PHASE 1

OKLAHOMA COMPREHENSIVE WATER PLAN

Publication 60

This report is submitted in fulfillment of the legislative directive given in Senate Bill 510 of the 1st session, 34th Legislature of the State of Oklahoma

September 1, 1975

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OKLAHOMA WATER RESOURCES BOARD

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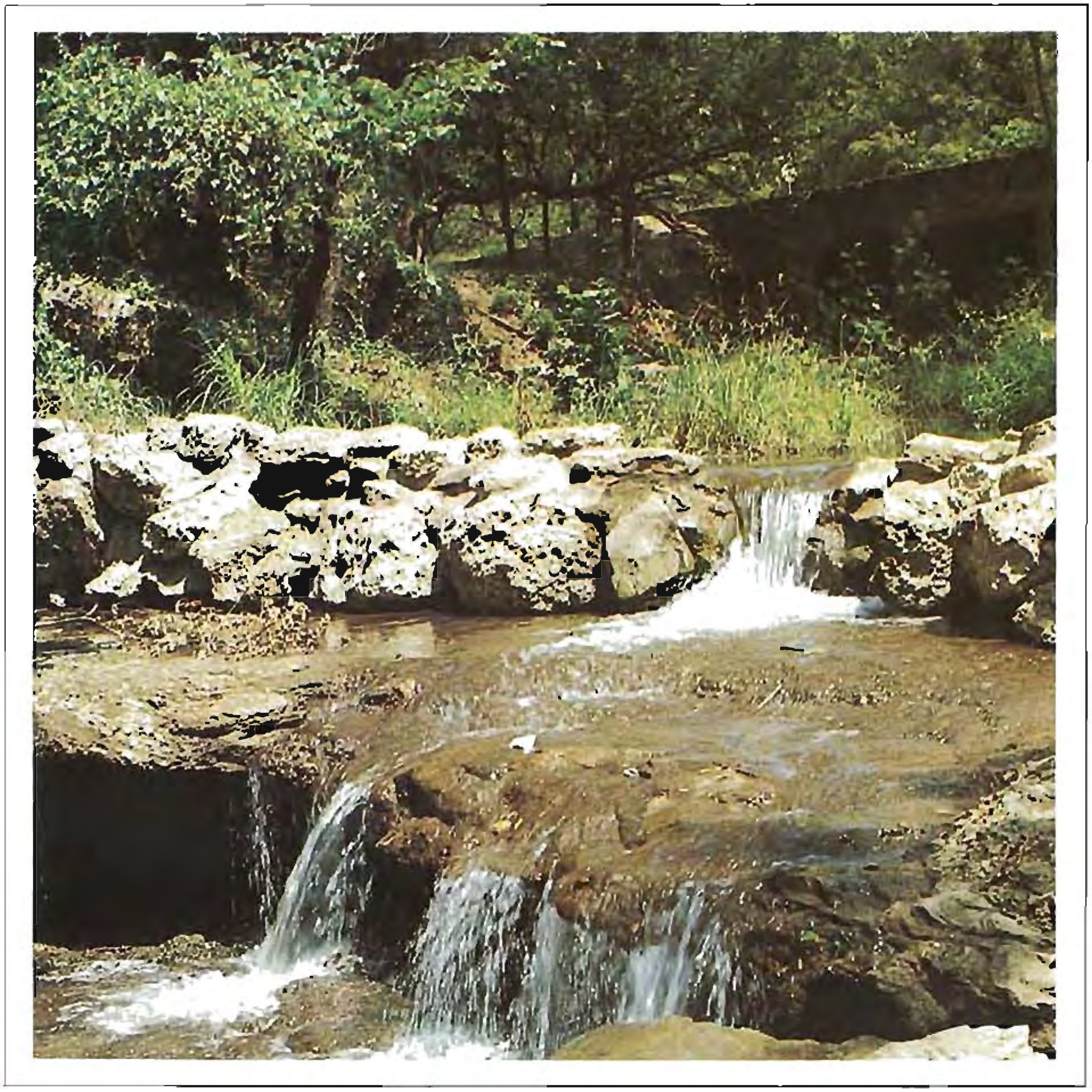

FOREWORD

Oklahomans today are at the crossroads. Oklahoma does not have enough water in the right places to meet present or foreseeable needs. Water demands are increasing sharply throughout the State. The worldwide demand for food stuffs require more and more water for food production. By year 1990, central Oklahoma will urgently need more water for municipal and industrial use. Increasing demands on ground water in western Oklahoma is rapidly depleting that resource. By year 2000 much of this ground water will be depleted. In eastern Oklahoma municipal and industrial water demands are steadily increasing. Throughout the State many cities, towns and small communities are experiencing distressing water shortages.

Although grave, the situation is not hopeless—Oklahoma has sufficient water within its boundaries to supply all present and future needs. Urgent and immediate action must be undertaken by the State with federal assistance where available, to see that a program is undertaken to insure the distribution of this water to all areas of need. The magnitude of the job is tremendous and must not be underestimated nor the tragic consequences of delay. The State must move boldly forward with a dynamic program geared toward meeting these critical needs of today and of the future.

Toward that end the preparation and release of Phase I of the Oklahoma Comprehensive Water Plan is the first step in an orderly plan to effectively protect, conserve and develop the State's water resources. This Phase I Plan will serve as a 50 year guide for the southern portion of the State. Phase II of the planning study should begin immediately to insure complete coverage of the State in this important undertaking.


STATE OF OKLAHOMA

OKLAHOMA WATER RESOURCES BOARD

FIFTH FLOOR • JIM THORPE BUILDING • OKLAHOMA CITY, OKLA. 73105

The Honorable David L. Boren
Governor of Oklahoma

The Legislature of the State of Oklahoma

Transmitted herewith is the Phase I report of the Oklahoma Comprehensive Water Plan, a study of the orderly control, protection, conservation, development and utilization of the State's water resources to meet expanding needs to the year 2030. This report is in response to Senate Bill 510 of the Thirty-fourth Legislature.

This report presents an overview of Oklahoma's water resources and requirements on a Statewide basis. Information was obtained from Board data and various local, State and federal agencies. This study contains feasibility level economic and engineering data for the southern 33 counties of the State and reconnaissance level information on the northern 44 counties.

Dependable water supplies are vital to the preservation and expansion of Oklahoma and its economy, necessitating full water resource development and conservation. We submit this report as a guide for legislative action and strongly urge its adoption. We further recommend that the necessary legislative action be taken to implement this plan and provide for completion of Phase II so that all present and future water needs will be met.

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SECTION I

SUMMARY

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SYNOPSIS - THE PLAN

Senate Bill 510 called for a feasibility (detailed engineering and economic) level study for the southern 33 counties and a reconnaissance (preliminary) level study for the northern 44 counties. Phase I of the Oklahoma Comprehensive Water Plan is presented in response to that bill. This study is a coordinated effort between State, federal and local agencies with participation from interested citizens.

The southern 33 counties' study resulted in the 50 year Plan shown on Figure I-1. Basically, the Plan will use independent reservoirs and ground water to meet water supply needs where feasible and the remaining areas will receive water from the Interconnected System.

Most of the local and sub-state regional water requirements in the southern 33 counties will be met by ground water sources, public and private structures, multi-purpose watershed projects and by 31 independent major reservoirs and lakes located throughout this area. The remaining local and sub-state regional water requirements will be met by water from reservoirs which will also be source reservoirs for the Interconnected System. Twenty of these independent reservoirs exist or are under construction. Six are in the southeast region, six in the central region, 13 in the south central region and six in the southwest region.

The Interconnected System is an integrated network of water storage, regulation and conveyance facilities which will supply surplus water from southeast Oklahoma to central and southwest Oklahoma. it will utilize a portion of the water supply storage of 13 reservoirs; four in southeast Oklahoma, two in central Oklahoma and seven in southwest Oklahoma. Nine of these reservoirs, which include the four in southeast Oklahoma, are either existing, under construction or authorized. The remaining four reservoirs are proposed terminal reservoirs. All necessary water from source reservoirs will be reserved to meet local and sub-state regional requirements.

The Interconnected System will transport 1,308,000 acre-feet of water annually from southeastern Oklahoma. Of this, 487,000 acre-feet per year will be transported to central Oklahoma and the remainder diverted to southwestern Oklahoma. Canal and transportation losses of 74,500 acre-feet per year will reduce the amount going into terminal storage in southwestern Oklahoma to 746,500 acre-feet annually, 89,600 acre-feet of which will be for municipal and industrial use and 656,900 acre-feet will be to irrigate 370,500 acres.

Initial construction cost for the Interconnected System will be approximately $1.7 billion and delivered water costs will vary based on type of use and point of delivery. Municipal and industrial water delivered to central Oklahoma will cost about 19 cents per thousand gallons. Municipal and industrial water delivered to terminal reservoirs in southwestern Oklahoma will cost about 27 cents per thousand gallons. Irrigation water for southwestern Oklahoma, when computed interest-free under Reclamation Law, will cost $68 per acre-foot at the terminal reservoirs or $87 per acre-foot delivered to the farms. The water required for irrigation varies from one to two acre-feet per acre. Thus, the cost per irrigated acre would vary from $87 to $174. It is estimated that annual direct and indirect benefits will be about $521 per irrigated acre within southwestern Oklahoma. Statewide economic impact benefits would probably be much greater than this amount. Total economic impact estimates will be made in Phase II of the study. Thus, from a State viewpoint, the Interconnected System appears to be well justified. Reports now being prepared by the Corps of Engineers and the Bureau of Reclamation will indicate feasibility from a federal standpoint. Projects considered in these reports will be sized for 100 year demands.

One of the provisions of Senate Bill 510 was to define "excess and surplus waters of the State." The Board has therefore defined "excess and surplus water" as that amount which would not result in deprival of a prior right to water to any inhabitant or property owner within a major drainage system wherein water originates. Methodology as used for study purposes herein considers such prior right to extend for the ensuing 50 years.

CONCLUSIONS

Oklahoma's Potential for Growth

Oklahoma is presently experiencing tremendous growth and expansion. The State has the capability for further population growth and industrial and agricultural expansion provided adequate supplies of suitable quality water can be distributed at reasonable cost. Oklahoma is fortunate in having sufficient water within State boundaries to supply all its needs if properly managed. The problem is primarily one of management. Areas of surplus water supplies must be balanced with areas of depleting or short supplies. Redistribution of State waters should be made so that no areas are left water deficient.

The Oklahoma Comprehensive Water Plan

The Plan, as described in the Synopsis, will provide the basis and guide for future planning and development of Oklahoma's water resources for the next 50 years. Phase I of the Oklahoma Comprehensive Water Plan, prepared in response to Senate Bill 510 First Session, 34th Legislature, is presented herein. Continued effort in Phase II will provide a feasibility level plan for the remaining 44 counties of the State by September, 1977.

Costs and Benefits - Phase I Interconnected System

The overall cost of the Phase I Interconnected System, based on 1974 price levels is approximately $1.7 billion. Annual costs would be about $115 million, including operation and maintenance. Cost of irrigation water in southwestern Oklahoma, when computed under Reclamation Law, as indicated in the Synopsis, will be about $87 per acre-foot.

Primary irrigation benefits will amount to $307 per acre and regional benefits will amount to $214 per acre, for a total benefit of $521 per irrigated acre. These benefits include direct benefits to the farmer and indirect benefits to the local and sub-state regional economy. Benefits to the statewide economy are expected to be much greater than this amount. On-going studies for Phase II will provide additional impact benefit estimates and will pinpoint the amounts accruing to each level of the economy. Overall, irrigation benefits far exceed costs.

Benefits accruing to municipal and industrial water will, by federal standards, be equivalent to the costs and would have a benefit-cost ratio of at least one to one. When total economic impact is considered for municipal and industrial water usage, the statewide benefit-cost ratio should increase greatly.

Feasibility

From a state level, the projects included in Phase I of the Oklahoma Comprehensive Water Plan are justified from economic and engineering standpoints. There is sufficient water to supply local needs and provide a surplus for transport to water deficient areas of the State. The projects needed are engineeringly feasible and much of the system is already in place. Other portions of the Plan are authorized for construction by federal agencies. In the Phase II studies, a thorough analysis will be made of possible interconnections between the northern and southern portions of the State. Streamflow diversity between the Arkansas and Red River systems will result in flexibility of operations and an overall saving in costs. Complete statewide benefits are difficult to assess until the northern system has been evaluated. For that reason, Phase II of the study should proceed as quickly as possible. Additional refinements are expected in the Phase II study which will improve the economic justification for the southern system as well.

The State must exercise strong leadership in guiding the role of water resource development in Oklahoma. The federal agencies should be encourage to construct portions of the Plan which can be justified from a federal standpoint.

RECOMMENDATIONS

The Oklahoma Water Resources Board recommends that the following actions be taken:

A. By the Governor and Legislature of the State of Oklahoma

1. Exert a strong leadership role in water resource development in Oklahoma by adopting Phase I of the Oklahoma Comprehensive Water Plan as the first portion of the official State Water Plan.

2. Support the preparation of Phase II of the Oklahoma Comprehensive Water Plan through appropriate funding and legislative programs so that the Phase II Plan will be completed for the northern 44 counties of the State.

3. That the Comprehensive State Water Plan become a flexible guide for future water resource development of the State; that modifications thereto be made as required by changing water requirements; and that the Legislature be notified of such changes on an annual basis.

4. Establish a Financial Study Group to investigate methods of financing the construction and operation of the Plan. Findings and recommendations to be made to the people of Oklahoma through the Governor and Legislature.

5. Create a water development funding and loan program to provide assistance in the development of local and sub-state regional water distribution and storage projects throughout the State. A revolving fund of not less than $100 million should be established with reimbursement to be made from user revenues.

6. Provide a constitutional guarantee to protect the areas of origin so they shall never be made water deficient as a result of transfer of water outside the area.

7. Encourage the formation of special purpose districts throughout the State as needed to purchase local and transported water, operate and maintain facilities and to properly manage the water available to the district.

8. That the State underwrite portions of the costs of federal projects which fail to meet economic justification by federal standards or which exceed the repayment capability of the irrigation users.

B. By Local Interests

1. Take steps as necessary to form special purpose districts, covering areas which desire to be supplied with transported water. These districts would have adequate powers to contract with the State or federal Governments for water supply and other purposes, to raise revenue necessary to repay the reimbursable costs involved and to take other actions needed to put the water to beneficial use.

2. Examine the desirability of forming, and form where feasible, regional organizations or entities serving major metropolitan areas, or groups of cities or towns, for water distribution purposes. Funds for construction of required facilities could be supplied from a State fund to be repaid by user fees.

3. Immediately undertake studies of the amounts and timing of needs for local and transported water, the paints of delivery and the necessary legal and financial arrangements to assure capability of meeting contractual repayment obligations.

C. By the Federal Government

1. Continue funding of programs for the Bureau of Reclamation, Corps of Engineers and Soil Conservation Service within their areas of responsibility within Oklahoma. Continue to fund the U.S. Geological Survey in its supporting role as required by the Plan.

2. Recognize the Oklahoma Comprehensive Water Plan and subsequent modifications os the general guide for future water resource development in Oklahoma.

3. Establish policy as to the national interest in planning and development of viable State water plans.

INTRODUCTION

In the early days of American history, people lived on farms, grew their own food and took care to protect land and water resources. However, the coming of World War I brought increased use and rapid depletion of natural resources, with no thought about the future. Fortunately, people have become aware of this previous misuse of resources and are realizing the need for conservation of natural resources of all kinds—especially water.

The Oklahoma Water Resources Board has been directed to prepare a comprehensive water plan for the State. The overall objective of this plan is the orderly control, protection, conservation, development and utilization of State water resources by all citizens.

Most of the State's water resources are located in eastern Oklahoma, while western Oklahoma suffers from a lack of water sources. Central Oklahoma is the median of the two areas, experiencing both drought and abundant periods. However, spot shortages can and do occur in all areas of the State. Oklahomans can be justifiably proud of the progress since the "dust bowl" days, but steps must be taken now to prevent another one. Without a viable water distribution plan for the future, the economy of the entire State, with its agriculture, agribusiness and related industries, could suffer.

The Comprehensive Water Plan is designed to provide water for all areas of Oklahoma, through the maximum utilization of multipurpose dams, reservoirs and water storage areas. The Plan will not deprive one region to benefit another.

For almost 40 years, the Bureau of Reclamation, the Corps of Engineers and the Soil Conservation Service have been developing water resources projects for the State of Oklahoma. These projects, excluding the Grand River Dam Authority, will be incorporated in the Plan.

Water resources planning should be of major concern to everyone. In order for Oklahoma to prosper and grow, immediate steps must be taken to insure that all Oklahomans have the water they need—for today and tomorrow.

Authority

The Oklahoma Water Resources Board received general statutory authority to begin long-range water need studies in 1963, under Title 82, Section 1072 (d):

"...to develop statewide and local plans to assure the best and most effective use and control of water to meet both the current and long-range needs of the people of Oklahoma; and to cooperate in such planning with any public or private agency, entity or person interested in water, and are directed to prepare such plans for consideration and approval of the Legislature..."'

Senate Bill 510 gave specific statutory authority to the Oklahoma Water Resources Board:

"...to prepare a comprehensive state water plan, including feasibility and cost studies on designated projects within the plan and on the plan itself, for submission to the Legislature... in final and completed form not later than September 1, 1975... Said plan [for 33 southern counties] shall include findings and conclusions for an investigation to determine the economic and engineering feasibility for the development of the land, water and related resources of all proposed projects, and shall be of sufficient detail to serve as a basic document for securing legislative authorization. For the balance of the State, the plan shall include office studies of existing data and sufficient reconnaissance field surveys, to indicate whether further detailed investigations are justified, and if so, the scope of such investigations..."

Need For A Plan

Unlike many western states, Oklahoma is fortunate in that there are sufficient water resources within State boundaries to supply all of its needs. There has been much water resource development in the State, but the need for blending this work into a totally coordinated Statewide effort is imperative if optimum benefits are to be realized from the State's resources. The problem is one of management and Oklahoma's need for management through a comprehensive water plan is great. This need becomes greater as the State's population and the demand for water increases. Through maximum utilization and proper water resource management, agriculture and other water-dependent industries can maintain and expand operation in all areas of the State, regardless of climate or other factors.

Many small cities and towns in Oklahoma have inadequate raw water supplies. In other areas, ground water resources are being used faster than they can be replaced. Thus, a plan is needed to provide ample water supplies for both urban and rural areas. Without a plan, part of Oklahoma will continue to suffer in times of water shortages. This, in turn, will affect the economic growth and well-being of the entire State.

Background and Present Status

The Constitution of the State of Oklahoma, under Article 16, Section 3, gives the Legislature power to provide for levees, ditches and irrigation in the State. The eighth Legislative Assembly of the Territory of Oklahoma enacted the first water law in 1905, outlining the procedure for acquiring water rights, regulating its use, creating the office of Territorial Engineer and outlining his duties as administrator of the water laws. Upon granting of statehood in 1907, these duties were delegated to the State engineer.

The first principles in the original act of 1905 have been the foundation of subsequent legisla-

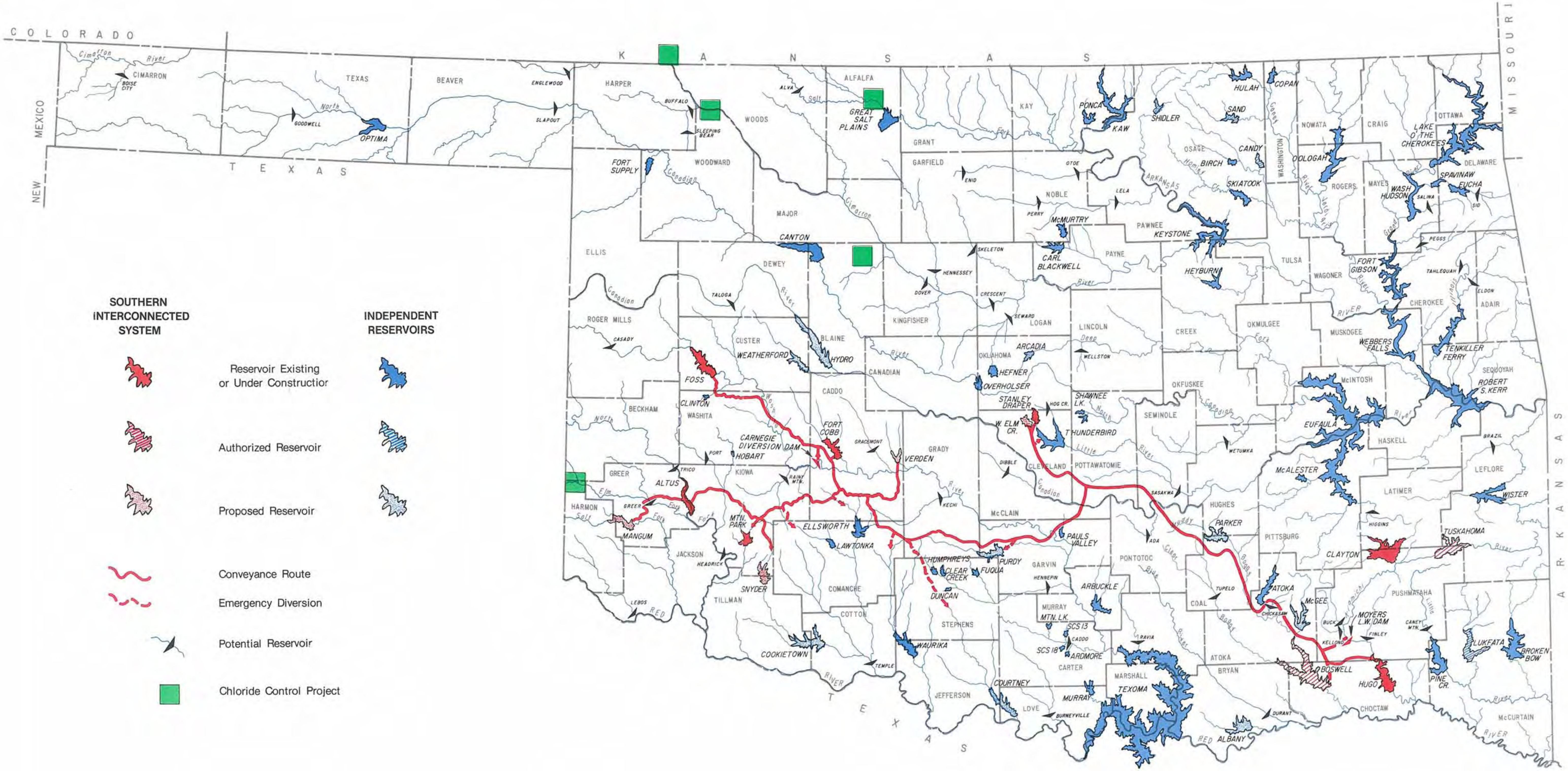


FIGURE I-1
PHASE I SOUTHERN INTERCONNECTED SYSTEM TO YEAR 2030

tion. These principles are that beneficial use is the basis, measure and limit of the right to use water and that water is a public property and the development of the State's resources should be planned to adequately serve all segments of the economy.

Most of this original act is still in effect, having been enlarged to include not only irrigation, but also municipal and industrial water supply, streamflow regulation, water resource development planning and data collection.

The predecessor to the Oklahoma Water Resources Board, the Planning and Resources Board, was created in the 1930's. Its jurisdiction included parks and forestry, as well as water resources.

In 1955, House Joint Resolution 520 provided for a water study committee. Composed of State Legislators and citizen representatives of agriculture, industry, municipalities and recreation and wildlife, the committee reviewed Oklahoma's water problems and recommended the establishment of a separate authority. Thus, in 1957, the 26th Legislature created the Oklahoma Water Resources Board under Senate Bill 138, giving it all the powers and duties of the former agencies.

Under general authority granted in Title 82 of the Oklahoma Statutes, the Board prepared an eleven book series appraising the water and land resources in each of 12 regions in Oklahoma. Meetings were held in each region, apprising the public of the natural resources in their area.

A State water planning committee, composed of members of the Oklahoma Water Resources Board and other State and federal agency representatives, was established in 1967 to do preparatory work toward the goal of a comprehensive water plan, beginning with the region appraisal books.

But the idea of a water plan is not new. In 1966, the Bureau of Reclamation published a reconnaissance appraisal of Oklahoma's water needs, outlining the possibilities of such a plan.

The Soil Conservation Service of the U.S. Department of Agriculture has followed continuing programs of soil and water conservation for the entire State. One of the earliest upstream watershed projects completed in the nation was on Sandstone Creek, a tributary of the Washita River in western Oklahoma. Soil Conservation Service's multipurpose structures have not only provided protection from floods, but also have afforded municipal, industrial, irrigation and recreation water supplies as well.

Currently, federal water resource projects include the McClellan-Kerr Arkansas River Navigation System, 17 completed reservoirs, seven under construction and seven authorized for construction by the Corps of Engineers; five completed and one under construction by the Bureau of Reclamation and two completed reservoirs by the Grand River Dam Authority.

Uses of the federal projects include water supply for municipal, industrial and agricultural purposes, flood control, navigation, hydroelectric power generation, water quality control, recreation and fish and wildlife propagation.

Additional information on water resources has been obtained from the U.S. Geological Survey.

PLANNING CONCEPTS AND CONSTRAINTS

Objectives, Scope of Study and Master Planning Schedule

Senate Bill 510 directed the Oklahoma Water Resources Board to prepare a comprehensive State water plan. The overall objective of the study, as stated in the bill, is the orderly control, protection, conservation, development and utilization of the State's water resources for all the people of Oklahoma. Specific objectives call for optimum development and utilization of water within an area of origin and use of excess and surplus water in deficient areas.

The scope of the Plan includes a feasibility or working level study for the southern 33 counties of the State. This portion of the Phase I report, herein designated, contains sufficient information, details and conclusions on economic and engineering possibilities of water resource development to serve as a guide for legislative authorization for the Plan in these counties.

The bill also called for a reconnaissance or information level study on the remaining 44 counties to complete the Phase I report. This portion contains information on land and water resource development potentials for justification of further detailed investigations.

