation storage and yield of 69,000 acre-feet and 2,240 acre-feet per year, respectively.

[2]Waters of project are unsuitable for use because of high mineral content.

[3]These are terminal storage reservoirs and develop very little yield of their own.

[4]Additional yield with modification.

FIGURE 89 STREAM WATER RIGHTS

COUNTY	MUNICIPAL		INDUSTRIAL		IRRIGATION		SECONDARY OIL RECOVERY		COMMERCIAL		RECREATION		TOTAL	
	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated
Alfalfa	—	—	—	—	21	6,208	—	—	—	—	4	1,037	25	7,245
Beaver	—	—	—	—	17	2,054	—	—	—	—	2	644	19	2,698
Blaine	1	240	—	—	12	2,144	—	—	—	—	2	356	15	2,740
Cimarron	—	—	—	—	16	7,076	—	—	—	—	2	652	18	7,728
Dewey	—	—	—	—	3	308	—	—	—	—	—	—	3	308
Ellis	—	—	—	—	16	1,692	—	—	1	1,225	—	—	17	2,917
Harper	—	—	—	—	27	15,344	—	—	—	—	1	356	28	15,700
Major	—	—	—	—	14	2,490	—	—	1	6	—	—	15	2,496
Texas	—	—	—	—	9	1,220	—	—	—	—	1	750	10	1,970
Woods	—	—	—	—	9	1,870	—	—	—	—	—	—	9	1,870
Woodward	1	6,722	—	—	10	1,838	—	—	1	892	1	40	13	9,492
Total	2	6,962	—	—	154	42,244	—	—	3	2,123	13	3,835	173	55,164

Ground Water

Major ground water basins in the Northwest Planning Region are the Rush Springs Sandstone, Ogallala Formation and alluvium and terrace deposits. See Figure 28 .

Ogallala Formation (Tertiary) consists of a heterogeneous mixture of sand, gravel, silt, clay, caliche and local beds cemented with calcium carbonate. The various rock types generally occur as lenses and poorly sorted beds of loosely cemented material. The maximum thickness of the Ogallala in the region is about 650 feet, but it thins along major drainageways and over bedrock highs.

The Ogallala is the principal source of ground water in the Oklahoma Panhandle. Well yields range from a few gallons per minute to more than 2,000 gpm, with those yielding less than 360 gpm usually not completed for irrigation wells.

Although most water from the aquifer contains more than 180 mg/L hardness, it is suitable for most purposes. Some wells tapping the lower zones of the Ogallala pump water containing dissolved solids in excess of 5,000 mg/L.

Alluvium and terrace deposits (Quaternary) consist of poorly sorted, unconsolidated, interfingering lentils of clay, sand and gravel. The most favorable deposits are along the North Canadian and Cimarron Rivers, where deposits are thick and permeable and yield as much as 700 gpm. Average yields for the alluvium and terrace are 100 to 300 gpm.

Even though the quality is often adversely affected by nearby streams, the water is generally suitable for most uses where the deposits directly overlie the Ogallala and are not in contact with the Permian redbeds.

Rush Springs Sandstone (Permian) in Blaine and Dewey Counties is a fine-grained sandstone, gradational northward into shale and thinning. Near Eagle City in Blaine County, the aquifer is approximately 247 feet thick; near Taloga in Dewey County it is about 186 feet thick.

The Rush Springs Sandstone provides water for domestic and municipal uses and a few irrigation wells in the area. Yeilds are generally less than 150 gpm, and the quality of the water ranges from good to poor due to concentrations of sulfate.

GROUND WATER DEVELOPMENT

The Ogallala Formation is the state's most important source of ground water, due to its areal extent, thickness, high permeability and most importantly, location in a water-short area of the state. It contains approximately 76,000,000 acre-feet of water in storage, and supplies most of the water requirements of the Panhandle. Water from the Ogallala is used to irrigate over 400,000 acres of agricultural land, as well as meeting the industrial, municipal and domestic needs of the region.