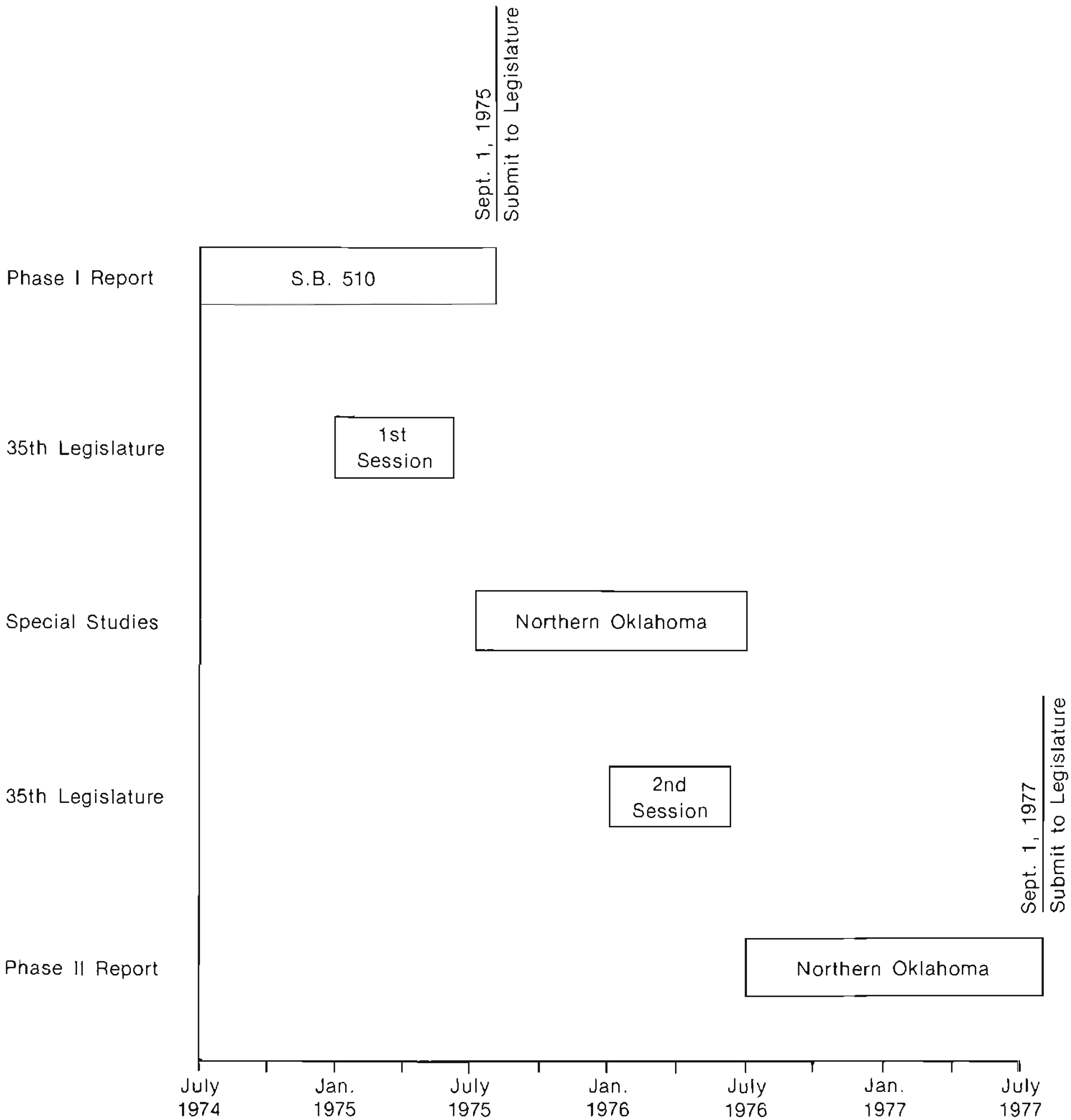
The study was divided in this manner because of the immediate water needs of southern Oklahoma and the wealth of information available about this area. Sufficient data are currently unavailable for a feasibility level study for the northern counties. When the Legislature approves the preparation of a Phase II report, feasibility level studies will be completed for the northern 44 counties of the State.

The planning schedule was expanded over a two-year period. This Phase I report will be reviewed by the second session of the Legislature in January, 1976. When necessary funds are appropriated in the first legislative session, detailed hydrologic and economic studies for the Phase II report will have been started. When so directed, the second report will be completed and submitted to the Legislature in September, 1977. The master planning schedule for Phases I and II is shown on Figure I-2.

Federal Agency Planning Roles

Maximum utilization of existing federal programs in the Oklahoma Comprehensive Water Plan was an important consideration in development of the total Plan. The various federal agencies were encouraged to continue their present plans and programs.

FIGURE I-2
MASTER PLANNING SCHEDULE



Construction of authorized projects and continuation of other study proposals were also stressed so that this effort could be blended into a total water development program to meet the future needs of the State.

Maximum Site Potential Development

One of the major policies of the State in total plan development is the encouragement of federal construction agencies to develop lake and reservoir sites to their maximum potential. Because reservoir land areas are becoming scarce and more expensive to develop, reservoirs must be developed to the maximum advantage. When it is not economical to build facilities to meet optimum limits initially, development should be planned so that subsequent enlargement will be possible.

In addition, many towns and communities utilize multi-purpose sites for water supply, among other uses. The expansion of single purpose sites to multipurpose where possible has also been encouraged so that all existing resources may be used to their fullest extent.

Water Rights and Permits

One of the major responsibilities of the Oklahoma Water Resources Board is issuance of stream water rights and ground water permits. This was also a main consideration in development of the Plan, involving many restraints and restrictions. Stream and ground water use for domestic purposes is specifically exempt.

Oklahoma law states that a landowner owns any ground water underneath his property. For this study, no mass transfer of ground water will take place because of the detrimental effects on adjacent landowners.

The law also states that permits may be issued for two acre-feet of water for each acre of owned, leased or platted land overlying a ground water basin. This legally restricts irrigators and other water users and sometimes limits maximum water use.

Another restriction on ground water permits is that these rights are considered temporary until a detailed hydrogeologic study of the ground water basin is completed. Consequently, all ground water permits must be renewed each year.

Stream water rights also present restraints. Many streams and rivers in Oklahoma have been fully appropriated, while others are subject to restriction during periods of low flow. This limits water use in many areas. Laws for area of origin protection also present limitations. These laws and limitations will be explained in detail later in this section.

All factors restricting water use were carefully considered in order to provide maximum utilization of existing water resources.

Protection of Areas of Origin, Methodology for Determining Surplus Water and Interbasin Water Transfer

All stream water within the State of Oklahoma is property of the State, but the law provides for area of origin protection. This was one of the major considerations in preparation of the Oklahoma Comprehensive Water Plan.

Senate Bill 510, as well as directing the preparation of this Plan, further stated that no water shall ever be moved out of an area of origin until all needs of that basin are met.

This requirement was an additional safeguard to Title 82 O.S., Section 105.12, Subsection 4, passed in 1972. This law states that all water rights applicants within a stream system shall be adequately supplied before any rights for transportation and use outside the system are considered.

Senate Bill 510 called for the definition of excess and surplus water, insuring that procedures used in development of this definition would leave no area of origin water deficient. The bill further stated that only this excess and surplus water shall be used outside the areas of origin and residents within the area shall have prior rights to the fullest extent necessary for beneficial purposes.

Methodology used herein in development of the Plan used the term 'excess and surplus water' to mean that water within the area of origin which is greater than the potential water development needed to meet the projected in-basin requirements for the next 50 years.

Inter-area water transfer, in this study, has taken all factors into consideration. All area needs will be met before water is classified as excess and surplus. Area residents will be granted water necessary for maximum beneficial uses over those outside the area.

Municipal Water Supply Requirements

Satisfaction of municipal water supply needs was given every consideration possible within the timetable set for completion of the Phase I report. Personal interviews were conducted with officials of cities and towns in the southern 33 counties to determine present water supply adequacy, foreseeable water related problems and if so, possible solutions to these problems. In addition to the municipal surveys, information was collected from various State and federal agencies on water supply sources available to each town. Upon completion of these surveys, information for each town was analyzed. Infeasible sources were eliminated and alternative solutions were proposed.

Rural water districts were considered along with cities and towns. The rural water districts generally cover a wide area and can select ground or stream water sources to utilize the best water available in service areas.

Indian Water Requirements

The overall objective of the Plan is the maximum utilization of the

State's water resources for all citizens. Because State law notes that all stream water originating in or flowing through the State, within limits of interstate compacts, is the property of the State of Oklahoma, tribes must file for water rights. Equal care is taken to insure that these water rights are protected.

Stream and ground water rights currently held by various tribes were given full consideration in the formulation of the Plan to insure this protection, and water needs for present and long-range tribal development have also been considered.

Water Quality

Water quality considerations were an important part of the total Plan development. Water quality which restricts maximum beneficial use or reuse is affected by several factors, including population growth, industrial expansion, increased irrigation and recreation and natural pollution sources.

Generally, water quality is good in the eastern part of the State and poor in the west. The quality of water that will be transported to central and southwestern Oklahoma under the Plan is excellent. This water would dilute pollutants now in streams of these areas, improving the present quality.

Water quality management goals have been established for the Plan. They include compliance with current State water quality standards for abatement and prevention of pollution, investigation and control of natural pollution sources and continuation and implementation of desalting and other quality improvement programs for the preservation and enhancement of State water resources.

Stream and Ground Water Uses

Oklahoma's water problem is one of management and distribution rather than shortage. The variability in quality and quantity from east to west placed great restraints on the overall planning effort.

Agricultural needs, municipal supply and industry are the major uses of stream and ground water in the State. Water is also used for secondary oil recovery, hydroelectric power, navigation, recreation and fish and wildlife purposes. All current uses and future needs and requirements were incorporated in the development of the Plan.

About 90 percent of the total irrigation operations take place in western Oklahoma. This has resulted in overdevelopment of many ground water basins, the major source of irrigation water. Within the next 20 years, pumping may become financially infeasible in many areas and alternative sources will be needed.

Many small rural towns and communities depend on ground water for municipal supplies, and these towns in western Oklahoma face immediate problems due to a lack of good quality water.

While excellent quality stream water is readily available in the east, many streams in the west suffer from natural chloride pollution. Other streams have been completely appropriated or are subject to restrictions, further limiting their use.

Industrial water use is steadily increasing as new firms locate in the State. Additional water for further industrial growth must be provided so that Oklahoma may grow with it.

The Plan must consider these restraints in providing adequate water for all uses and requirements.

Special Purpose Districts

Special purpose districts are legal local or private entities empowered with distribution, regulation, contracting and payment for water for municipal, industrial and irrigation needs. Presently, there are four types of special purpose districts in the State. These are master conservancy, irrigation, weather modification and rural water districts. The current needs of these districts and their future requirements must be considered in the overall development of the Plan.

These districts are presently important in that they provide water services to areas that would otherwise have difficulty obtaining sufficient water to meet all needs. They will become increasingly important upon implementation of the Plan. They will aid in distributing the additional water provided by the conveyance system, as well as providing repayment through assessment of district participants.

The Board has statutory responsibility to offer assistance in the formation of new districts with full legal and financial authority. They will assume the necessary responsibilities and obligations required by the Oklahoma Comprehensive Water Plan.

Interstate Compacts

All states bordering Oklahoma have an interest in stream water originating in or flowing through the State. In order to avoid disputes and insure equal distribution, Congress allows involved states to enter into compacts for appropriation of waters.

Oklahoma participates in three interstate compacts, with an additional one under negotiation. The Arkansas River Commission, between Arkansas and Oklahoma, allows for percentage distribution of the river and its tributaries ranging from 40-60 percent, depending upon the tributary. Conservation storage for municipal, domestic and irrigation purposes is allocated by the Canadian River Commission, involving New Mexico, Texas and Oklahoma and the Kansas-Oklahoma Arkansas River Commission. The Red River Compact Committee, involving Arkansas, Louisiana, Texas and Oklahoma, has been under negotiation since 1956.

These compacts and their individual specifications must be considered in any water development planning in Oklahoma. In order to fully utilize all available

CONVEYANCE ROUTE	CONVEYANCE LENGTH IN MILES (APPROX.)	CONVEYANCE LIFT IN FEET (APPROX.)
Hugo Lake to Central Oklahoma	180	801
Central Oklahoma to Western Oklahoma	209	852
TOTAL	389	1,653

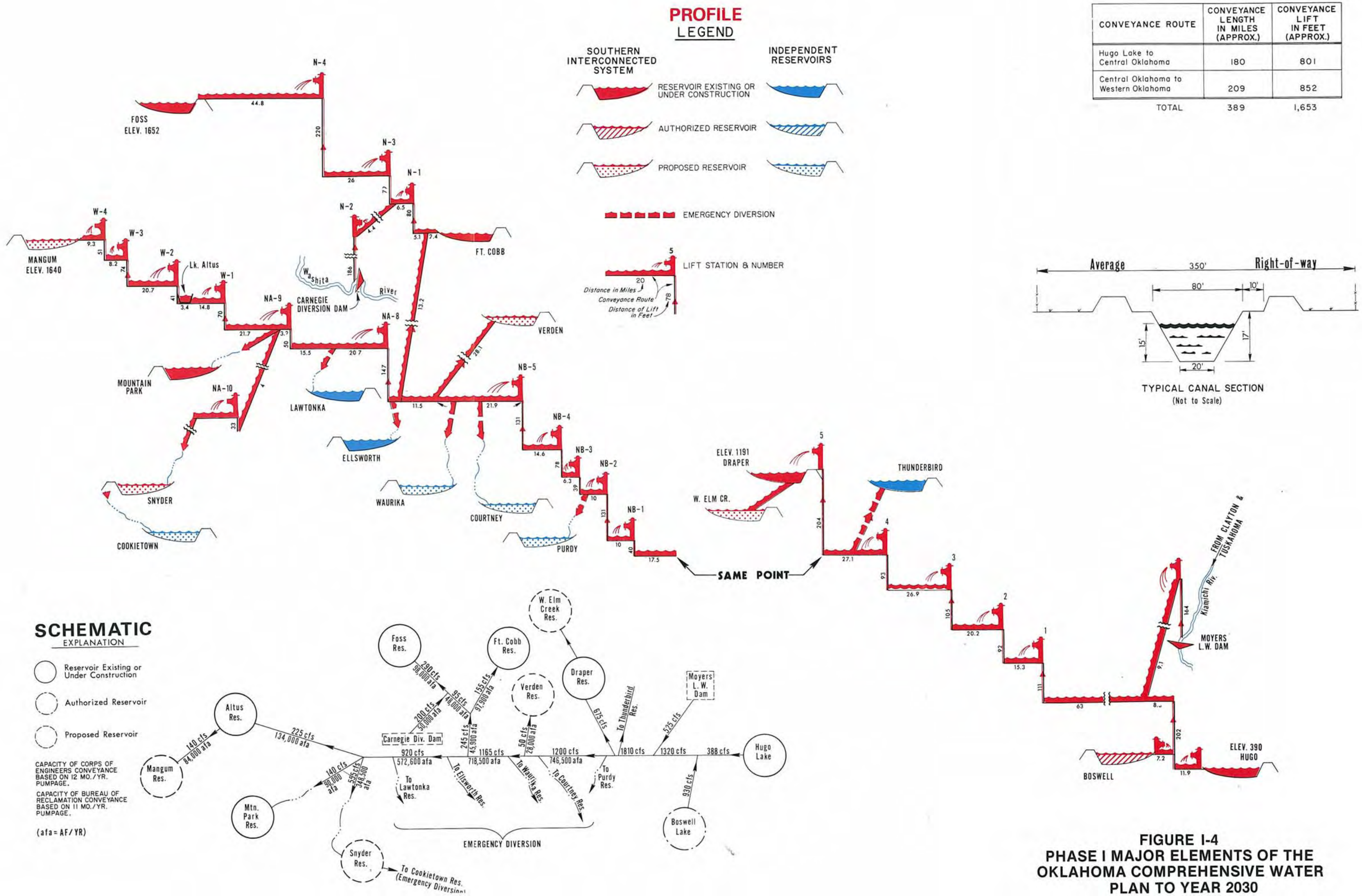


FIGURE I-4
PHASE I MAJOR ELEMENTS OF THE OKLAHOMA COMPREHENSIVE WATER PLAN TO YEAR 2030

stream water supplies, the State must use all water allocated under these agreements, while staying within compact requirements.

Grand River Dam Authority

In 1935, the State established the Grand River Dam Authority (GRDA) as a State agency with authority to control, store and preserve the Grand (Neosho) River and to use, distribute and sell these waters. Provisions of Senate Bill 510, under which the present feasibility level report is authorized, specifically exempts all dams, water and land under the control of the GRDA from inclusion in the Plan.

The water under authority of the GRDA is primarily used for hydroelectric power generation, with a portion being utilized as municipal water supplies. The three major Grand (Neosho) River lakes, Fort Gibson, under the control of the Corps of Engineers, and Grand Lake O' the Cherokees and Lake Hudson, under GRDA control, are also used extensively for recreation.

THE OKLAHOMA COMPREHENSIVE WATER PLAN

State Water Resources and Requirements

The development of the Oklahoma Comprehensive Water Plan required evaluation of existing and potential stream and ground water development and determination of present and future requirements.

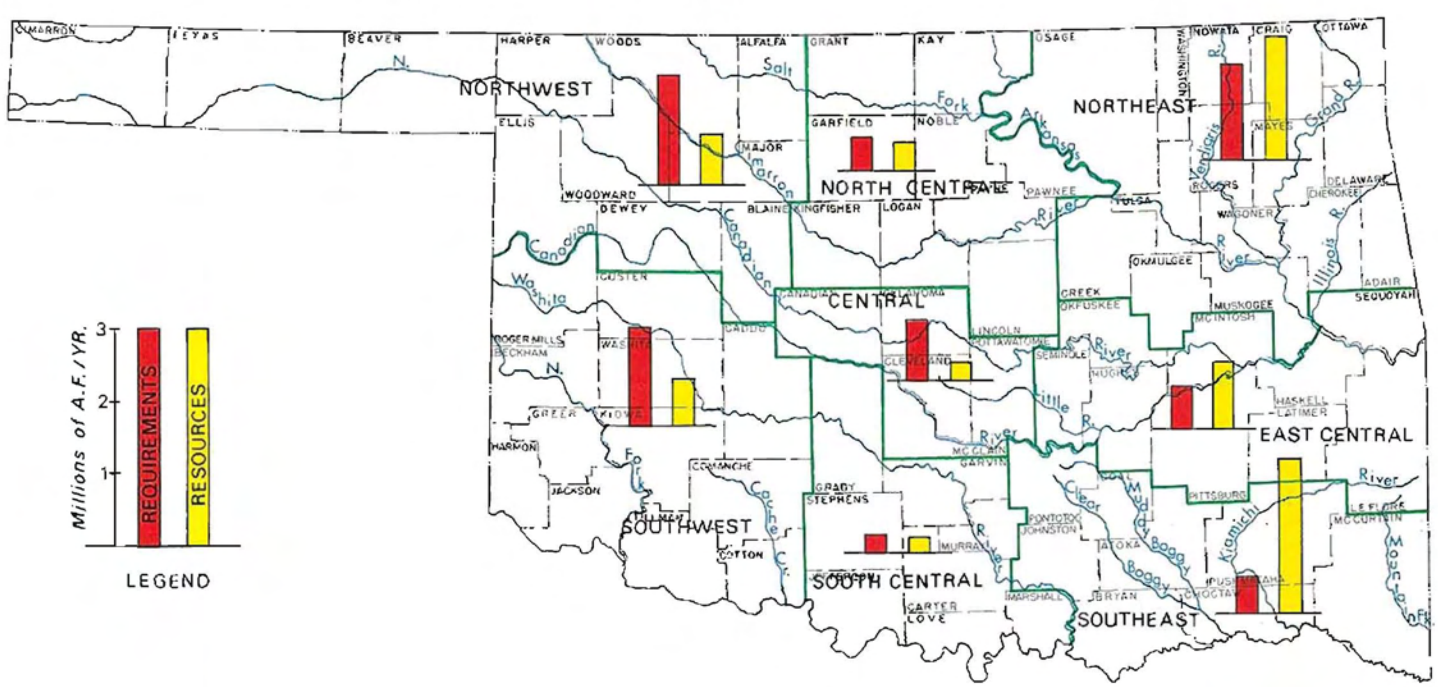
Stream water is extremely varied in characteristics and behavior. The quantity of stream water in the semiarid western portion of the State is only a fraction of that flowing in streams in eastern Oklahoma. Many streams are swollen by floods during periods of heavy rainfall. However, these same streams may have long no-flow periods during drought times. Despite erratic flow rates, many streams can provide dependable water supplies by storing water during high flow periods. Other streams cannot provide water for beneficial use due to insufficient stream water or poor quality runoff.

Ground water is also a major water supply source. In many areas it is the only practical source available. In other areas, ground water is utilized because it can be developed more economically than stream water. Projected resources and requirements for the eight planning regions of the State for the year 2030 are shown on Figure I-3.

Trends toward conjunctive water use to meet future needs have been indicated. That is, the most economical water supply alternative will be to develop the ground water, where available, to its maximum safe yield, then utilize stream water to meet the remaining needs.

Water in Oklahoma is required for a wide variety of uses. Present statewide requirements range from such standard uses as municipal, industrial, agricultural and domestic needs, to relatively new uses, such as in-land navigation. Requirements for present water use are increasing and new uses are continually being discovered. These demand increases will require an orderly, yet flexible development scheme.

FIGURE I-3
2030 STATEWIDE WATER RESOURCES AND REQUIREMENTS



Phase I of the Oklahoma Comprehensive Water Plan was developed to provide a guide for the southern 33 counties. A comparable guide for the remaining 44 counties will be developed in Phase II of the Plan.

Phase I - Southern 33 Counties

Phase I of the Plan is shown on Figure I-1. The Plan is of a feasibility level for the southern 33 counties and reconnaissance level for the northern 44 counties. Shown on Figure I-1 are present proposed water development projects needed within the 33 southern counties by the year 2030. The configuration of the proposed Interconnected System is illustrated in a different color. For the northern 44 counties, Figure I-1 shows existing, authorized and potential water development projects. Pertinent information relating to each project is given on tables in Section IV.

INTERCONNECTED WATER SUPPLY SYSTEM

The proposed Interconnected System for the southern 33 counties is shown in red on Figure I-1. A schematic of the profile and canal capacity is shown on Figure I-4. Basically, the 13 reservoirs, two diversion dams and the interconnecting conveyance system will furnish surplus waters from southeastern Oklahoma to central and southwestern portions of the State. Surplus waters will be taken from Hugo, Clayton, Tuskahoma and Boswell lakes and conveyed to terminal storage reservoirs, West Elm and Draper, in central Oklahoma.

A turn-off will be provided near Wayne, Oklahoma, for water transportation to southwestern Oklahoma. Such water will be distributed to several terminal reservoirs in that area. Verden, Ft. Cobb, Foss, Mountain Park, Snyder, Altus and Mangum reservoirs will serve as terminal reservoirs. Means for delivery of water from these terminals must be developed by local users and is not the subject of this report. Diversion canal stubs will be provided upstream of Lakes Thunderbird, Purdy, Courtney, Waurika, Ellsworth and Lawtonka for emergency releases into these reservoirs, insuring future operational flexibility.

The proposed 2030 system will transport 1,308,000 acre-feet of water annually from southeastern Oklahoma. Of this, 487,000 acre-feet per year will be transported to central Oklahoma and 821,000 acre-feet per year will be diverted to southwestern Oklahoma. Canal and transportation losses of 74,500 acre-feet per year will reduce the amount going into terminal storage in southwestern Oklahoma to 746,500 acre-feet annually.

Interconnected System - Implementation Schedule

The Interconnected System should be completed sometime during the period 1985-1990. Central Oklahoma's municipal and industrial water supply needs require that additional transported water be available by that time. Oklahoma City's water requirements will be the determining factor in the timing of transported water into the central Oklahoma area. Irrigation water needs in southwestern Oklahoma already exceed the supply in some local areas and will require a substantial quantity of supplemental water by 1985-1990.

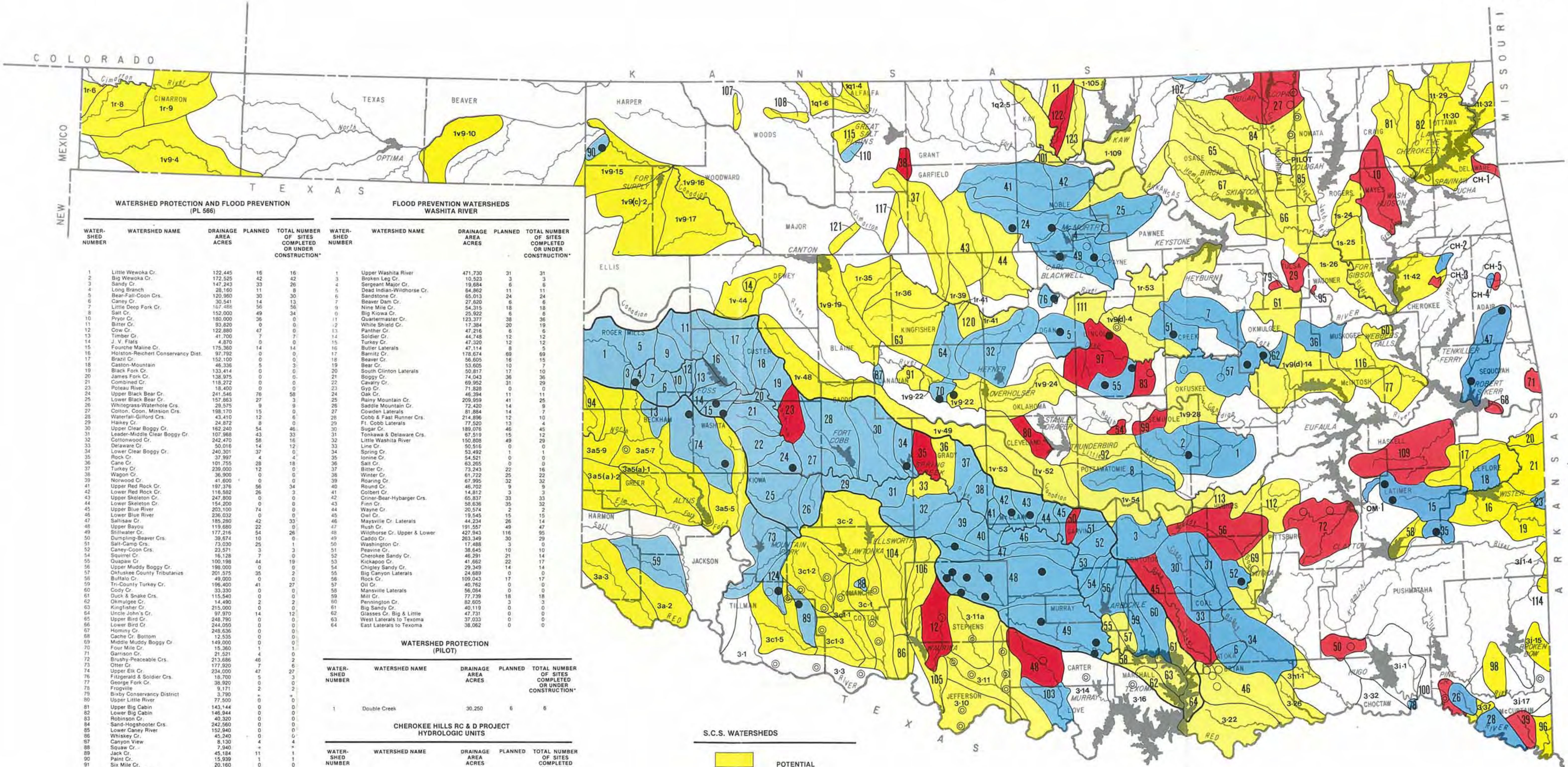
The Kiamichi River system of reservoirs in southeastern Oklahoma will be the first increment of the source reservoir system. The existing Hugo Lake, Clayton Lake, which is under construction and the authorized Tuskahoma Lake will serve the system until after year 2000. The authorized Boswell Lake on Boggy Creek will complete the fourth source reservoir and will be needed after year 2000. These four reservoirs will supply the Interconnected System until year 2030.