In 1960 there were approximately 400 ground water wells in the Panhandle; by 1965 the number had risen to 975; and in 1974 there were 2,067. High capacity wells are concentrated in areas south of Guymon, north of Goodwell and in the northwestern part of Texas County. In Cimarron County, closely spaced wells occur in the Boise City area and in the southwestern corner of the county near Felt. Such closely spaced wells pumped at high rates for significant periods of time create a cone of depression around the pumped wells, causing interference between wells and reducing their productivity. Declines in water levels up to 102 feet have been recorded over the past 25 years. See Figure 90 .

The Economic Development Administration is presently evaluating the economic effects of ground water depletion in the Ogallala in a 6-state area, including Oklahoma. The objectives of the EDA study are to determine potential development alternatives for the High Plains region and identify policies required to achieve promising development strategies.

The U.S. Geological Survey is also evaluating the Ogallala in an 8-state area, including Oklahoma. This study will develop the geohydrologic data base and computer models

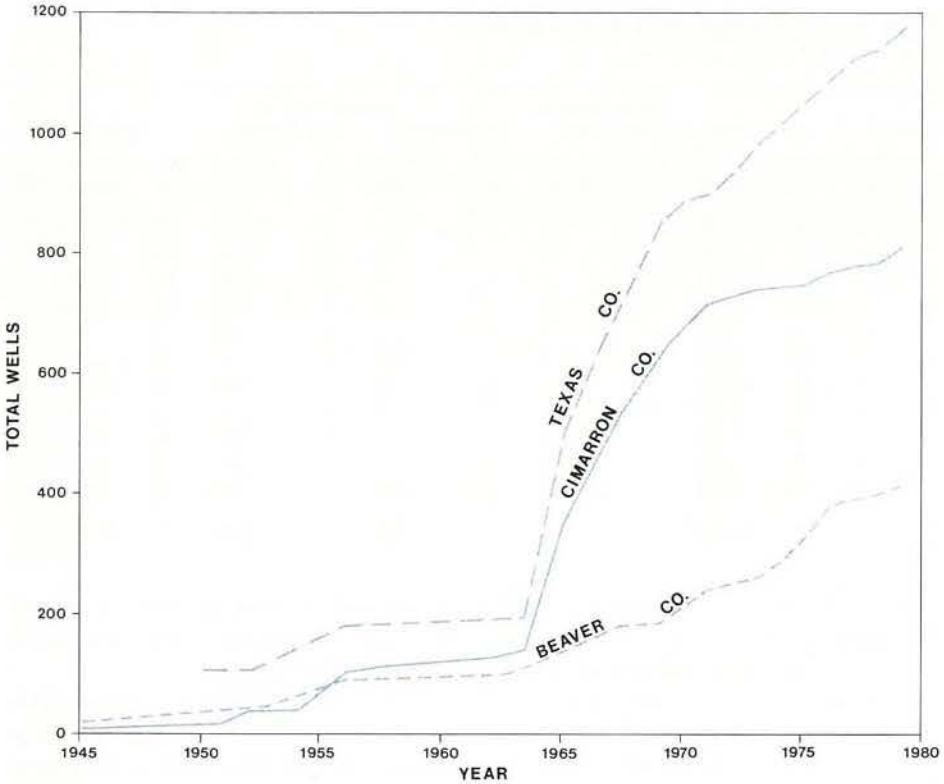


FIGURE 90 HIGH CAPACITY WELL DEVELOPMENT IN PANHANDLE COUNTIES (Domestic Wells Not Included)

of the ground water flow system needed to evaluate the response of the Ogallala Formation to ground water management alternatives.

The Rush Springs Sandstone provides municipal water supplies to Oakwood, Leedy and Putnam in Dewey County and to Canton in Blaine County.

GROUND WATER RIGHTS

As of July 1979, 2,955 ground water permits had been issued in the Northwest Planning Region. See Figure 91 . Prior rights have been established in eight counties in the Northwest Planning Region: Cimarron, Beaver, Texas, Woodward, Major, Harper, Dewey and Blaine.

PRESENT WATER USE AND FUTURE REQUIREMENTS

The Northwest Planning Region currently uses an estimated 885,200 acre-feet annually to meet its total water demands. Over 95 percent of this total is utilized for irrigation, enabling the region to support a thriving agricultural economy. Projections indicate that by the year 2040 the region will require 1,953,500 acre-feet per year to meet its water needs.