The terminal reservoir system in

CONSERVATION NEEDS INVENTORY (CNI)*

CNI NUMBER	WATERSHED AREA ACRES
1-105	14,500
1-109	187,000
3-10	125,620
3-11	292,810
3-11(a)	176,300
3-22	213,576
3-26	72,357
3-32	74,363
3-37	23,654
3a2	109,420
3a3	189,725
3a5-5	143,742
3a5-7	313,342
3a5-9	140,974
3a5(a)-1	136,946
3a5(a)-2	177,006
3c-1	194,361
3c1-1	109,646
3c1-3	111,783
3c1-5	218,772
3h1-1	45,855
3i1	281,448
3j1-4	
3j-15	
1q1-4	25,000
1q1-6	86,142
1q2-5	270,075
1r-6	35,362
1r-8	196,448
1r-9	288,090
1r-35	135,000
1r-36	107,446
1r-39	30,157
1r-41	92,000
1r-53	190,856
1s-24	83,684
1s-25	137,550
1s-26	162,343
1t-29	139,152
1t-30	243,442
1t-32	71,760
1v9-4	358,000
1v9-10	160,400
1v9-15	248,354
1v9-16	123,500
1v9-17	275,735
1v9-19	20,160
1v9-22	83,000
1v9-24	
1v9-28	160,300
1v-44	143,500
1v-48	207,019
1v-49	180,000
1v-52	209,606
1v-53	122,372
1v-54	300,653
1v9(c)-2	296,106
1v9(d)-4	230,426
1v9(d)-14	284,828

* PL 566 Planning has not been requested.



WATERSHED PROTECTION AND FLOOD PREVENTION (PL 566)

WATERSHED NUMBER	WATERSHED NAME	DRAINAGE AREA ACRES	PLANNED	TOTAL NUMBER OF SITES COMPLETED OR UNDER CONSTRUCTION*
1	Little Wewoka Cr.	122,445	16	16
2	Big Wewoka Cr.	172,525	42	42
3	Sandy Cr.	147,243	33	26
4	Long Branch	28,160	11	8
5	Bear-Fall-Coon Crs.	120,960	30	30
6	Caney Cr.	30,541	14	13
7	Little Deep Fork Cr.	167,488	56	56
8	Salt Cr.	152,000	49	34
10	Pryor Cr.	180,000	36	0
11	Bitter Cr.	93,820	0	0
12	Cow Cr.	122,880	47	0
13	Timber Cr.	41,700	7	7
14	J. V. Flats	4,870	0	0
15	Fourche Maline Cr.	175,380	14	14
16	Holston-Reichert Conservancy Dist.	97,792	0	0
17	Brazil Cr.	152,100	0	0
18	Caston-Mountain	46,336	5	3
19	Black Fork Cr.	133,414	0	0
20	James Fork Cr.	138,975	0	0
21	Combined Cr.	118,272	0	0
23	Poteau River	18,400	0	0
24	Upper Black Bear Cr.	241,546	76	58
25	Lower Black Bear Cr.	157,863	27	3
26	Whitegrass-Waterhole Crs.	29,575	9	9
27	Cotton, Coon, Mission Crs.	198,170	15	0
28	Waterfall-Gilford Crs.	43,410	12	6
29	Haikey Cr.	24,872	8	0
30	Upper Clear Boggy Cr.	162,240	54	46
31	Leader-Middle Clear Boggy Cr.	107,968	43	33
32	Cottonwood Cr.	242,470	58	16
33	Delaware Cr.	50,016	14	12
34	Lower Clear Boggy Cr.	240,301	37	0
35	Rock Cr.	37,997	4	4
36	Cane Cr.	101,755	28	18
37	Turkey Cr.	239,000	12	0
38	Wagon Cr.	36,900	0	0
39	Norwood Cr.	41,600	0	0
41	Upper Red Rock Cr.	197,376	56	34
42	Lower Red Rock Cr.	116,582	26	3
43	Upper Skeleton Cr.	247,800	0	0
44	Lower Skeleton Cr.	154,200	0	0
45	Upper Blue River	203,100	74	0
46	Lower Blue River	236,032	0	0
47	Sallisaw Cr.	185,280	42	33
48	Upper Bayou	119,680	22	0
49	Stillwater Cr.	177,216	54	26
50	Dumpling-Beaver Crs.	39,674	10	0
51	Salt-Camp Crs.	73,030	25	1
52	Caney-Coon Crs.	23,571	3	3
54	Squirrel Cr.	16,128	7	0
55	Quapaw Cr.	100,198	44	19
56	Upper Muddy Boggy Cr.	198,000	0	0
57	Okfuskee County Tributaries	201,575	35	2
58	Buffalo Cr.	49,000	0	0
59	Tri-County Turkey Cr.	196,400	41	27
60	Cody Cr.	33,330	0	0
61	Duck & Snake Crs.	115,540	0	0
62	Okmulgee Cr.	14,490	2	2
63	Kingfisher Cr.	215,000	0	0
64	Uncle John's Cr.	97,970	14	12
65	Upper Bird Cr.	248,790	0	0
66	Lower Bird Cr.	244,050	0	0
67	Hominy Cr.	248,636	0	0
68	Cache Cr. Bottom	12,535	0	0
69	Middle Muddy Boggy Cr.	149,000	0	0
70	Four Mile Cr.	15,360	1	1
71	Garrison Cr.	21,521	4	0
72	Brushy-Peaceable Crs.	213,686	46	2
73	Otter Cr.	177,920	7	6
74	Upper Elk Cr.	234,000	47	27
76	Fitzgerald & Soldier Crs.	18,700	5	3
77	George Fork Cr.	38,920	0	0
78	Frogville	9,171	2	2
79	Bixby Conservancy District	3,790	*	*
80	Upper Little River	77,500	0	0
81	Upper Big Cabin	143,144	0	0
82	Lower Big Cabin	146,944	0	0
83	Robinson Cr.	40,320	0	0
84	Sand-Hogshooter Crs.	242,560	0	0
85	Lower Caney River	152,940	0	0
86	Whiskey Cr.	45,240	0	0
87	Canyon View	8,130	4	4
88	Squaw Cr.	7,940	*	*
89	Jack Cr.	45,184	11	1
90	Paint Cr.	15,939	1	1
91	Six Mile Cr.	20,160	0	0
92	Central Little River	220,168	0	0
94	Lower Sweetwater Cr.	137,911	0	0
95	Kadashan Bottom	6,000	6	0
96	Walnut Bayou	42,750	0	0
97	Kickapoo Nations	165,300	0	0
98	Lukfata Cr.	34,458	0	0
99	Pott-Sem-Turkey Cr.	34,560	0	0
100	McKinney-Buzzard Cr.	13,865	0	0
101	Birds Nest Cr.	24,500	0	0
102	Big Caney	228,000	0	0
103	Lower Bayou	95,488	20	6
104	Big Beaver Cr.	177,000	0	0
105	Lower Beaver Cr.	124,900	0	0
106	Little Beaver Cr.	124,800	0	0
107	Houston Cr.	18,000	0	0
108	Turkey Boggy Cr.	37,900	0	0
109	Sansbois Cr.	205,000	0	0
110	Lambert Cr.	8,000	2	2
111	Perkins Laterals	61,800	0	0
112	Coal Cr.	132,000	0	0
113	Atwood-Calvin Tributaries	72,000	0	0
114	Cove-Hatfield	22,500	0	0
115	Cottonwood Canyon	36,000	0	0
116	Dirty Cr.	215,000	0	0
117	Hoyle	36,768	0	0
120	Campbell	41,420	0	0
121	Sand	35,000	0	0
122	Lost-Duck	55,040	12	0
123	Bois 'D 'Arc - Cowskin	80,000	0	0
124	Deep Red Run & Coffin Cr.	58,600	2	1

FLOOD PREVENTION WATERSHEDS WASHITA RIVER

WATERSHED NUMBER	WATERSHED NAME	DRAINAGE AREA ACRES	PLANNED	TOTAL NUMBER OF SITES COMPLETED OR UNDER CONSTRUCTION*
1	Upper Washita River	471,730	31	31
3	Broken Leg Cr.	10,523	3	3
4	Sergeant Major Cr.	19,684	6	6
5	Dead Indian-Wildhorse Cr.	64,862	11	11
6	Sandstone Cr.	65,013	24	24
7	Beaver Dam Cr.	27,620	6	6
9	Nine Mile Cr.	54,315	18	18
10	Big Kiowa Cr.	25,922	6	6
11	Quartermaster Cr.	123,377	38	36
12	White Shield Cr.	17,384	20	19
13	Panther Cr.	47,216	6	6
14	Soldier Cr.	44,748	12	12
15	Turkey Cr.	47,320	12	12
16	Butler Laterals	47,114	8	5
17	Barnitz Cr.	178,674	69	69
18	Beaver Cr.	56,605	16	15
19	Bear Cr.	53,605	10	7
20	South Clinton Laterals	50,817	17	10
21	Boggy Cr.	74,043	36	36
22	Cavalry Cr.	69,952	31	29
23	Gyp Cr.	71,828	0	0
24	Oak Cr.	46,394	11	11
25	Rainy Mountain Cr.	209,959	41	25
26	Saddle Mountain Cr.	72,420	14	9
27	Cowden Laterals	81,884	14	7
28	Cobb & Fast Runner Crs.	214,896	12	10
29	Ft. Cobb Laterals	77,520	13	4
30	Sugar Cr.	189,076	46	45
31	Tonkawa & Delaware Crs.	67,519	15	12
32	Little Washita River	150,808	49	29
33	Line Cr.	50,516	0	0
34	Spring Cr.	53,492	1	1
35	Ionine Cr.	54,521	0	0
36	Salt Cr.	63,265	0	0
37	Bitter Cr.	73,243	22	16
38	Winter Cr.	61,722	25	22
39	Roaring Cr.	67,995	32	32
40	Round Cr.	46,702	9	9
41	Colbert Cr.	14,812	3	3
42	Criner-Bear-Hybarger Crs.	65,837	33	33
43	Finn Cr.	58,636	35	32
44	Wayne Cr.	20,574	2	2
45	Owl Cr.	19,545	15	15
46	Maysville Cr. Laterals	44,234	26	14
47	Rush Cr.	191,557	49	47
48	Wildhorse Cr. Upper & Lower	427,943	116	95
49	Caddo Cr.	263,349	30	29
50	Washington Cr.	17,488	3	0
51	Peavine Cr.	38,645	10	10
52	Cherokee Sandy Cr.	46,291	21	14
53	Kickapoo Cr.	41,662	22	17
54	Chigley Sandy Cr.	29,349	14	14
55	Big Canyon Laterals	24,689	0	0
56	Rock Cr.	109,043	17	17
57	Oil Cr.	40,762	0	0
58	Mansville Laterals	56,064	0	0
59	Mill Cr.	77,739	18	18
60	Pennington Cr.	82,605	3	3
61	Big Sandy Cr.	40,119	0	0
62	Glasses Cr. Big & Little	47,731	0	0
63	West Laterals to Texoma	37,033	0	0
64	East Laterals to Texoma	38,062	0	0

WATERSHED PROTECTION (PILOT)

WATERSHED NUMBER	WATERSHED NAME	DRAINAGE AREA ACRES	PLANNED	TOTAL NUMBER OF SITES COMPLETED OR UNDER CONSTRUCTION*
1	Double Creek	30,250	6	6

CHEROKEE HILLS RC & D PROJECT HYDROLOGIC UNITS

WATERSHED NUMBER	WATERSHED NAME	DRAINAGE AREA ACRES	PLANNED	TOTAL NUMBER OF SITES COMPLETED OR UNDER CONSTRUCTION*
CH-1	Whitewater	19,738	3	2
CH-2	Fourteen Mile	12,594	2	2
CH-3	Townbranch	4,640	2	0
CH-4	Scraper Hollow	5,338	2	2
CH-5	England Hollow	4,960	2	0

OUACHITA MOUNTAINS RC & D PROJECT HYDROLOGIC UNITS

WATERSHED NUMBER	WATERSHED NAME	DRAINAGE AREA ACRES	PLANNED	TOTAL NUMBER OF SITES COMPLETED OR UNDER CONSTRUCTION*
OM-1	Boiling Springs	5,160	1	1

Includes structures on which contracts have been awarded but work is not complete.

No floodwater retarding structures have been planned, only channel improvement measures.

S.C.S. WATERSHEDS

- POTENTIAL
- PLANNED
- COMPLETED OR UNDER CONSTRUCTION

MULTI-PURPOSE SITES

- BUILT
- PLANNED
- POTENTIAL

INDICATES NUMBER OF SITES ONLY—NOT EXACT LOCATION

FIGURE I-5
SOIL CONSERVATION SERVICE PROGRAM SHOWING MULTIPURPOSE SITES
July 1975
Soil Conservation Service

the southwest 20 counties of the State will consist of four existing reservoirs: Foss, Fort Cobb, Altus and Mountain Park, plus the proposed Verden, Snyder and Mangum reservoirs. Associated reservoirs which could receive transport water on an emergency basis are Purdy, Courtney, Waurika and Cookietown. Existing reservoirs will receive transport water upon completion of the conveyance system sometime between 1985-1990. The proposed terminal reservoirs will come on line as soon as they are constructed. Detailed studies will be made by the Bureau of Reclamation to determine the exact time phasing of the entire system in the southwest 20 counties.

INDEPENDENT RESERVOIRS

Reservoirs and lakes needed to supply local and regional water requirements are included in the 2030 plan in each of the planning regions. These are shown in blue on Figure I-1 for the southern 33 counties. Thirty-one reservoirs are included in this group of independent reservoirs. Twenty are existing or under construction, six lie within the southeast region, six within the central region, 13 within the south central region and six within the southwest region. Cost for those under study are shown in Table I-3.

WATERSHED PROTECTION PROGRAM

The statewide program for watershed protection is shown on Figure I-5 and I-5a. The Soil Conservation Service has responsibility for planning and implementation of this program.

There are a total of 171 small S.C.S. watersheds in the southern 33 counties. Of these, 89 are complete or under construction, 34 are planned and 48 have development potential within the next 50 years.

To date, a total of 1,215 upstream detention structures have been built in the southern 33 counties and an additional 491 structures are planned.

There are 58 existing, planned or potential multi-purpose structures in the southern 33 counties. Purposes include municipal and industrial water supply, recreation, irrigation and fish and wildlife propagation, in addition to the basic purpose of flood detention.

The program for the northern 44 counties will be defined in Phase II of the Plan.

BENEFITS OF THE SOUTHERN INTERCONNECTED SYSTEM

Irrigation

The benefit analysis was a joint effort between the Bureau of Reclamation, the Oklahoma Water Resources Board and Oklahoma universities. Primary benefits from project irrigation are measured by the additional net farm income from increased agricultural production. Benefits accrued from irrigation are measured by the difference between net farm income with irrigation and net farm income with dry-farmed land. Irrigation costs must be weighed against the increment of return, with allowances for a return to management. These primary benefits represent reasonable estimates of the average return from irrigation.

In deriving primary benefits, current levels of unit prices received by farmers were assumed to remain constant. Irrigated and dry land crop yields, cropping patterns and costs by crop were projected to the year 2030. Primary benefits per acre were determined by comparing costs and returns on a composite or typical land acre to costs and returns on a composite dry land acre. The composite acre contains all the applicable crops in relative proportions estimated to represent the overall cropping pattern for the study areas under both dry-farmed and irrigated conditions.

In addition to primary benefits, regional development benefits from irrigation were calculated based on coefficients derived by the Bureau of Reclamation. The resulting regional development benefit estimate is limited to the increment in net income of all enterprises between the farmer and the final consumer through handling, processing and marketing the increased farm production from irrigation. Only that portion of irrigation-induced value added by processing and marketing establishments that constitutes profit and proprietor income is defined as regional development benefits. Compensation of employees, capital consumption allowances and other factors have been excluded.

A preliminary economic impact study was done by the University of Oklahoma Bureau for Business and Economic Research entitled "Water Transference Study." It investigated the impact of water on the economy of Oklahoma. The study, using available data, attempted to measure the effects which forecasted water shortages in western Oklahoma will have on that region, as well as the State as a whole.

This was intended as a pilot preliminary study. Other studies of more detail are continuing at this time to further determine the economic impacts of water on the entire economy of Oklahoma.

Current estimates show primary benefits totalling $307 per acre and regional development benefits totalling $214 per acre, for a total irrigation benefit of $521 per acre. Substantial additional statewide benefits will accrue as a result of the transfer system. Studies indicate that the beneficial impact on the State's economy through provision of irrigation water supply from the system is at least twice the benefits shown above.

Municipal and Industrial

It is assumed that municipal and industrial water supply benefits equal the cost of the least costly single purpose alternative project. Water supply benefits would go to cities, towns, rural water systems, utility companies, energy related uses and all other industries.

TABLE I-1
COSTS OF SOUTHERN OKLAHOMA INTERCONNECTED SYSTEM
Based On January, 1974 Prices
(Figures In $1,000's)

	TOTAL	MUNICIPAL AND INDUSTRIAL	IRRIGATION
Southeastern Oklahoma System Storage Reservoir Facilities[1]	166,200	91,200	75,000
Conveyance Facilities[2]	754,800	451,800	303,000
SUBTOTAL	921,000	543,000	378,000
Southwestern Oklahoma System[3] Storage Reservoir Facilities[4]	80,200	9,600	70,600
Conveyance Facilities	338,700	40,600	298,100
Distribution Canals and Laterals	333,500	—[5]	333,500
SUBTOTAL	752,400	50,200	702,200
TOTAL SOUTHERN OKLAHOMA INTERCONNECTED SYSTEM	1,673,400	593,200	1,080,200

[1]Estimated water supply storage costs shown for this system include Boswell, Tuskahoma, Hugo, Clayton and West Elm.

[2]At this time the Corps of Engineers is still conducting detailed studies of the Central Oklahoma Project. Presently, a canal system, as well as pipeline system or combination of both are being considered by the Corps of Engineers in its studies. Either or both of these studies may be shown in their reports to Congress. These studies also include sizing of the conveyance of a 100 year capacity.

[3]At this time the Bureau of Reclamation is continuing studies on the southwestern Oklahoma system. These studies include storage and conveyance facilities for irrigation and municipal and industrial water in southwestern Oklahoma.

[4]Reservoir costs shown for this system include Verden, Snyder, Mangum, Carnegie Diversion Dam, Altus, Fort Cobb, Foss and Mountain Park.

[5]Municipal and industrial distribution costs have not been determined for this report.

COSTS OF THE SOUTHERN INTERCONNECTED SYSTEM

Estimated capital cost of major water facilities based on January, 1974 prices are given in Table I-1. The effects of inflation on prices during construction have been excluded from the cost estimates. Estimated irrigation distribution canals and laterals costs from the terminal reservoirs to the on-farm irrigation project are also shown, as these computations were necessary in the total analysis of the system. The cost estimates came from the plans and estimates appendix of the Bureau of Reclamation's preliminary report on the southwest 20 counties in Oklahoma and the Corps of Engineers' preliminary studies of the central Oklahoma project.

The estimated construction costs of lakes, dams and conveyance facilities were generally based on cost curves with allowances for unlisted items. In the final estimates, the "Engineering News Record" indices were used to bring all construction cost to the January, 1974 level.

The costs of water from the Interconnected System are given in Table I-2. Annual costs include maintenance and operation and first costs amortized at 5-7/8 percent.

Energy Requirements

The availability of electrical energy was also considered in the development of the Interconnected System. Preliminary data indicates the conveyance system, at ultimate development, will require approximately 270,000 kilowatts of electrical power and 2.1 billion kilowatt hours of electrical energy annually. This figure represents approximately four percent of Oklahoma's present electrical power generating capacity; thus, the conveyance system's total electrical power requirements are well within the State's total generating capacity.

Independent Reservoir Costs

Capital reservoir costs, based on January, 1974 prices, are shown in Table I-3. These are additional costs and are independent of the Interconnected System. All reservoirs are proposed at this time and will supply local water needs. Individual reports on each reservoir will be made to Congress by the appropriate federal agency.

Phase I - Northern 44 Counties

Although no specific plan was developed for the northern 44 counties of the State, reconnaissance findings were determined. An inventory of resources and assessment of needs was made for each of the four northern regions. Such findings indicated that existing and authorized reservoirs will not meet the 50 year needs in any of these regions, except through diversion of hydropower storage or releases. A huge deficit will exist in the northwestern portion of the State by the year 2030. These deficits are listed by region in Section IV.

Means to satisfy the water supply needs of the northern 44 counties will require further detailed studies. These studies will include a detailed hydrologic survey of stream waters of the Arkansas River basin. This survey will consider a systems operation of all existing and authorized flood control, hydropower, water supply and navigation projects for periods of record flows. The systems operation will include expected hydropower and navigation needs and withdrawal requirements for in-basin municipal, industrial and irrigation needs. The studies will also observe operating rules of existing interstate compacts. Such studies are needed to accurately define areas of surplus, locations of expected deficits and timing of these occurrences. These detailed studies are scheduled to begin in Fiscal Year 1976 and will be considered as a part of Phase II of the Comprehensive Water Plan.

TABLE I-2 APPROXIMATE COSTS OF WATER FOR INTERCONNECTED SYSTEM AT YEAR 2030

MUNICIPAL AND INDUSTRIAL[1]	WATER COSTS ¢/1000 GAL.
Total to Central Oklahoma	19
To Wayne, OK	13
From Wayne, OK to Southwest OK Terminal Reservoirs	14
Total to Southwest OK Terminal Reservoirs	27
IRRIGATION	**$/ACRE-FOOT**
To Wayne, OK	28.92
From Wayne, OK to Southwest OK Terminal Reservoirs	39.58
Total to Terminal Reservoirs	68.50
To Terminal Reservoirs	68.50
From Terminal Reservoirs to Farm	18.27
Total to Farm	86.77[2]

[1]Computed at 5 7/8 percent interest.
[2]Cost per acre-foot at 5 7/8 interest will equal $135.94.

TABLE I-3 INDEPENDENT RESERVOIR CAPITAL COSTS (1974 Prices in $1,000's)

SOUTHEASTERN OKLAHOMA	
Albany[1]	17,680
Parker[1]	16,480
McGee Creek[2,3]	19,000
SUBTOTAL	53,160
SOUTHWESTERN OKLAHOMA[3]	
Cookietown	39,670
Courtney	27,090
Hydro	56,960
Purdy	28,930
Weatherford	30,187
SUBTOTAL	182,837
TOTAL SOUTHERN OKLAHOMA	235,997

[1]Reservoirs under study by the Corps of Engineers.
[2]Detailed costs of McGee Creek are not available at this time.
[3]Reservoirs under study by the Bureau of Reclamation.

CONSIDERATIONS RELATED TO FUTURE DEVELOPMENT

Water resource development in Oklahoma has progressed significantly since its beginning. Initially, development was for satisfaction of local or private needs with little or no consideration given to the adverse impact which might result. Sparse settlement and abundant water for all beneficial uses required few controls on water resource development. However, as the State's population and water requirements increased, exploitative and sometimes haphazard water resource development occurred.

Since then, stricter controls and better planning procedures have gradually been implemented. These measures have alleviated many water related problems in Oklahoma. However, a concise, well defined plan of development will be necessary to meet future water requirements. Sound planning procedures must be followed and applied on a statewide basis and a well defined, yet flexible implementation schedule must be developed. Following these principles will insure adequate water for all areas of the State for many years.

Planning Procedures

Proper planning has become a necessary prerequisite to water resource development. Each new concern adds a new dimension in consideration of the overall planning procedure.

This increased complexity has reemphasized the need for constant review of all planning aspects. A continuing data collection and research program is needed to insure full utilization of all available resources. Environmental planning must also be recognized as a vital part of resource development. Since resource development involves large expenditures, future plans should be developed to meet federal funding requirements. Federal requirements are only one of the institutional problems which must be resolved if any plan is to be implemented.

DATA COLLECTION

Accurate, complete data is the basic element necessary in plan formulation. Planning based on incomplete or inaccurate data can result in expensive and possibly tragic errors. Information must be collected on a regular, long term basis to insure consideration of a complete range of possible values prior to resource development.

The dynamic nature of hydrologic systems necessitates programs which periodically monitor these systems' reactions to man's activities. Changes generally occur gradually and sometimes years of monitoring are necessary before definite trends can be shown. Therefore, information collected over a long period of time is more representative than short term data. Climatology, well monitoring and streamflow gauging are among the data which need to be collected. A more detailed type of data is necessary for specific plan formulation, project design and operation and regulation program development. Programs to gather this more detailed data are underway and other programs need to be initiated.

Hydrologic studies of ground water basins were started in 1967. These studies include collection of basic data, mapping of hydrologic characteristics and determination of maximum yields for each ground water basin.

The data being collected relates to water level fluctuation, water quality and saturated thickness. Data from each ground water basin will be correlated, analyzed and mapped, and a maximum yield determined. In addition to these studies, ground water management programs will be implemented and well monitoring will be continued to determine the program's effects on the basins.

Hydrologic studies of State stream systems must be made to determine the availability of water for appropriation. These studies will include tabulating, mapping and quantifying stream water yields and depletion. Time, location and recurrence probabilities of deficient and surplus streamflows must also be determined. Preliminary studies have already been made on some of the more critical stream systems, primarily in western Oklahoma.

Computer services will aid in data collection programs. These programs include determination of ground water development through ground water basin studies, evaluation of future stream water availability by comparison of current water rights, scheduling of industrial pollution control inspections, evaluation of structural adequacy of dams to prevent losses from failure and analysis of legal descriptions and possible duplication of water rights.

Topographic maps, valuable aides in resource development planning, are available for much of the State. The mapping program is continuing and older maps are being updated. Soil surveys, land use information and economic data are available from various State and federal agencies.

RESEARCH

Research provides the additional information necessary in formulation of planning techniques. Additional research is needed to develop new techniques and programs for more effective utilization of existing data. Research is also necessary to increase general knowledge of existing resources. Continued research will overcome the problems of resource development.

Some research programs have begun but should be expanded. These include the interdependence of ground and stream water and its use and replenishments and the interrelation between ground water systems and influential factors. These influencing factors are return flows, natural and artificial recharge, conservation practices and wastewater reuse. Understanding these processes and their effects will promote the efficient use of available ground water resources.

Other aspects of stream water planning, such as flood control, weather modification, evaporation minimization, seepage control and appropriations could also be improved through continued research in these areas.

Research using computerized models to simulate the hydrologic behavior of ground and stream water systems is needed. Through use of these models, effects of different alternatives can be determined without physically implementing these alternatives. Thus, a wider array of alternatives can be considered in the development of future plans.

Water quality research programs also need to be expanded. Further research on desalination, reduction of nutrient content in runoff, industrial waste treatment and urban runoff effects is needed to prevent further degradation of State water resources.

ROLE OF THE FEDERAL AGENCIES

The three major federal construction agencies, the Bureau of Reclamation, the Corps of

Engineers and the Soil Conservation Service, have actively participated in the planning efforts and development of the Oklahoma Comprehensive Water Plan.

The Corps of Engineers is preparing authorizing documents for submission to Congress on the portion of the Interconnected System from southeastern to central Oklahoma and on the independent Parker and Albany reservoirs.

The Bureau of Reclamation is making appraisal level studies on projects in the southwest 20 counties, including the Interconnected System from central Oklahoma westward. These will be used to justify further studies leading to the authorization of that portion of the total project. The Bureau of Reclamation is also making studies of the independent McGee Creek reservoir in southeastern Oklahoma, leading to an authorization report for Congressional action.

The Soil Conservation Service has a continuing planning program leading toward Congressional authorization of watershed development. Continued multipurpose reservoir development is needed to serve those towns and communities having water supply problems.

Though not a construction agency, the U.S. Geological Survey (U.S.G.S.) participates as a data gathering and analysis agency. The U.S.G.S. is continuing ground water basin reconnaissance studies needed in water resource development.

ROLE OF THE STATE OF OKLAHOMA

The State will assist federal construction agencies in providing necessary repayment assurances for federally-built projects. However, the State must be prepared to underwrite by assurance of a lump sum payment, any components of the Plan which cannot be authorized and constructed by the federal agencies. The State must take immediate steps to insure enactment of legislative and administrative programs which provide needed implementation and operation authority. Legislative task forces or similar groups should study and recommend the desired role of the State of Oklahoma in planning and development.

INSTITUTIONAL CONSIDERATIONS

Institutional modifications are needed in several areas to achieve full development potential of State water resources. Powers and authorities must be clearly defined and overlapping authorities must be resolved to eliminate duplication of efforts. Action is also needed to minimize delays encountered in implementation of resource development plans.

Increased ground water use has produced local and area-wide problems which must be resolved to insure continued reliable ground water sources. Many problems, such as depletion, local overdevelopment and salt water intrusion could be alleviated through ground water management programs. The Oklahoma Water Resources Board should be made responsible for these programs and given the power to provide technical assistance in program development.

Although the present area-of-origin law protects in-basin interests, stronger legislation is needed, emphasizing that all area-of-origin needs will be satisfied before any excess water is conveyed to other areas.

Action is also needed to create a water resource development funding and loan program. The program will particularly help small towns raise the capital necessary to utilize water resources once they become available. Factors such as current municipal indebtedness, lower per capita income and small populations contribute to this problem. Thus, a small community may suffer from water supply shortages while a major water supply source a few miles away remains unutilized. In order to rectify this situation, the program should be of sufficient magnitude to assist in all stages of local and regional water development, ranging from raw water development to renovation of municipal distribution systems. This program, or a similar one, will also aid in the establishment of special purpose districts for area water management and conservation.

ENVIRONMENTAL CONSIDERATIONS

Consideration of environmental impacts resulting from future resource development must be considered. Environmental considerations once covered only physical and biological systems, but now include such factors as socio-economic impacts and possible inundation of archaeological and historical sites.

Prior to implementation of the Oklahoma Comprehensive Water Plan, environmental effects will be evaluated. If the Plan is federally financed, the responsible federal agencies will do a detailed environmental impact study. If the State finances the Plan, the State agency or agencies involved will make the environmental evaluation. Environmental aspects include investigation of archaeological sites, biological studies to determine disruption of rare or endangered plants and animals and planning to minimize aesthetic losses and displacement of families, farms, businesses and cemeteries.

Various environmental impacts will result from development of the source and terminal reservoirs, canals and pipelines of the Interconnected System. Impacts resulting from development of source and terminal reservoirs will be similar. Canals and pipelines will also produce comparable environmental impacts during the construction period. However, the impacts of the canals will continue after construction, whereas post-construction pipeline effects will be minimal.

The Plan will stimulate the economy on all levels. Local economies will be stimulated during construction and increases in water available for municipal, industrial, recreational and irrigation purposes will aid the economy on a state, as well as on a local level. This will provide more money for education, cultural facilities and improve the quality of living.

However, adverse effects will also occur. These include a loss of tax dollars on inundated land and division of farms into sections which are inaccessible or too small to be farmed economically.

Increased recreation could lower the air quality in reservoir areas. Temporary increases in air and noise pollution will also occur during construction. A minor noise pollution increase will occur near the pumping stations because of operation and maintenance activities.

Land for pumping stations, canals and reservoirs will no longer be available for wildlife habitat, feeding grounds and cover. Wildlife may be disturbed by the increased noise around pumping stations.

Reservoir construction will decrease stream fishing, but will create new reservoir fishing, with new types of aquatic habitat. In addition, better quality water will be available for downstream releases, indirectly improving downstream fishing.

Water from the canal could be released to intersecting streams to maintain favorable flow rates during dry periods, also indirectly improving downstream fishing.

Vegetation will be displaced or destroyed along the canal route and in inundated reservoir areas. Vegetation in flood control and conservation pools may be adversely affected by periodic flooding and drawdown of source reservoir during pumping periods. Revegetation through seeding may be necessary along canal banks and in reservoir construction areas. Disruption of vegetation along the canal route may effect the aesthetics of areas near the canal, but no unique scenic areas will be affected.

The canal can become a major recreational attraction. Development of trails parallel to the canal will provide a relatively level surface for hiking, sightseeing, biking and horseback riding. The canal's meandering course will also provide contrasting scenic areas and a diversity of wildlife. Similar trails have been incorporated along sections of California's canal system with excellent public response. Camping sites at intervals along the trails will further increase recreation possibilities. Any recreational development will necessarily include protection of surrounding scenic beauty and prevention of system pollution.

Reduced flooding below reservoirs will result in increased agricultural output and more stable downstream environmental conditions. The system will also alleviate fear and anxiety caused by potential flooding, water supply shortages and future degradation of stream water quality.

Some utility lines, railroads and highways may need to be relocated, resulting in extended travel time and cost. Water stored in terminal reservoirs will increase their efficiency. Water use in terminal areas will increase return flows and indirectly increase base flows.

SECTION II

STATEWIDE RESOURCES

LIST OF TABLES AND FIGURES

TABLE

FIGURE

CLIMATE

The climate of Oklahoma is mostly continental in type, as in all of the central Great Plains. Summers are long and hot, winters are shorter and less rigorous than those of more northern plains states. Moist air currents from the Gulf of Mexico influence the weather during most of the year, although cool moist air masses from the Pacific and cold dry air masses from Canada predominately influence the weather during winter months. Maximum precipitation occurs in the spring, decreasing through the summer months. Maximum secondary precipitation occurs in the fall. May is usually the wettest month and January the driest month.

Precipitation

The geographical distribution of rainfall decreases sharply from east to west. Average annual precipitation ranges from about 56 inches in southern LeFlore County in the southeastern corner of the State to approximately 15 inches in the western section of the Panhandle. Precipitation in the form of snow rarely remains on the ground more than a few days. The rainfall distribution is shown on Figure II-1.

Temperature

Mean annual temperature over the State ranges from 64 degrees along the southern border to about 60 degrees along the northern border. The temperature decreases westwardly across the Panhandle to about 57 degrees. A maximum of 120 degrees Fahrenheit has been recorded by the weather bureau. Temperature variations are shown on Figure II-2.

Evaporation

Average annual lake evaporation varies from about 48 inches in the extreme eastern section of the State to as high as 65 inches in the southwestern corner. Evapotranspiration and percolation amount to approximately 85 percent of the annual rainfall. Figure II-3 illustrates lake evaporation ranges.

Runoff

The contrast in runoff figures is dramatic, ranging from .2 inches in the Panhandle to 20 inches in the southeast corner. See Figure II-4. In the northwest region, average annual runoff is about 820,000 acre-feet per year, compared to 6,000,000 acre-feet per year in the southeast region. Average annual runoff for the entire State is about 22,000,000 acre-feet.

FIGURE II-1
AVERAGE ANNUAL PRECIPITATION (In Inches)

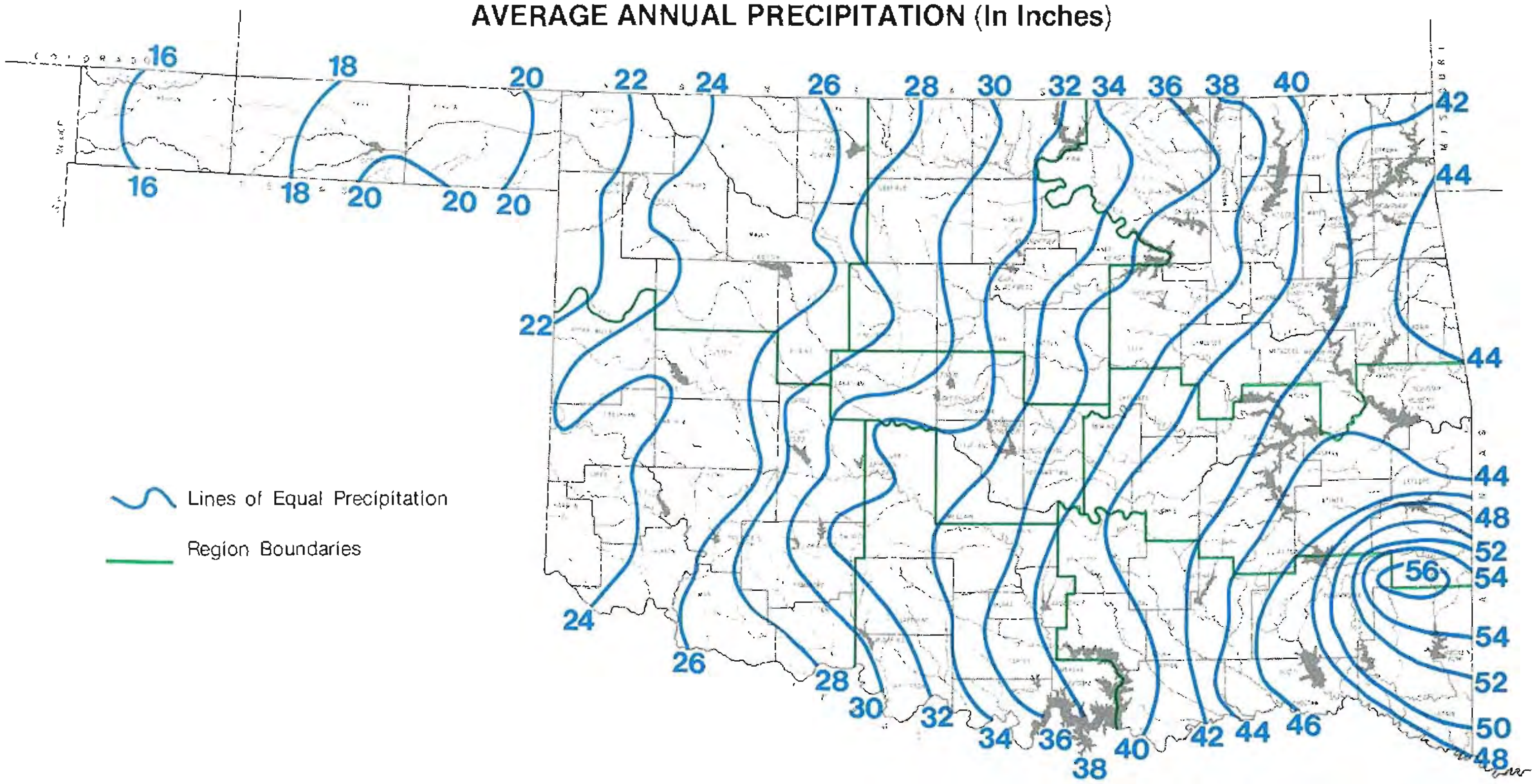


FIGURE II-2 MEAN ANNUAL TEMPERATURE (In Degrees Fahrenheit)

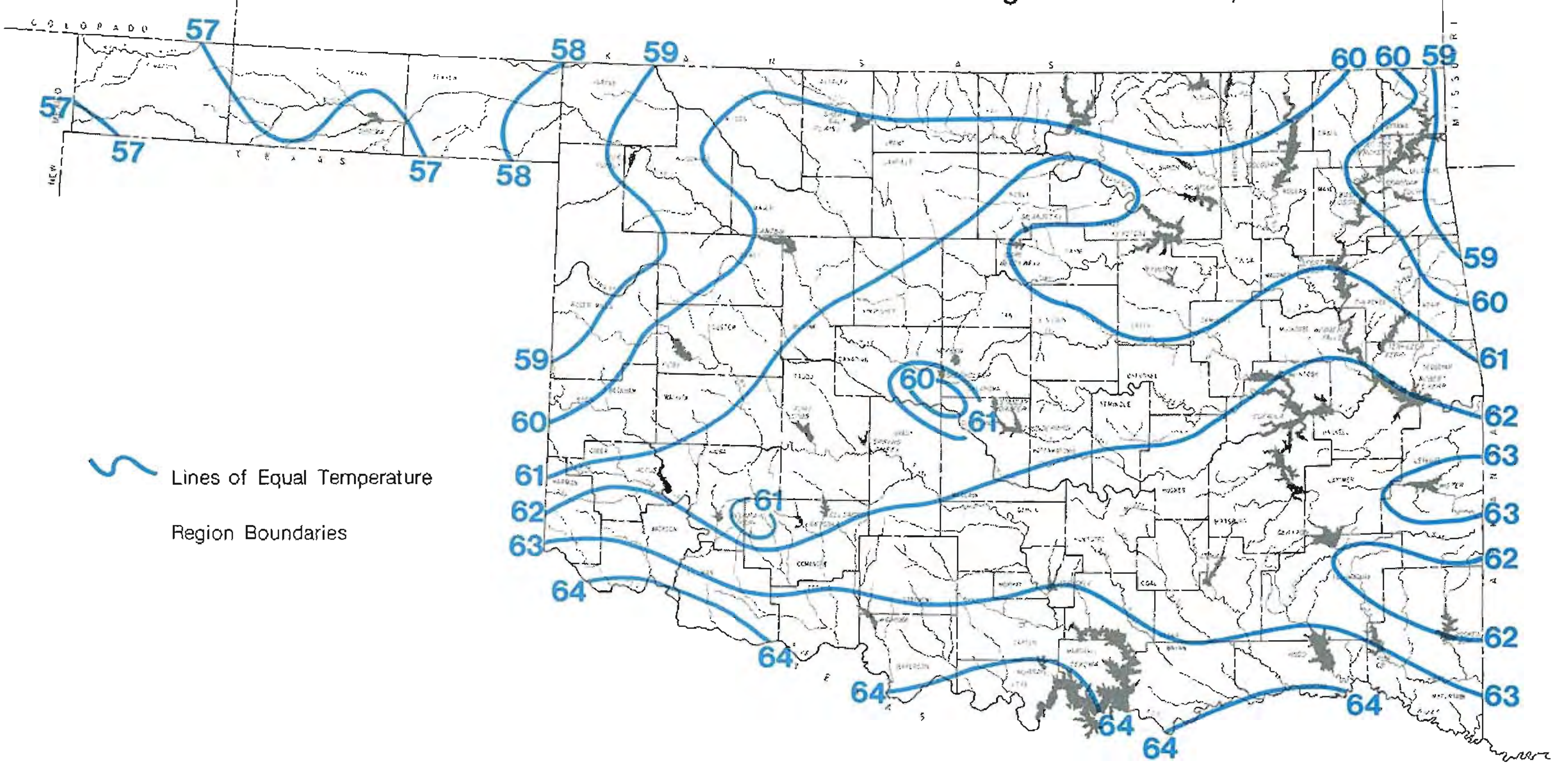
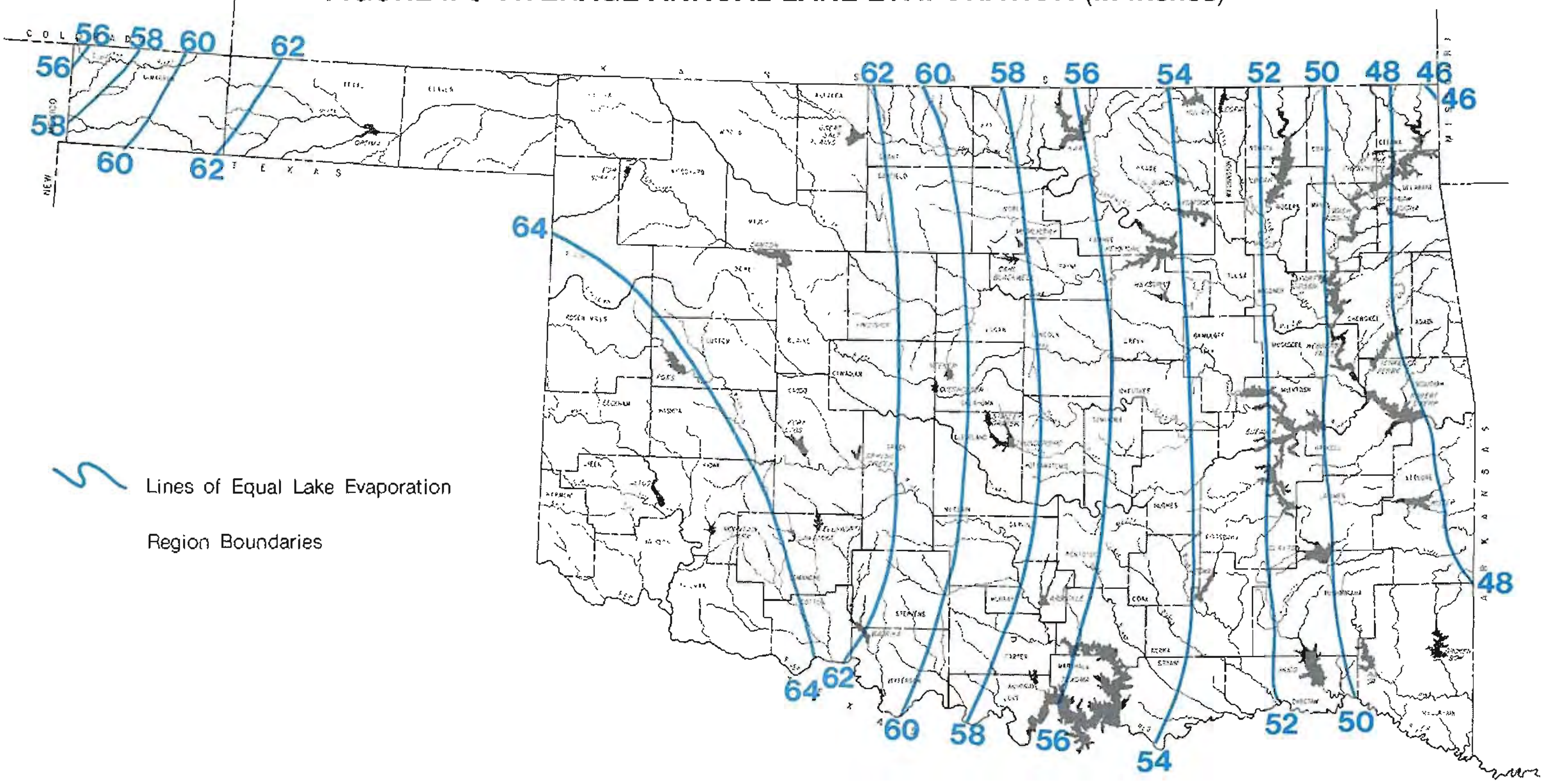


FIGURE II-3 AVERAGE ANNUAL LAKE EVAPORATION (In Inches)



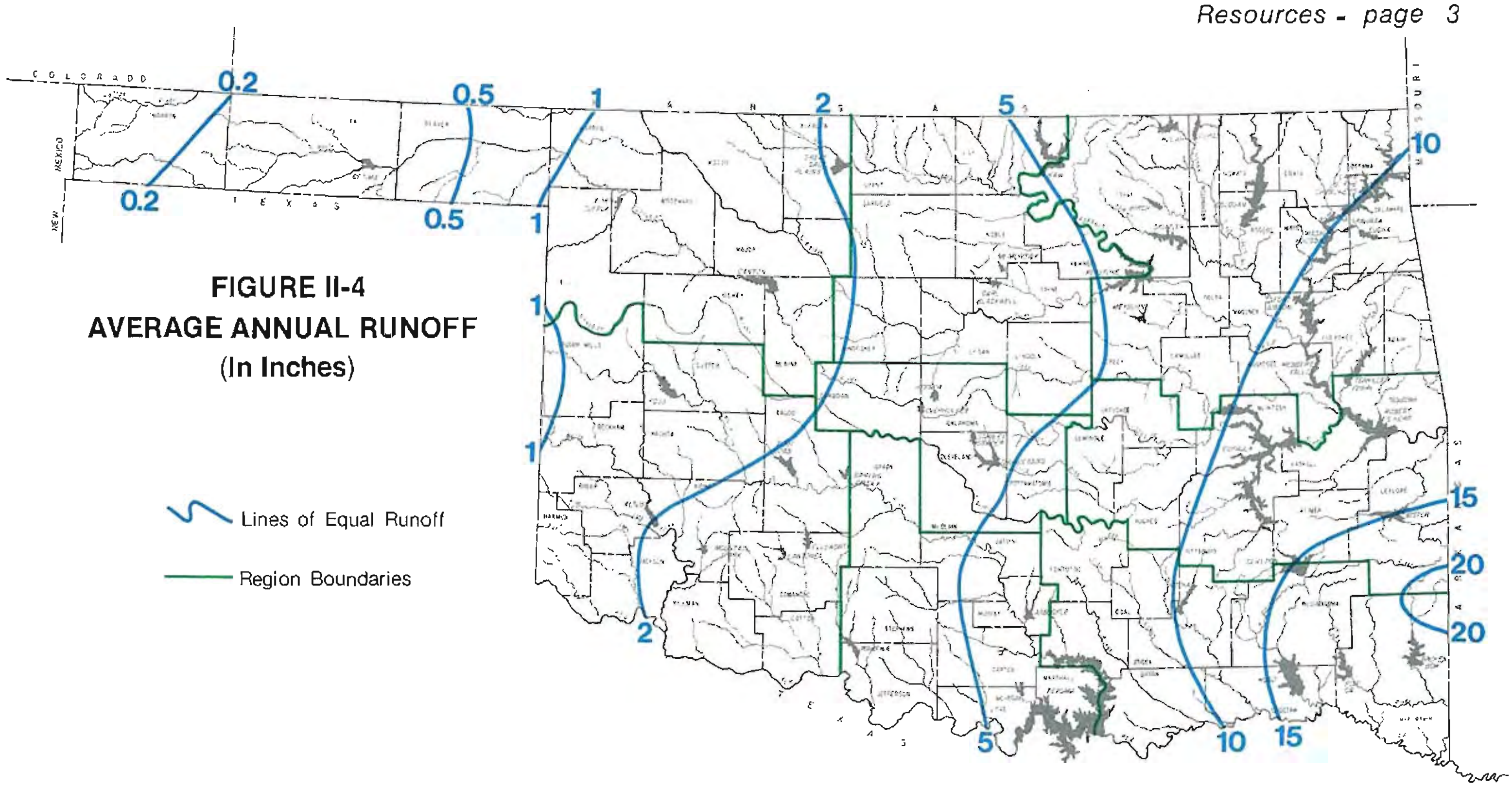


FIGURE II-4
AVERAGE ANNUAL RUNOFF
(In Inches)

Droughts

Oklahoma, along with other states in the southern Great Plains, has at times been subject to droughts of varying degree and duration, although drought years have been far less frequent than dry summers and falls.

Most notable of the drought periods in Oklahoma were the dry years which occurred in the late 1890's, the drought of 1910 and 1919, the very severe one of the 1930's and more recently the 1950's and 1960's.

The drought of the 30's was the most protracted in Oklahoma's history, but that of the 50's was more widespread and more severe for the length of time involved. The drought of the 50's ranks among the most severe of the past 400 years.

Floods

Western Oklahoma is subject to long dry periods and frequent floods. The northwest has two reservoirs built to control flooding, Canton and Fort Supply. The southwest has numerous flood control structures erected by the U. S. Soil Conservation Service and the Bureau of Reclamation. The U. S. Army Corps of Engineers has made a sizable contribution to main stem flood control in the north central region through reservoir storage.

In central Oklahoma most floods are caused by thunderstorms, in which waters are usually back within their banks in a few hours. Serious flood and drainage problems exist along the Deep Fork basin.

In the northeast, the Corps of Engineers has helped relieve the flood situation through reservoir storage, but this region still has some remaining flood damage. In east central Oklahoma rapid runoff from a mountainous drainage area results in floods of short duration during storms. In the southeast the Glover River leaves its usual banks frequently and causes severe flooding.

The U. S. Soil Conservation Service maintains a continuous program of planning and building watershed protection and flood prevention structures throughout the entire State.

The combined programs of the Soil Conservation Service and the Corps of Engineers produce an average annual benefit of $180 million in the State.

STREAM WATER RESOURCES AND DEVELOPMENT

Over the past quarter century, Oklahoma has developed an impressive system of artificial lakes. These have been developed through the efforts of the Corps of Engineers, the Bureau of Reclamation, the Grand River Dam Authority and several State agencies and cities throughout the State.

Most major lakes in Oklahoma have been designed as multi-purpose projects. These multipurpose projects allocate typical storage for flood control, power and conservation pools consisting of municipal, industrial, irrigation, water quality control, recreation and fish and wildlife uses.

In the twenties, there were only three major lakes in Oklahoma. During the thirties and forties, twelve more were completed. However, during the past 25 years, 23 major lakes have been completed and eight more are currently under construction. Seven lakes have been authorized by Congress for construction.

The McClellan-Kerr Arkansas River Navigation System, the largest civil works project ever undertaken by the Corps of Engineers, was extended to Tulsa in the early seventies.