The 1977 estimated population of the region was 102,000 and the projected 2040 population is 135,200. Municipal water demand is anticipated to increase from the annual 16,800 acre-feet presently used to 27,600 acre-feet per year by 2040, with the Cities of Woodward and Guymon experiencing the largest increases.

Twenty-three rural water districts now serve over 10,000 customers in the Northwest Planning Region. The importance of these districts will increase in the future as rural populations grow and the areas further develop.

Present industrial water use in this region amounts to only 15,000 acre-feet per year, used largely by the oil and gas industry in processing and refining. Projected demand for industrial water indicates an increase of only nine percent to 17,800 acre-feet annually in 2040.

Cooling water used for power generation purposes presently ac-

FIGURE 91 GROUND WATER RIGHTS

	MUNICIPAL		INDUSTRIAL		IRRIGATION		SECONDARY OIL RECOVERY		COMMERCIAL		RECREATION		TOTAL	
COUNTY	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated	# of app.	acre-feet allocated
Alfalfa	16	9,637	1	20	61	17,767	5	2,140	3	323	1	100	87	29,987
Beaver	10	3,943	5	992	340	137,915	—	—	2	510	—	—	347	143,360
Blaine	11	9,212	1	150	61	17,198	—	—	—	—	2	400	75	26,960
Cimarron	5	3,743	1	1,610	566	445,358	—	—	—	—	—	—	572	450,711
Dewey	2	730	4	173	47	14,326	—	—	—	—	—	—	53	15,230
Ellis	3	1,409	—	—	142	61,484	—	—	—	—	1	80	146	62,973
Harper	5	1,299	4	432	111	42,946	—	—	1	350	—	—	121	45,027
Major	77	29,262	8	873	183	5,312	3	567	—	—	1	15	272	84,029
Texas	20	12,112	4	1,516	1,001	613,489	3	543	6	3,004	1	10	1035	630,674
Woods	7	37,149	—	—	60	16,408	—	—	—	—	—	—	67	53,557
Woodward	26	31,665	4	5,842	136	43,411	—	—	2	220	2	15	170	81,153
Total	182	140,161	32	11,608	2,708	1,463,625	11	3,250	14	4,407	8	620	2,955	1,623,661

These tabulations reflect the total water rights issued by the Board as of a specific date and are not an accurate reflection of the actual amount of water presently being put to use. The data indicate prevalent trends of beneficial water use by county and region.

FIGURE 92 PRESENT AND PROJECTED WATER REQUIREMENTS (In 1,000 Af/Yr)

Use	Present	1990	2000	2010	2020	2030	2040
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	1077.6	1205.4	1377.8	1557.0	1724.4	1886.8
Total	885.2	1117.5	1250.0	1428.5	1612.7	1784.9	1953.5

counts for only 3,400 acre-feet per year in this region. Oklahoma Gas and Electric Company operates two small plants with a net capability of 15 megawatts, and Western Farmers Electric Cooperative maintains one plant in the area with a capacity of 313 megawatts. Future demand for power generation water is expected to rise to 21,300 acre-feet annually.

Since good quality stream water is very scarce, ground water resources have traditionally supplied most of the region's irrigation water needs. An estimated 850,000 acre-feet of water per year is currently used for the irrigation of 469,671 acres on 1,732 farms. It is projected that by the year 2040, the 11-county region will be irrigating 943,400 acres, requiring 1,886,800 acre-feet of water per year.

PROPOSED REGIONAL PLAN OF DEVELOPMENT

Due to low average annual rainfall and runoff, surface water development in the Northwest Planning Region has been very limited. Ground water presently provides most of the area's water needs. The Ogallala aquifer, underlying eight of the 11 counties, is the most productive and most utilized of the ground water sources. However, in recent years local water tables have dropped and overdrafting threatens the continued usage of this important aquifer. It has become apparent that ground water resources cannot be relied upon as a long-term water supply.

Existing water sources in the region can supply 865,000 acre-feet per year from ground water, SCS and municipal lakes, and three major reservoirs. Potential development could provide an additional 141,400 acre-feet per year, however, as Figure 93 indicates, the region would still face a future deficit of 947,100 acre-feet per year which must be supplied from sources outside the region.