Most stream water development has taken place in the eastern part of the State. Stream water in western Oklahoma is limited. In many areas it has been fully appropriated and therefore, unavailable for further development. Quality restrictions also limit the beneficial use of water in some areas.

Availability And Quantity

Availability and quantity of water in Oklahoma follows the familiar pattern of plenty in the east and insufficiency in the west. The lowest average annual rate of precipitation in the State is 15 inches in the Panhandle. The highest evaporation rate is 65 inches in the southwest. Conversely, the highest precipitation rate is in LeFlore County in the extreme southeast with an average annual rate of 56 inches.

It must be considered that these are average figures. Western Oklahoma is subject to flooding and there are prolonged periods in the east when precipitation drops to a fraction of the figures quoted above.

In many areas of the State, no water is available for appropriation, and other critical areas have some water available at times under certain conditions. To assure the maximum utilization and orderly development of Oklahoma's available water supplies, the Oklahoma Water Resources Board has begun hydrologic studies of the most critical stream systems.

There are 8.4 million acres of land in western Oklahoma where all stream water has been allocated, making further municipal or irrigation water supply development impossible. No stream water is available for future needs and economic growth, and in some areas, water is insufficient to provide for present needs.

There are an additional 3.1 million acres where restrictions are applicable to allocations of stream water. These restrictions specify that water can only be captured or diverted during periods of high flow. Figure II-5 shows the areas in Oklahoma where no stream water is available for additional appropriation.

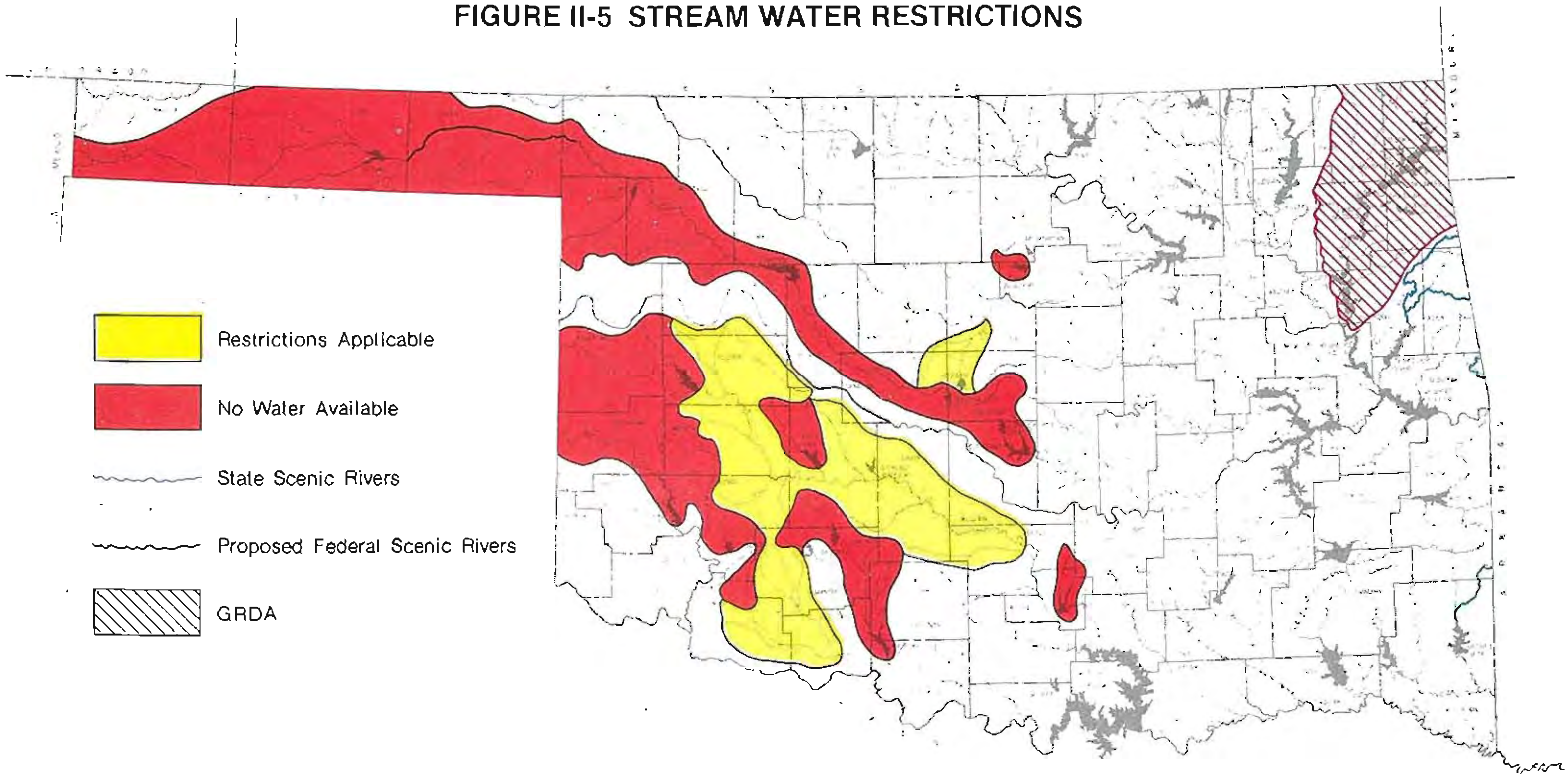
Quality

All water has a characteristic called "quality." Sea water, lake water, ground water and distilled water have this characteristic. A discussion of "quality" is primarily about materials dissolved in water. The kind and amounts of dissolved materials in water depend on such factors as geology, flow characteristics of streams and man's activities which result in wastewater discharges to streams or alteration of the basin hydrology.

Water falling as rain contains only a small amount of dissolved materials. As water moves over and through rock and soil, more materials are brought into solution. The kinds and amounts of minerals dissolved depend on the availability of soluable minerals in the rock formation.

Man's activities also contribute materials to water. Oil and livestock production and municipal and industrial waste disposal plant operation produce liquid and solid wastes. Water quality may

FIGURE II-5 STREAM WATER RESTRICTIONS



be affected by construction of storage and diversion facilities, by land treatment and by fertilization and irrigation of croplands.

Variable streamflow is accompanied by variable stream water quality. Quality may be significantly poorer during periods of low streamflow than during periods of high flow, but at times other than high or low flow, dissolved mineral content will be between maximum and minimum values. However, the relationship between dissolved solids content and streamflow usually is not precise.

Variability is a distinguishing characteristic of stream water quality in both the Arkansas and Red River stream systems. Variation is of two kinds, areal and that related to streamflow characteristics. The kinds of dissolved constituents which are predominant and the total amount of these constituents change radically from one end of the State to the other.

The water quality of the Arkansas River in Oklahoma varies markedly. As the river crosses the State, the dissolved solids content of the water increases in the west and then decreases as it travels eastward. The weighted average dissolved solids content of the water of the Arkansas River just above the Kansas line is about 855 mg/l. Below the junction of the Cimarron River, the average is nearly 1,500 mg/l. Tributary inflow with low dissolved solid content downstream from the Cimarron River markedly improves the quality. Just below the Arkansas line, the weighted average dissolved solids content of the water is less than 600 mg/l.

Two tributaries of the Salt Fork Arkansas River and the Cimarron River, contain large amounts of dissolved solids derived from salt plains in their upper basins. Stream water above the salt plains and the water of tributary streams contain relatively moderate amounts of dissolved solids.

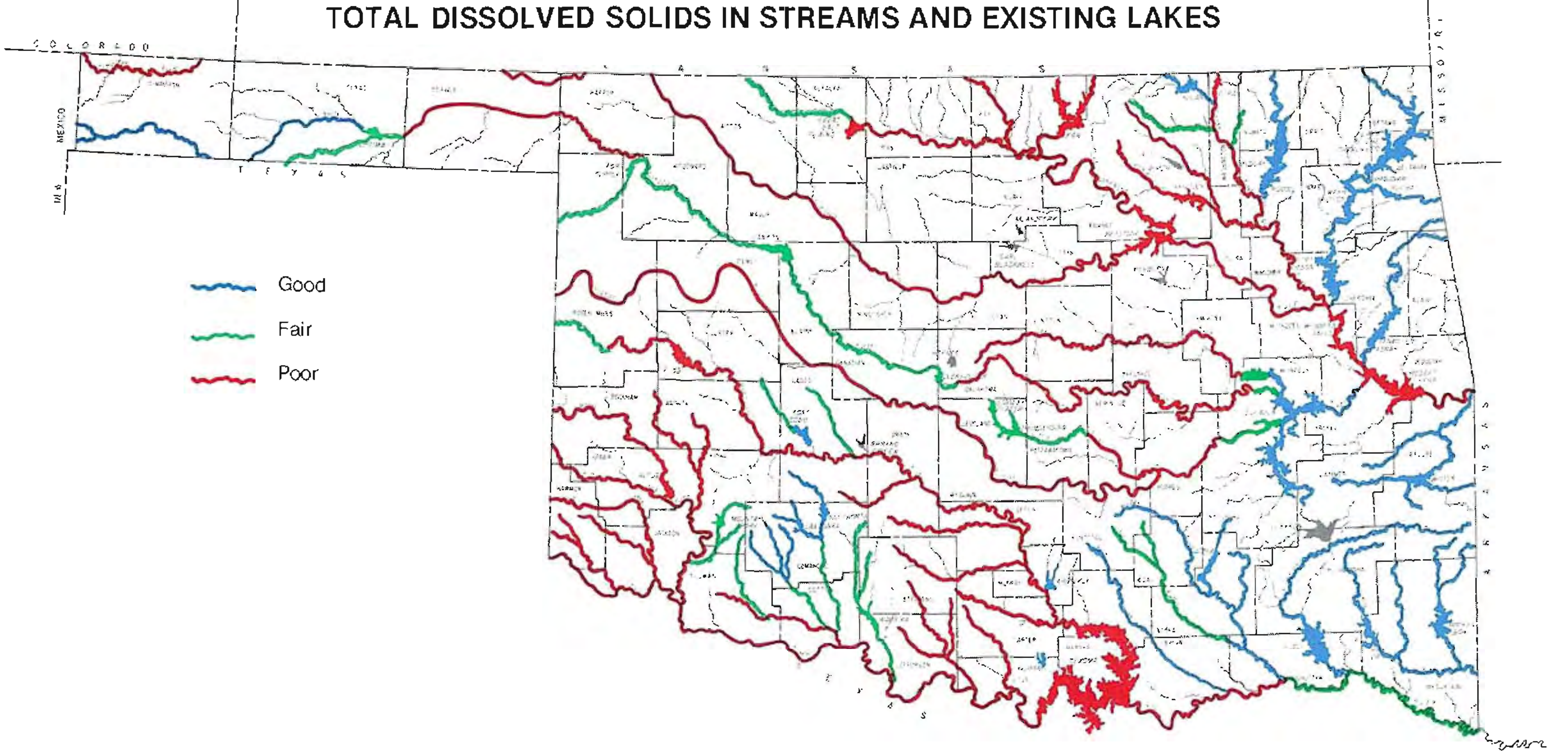
The water quality of the Red River from the Texas-Oklahoma line eastward to the Arkansas-Oklahoma line changes radically. At the western state line, the dissolved solids content is extremely high, primarily because of the large amount of dissolved natural salt and gypsum in its tributary streams. Below Lake Texoma, waters of all tributaries to the Red River are very low in dissolved constituents. Inflow from these tributaries markedly reduce the dissolved solids content of the Red River near the Arkansas-Oklahoma line. At Index, Arkansas, the average concentration of dissolved solids is about 600 mg/l compared to an average concentration of about 3,000 mg/l at the Texas-Oklahoma line.

Figure II-6 illustrates the chemical water quality in major reservoirs existing and under construction and the general quality range of the major State rivers and tributary streams in terms of the discharge-weighted average concentrations of total dissolved solids. A discharge-weighted average represents the average concentration of dissolved solids in all flows of a stream over an extended period of time, thus providing an indication of the water quality which will be impounded in proposed and potential reservoirs.

Information upon which Figure II-6 is based was collected by the U. S. Geological Survey in cooperation with the Oklahoma Water Resources Board and other State and federal agencies.

A discussion of the stream water quality in each region is presented in Section IV.

FIGURE II-6 DISCHARGE-WEIGHTED AVERAGE OF CONCENTRATIONS OF TOTAL DISSOLVED SOLIDS IN STREAMS AND EXISTING LAKES



Wastewater Reuse

Return flows and recoverable wastewater discharged into streams and rivers by municipalities and industries constitute an appreciable portion of the available stream water supplies. These must be recognized as an essential and valuable water resource that should be managed and administered conjunctively with other water resources.

Most of the return flows in Oklahoma originate from the larger cities and metropolitan areas. Return flows from smaller towns, especially in western Oklahoma where evaporation rates are highest, do not constitute an appreciable portion of the available stream water supplies because most of these towns have adopted the total retention type of sewage treatment process.

The present municipal return flow-water use ratio throughout the State is about 0.6. Of the 306,300 acre-feet of reported water used by industry, 176,700 acre-feet was reported as returned, making the ratio for industry .57. It should be noted that this is reported use and does not represent the total use in Oklahoma.

The actual return flow ratio for irrigation is unknown. It can be assumed, however, that at least one-third of the water used is returned to receiving streams by overflows, runoff or seepage and that the chemical concentrations in the water are increased approximately three times. The reuse of irrigation water captured in tailwater pits not only conserves water and increases the efficiency of the irrigation system, but also keeps the highly chemically concentrated water from degrading receiving streams.

Return flow-water use ratios are expected to decrease in the future. This decrease will be a result of more efficient water use as readily available water supplies decline and costs of these supplies increase. Also, as waste treatment requirements become more stringent and costs of such treatment increase, wastewater may become too valuable to discard and reuse will increase substantially.

The use of municipal and industrial effluents for irrigation is becoming widely practiced in Oklahoma. The generally high nutrient content of these effluents contributes to agricultural yields, which are generally greater than those realized from conventional irrigation with fertilization.

Municipal wastewater is also being used for industrial purposes in several areas of the State. Several public utility companies have built lakes to catch the return flows and are utilizing this water in their cooling towers. These lakes also have recreational uses and fish farming and aquaculture is being applied to them. There is a tremendous potential in the reuse of wastewater for growing aquatic species for food supplement.

When it becomes economically feasible, advanced treatment processes may one day permit direct reuse of wastewater for municipal use. Wastewater reclamation has already been proven economically feasible by industry.

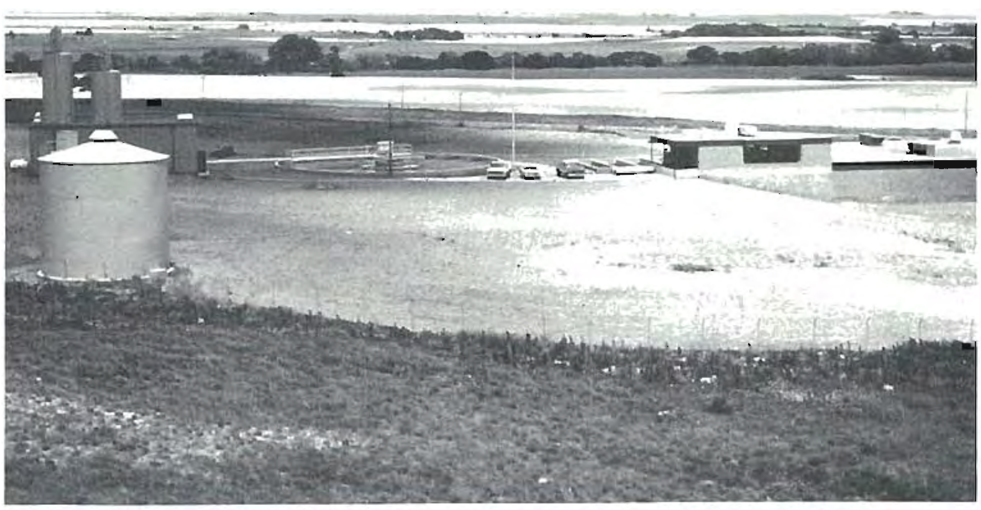
As water uses increase in the future, the volume of return flows will increase. Since the new sources of water which can be exploited are strictly limited, methods of renovating return flows for reuse must necessarily be employed.

Chloride Control And Desalting

Oklahoma has large quantities of saline ground and brackish stream water available for beneficial purposes if methods were available for improving its quality.

Saline ground water basins underlie substantial areas of the State, particularly in western Oklahoma. These ground water basins occur at depths of up to 1,000 feet and have a salinity level of between 1,000 and 3,000 mg/l. Little information is available on these saline ground water basins because most ground water studies in Oklahoma have dealt with fresh water.

Water has migrated through salt deposits emerging as salt seeps and springs and have naturally polluted several streams. These include the Arkansas, Cimarron and Salt Fork of the Arkansas in northwestern Oklahoma and the Red River and its tributaries, the



Water desalting operations at Foss desalination plant in Custer County

North Fork, Salt Fork, Elm Fork and Prairie Dog Town Fork in southwestern Oklahoma. The Canadian and Washita Rivers in west central Oklahoma have this natural pollution, but it is of a sulfate type coming from gypsum deposits instead of salt deposits.

Lakes developed on these streams include Altus Lake on the North Fork of the Red River, Lake Texoma on the main stem of the Red River, Great Salt Plains Lake on the Salt Fork of the Arkansas River, Keystone Lake on the main stem of the Arkansas River and Foss Lake on the Washita River. The water quality in these impoundments is of a somewhat better quality than in the streams because of the mixing of good quality storm runoff during periods of high flows.

Extensive studies of the salinity problem by the U. S. Public Health Service and the Corps of Engineers have shown that the natural chloride pollution could be substantially reduced through control measures at principal brine emission areas both in and out of state. Identified brine sources in Oklahoma are shown in Figure II-6 . The various measures proposed in previous studies would reduce salt discharge to the Red River from 40-50 percent and would control approximately 90 percent of the chloride now flowing into the Cimarron River.

Besides control measures, desalting technology is available for the demineralization of this highly mineralized water. Research and development activities have brought desalting technology to a point where its impact as a source of municipal water supply for current and future needs is recognized. Desalting costs are presently too high to consider this process for producing irrigation water.

These saline ground water basins and brackish streams and lakes could provide enormous amounts of feedwater to a desalting plant. Recently, a 3 mgd electrodialysis desalting plant was put in operation at Foss Lake in Custer County. When in full production, it will help supply water to the towns of Cordell, Clinton, Hobart and Bessie.

Much additional study is needed in order to estimate the amount of fresh water which might be salvaged for beneficial development through the use of control measures and desalting technology.

Weather Modification

Recurrent droughts alternating with periods of excessive rainfall common to western Oklahoma have generated a sustained interest in the possibilities offered by weather modification. For years, attempts at weather modification have been made, but only in the last few decades have real technological advances been recorded.

Weather modification, or precipitation management, consists of techniques for seeding clouds to increase rainfall, suppress hail and severe storms, modify precipitation distribution or decrease precipitation.

The Bureau of Reclamation has conducted a number of cloud-seeding development and application projects in the southern plains, including summer research in southwestern Oklahoma and emergency drought relief seeding in both Texas and Oklahoma. In addition, locally funded commercial operations have been in existence for several years throughout western Oklahoma.

In 1973 the legislature delegated to the Oklahoma Water Resources Board the responsibility of administering the Oklahoma Weather Modification Act. This act provides for licensing and permits to all persons engaging in artificial weather modification. It also provides for research and development activities. It further provides for formation of weather modification districts and assessments levied to pay for the costs of contracting for weather modification.

Oklahoma has the statutory authority and potential for examining methods of producing additional water supplies through weather modification. The federal government and many other agencies are continuing research in this field and weather modification efforts are expected to increase in the future.

Watershed Protection And Flood Prevention

The first watershed program was authorized by the Flood Control Act of 1944 which specifically called for soil erosion prevention, waterflow retardation and other works of improvement to prevent flood water and sediment damage. Since then, three other watershed programs have been initiated to improve and broaden its application.

These programs emphasize the importance of local leadership in instigating and applying needed measures for protection of watershed drainage areas and reduction of flooding on productive bottomlands. Local sponsors of watershed projects usually include such entities as conservation districts, conservancy districts and local towns and cities. After such groups have made application for assistance, the Governor of Oklahoma, acting through the State Soil Conservation Commission, establishes priority for planning of the various projects. Technical and financial assistance in planning and installing the works of improvement are then given by the U. S. Department of Agriculture, Soil Conservation Service.

In all, 128 watersheds covering 11,400,000 acres are presently under development in the State. See Figure I-5 for names and locations. In these watersheds, 2,525 floodwater retarding structures have been planned with a combined capacity for all purposes of 2,489,000 acre-feet. Of these, 1,648 sites and approximately 100 miles of channel improvements have been completed.

Increased emphasis has been given in recent years to multiple use lakes installed for floodwater detention. In addition to widespread recreational use of sediment pools of watershed structures, many local sponsors have added water storage for municipal, irrigation, recreation and fish and wildlife purposes. Presently, 27 multi-purpose structures having municipal water storage of 167,000 acre-feet are used by municipalities in Oklahoma. These and other planned multi-purpose structures are shown in Figure I-5, Section I.

Multi-purpose lakes such as these make a tremendous difference in the economic life of smaller cities and rural areas by providing dependable water supplies and convenient recreational areas for the people. Land owners in watersheds not only have been able to develop and intensify their farming and ranching operations due to the flood protection provided by those structures, but also are utilizing these sites as irrigation water supplies.

Present And Potential Development

Within the State, there are 38 major existing lakes and eight under construction. Seven more have been authorized by Congress for construction. For location of these projects, see Figure II-7. There are approximately 2,500 lakes with a surface area of 10 acres or more and about 190,000 farm ponds with less than 10 surface acres. Many potential dam sites exist throughout the State. These have been studied by various State and federal agencies and appear promising for future development. Data on these potential sites can be found, by region, in Section IV of this report.

Total water supply storage of facilities constructed and under construction is approximately 3,690,300 acre-feet. This storage provides a yield of 1,979,800 acre-feet per year. The seven major lakes authorized for construction will add an additional 1,710,000 acre-feet of conservation storage and provide a yield of 963,800 acre-feet annually.

Pertinent data on these existing, under construction and authorized projects are listed in Table II-1.

The uneven nature of current and potential lake development must be stressed. In the east, where development is greatest, potential is also the greatest. The opposite is true in western Oklahoma. Northeast Oklahoma has 12 existing or under construction lakes with a water supply yield of 390,500 acre-feet annually and the potential for an additional 1,946,000 acre-feet. The southeast, with a present water supply yield of 927,100 acre-feet per year has the potential for over 2,389,000 acre-feet of additional annual yield. Conversely, the northwest and southwest regions have a present water supply yield of 118,700 acre-feet annually and the potential for only an additional 827,700 acre-feet.

GROUND WATER RESOURCES AND DEVELOPMENT

Ground water, one of the State's most valuable resources, is available almost everywhere in Oklahoma. It supplies 48 percent of the water used in Oklahoma. More than 80 percent of present irrigation water comes from ground water reservoirs. Approximately 300 towns and cities obtain their water supplies from wells and springs.

Ground water is water that has percolated downward from the surface filling voids or open spaces of rocks. Below a certain level, the voids are completely saturated with water. This is called the zone of saturation. The upper surface of the zone of saturation is the water table. See Figure II-8.

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

Ground water in Oklahoma occurs in a variety of rock formations. Sand, gravel, limestone, dolomite, sandstone and

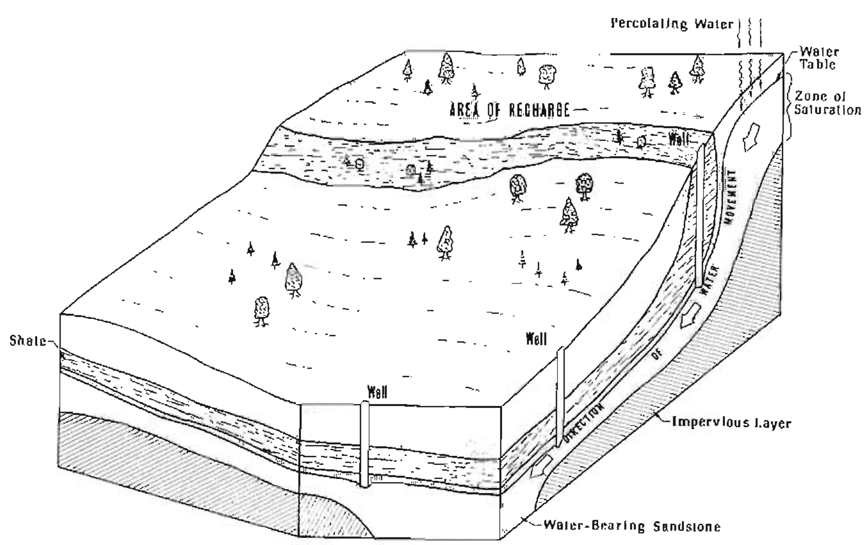


FIGURE II-8 WATER BEARING LAYER, UNDERGROUND AND AT EARTH'S SURFACE

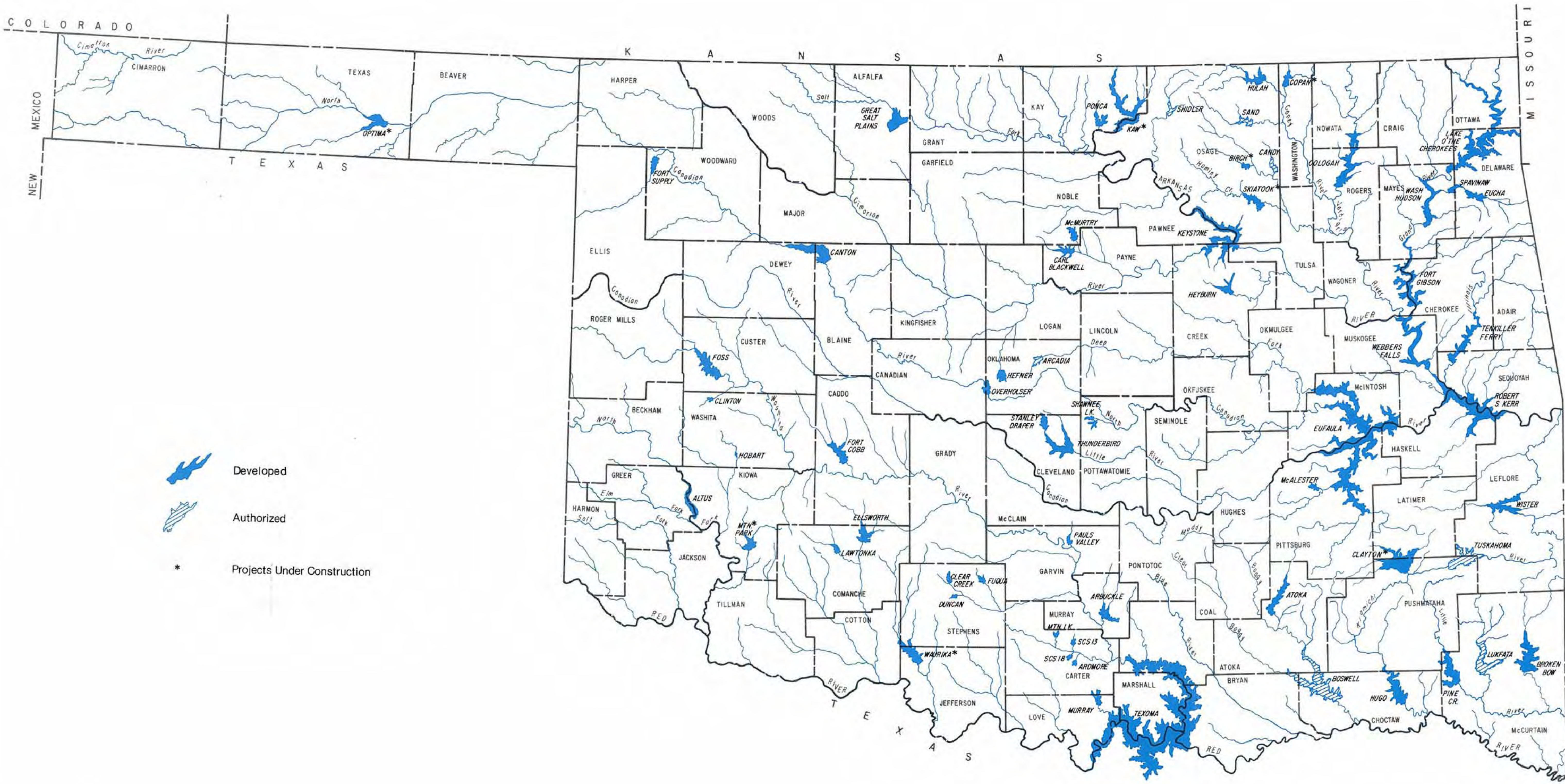


FIGURE II-7
WATER RESOURCES DEVELOPMENT
July 1975

TABLE II-1
PRESENT AND POTENTIAL WATER RESOURCE PROJECTS

NAME OF SOURCE	LOCATION	PURPOSE*	FLOOD CONTROL STORAGE ACRE FT.	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
		DEVELOPED			
Altus Lake	North Fork of Red River	WS,FC,R,I	19,600	146,000	16,800
Arbuckle Lake	Rock Creek	WS,FC,R	36,400	62,600	22,700
Atoka Lake	North Boggy Creek	WS,R	0	123,500	65,000
Birch Lake+	Birch Creek	WS,FC,WQ,R,FW	39,000	15,200	6,700
Broken Bow Lake	Mountain Fork River	WS,FC,P,R,FW	450,000	152,500	195,900
Canton Lake	N. Canadian River	WS,FC,I	267,600	107,000	13,400
Lake Carl Blackwell	Stillwater Creek	WS,R	0	55,000	7,000
Clayton Lake+	Jack Fork Creek	WS,FC,R,FW	128,200	297,200	156,800
Copan Lake+	Little Caney River	WS,FC,WQ,R,FW	184,300	33,600	21,300
Draper Lake	E. Elm Creek	WS,R	0	100,000	41,000[1]
Lake Ellsworth	East Cache Creek	WS,R	0	68,700	9,500
Eucha Lake	Spavinaw Creek	WS,R	0	79,600	84,000[2]
Eufaula Lake	Canadian River	WS,FC,N,P	1,470,000	56,000	56,000
Fort Cobb Lake	Cobb Creek	WS,FC,R,I	62,500	77,600	13,300
Fort Gibson Lake	Grand (Neosho) River	FC,P	919,200	0	0
Fort Supply Lake	Wolf Creek	WS,FC,R	87,200	400	200
Foss Lake	Washita River	WS,FC,R,I	177,000	203,700	18,000
Grand Lake O' the Cherokees	Grand (Neosho) River	FC,P	525,000	0	0
Great Salt Plains Lake	Salt Fork of Arkansas River	FC,R	242,700	0	0
Lake Hefner	Bluff Creek	WS,R	0	75,000	17,000
Heyburn Lake	Pole Cat Creek	WS,FC	49,100	1,900	1,900
Hudson Lake	Butler Creek	FC,P	244,200	0	0
Hugo Lake	Kiamichi River	WS,FC,WQ,R,FW	809,200	121,500	375,100
Hulah Lake	Caney River	WS,FC,low flow regulation	257,900	27,000	19,000
Kaw Lake+	Arkansas River	WS,FC,WQ,R,FW	866,000	203,000	230,700
Keystone Lake	Arkansas River	WS,FC,P,FW	1,216,000	20,000	22,400
Lake Lawtonka	Cache Creek	WS,R	0	64,000	8,500
McAlester Lakes	Coal Creek	WS,FC,R	25,000	24,300	10,500
Lake McMurtry	N. Stillwater Creek	WS,FC,R	5,000	13,500	3,000
Mountain Park Lake+	Otter Creek	WS,FC,R	19,500	88,400	16,000
Lake Murray	Tributary of Hickory Creek	R	0	0	0
Oologah Lake	Verdigris River	WS,FC,N	965,600	544,100	172,500
Optima Lake+	N. Canadian River	WS,FC,R,FW	71,800	76,200	18,600
Lake Overholser	N. Canadian River	WS,R	0	17,000	5,000
Pine Creek Lake	Little River	WS,FC,WQ,FW	388,100	70,500	134,400
Lake Ponca	Big and Little Turkey Creeks	WS,R	0	15,300	9,000
Robert S. Kerr Lake	Main Stem Arkansas River	N,P,R	0	0	0
Shawnee Lake	S. Deer Creek	WS,R	0	34,000	4,400
Skiatook Lake+	Hominy Creek	WS,FC,WQ,R,FW	182,300	304,800	85,100
Spavinaw Lake	Spavinaw Creek	N,P,R,FW	0	30,600	-[2]
Tenkiller Lake	Illinois River	WS,FC,P,R	576,700	25,400	17,900
Lake Texoma	Red River	WS,FC,P	2,660,000	38,900	23,700
Lake Thunderbird	Little River	WS,FC,R	76,600	105,900	21,700
Waurika Lake+	Beaver Creek	WS,FC,WQ,R,FW,I	140,400	170,200	46,500
Webbers Falls Lock & Dam	Arkansas River	N,P,R,FW	0	0	0
Wister Lake	Poteau River	WS,FC,R,FW	400,000	9,600	6,700
Sub Total			13,562,100	3,659,700	1,936,200
		AUTHORIZED		CONSERVATION STORAGE	
Arcadia Lake	Deep Fork	WS,FC,R	70,700	63,000	12,100
Boswell Lake	Boggy Creek	WS,FC,R,FW	1,096,000	1,243,800	621,400
Candy Lake	Candy Creek	WS,FC,WQ,R,FW	31,250	43,100	8,950
Lufkata Lake	Glover Creek	WS,FC,R,FW	171,100	39,400	67,200
Sand Lake	Sand Creek	WS,FC,WQ,R,FW	51,700	35,000	13,450
Shidler Lake	Salt Creek	WS,FC,WQ,R	49,050	54,900	16,800
Tuskahoma Lake	Kiamichi River	WS,FC,R,FW	138,600	231,000	223,900
Sub Total			1,608,400	1,710,200	963,800
TOTAL			15,170,500		2,900,000

*WS = Municipal Water Supply, FC = Flood Control, WQ = Water Quality, P = Power, R = Recreation, FW = Fish and Wildlife, I = Irrigation, N = Navigation, CC = Chloride Control +Under construction

[1] Present capacity of pipeline from Atoka Reservoir. Yield not included in total. [2] Combined yield of both lakes.

gypsum are the major water bearing formations. These range in age from Cambrian and Ordovician, represented by the Arbuckle Group to Quaternary stream-laid deposits.

Ground water development is greatest in the western part of the State. In that area, ground water is used extensively for irrigation, municipal and domestic needs. In contrast, ground water in central and eastern Oklahoma is used only by small towns and communities. Therefore, potential exists for increased development of this natural resource to help meet future water needs.

TABLE II-2
TOTAL GROUND WATER RECOVERABLE FROM STORAGE

GROUND WATER BASIN	WATER IN STORAGE (IN ACRE-FEET)	ESTIMATED PERCENT RECOVERABLE	ESTIMATED TOTAL AVAILABLE WATER (IN ACRE-FEET)
Alluvium and terrace deposits	18,400,000	.50	9,200,000
Ogallala Formation	70,000,000	.50	35,000,000
Antlers Sand	73,700,000	.40	29,500,000
Elk City Sandstone	1,400,000	.30	400,000
Rush Springs Sandstone	31,200,000	.35	10,900,000
Dog Creek Shale and Blaine Gypsum	530,000	.50	270,000
Garber-Wellington Formation	40,300,000	.30	12,100,000
Oscar Formation	8,900,000	.30	2,700,000
Vamoosa Formation	39,000,000	.30	11,700,000
Simpson Group	3,300,000	.35	1,200,000
Arbuckle Group	15,000,000	.50	7,500,000
Roubidoux	7,200,000	.30	2,200,000
STATEWIDE TOTAL	308,930,000	.40	122,670,000

Availability And Quantity

Twelve major ground water basins occur in Oklahoma with an estimated 309 million acre-feet in storage. See Figure II-9. However, not all water in storage is recoverable due to technological, legal and economic restraints.

Determination of recoverable amounts is a complex problem. Factors to be considered are well spacing, number of wells, rate and schedule of pumping, methods of well construction and development and most significantly, hydraulic and hydrologic characteristics of the basin. Legal recovery problems relate to ownership of ground water by landowners. An area may overlie a ground water basin, but unless the owner chooses to drill a well, water is left in the basin. Costs are a restraint because as a ground water basin is dewatered, pumping costs become greater. Even though the ground water basin never becomes completely depleted, pumping eventually becomes financially infeasible.

Recovery rates for Oklahoma ground water basins range from 30-50 percent. For this study, a mean recovery rate of 40 percent has been chosen. See Table II-2. This means that of the 309 million acre-feet of water in storage approximately 123 million acre-feet is recoverable.

Nearly one-half of the ground water resources occur in the western part of the State. Major ground water basins are the Dog Creek Shale and Blaine Gypsum, Rush Springs Sandstone, Elk City Sandstone, Ogallala Formation and alluvium and terrace deposits. Wells yield as much as 2,000 gpm and average about 300 gpm. Ground water serves the needs of irrigation farmers and most rural homes and communities. Total water in storage and the amount recoverable from western ground water basins can be determined from Table II-2.

Central Oklahoma contains about one-third of the ground water resources. They occur in six major ground water basins: the Arbuckle Group, Simpson Group, Vamoosa Formation, Oscar Formation, Garber-Wellington Formation and alluvium and terrace deposits. Wells commonly yield 200 gpm. Ground water supplies most rural homes and some towns and industries. Total ground water in storage and recoverable amounts can be determined from Table II-2.

Eastern Oklahoma contains one-fourth of the State's ground water resources. The major ground water basins are Roubidoux, Antlers Sand and alluvium deposits. Average yields are 100 gpm. Water recoverable from storage can be determined from Table II-2. More hydrogeologic data needs to be collected in the east to make precise determinations on availability and quantity of ground water.

Quality

The chemical quality of ground water reflects the chemical composition of the rocks with which the water comes in contact. Water percolating down through soil and rocks dissolves minerals in its movement through a ground water basin. The amounts and kinds of minerals depend on the types available and the duration of contact.

Water quality standards have been established for municipal, industrial and irrigation supplies. Sulfate and chloride concentrations for drinking water should not exceed 250 mg/l, nitrate levels not exceed 45 mg/l and dissolved solids content not exceed 500 mg/l. Irrigation water suitability is similarly determined by chemical constituents. Chemical parameters for irrigation use are specific electrical conductance, sodium adsorption ratio, residual sodium carbonate and boron concentration.

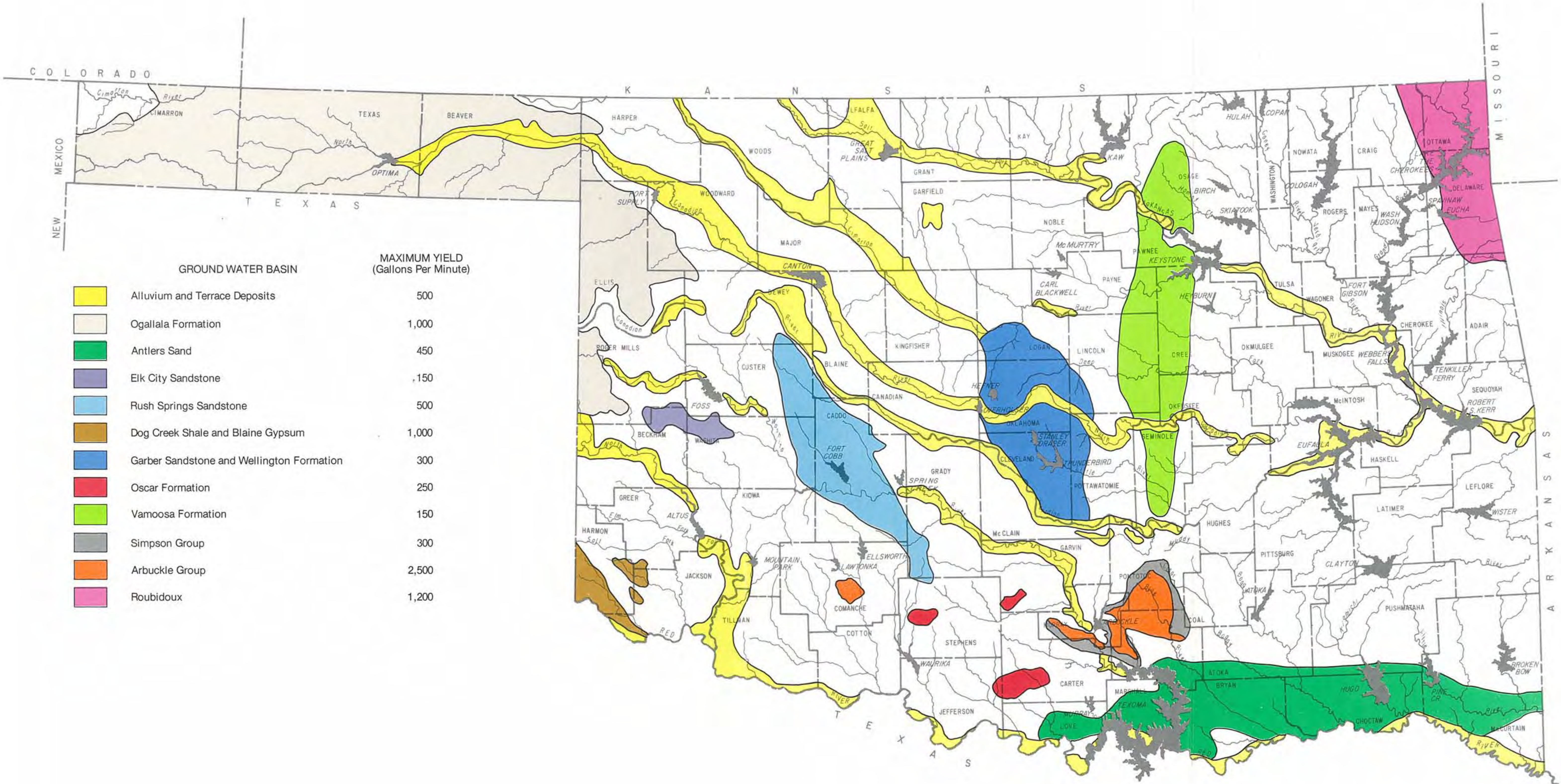


FIGURE II-9
MAJOR GROUND WATER BASINS

United States Geological Survey
Oklahoma Geological Survey
Oklahoma Water Resources Board

The water quality of ground water resources is generally good. The most developed ground water basins, such as the Ogallala, Tillman Terrace and Rush Springs Sandstone, have excellent quality water, suitable for municipal, industrial and irrigation use. The Garber-Wellington ground water basin has a low total dissolved solids concentration and meets recommended standards.

Some water quality problems do exist. The Dog Creek Shale and Blaine Gypsum is high in sulfates and exceeds water quality standards; however, the water can be used for irrigation. Brine infiltration is a major problem in the Vamoosa Formation. Abandoned, improperly plugged oil and gas wells are a source of contamination. Possible contamination exists from wells used by the petroleum industry for brine disposal and by other industries for chemical waste disposal. Sanitary landfills, when improperly constructed, can also pollute ground water.

More study is needed on the quality of Oklahoma's ground water resources. Currently, water quality samples are only taken for complaint investigations or U. S. Geological Survey reports on ground water resources of an area. A periodic monitoring program, as exists for stream water, is needed for ground water. This will help supply information to citizens wishing to use ground water to meet their needs. A monitoring program will also alert regulatory agencies to developing pollution problems.

Present and Potential Development

Due to the lack of available stream water, present ground water development is mainly in western Oklahoma. Eighty percent of all ground water used in the State is in this region. The result in many areas is overdevelopment of ground water basins, as pumpage exceeds recharge from precipitation. Wells closely spaced and pumped at high rates for significant periods of time create cones of depression around wells, causing interference, water level declines and yield and storage reduction. Although local potential exists in the Elk City Sandstone and some of the alluvium and terrace deposits, major ground water basins like the Tillman Terrace, Ogallala Formation and Rush Springs Sandstone are being dewatered; within the next 20 years, pumping may become financially infeasible and therefore alternative water sources will be needed.

The central region has potential for increased development. The Garber-Wellington Formation contains water in storage which could supplement future water needs of Oklahoma City and surrounding towns. The Vamoosa Formation and alluvium and terrace deposits are not fully utilized.

Eastern Oklahoma, in contrast, has experienced little ground water development because of readily available stream water. Ground water is predominantly used for domestic wells or stream water supplement. Development potential is good, as there is ground water in storage and recharge exceeds present pumpage rates.

Of the 309 million acre-feet in storage, it is estimated that 40 percent or about 123 million acre-feet, is recoverable. To know precisely how much is available will require more hydrogeologic data than is currently available. Water level measurements must be taken over the whole State. Presently, measuring is done only on western ground water basins. A program of water quality monitoring must be initiated. Computer models, based on historical water level data of basins, are needed to accurately predict useful life and depletion rates. Efficient development can only occur with proper management of the State's ground water resources.

MINERALS RESOURCES

The mineral resources of Oklahoma consist primarily of oil and gas. In 1973, approximately 191 million barrels of oil were produced, representing a value of about $723 million. Natural gas production for that year was 1.4 trillion cubic feet, with a value of $284 million. Virtually all of Oklahoma's oil and gas occurs in Paleozoic rocks, with Pennsylvanian and Ordovician formations being the most productive. In 1973, there were 81,825 oil and gas producing wells in the State. The world's deepest productive gas well, with a total depth of 24,548 feet, is located in Beckham County.

Coal is a major resource in a 15,000 square mile area of eastern Oklahoma. Coal beds range in thickness from one to eight feet. Approximately 7.2 billion tons of remaining coal resources occur in the area. A coal gasification plant is under consideration on Lake Eufaula in central Pittsburg County. This plant would produce 500 million cubic feet of pipeline-quality methane gas daily. Coal gasification requires huge amounts of water for use in production, as well as cooling.

Thick sequences of salt underlie most of western Oklahoma at depths ranging from 30-30,000 feet. Reserves, estimated at 20 trillion tons, are virtually untapped. Current production is from three solar evaporation plants located in Harmon and Woods counties. Underground storage facilities are easily and economically made by dissolving salt and forming cavities in salt beds.

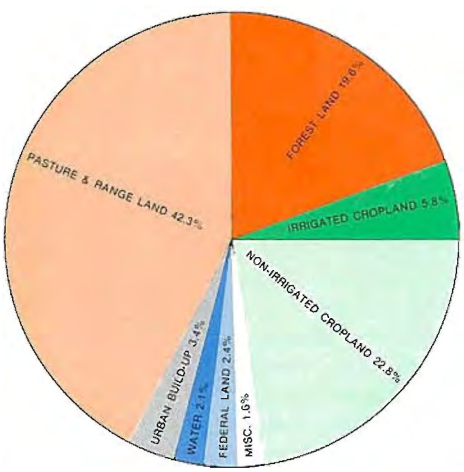
Other resources produced in the State are dolomite, limestone, granite, sand and gravel, glass sand, gypsum, lead and zinc. Dolomite is quarried for crushed stone production. Limestone is quarried from the Arbuckle Mountains, crushed and used for concrete and road metal. Granite is quarried near Snyder and Granite for monument and dimension stone production. Sand and gravel are produced from the alluvium and terrace deposits and used for construction, concrete aggregate and road metal. Glass sand is produced in the south central region and used for high purity glass. Gypsum outcrops in western Oklahoma, with almost 800,000 tons produced annually. Present uses are plaster, wall-board and portland cement retarder. Approximately 1.3 million tons of lead and 5.2 million tons of zinc have been produced from deposits in Ottawa County over the past 80 years.

LAND RESOURCES

Oklahoma has a total area of 44,748,160 acres, with 43,819,100 land acres. Of this land area, 1,545,584 acres are classified as built-up and urban land, 14,712,700 acres as rangeland, 4,240,900 acres as pastureland, 12,992,600 acres as cropland and 8,580,900 acres as forestland There are 523,938 reported acres under irrigation, with most of this figure in western Oklahoma. See Figure II-10. Agriculture is the State's leading industry in terms of numbers of people employed. In terms of dollar volume, agriculture and petroleum are in close contention.

The principal agricultural industry in the State is beef, followed by wheat and dairy cattle. This predominance of beef production extends throughout western and central Oklahoma. Beef is also a major product of east central Oklahoma, but the northeast and southeast have more diversified patterns.

FIGURE II-10
PRESENT LAND USE
(By Percent)



Other crops are barley and oats, sorghum, soybeans, corn and hay. In the northeast, soybean production has doubled every ten years since 1940. East central and south central Oklahoma have thriving commercial timber and wood products industries.

SOILS

The first detailed soil surveys were conducted in Oklahoma County and a small area near Tishomingo in 1905. Soil survey maps and reports are available for 58 counties, with reconnaissance level work being done on the remaining 19 counties.

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

Soil associations occur together naturally in a defined proportional pattern on a unique type of landscape. These associations are comprised of several series whose characteristics, including climate, parent materials and natural vegetation, are similar. A detailed map showing existing soil associations and series with each association are listed on Figure II-11.

Broad differences exist in State soils. In the eastern part soils were developed under humid conditions where leaching is intense. They are low in phosphorus, lack adequate potassium and range from moderate to strongly acid.

The vast western prairies developed under lower rainfall levels, have a light red color and are less leached than eastern soils. They are moderately acid, but low in phosphorus and nitrogen.

Soils in the northwest region contain great amounts of lime. They are neutral to alkaline at the surface with calcium carbonate accumulations found at shallow depths. Nitrogen is low, but not a limiting factor. Wind erosion is often the most serious soil management and production problem.

ENVIRONMENTAL RESOURCES

With a broad range of climate and terrain the strength of Oklahoma's scenery is its variety. Rich with rainfall and stream water, eastern Oklahoma gradually changes to dry prairie and rugged canyons in the west.

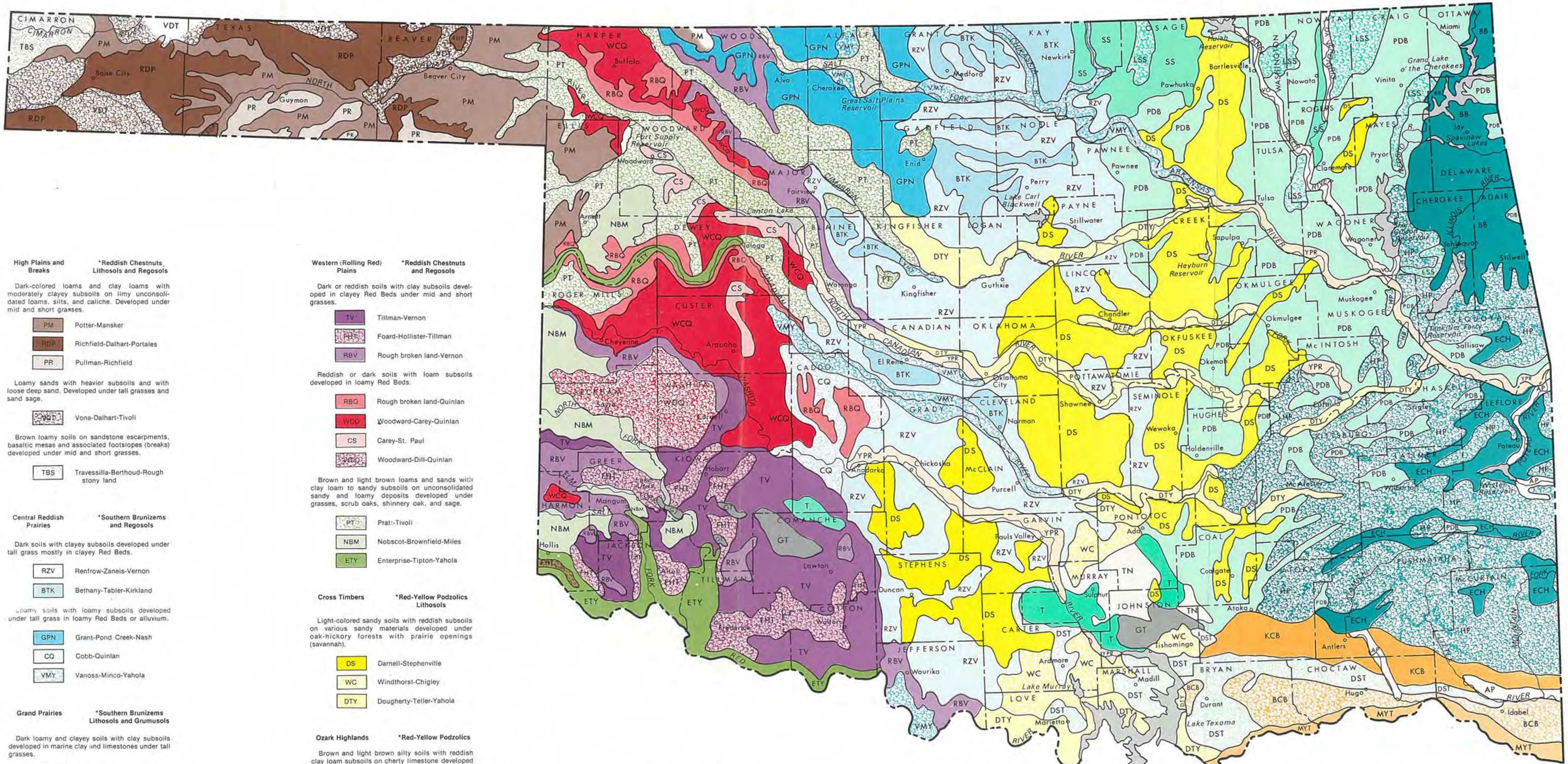
The world's largest alabaster caverns are in Woods County. The State's principal waterfall is Turner Falls in south central Oklahoma. Also in the south central region is Platt National Park, the nation's smallest.