The Oklahoma Comprehensive Water Plan proposes a Regional Plan of Development which would utilize local water resources and include construction of two new reservoirs and pertinent municipal, industrial and irrigation distribution facilities. (See Figure 94 .) In addition, the plan would require increased usage of ground water (where supplies are available) and SCS and municipal lakes.

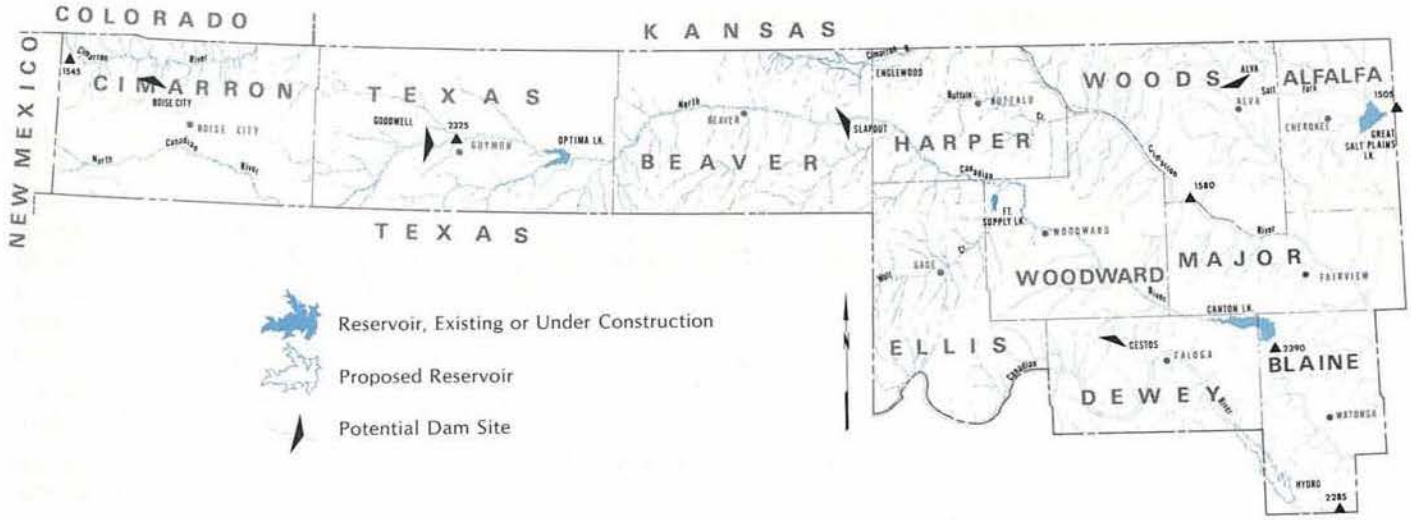
The two proposed reservoirs, Hydro and Englewood, would annually yield 91,700 acre-feet of water,

FIGURE 93 SUPPLY AND DEMAND ANALYSIS PROPOSED PLAN OF DEVELOPMENT (In 1,000 Af/Yr)

Source	Alfalfa	Beaver	Blaine	Cimarron	Dewey	Ellis	Harper	Major	Texas	Woods	Woodward	Total
					Municipal and Industrial Component[1]							
Ground Water & SCS & Municipal Lakes	1.1	0.7	4.9	1.0	—	1.5	1.7	2.0	2.8	6.0	8.2	29.9
Canton	—	—	—	—	1.4	—	—	1.0	—	—	—	2.4
Fort Supply	—	—	—	—	—	—	—	—	—	—	6.5	6.5
Optima	—	0.8	—	—	—	—	—	—	4.6	—	—	5.4
Englewood	—	—	—	—	—	—	—	—	—	—	—	—
Hydro	—	—	1.5	—	—	—	—	—	—	—	—	1.5
M & I Supply	1.1	1.5	6.4	1.0	1.4	1.5	1.7	3.0	7.4	6.0	14.7	45.7
					Irrigation Component							
Ground Water & SCS Lakes	12.0	86.4	12.8	186.4	—	9.8	12.8	15.2	492.0	3.8	16.0	847.2
Canton	—	—	7.0	—	2.0	—	—	2.0	—	—	—	11.0
Fort Supply	—	—	—	—	—	—	—	—	—	—	12.3	12.3
Englewood	—	—	—	—	—	—	31.2	—	—	—	—	31.2
Hydro	—	—	59.0	—	—	—	—	—	—	—	—	59.0
Irrigation Supply	12.0	86.4	78.8	186.4	2.0	9.8	44.0	17.2	492.0	3.8	28.3	960.7
TOTAL LOCAL SUPPLY	13.1	87.9	85.2	187.4	3.4	11.3	45.7	20.2	499.4	9.8	43.0	1,006.4
2040 DEMAND	62.1	201.7	85.2	529.4	10.0	63.7	45.7	28.2	822.9	45.3	59.3	1,953.5
NET DEFICIT	49.0	113.8	—	342.0	6.6	52.4	—	8.0	323.5	35.5	16.3	947.1