The only untamed river is the beautiful, but treacherous Glover. Our national scenic drive is the Talimena (Skyline) Drive in the southeast. In the northeast, there is an engineering achievement which rivals the Suez Canal, the McClellan-Kerr Arkansas River Navigation System. This system carries barge traffic to the heart of the North American continent.

There is not an area which does not offer excellent hunting and fishing, and the State is studded with well-stocked lakes and rivers, filled with a wide variety of freshwater fish. Hunting for small game is superb throughout the State and for large game, most areas offer whitetail deer. The dry, open northwest also has mule deer and antelope. There are many public hunting areas and wildlife refuges where unique species of animals are preserved and enjoyed by campers and travelers.

The State also offers recreational facilities attesting to its colorful and unique history. Prominent among them are the Cowboy Hall of Fame in Oklahoma City, housing western memorabilia from 14 states, Tsa-La-Gi Cherokee Indian Village in Tahlequah, the Creek Council House in Okmulgee, the Philbrook Museum in Tulsa and the Will Rogers Museum in Claremore.

The Wichita Mountain Wildlife Refuge near Lawton is one of four national refuges for buffalo, housing nearly 1,000 of this almost extinct species which once covered the plains in seemingly inexhaustible numbers.



High Plains and Breaks — *Reddish Chestnuts, Lithosols and Regosols

Dark-colored loams and clay loams with moderately clayey subsoils on limy unconsolidated loams, silts, and caliche. Developed under mid and short grasses.

PM	Potter-Mansker
RDP	Richfield-Dalhart-Portales
PR	Pullman-Richfield

Loamy sands with heavier subsoils and with loose deep sand. Developed under tall grasses and sand sage.

VDT	Vona-Dalhart-Tivoli

Brown loamy soils on sandstone escarpments, basaltic mesas and associated footslopes (breaks) developed under mid and short grasses.

TBS	Travessilla-Berthoud-Rough stony land

Central Reddish Prairies — *Southern Brunizems and Regosols

Dark soils with clayey subsoils developed under tall grass mostly in clayey Red Beds.

RZV	Renfrow-Zaneis-Vernon
BTK	Bethany-Tabler-Kirkland

Loamy soils with loamy subsoils developed under tall grass in loamy Red Beds or alluvium.

GPN	Grant-Pond Creek-Nash
CQ	Cobb-Quinlan
VMY	Vanoss-Minco-Yahola

Grand Prairies — *Southern Brunizems Lithosols and Grumusols

Dark loamy and clayey soils with clay subsoils developed in marine clay and limestones under tall grasses.

DST	Durant-San Saba-Tarrant
T	Tarrant
TN	Tarrant-Newtonia

Eastern (Cherokee) Prairies — *Brunizems Planosols, Lithosols

Dark-colored soils mostly with clayey subsoils developed on shales, sandstones, and limestones under tall grasses.

LSS	Labette-Summit-Sogn
SS	Sogn-Summit
PDB	Parsons-Dennis-Bates

Western (Rolling Red) Plains — *Reddish Chestnuts and Regosols

Dark or reddish soils with clay subsoils developed in clayey Red Beds under mid and short grasses.

TV	Tillman-Vernon
FHT	Foard-Hollister-Tillman
RBV	Rough broken land-Vernon

Reddish or dark soils with loam subsoils developed in loamy Red Beds.

RBQ	Rough broken land-Quinlan
WCQ	Woodward-Carey-Quinlan
CS	Carey-St. Paul
WDQ	Woodward-Dill-Quinlan

Brown and light brown loams and sands with clay loam to sandy subsoils on unconsolidated sandy and loamy deposits developed under grasses, scrub oaks, shinnery oak, and sage.

PT	Pratt-Tivoli
NBM	Nobscot-Brownfield-Miles
ETY	Enterprise-Tipton-Yahola

Cross Timbers — *Red-Yellow Podzolics Lithosols

Light-colored sandy soils with reddish subsoils on various sandy materials developed under oak-hickory forests with prairie openings (savannah).

DS	Darnell-Stephenville
WC	Windthorst-Chigley
DTY	Dougherty-Teller-Yahola

Ozark Highlands — *Red-Yellow Podzolics

Brown and light brown silty soils with reddish clay loam subsoils on cherty limestone developed under oak-hickory-pine forests and tall grasses.

BB	Bodine-Baxter

Bottomlands — *Alluvial soils

Nearly level, deep sandy to clayey bottomland soils. Some areas flood frequently; most flood occasionally, and some rarely. Soils are developed under lowland hardwoods which decrease in density from east to west.

MYT	Miller-Yahola-Teller
AP	Atkins-Pope
VO	Verdigris-Osage
YPR	Yahola-Port-Reinach

Forested Coastal Plain — *Red-Yellow Podzolics

Light-colored acid sandy soils with sandy clay loams to clay subsoils developed in Coastal Plain sediments under forest (pine-oak in eastern part; oak-hickory in western).

KCB	Kirvin-Cuthbert-Bowie
BCB	Bowie-Caddo-Boswell

Granitic Soils — *Lithosols

Granitic Mountain area and brown, thin stony granitic soils developed under mid grasses, cedars and shrubs.

GT	Granitic Mountains-Tishomingo soils

Ouachita Highlands — *Red-Yellow Podzolics and Lithosols

Light-colored acid sandy to loamy soils with heavier subsoils and shallow soils developed on sandstones and shales under oak-hickory-pine forests.

HP	Hector-Pottsville
ECH	Enders-Conway-Hector

*Dominant Great Soil Group(s) of the area.

FIGURE II-11
SOIL ASSOCIATIONS
Oklahoma State University

SECTION III

STATEWIDE WATER USES AND REQUIREMENTS

LIST OF TABLES AND FIGURES

TABLE

FIGURE

GROWTH AND EXPANSION

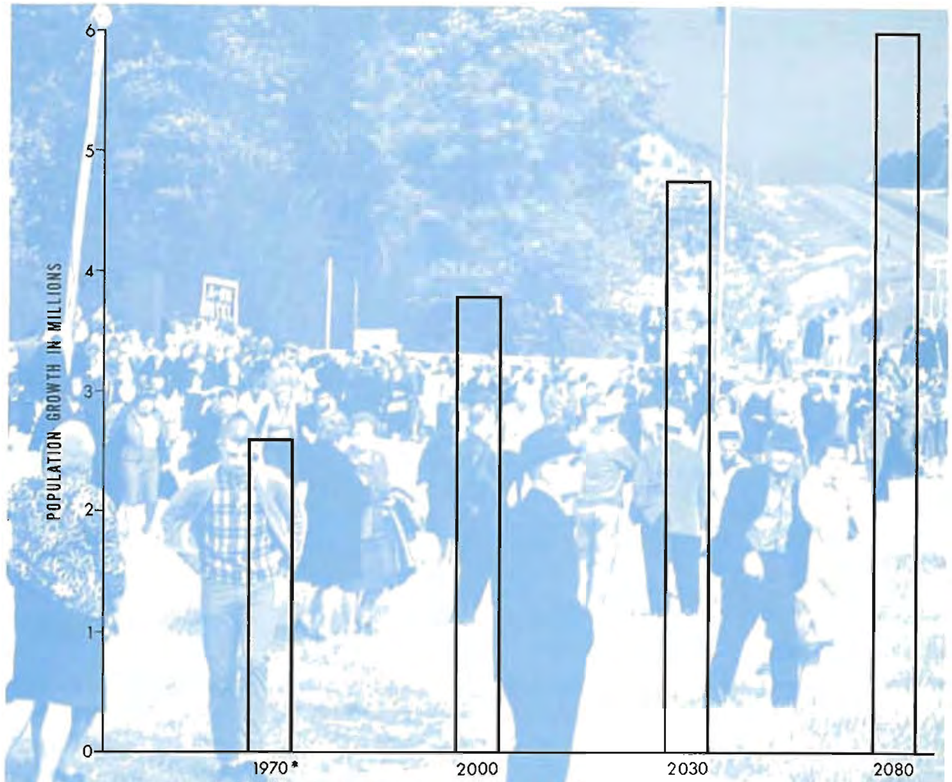
Oklahoma is experiencing tremendous growth and expansion. Population growth, industrial development and agricultural irrigation expansion will make increasing demands on available water resources. To meet these increased water needs, Oklahoma must be concerned with an adequate water supply to serve the entire State. As water resources are not inexhaustible, efficient, optimum use must be carefully planned. Areas of surplus water supplies must be balanced with areas of depleting or short supplies. Redistribution within the State will be required to maintain Oklahoma's growth rate and avoid economic deterioration.

Population

Population growth has varied over the past century. History tells a story of evolution from early in-migration prior to the 1920's to a period of out-migration caused by economic distress and extended drought in the 1930's. A slow in-migration began again in the 1960's, with an increasing population rate in the early 70's. Oklahoma City and Tulsa contain a large portion of the State's population. Smaller cities (over 2,000) have maintained their population or grown slightly. Those cities under 2,000 and rural areas have declined according to the 1970 census.

Between 1890 and 1970, the population grew from 258,657 to 2,559,229, an increase of more than nine times. In 1910, only 19.2 percent of the population was classified as urban (residing in towns or cities with a population of 2,500 or more). By 1940, this figure had increased to 37.6 percent and in 1970, reached 68 percent.

Based upon projections of the Oklahoma Employment Security Commission, the State's population is expected to reach over 2.9 million by 1980, more than 3.7 million by 2000 and be in excess of 6.7 million by the year 2030. By 2080, the population could reach over 6 million. See Figure III-1 for population projections. Most of these people will be concentrated in urban areas.



*SOURCE: Bureau of Census – U.S. Census of Population, 1970

FIGURE III-1
OKLAHOMA POPULATION GROWTH

Table III-1 indicates the projected population growth within the three Standard Metropolitan Statistical Areas of the State. In 1970, these three principal urban areas had approximately 53 percent of the State's population. By 2030, about 60 percent of the total projected population is expected to be centered in these areas.

Between 1940 and 1970, the number of cities and towns having a population of more than 2,500 increased from 74 to 100, further indicating a trend toward population concentration.

Industrial

The growth and expansion of Oklahoma's industry originated with production of goods in self-sufficient frontier communities. Principal products were

TABLE III-1
PROJECTED URBAN POPULATION GROWTH

STANDARD METROPOLITAN STATISTICAL AREA	YEAR 1970	1990	2030
Lawton	108,144	134,500	171,400
Oklahoma City	699,092	1,059,100	1,400,400
Tulsa	549,154	738,500	1,067,300
TOTAL	1,356,390	1,932,100	2,639,100
STATE TOTAL	2,559,463		
PROJECTED TOTAL		3,339,000	4,429,000

TABLE III-2
1972 INDUSTRIAL ACTIVITY

MAJOR INDUSTRIES	NUMBER OF ESTABLISHMENTS	NUMBER OF EMPLOYEES
Lumber & Wood	99	3,090
Furniture & Fixtures	82	2,371
Stone, Clay & Glass	219	9,931
Primary Metal Industries	57	4,650
Fabricated Metal Products	370	16,677
Machinery, except electrical	425	22,502
Electrical Machinery	122	14,346
Food	371	16,498
Apparel	111	12,538
Printing & Publishing	476	8,891
Chemicals & Allied Products	90	1,672
Refining & Coal Products	39	8,249
Other	450	29,999
TOTAL	2,911	151,414

agriculturally based and developed as basic needs arose. Since those early days, Oklahoma's industrial activity has expanded dramatically.

Lower establishment costs, coupled with lower living costs and a large labor force often provide the incentives for firms to locate in Oklahoma. Wood and pulp manufacturing industries are finding bountiful supplies of water needed for processing.

Agriculturally based firms have likewise been attracted, since Oklahoma is predominantly an agricultural state. Processing, packing and canning operations have flourished in several areas.

There were 2,911 industries in 1972, with a payroll of over $1.1 billion. Oklahoma ranks 33rd among all states in industry. For a breakdown of major industries and the number of employees, see Table III-2.

It is anticipated that Oklahoma's unique advantages will continue to draw people and industry to the State.

Agricultural

Early Oklahoma settlers found the climate, soils and vast expanses favorable for agriculture. Cattle, grains and feed seed crops were major contributors to this early growth.

Oklahoma's total land area in acres is 43,819,111. Of this total, 12,992,641 acres are in cropland, 18,953,655 acres are in range and pastureland, 8,580,907 acres are in forestland and the remainder is not in agricultural use. The number of irrigated acres, according to the 1973 Reported Water Use, was 523,938. This includes only reported irrigation acres and does not represent the state total. Oklahoma State University Extension Service reports a state total irrigated acreage of 758,036. The State has 11,112 tenant farm operators, 26,869 part-owners and 44,457 full owners.

For the past three years, Oklahoma has ranked second in winter wheat and hay production and fifth in cattle production. According to the Oklahoma Crop and Livestock Reporting Service, the value of principal crops and livestock has increased from $1,002 million in 1971 to a record $1,017 million in 1973.

Much of the State's industrial economy is dependent upon agriculture. These include food and allied products, agricultural supplies, materials, equipment and services, transportation and marketing. These agriculturally oriented segments of the economy constitute a multibillion dollar contribution to the total economy of the State.

Urbanization, industrialization, highway development, reservoirs and other land uses are encroaching on farm and forest area. New pressures on agricultural production capabilities are being seen. Areas devoted to wildlife and recreation are also expected to increase.

Direct employment in agriculture has remained somewhat stable over the past years with 126,000 in 1970, 124,000 in 1971 and 125,000 in 1972. Farm families supplied 86 percent of the labor force, with the remainder being hired workers.

WATER REQUIREMENTS

During the Dust Bowl of the 30's, there was a migration of industry and people out of the State. Since that era, Oklahoma has redeveloped into a frontier where incentives for economic growth exist. Agricultural, industrial and urban expansion have reached a level requiring new concepts in management and distribution of Oklahoma's water supply to maintain a viable economic environment. In order to maintain growth rates and avoid economic retrogression, development of the State's remaining resources must be carefully planned and carried out.

Municipal And Industrial

Determination of the current level of municipal and industrial water use and projections of future usage is needed. An explanation of the methodology used to develop usage rates and projections follows.

Municipal and Domestic: The base area population forecast made by the Oklahoma Employment Security Commission was applied to the per capita use rates to arrive at a total area municipal and domestic water use forecast.

Industrial: The economic data which provided a basis for a part of the industrial water requirement projections are disaggregates of

TABLE III-3
STATE WATER REQUIREMENTS
In Thousands Of Acre-Feet Per Year

REGION		1970+	2000	2030	2080
		RED RIVER BASIN			
Southwest	Irrigation	228.0	579.0	1219.1	1204.0
	Mun. & Ind.	87.1	129.9	173.7	262.5
	Total	315.1	708.9	1392.8	1466.5
South Central	Irrigation	27.5	70.4	147.4	219.0
	Mun. & Ind.	53.9	63.8	81.4	137.6
	Total	81.4	134.2	228.8	356.6
Southeast	Irrigation	11.9	174.5	282.2*	564.4**
	Mun. & Ind.	45.3	144.2	226.0	281.2
	Total	57.2	318.7	508.2	845.6
Irrigation Water Totals		267.4	823.9	1648.7	1987.4
M & I Water Totals		186.3	337.9	481.1	681.3
Total Water Requirements		453.7	1161.8	2129.8	2668.7
		ARKANSAS RIVER BASIN			
Northwest	Irrigation	455.5	1153.8	1489.2	2322.4
	Mun. & Ind.	28.5	39.5	57.0	86.5
	Total	484.0	1193.3	1546.2	2408.9
North Central	Irrigation	11.6	143.2	241.0	485.8
	Mun. & Ind.	75.0	162.6	247.0	314.9
	Total	86.6	305.8	488.0	800.7
Central	Irrigation	18.0	40.2	71.5	94.9
	Mun. & Ind.	181.9	310.6	705.0	944.0
	Total	199.9	350.8	776.5	1038.9
Northeast	Irrigation	18.8	316.7	521.1*	1042.3**
	Mun. & Ind.	234.7	478.8	822.0	1327.7
	Total	253.5	795.5	1343.1	2370.0
East Central	Irrigation	9.7	133.2	215.0*	429.9**
	Mun. & Ind.	31.3	208.5	382.0	526.1
	Total	41.0	341.7	597.0	956.0
Irrigation Water Totals		513.6	1787.1	2537.8	4375.3
M & I Water Totals		551.4	1200.0	2213.0	3199.2
Total Water Requirements		1065.0	2987.1	4750.8	7574.5
		STATE TOTAL			
Irrigation Water Totals		781.0	2611.0	4186.5	6362.7
M & I Water Totals		737.7	1537.9	2694.1	3880.5
Total Water Requirements		1518.7	4148.9	6880.6	10243.2

*Based on ¼ of soils suitable for irrigation in greater than or equal to 40 acre tracts to be irrigated in year 2030.

**Based on ½ of soils suitable for irrigation in greater than or equal to 40 acre tracts to be irrigated in year 2080.

+In some instances these figures may not agree with reported water use figures due to the method used in reporting water use.

the United States Water Resources Council's regional forecasts. The trends indicated by these forecasts between the years 1970 and 2030 were graphically projected to 2080. The employment rates given under these forecasts were multiplied by the Employment Security Commission's total area population projections to arrive at Oklahoma's portion of the industrial census. These were then factored into the various industrial categories for Oklahoma at the same rates as for the total W.R.C. areas. The per capita water use rates were applied for a total industrial water requirement. The industrial water requirement forecasts for W.R.C. areas in Oklahoma were then broken into eight regions.

Utilities: The 1970 consumptive water use by utilities was computed at the rate of 1.84 acre-feet of water per million kilowatt hours (MKWH) and does not include cooling water that is not actually consumed. The total state utility water use forecasts were made jointly by Oklahoma Gas and Electric Company and Public Service Company and are based on projections made by the Federal Power Commission.

The 1980 through 2030 cooling water requirements were assumed to be 0.814 gallons per kilowatt hour or 2.5 acre-feet per MKWH. The distribution of generating stations in the various areas was held constant from the year 2000 to 2030.

The 1980 through 2030 energy estimates were derived from *Oklahoma's Energy Needs for the Future, An Interim Report*, October 1973, published by the Bureau for Business and Economic Research, University of Oklahoma. As suggested in Appendix E of the 1970 *National Power Survey* published by the Federal Power Commission, the 2030 energy estimate was obtained by projecting a straight line utilizing the 1985 and 1990 usage points as specified in *Oklahoma's Energy Needs for the Future.*

Note: Municipal, domestic, rural water systems, industrial, utility and energy related water requirements have been combined into one water use category, Municipal and Industrial.

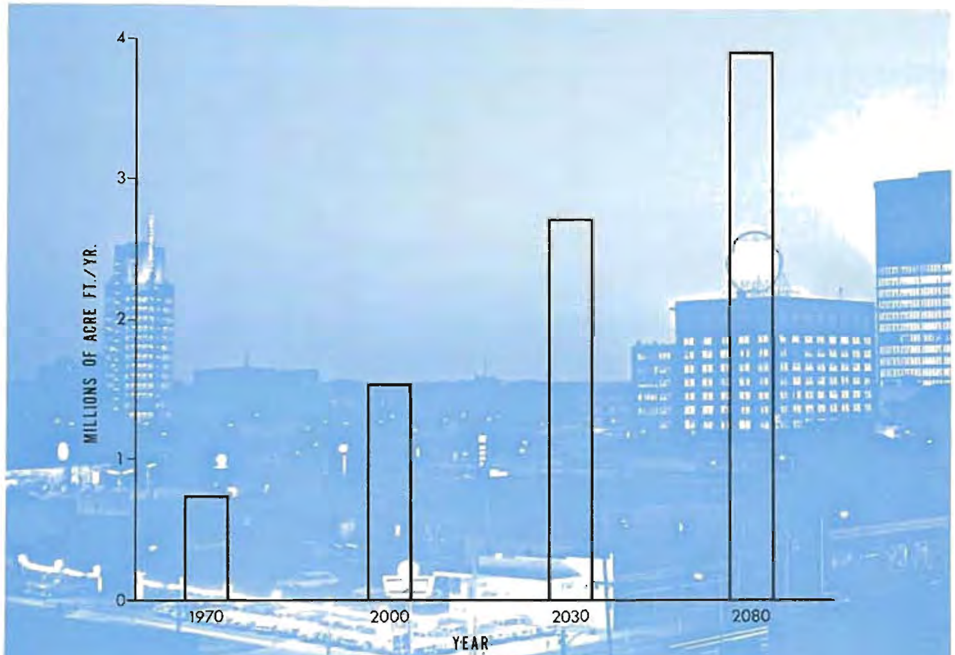


FIGURE III-2
FUTURE MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS

Future Water Requirements: Current usage and future estimates are shown in Table III-3 and Figure III-2. Statistics show that in 1970, water usage for the State was 737,700 acre-feet. This figure includes usage by utility companies, domestic (households), municipalities and industrial concerns. Projections show that in 2000, 1,538,000 acre-feet will be used. Increases in usage are predicted to increase significantly and by 2080, will reach 3,881,000 acre-feet.

In addition to meeting domestic demands, municipalities use water for fire protection, street flushing, lawn and garden irrigation and industry and commerce. These municipalities are served water by both publicly and privately owned distribution systems. Water for rural domestic purposes is not served by public or community facilities and is used primarily for household use and lawn and garden irrigation.

Many factors, such as climate, local economy, urbanization, water distribution facilities, cost to consumers, availability and variability of the water source and kinds of commercial and industrial establishments supplied from the municipal system determine quantities of water withdrawn.

The industrial sector, as it increases output to meet the demands of a growing market, will continue rapid construction and expansion of facilities and will require more water to support production growth.

Except for a few primary product industries whose plant locations are determined by raw product sources or similar factors, most industries will continue to locate in urban areas that constitute their major markets or points of transfer.

Ultimately, the degree to which water conservation alternatives are employed by industry will depend upon the relative cost of available water, the degree of treatment required for waste discharge and management practices.

Rural Water Systems

Rural water systems are legal State entities created to serve consumers within its district boundary. They also have taxing and borrowing authority and provide water to rural areas and some small communities. Rural water systems are especially important in that they provide water of acceptable quality and quantity to local areas which would otherwise have to depend on poorly-based sources. Ground water is the principal source for meeting consumer demands, although stream water is used in a supplemental capacity. There are 310 operating water systems in the State. Future increases in rural water demands are expected to result from increased per capita usage.

Consumers in 1974 numbered 261,900. The remaining 604,500 anticipated consumers not currently served meet their water demands through individual private sources.

According to population projections, consumers served will increase to 456,300 in 2030. Unserved consumers will number 148,200 in 2030 and it is estimated an additional 32,850 acre-feet of water will be needed in 2030 to serve these people's demands. Both daily and yearly consumption figures for present and future usage are shown in the following tabulation. These requirements are included as part of the municipal and industrial usage in Table III-3.

Energy Related

Water will be required in varying amounts for production and processing of different types of energy fuels. Secondary and tertiary petroleum recovery processes are expected to require increasing amounts of water. Other energy industries that use water are oil refineries, coal gasification and thermoelectric generation plants. They are expected to use more water with the increasing demands for different types of energy.

Municipal needs for energy related water requirements are expected to increase drastically, based on projected population figures. These and other energy related water requirements have been taken into consideration in projecting water requirements.