[1]Includes cooling water (power) demands.

FIGURE 94 PROPOSED PLAN OF DEVELOPMENT



Data—Oklahoma Water Resources Board, Corps of Engineers, Bureau of Reclamation
Mapping—Oklahoma Water Resources Board

primarily for irrigation purposes. Hydro Reservoir, on the Canadian River, would have a firm yield of 110,000 acre-feet annually and supply 60,500 acre-feet to Blaine County. Part of Hydro's remaining yield would be used in Caddo County in southwestern Oklahoma (44,200 acre-feet per year) and the rest (5,300 acre-feet per year) reserved for future demands. Englewood Reservoir, on the Cimarron River in Beaver County near the Kansas-Oklahoma line, would yield 31,200 acre-feet per year to serve the Harper County area.

Increased usage of ground water could yield 20,800 acre-feet per year, and development of new SCS structures could provide an additional 28,900 acre-feet of water per year. It is anticipated that these would be used solely for irrigation purposes.

A projected 480,000 acres would be irrigated in this region by the year 2040, based on two acre-feet of water per acre.

FIGURE 95 SUMMARY OF COSTS[1] PROPOSED PLAN OF DEVELOPMENT (In $1,000)

FACILITY	CONSTRUCTION COST	AVERAGE ANNUAL OMR&E[3]	TOTAL AVERAGE ANNUAL EQUIVALENT COST[3]
SCS Lakes[2]	$ 20,700	$ 14	$ 1,470
Ground Water Development	3,800	230	490
Major Reservoirs			
Englewood			
Dam & Reservoir	$ 68,800	$ 50	$ 2,910
Irrigation Distribution	33,500	250	1,620
Mitigation/Compensation	2,190	25	170
Subtotal	$104,490	325	$ 4,700
Hydro			
Dam & Reservoir	$ 85,300	$ 60	$ 6,800
Irrigation Distribution	63,400	860	5,560
M & I Distribution	2,100	30	180
Mitigation/Compensation	9,040	25	625
Subtotal	$159,840	$ 975	$13,165
TOTAL	$288,830	$1,544	$19,825

[1]Based on January 1978 prices.
[2]Energy costs computed at a 30-mil power rate.
[3]Includes interest and amortization as well as average annual OMR&E expenses.

Figure 93 shows the 11 counties in the region, their planned water sources and projected 2040 demands. Nine of the 11 counties will face water shortages due to the lack of available local water supplies.

The total cost of the local proposed development is estimated to be $288.8 million, with an average annual equivalent cost of approximately $20 million. (See Figure 95 .) The cost for new ground water development would be $3.8 million, and new SCS lakes are estimated to cost $21 million. The SCS cost would include local water supply storage costs for irrigation water in a multipurpose project. Distribution costs from ground water and SCS lakes are not included, but should be addressed in future planning.

The construction cost for the proposed reservoirs would be $264.3 million, which includes the two dams and reservoirs, irrigation distribution facilities from both reservoirs, municipal and industrial distribution transmission lines from Hydro and mitigation/compensation costs. Annual OMR&E costs would be $1.3 million, with an average annual equivalent cost of $17.9 million. Additional studies would be required on each proposed reservoir to determine economic feasibility under federal guidelines, as well as the amount of state or local contribution that could be necessary.