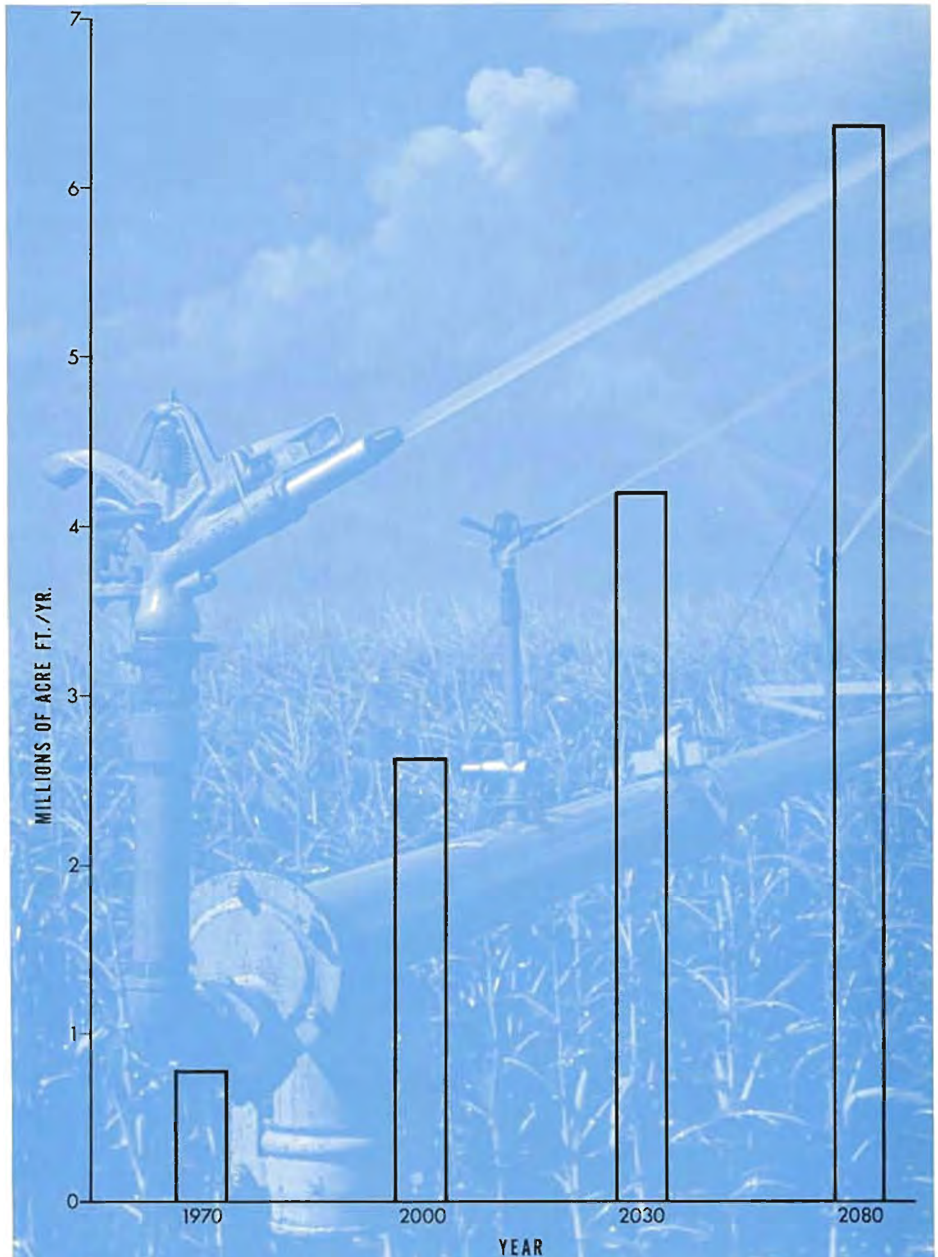


FIGURE III-3
FUTURE IRRIGATION WATER REQUIREMENTS

TABLE III-4
RURAL WATER SYSTEM REQUIREMENTS

YEAR	CONSUMERS SERVED	CONSUMPTION PER PERSON PER DAY	TOTAL DAILY REQUIREMENTS IN GALLONS	TOTAL ANNUAL REQUIREMENTS IN ACRE FEET
1970	261,900	140	36,666,000	41,066
1980	293,700	154	45,299,800	50,657
1990	333,050	168	55,952,400	62,667
2000	372,400	179	66,659,600	74,658
2010	414,350	192	79,555,200	89,102
2030	456,300	199	90,803,700	101,700

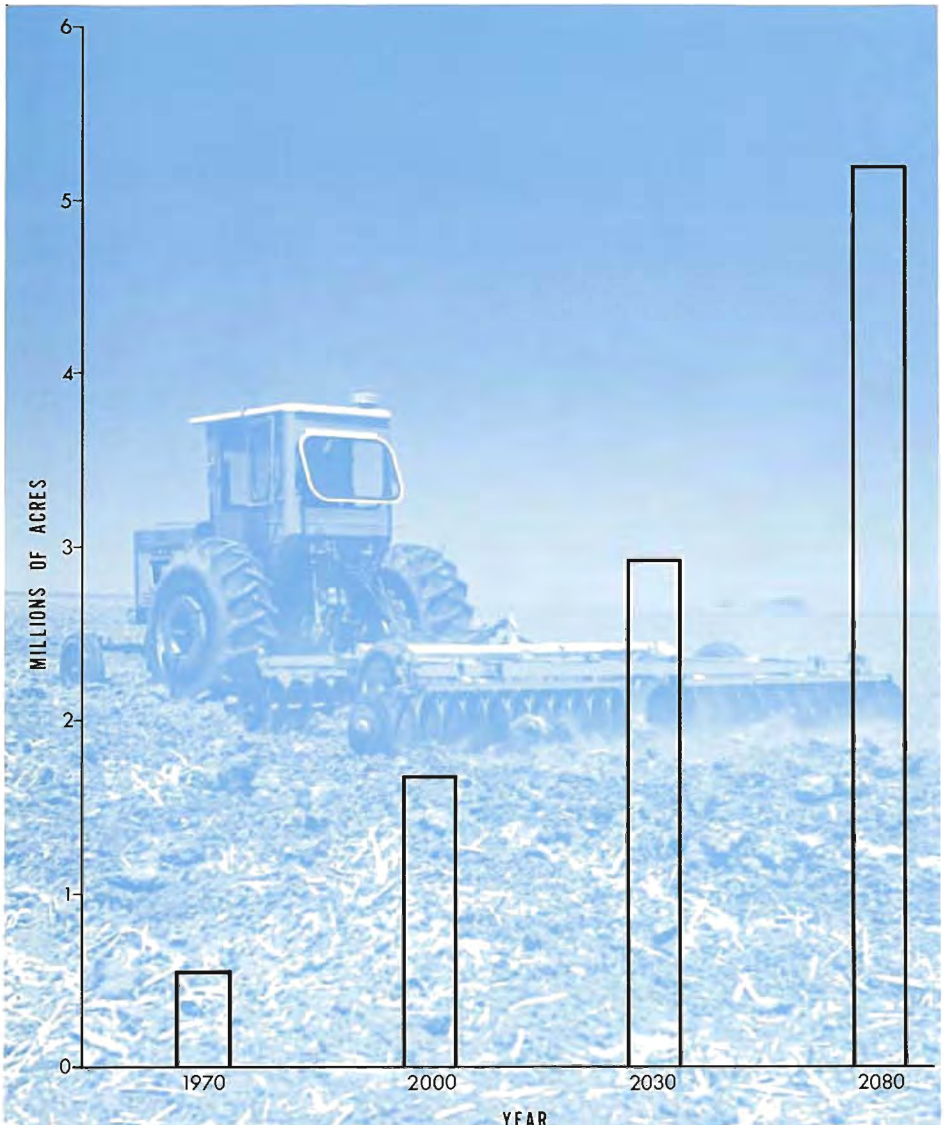


FIGURE III-4
PROJECTED IRRIGATED ACRES

Irrigation

Agriculture uses more water than any other single industry. While precipitation, particularly rainfall, directly supplies most of the water required by agriculture, it frequently needs to be supplemented by water diverted from streams, surface impoundments or from ground water.

Determination of current levels of irrigation water use and projections of future usage has been made. The methodology used to develop usage rates and projections was a joint effort by the Bureau of Reclamation and the Soil Conservation Service. Although their methods differ slightly, considerations were given to soil classifications and slopes, present and future irrigation methods and other factors.

Irrigation water rates, adopted by the planning committee, are one acre-foot of water required per acre of land irrigated in the three eastern areas, 1.5 acre-feet in the three central areas and two acre-feet in the two western areas.

Future irrigation water use depends upon climate, cropping patterns, irrigated acreage and efficiency levels attained by irrigators. See Table III-3 and Figure III-3 for present and future irrigation water usage and requirements.

The western half of the State accounts for about 90 percent of the total irrigation in Oklahoma. Presently, ground water provides 83 percent of irrigation needs. Storage and diversion of streamflow for irrigation has remained relatively constant.

The implementation of irrigation has not yet been fully developed, since less than 10 percent of the State's total irrigable acres are currently being irrigated. By the year 2030, some 2,959,000 acres are projected to be irrigated, requiring about 4,200,000 acre-feet of water. Table III-5 shows the projected irrigation acres for the planning regions of the State for the year 2030.

TABLE III-5
2030 IRRIGATED ACRES

REGION	ACRES
Southeast	282,000
South Central	77,000
Central	90,000
Southwest	523,000
East Central	215,000
Northeast	521,000
North Central	506,000
Northwest	745,000
TOTAL IRRIGATED ACRES	2,959,000

Other Water Requirements

The total spectrum of water uses and requirements must be considered during the operation of water supply and distribution systems. Overall water requirements for fish and wildlife, recreation and preservation of scenic streams are difficult to estimate. At best, one can only say how much water is used in these areas.

Navigation will need more hydrology studies in the Arkansas River basin to determine the exact amount of water required for navigation to insure maximum utilization. Hydroelectric power needs are known and water use can be measured.

As Oklahoma develops, it is obvious that water needs will expand. In order to develop a conception of this, it is necessary to see what role water has played for each area in the past.

NAVIGATION

The information available on waterborne commerce is related to established routes and improvements for navigation. While information on traffic and navigation equipment performance is available, specific data on facilities, particularly overall water or flow requirements will require further study.

Navigation water requirements of the McClellan-Kerr system under various assumptions of use will be undertaken in Phase II of the Oklahoma Comprehensive Water Plan. Navigation water requirements will be supplemented by return flows and releases from upstream lakes for power generation and various downstream uses.

Extension of the system into central Oklahoma via the Deep Fork River, as well as to Wichita, Kansas via the Verdigris River has been studied for several years. If plans are developed in the future, water requirements would need revision to provide the water necessary for navigation.

Potential navigation up the Red River to Denison Dam has been studied and is being considered as a possible long-range navigable stream. Power releases from Lake Texoma would supply supplemental flow for navigation requirements.

FISH, WILDLIFE AND RECREATION

Fish and wildlife are dependent on the quality of the environment. Many species are sensitive to measures taken in the development of water and related land resources. Water is absolutely essential to fish and wildlife as it is to all life, but the quantity and quality required varies enormously. In every case, water requirements of fish and wildlife must be met to insure survival and stability of desirable natural communities of plants and animals.

Private catfish farming is a new agricultural industry that is rapidly gaining economic importance. In 1974, 1,163 acres utilizing 17,000 acre-feet of water, were involved in fish production. Increases in water usage are expected in the fish farming industry.

Currently, there are 175 public recreation facilities, offering boating, skiing, picnicking, fishing and other water-oriented activities. Oklahoma's 1973 reported water use for recreation and wildlife was 23,000 acre-feet. Water for recreational purposes is considered adequate except for swimming, which will be provided by the individual community.

HYDROELECTRIC POWER

Except for the initial filling of a reservoir, hydroelectric power production usually does not involve permanent water withdrawal from rivers and streams. Power plants do not use water consumptively, except for normal evaporation associated with reservoirs.

Presently, there are ten existing hydroelectric projects in Oklahoma. In Table III-6, water use was calculated by using average annual energy and headwater data. Table III-6 shows a total installed capacity of 800 million watts, using 37,673,460 acre-feet of water for generating purposes. At this time, no new projects are under construction.

PRESERVATION OF SCENIC STREAMS

The scenic and wild rivers program must be integrated into the overall water use and development program so that a reasonable balance is struck between development and control of water resources and preservation of free-flowing, scenic streams.

Under the 1974 amendments to the Scenic Rivers Act (House Bill 1639), four areas were designated as scenic rivers. These include the Illinois River and Flint Creek in Cherokee, Adair and Delaware counties; Barren Fork Creek in Adair and Cherokee counties; Upper Mountain Fork River in McCurtain and LeFlore counties and Big Lee Creek in Sequoyah County.

These streams must remain free-flowing and cannot be impounded by any large dam or structure without specific authori-

TABLE III-6
EXISTING HYDROELECTRIC PROJECTS IN OKLAHOMA

PROJECT	STREAM	INSTALLED KILOWATT	WATER USE ACRE-FEET
Keystone	Arkansas	70,000	3,134,000
Webbers Falls	Arkansas	66,000	1,332,000
Tenkiller Ferry	Illinois	34,000	880,000
Eufaula	Canadian	90,000	3,735,000
Robert S. Kerr	Arkansas	110,000	13,009,000
Fort Gibson	Grand (Neosho)	45,000	3,738,000
Broken Bow	Mountain Fork	100,000	841,000
Denison	Red	70,000*	2,953,000
Pensacola	Grand (Neosho)	86,400	3,507,000
Markham Ferry	Grand (Neosho)	108,000	4,544,000
TOTAL		779,400	37,673,000

*35,000 KW used in Oklahoma, 35,000 KW used in Texas zation by the legislature. However, the streams may be used for municipal, industrial and domestic water supply.

OTHER WATER RELATED PROBLEMS

When developing a plan of action for water uses and requirements, consideration of water related problems arise. Certain aspects, such as flood control and flood plain management, sediment control, land drainage, control of water-wasting vegetation, water quality and stream water availability need to be considered.

Flood Control And Flood Plain Management

The term "flood" refers to overflow that comes from a river or other body of water and causes or threatens loss of life and/or damage to goods and services. Floods are classified as downstream for those on the main stem and major tributaries and upstream for those on creeks and headwaters.

Most floods in Oklahoma are caused by thunderstorms and waters are usually back within their banks in a few hours. Flooding in the east central region is caused by rapid runoff from a mountainous drainage area. These are usually of short duration during storms.

Upstream flood control programs are carried out by the Soil Conservation Service, while downstream flood control programs are carried out by the Corps of Engineers. The combined programs of the Soil Conservation Service and the Corps of Engineers produce an average annual flood benefit of $180 million in the State.

Flood plain management measures were designed to minimize losses. These measures are flood plain regulations, insurance, warning and flood proofing. Regulations do not attempt to reduce or eliminate flooding, but are designed to mold development to lessen the effects of flood damage. Flood insurance does not affect the level of property damage nor does it produce significant land enhancement benefits. It reimburses part or all of the losses to individuals with property in the flood plain. Warning systems protect communities from flash flooding and flood proofing insures structural safety during flooding.

Sediment Control

Sediments produced by erosion are the most extensive pollutants of stream waters. Excessive suspended sediments have a harmful effect on water supplies. Sediments adversely affect commercial and game fish habitats, power turbines, pumping equipment and irrigation distribution systems.

Sediment movement can be significantly reduced with improved land use and intensified treatment, control and management programs. Studies show that agronomic and mechanical practices reduce the amounts of sediments reaching reservoirs from 28-73 percent. Sediment yield may be reduced as much as 90 percent by changing poorly suited cropland to continuous vegetation.

Flood retarding structures have been responsible for decreasing sediment yields as much as 48-61 percent.

Land Drainage

Problems associated with excess water drainage exist on some 5.2 million acres in Oklahoma. Drainage is defined as improvement works designed for removing excess water from the plant root zone or from surface areas where normal precipitation, seepage or excess irrigation water keeps the soil too wet for economical agricultural production. Factors affecting drainage include slope, permeability of the soil, water table and lack of soil aeration.

The purpose of drainage is four-fold, providing increased crop yields, improved machinery efficiency, higher crop quality and better machinery adaptability.

Currently, numerous acres of land are in need of drainage programs. Excess water disposal measures include land forming to eliminate pockets and depressions, and intervals. Tile drains are the most common methods used for sub-surface drainage. Both types of drains require outlets into deeper channels or water courses.

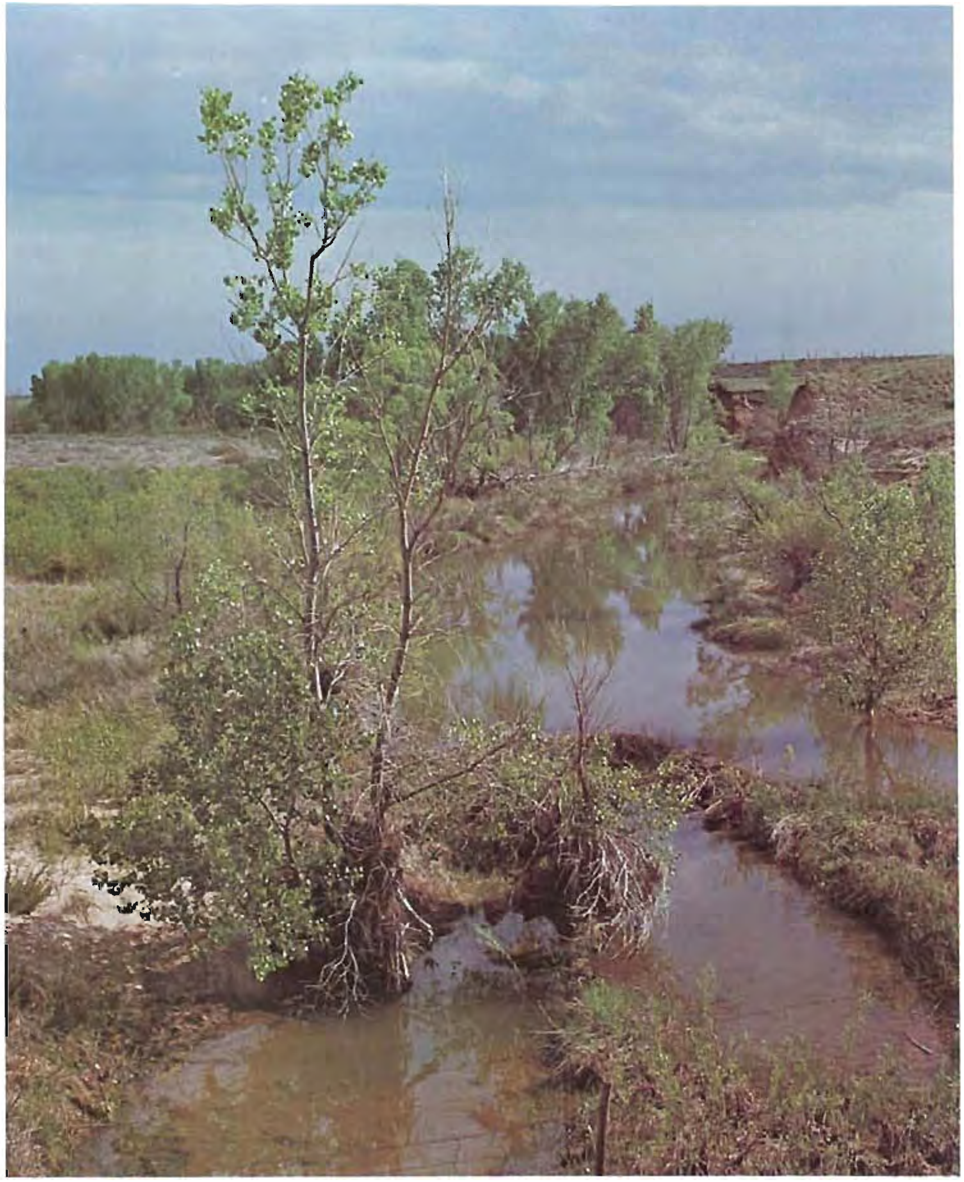
Other problems occur when residential, commercial and industrial projects do not allow for larger volumes of precipitation that will not flow evenly through altered flow channels. Insufficient drainage planning has resulted in costly street, sewer and highway flooding.

Drainage problems are not expected to increase except in areas under irrigation. The development of drainage problems would be considered part of irrigation development. The 1970 Oklahoma Conservation Needs Inventory made by the Soil Conservation Service identifies 83,105 acres in 123 watersheds within the Red River basin that needs project-type action.

Control Of Water-Wasting Vegetation

Certain species of plants exist which transpire large volumes of water and are of little economic value. Plants that depend upon ground water lying within reach of their roots for water supply are called phreatophytes. The most common species in Oklahoma are saltcedar, cottonwood, willow and mesquite. It is estimated that there are 50,000 acres of saltcedar and 620,000 acres of mesquite in the State. These plants reduce ground water storage and related stream-flow.

Phreatophytes are especially a problem along river valleys. They are heavy users of water. Many of Oklahoma's stream channels are



Water-wasting cottonwood trees along a State stream

lined with these plants. For example, cottonwood and willow trees lining the North Canadian River in Canadian County annually transpire more water than Oklahoma City uses from that stream. The spreading of saltcedar along the North Fork of the Red River is a problem in southwestern Oklahoma. The water use of phreatophytes across the State range from a few tenths of acre-foot per acre to more than seven acre-feet per acre annually. The huge volumes of water wasted by phreatophytes might otherwise move down valleys and streams and be utilized by man.

Several methods are being experimented with to eradicate and control water-wasting vegetation. The first step is clearing, either by cutting down or uprooting the plants by mechanical means, or through the use of chemical sprays. This is followed by replacement of useful grass. Eradication results in a net savings of water through additional natural recharge to ground water basins and increased streamflow.

At present, little is being done to control water-wasting vegetation in Oklahoma. In the interest of conserving water to meet growing demand, more attention should be given to the phreatophyte problem.

Water Quality

The quality of Oklahoma's stream and ground water is equally as important as its quantity. Water quality is influenced by many factors, including geology, climate, urbanization and agricultural land development, wastewater treatment and disposal practices, storage and diversion of lakes and their methods of operation. With increased discharge of wastes by municipalities, industries and agriculture, further degradation of the States's water resources can be expected unless adequate water quality management policies are instigated.

WATER QUALITY STANDARDS

In recent years, steps have been taken to protect and enhance the quality of the State's waters. In accordance with provisions of the Federal Water Pollution Control Act Amendment of 1972, the Oklahoma Water Resources Board has prepared water quality criteria for the State called "Oklahoma's Water Quality Standards." These rules and regulations designate the uses for which the various waters of the State shall be maintained and protected and prescribe the water quality standards required to sustain these uses.

SALINITY ALLEVIATION

Natural mineral pollution is a major quality problem in both the Arkansas and Red River basins. There are 15 major sources of natural salt pollution in the two basins, producing an average daily salt load of 15,000 tons. See Figure II-6 for sources located in Oklahoma.

Natural salt pollution in the Arkansas River basin begins in southern Kansas and western Oklahoma. Five major natural contamination sources account for about 70 percent of the total load carried past Tulsa each year.

The Red River basin is presently polluted with chlorides from the Palo Duro Canyon in west Texas to its confluence with the Mississippi River. Most of this pollution originates from ten natural salt sources along the upper tributaries to the Red River in Texas and Oklahoma. These ten areas comprise 60 percent of the entire chloride load in the Red River basin entering Lake Texoma.

It is estimated that 75 percent of the natural chloride load in the Red River and over 80 percent in the Arkansas River could be controlled with all the proposed control structures in place.

Authorization and construction of natural salinity alleviation projects proposed by the Corps of Engineers, together with continuing abatement of oil field pollution would result in substantial improvement in the quality of the Arkansas and Red Rivers. It would also provide substantial volumes of water for high priority use which has, in the past, been largely undeveloped because of salinity problems. Additional study is needed to estimate the amount of water that might be salvaged through these control measures.

DESALTING

Desalination in Oklahoma is, to a great extent, dependent upon the performance and cost of a desalting plant recently put into production at Foss Lake in Custer County. When Foss Lake was completed, it was discovered that the quality of the water with conventional treatment was too poor to be used as a municipal supply. A study was done to determine alternate water sources in the area and the most feasible method of alleviating the poor water problems. The study recommended the construction of the desalination plant because Foss Lake was the only long-term water source in the area.

The importance of desalting will depend on the success of the mechanical and environmental aspects of the plant and its application of such processing.

Demineralization of saline water resources may provide an alternative solution to water supply problems. However, it also creates a potential water quality problem through highly saline waste streams.

An attendant problem to the demineralization of water is the disposal of the concentrated brine effluent from the conversion process. Disposal methods include evaporation ponds, lined to prevent seepage; subsurface injection; sale of effluent to the petroleum industry for secondary recovery and discharge of diluted brine effluent into streams. This discharge must comply with State water quality standards.

Satisfactory effluent disposal to prevent stream and ground water pollution presents both technical and economic problems. Proper waste disposal costs may be the margin of economic feasibility in evaluation of water supplies produced by desalting.

RELATED PROBLEMS AND NEEDS

The quantity and variety of waste produced by our growing affluent society is increasing at an alarming rate. Inadequate treatment and handling of waste flows by cities and industries have caused serious pollution problems. Expected growth of cities and industries will intensify and create new water quality problems in the State.

In the future, all municipalities and industries will be required to provide adequate waste treatment facilities consistent with the characteristics of the wastes, quality of the receiving stream and nature of downstream water uses in order to comply with Oklahoma's water quality standards.

Brine releases from oil and gas production have contributed to the pollution of many streams and ground water supplies. Variable amounts of salt water are produced per barrel of oil, depending on the age of the oil field. In new fields or wells, little or no brine is produced, but older, nearly depleted fields may yield as much as 100 barrels of salt water per barrel of oil produced. The potential salt load from this source can be large and only the dedicated work of State and local agencies and the cooperation of petroleum producers has kept the situation in its present good condition. State water pollution control agencies now report that over 95 percent of the brine produced from petroleum activities is being reinjected into production strata for pollution control and secondary recovery.

Water pollutants associated with agricultural and ranching operations are fertilizers, herbicides, insecticides, salt concentrations in irrigation return flows, animal wastes and silt from overland runoff. Excessive concentrations of these pollutants can and do change the water quality of streams during periods of high runoff, and ground water through seepage. Farmers and ranchers will need to manage operations so that feedlot wastes, fertilizers and pesticides do not reach streams and ground water in quantities detrimental to their quality. Other sources that contribute to the pollution of streams and ground water are mining wastes and thermal pollution.

Consideration needs to be given in future water resource development to provision of adequate stream flows downstream from lakes to maintain stream quality. Water quality control storage has been and is being provided in Federal lake projects for maintenance of adequate low flows or dilution flows in streams which have been adversely affected by water resource development or waste discharges. When these releases have fulfilled their objectives, they would become a resource to the stream and available for reuse for other beneficial purposes.

SECTION IV

PLANNING AREA RESOURCES, REQUIREMENTS AND PLAN DEVELOPMENT

SOUTHEAST REGION

LIST OF TABLES AND FIGURES

TABLE

FIGURE

General Description

The southeast region covers 7,919 square miles. It is composed of Atoka, Bryan, Choctaw, Coal, Johnston, McCurtain, Pontotoc and Pushmataha counties. The area has vast mineral, timber and water resources. The north is characterized by rugged hills and mountains which become gently rolling hills and an alluvial plain where it meets the Red River to the south. Elevations range from over 2,500 feet in the north to about 300 feet in the southeast.

The region lies in a moist, subhumid climate where annual precipitation equals evaporation. Although precipitation is normally well distributed throughout the year, droughts of short duration are fairly frequent during the growing season. The growing season lasts about eight months.

Major stream systems of the region are Boggy Creek and the Blue, Kiamichi and Little Rivers. Minor stream systems are Island Bayou, Watergrass and Waterhole Creeks. The entire region is bounded on the south by the Red River.

The 1970 population of the eight county region was 130,954. The principal cities of the region, Ada, Tishomingo, Durant, Coalgate, Atoka, Hugo, Antlers, Broken Bow and Idabel are beginning to experience industrial growth and are pleasant places to live.

Planning Area Resources

PRECIPITATION

As shown on Figure II-1, average annual precipitation ranges from 40 inches in the west to 54 inches in the east. The State's heaviest rainfall occurs in the northern portion of McCurtain County over the Little River and Kiamichi River watersheds. Most of this precipitation occurs during the months of April and May with about 6 inches falling during each of these months. One station in McCurtain County recorded an amount of 12.3 inches during a 24-hour period on October 30-31, 1972. While this is not the highest recorded for the State, such rainfalls produce high volumes of storm runoff.

EVAPORATION AND TEMPERATURE

The average annual lake evaporation in this region is shown on Figure II-3. It ranges from 48 to 56 inches from east to west across the region. Compared with the western parts of Oklahoma, this is low and is probably due to the lack of sustained high velocity winds during the hot summer months. Mean annual temperature in the region ranges from 62 degrees in the north to 64 degrees in the south. See Figure II-2.

STREAM WATER CHARACTERISTICS

This region has a combined drainage area of 7,919 square miles inside the Oklahoma state line. Two streams originate in the State of Arkansas and flow westward into Oklahoma. One of these, the Little River, flows eastward again into the State of Arkansas.

In past drought periods, these streams and rivers have experienced little or no flows; however, usually flows are high and steady. Generally stream water is readily available in large quantities almost anywhere in this area.

Runoff

Average annual runoff from precipitation and springs is about 15 inches. This ranges from about eight inches in Bryan County to about 20 inches in the northeast corner of McCurtain County for an average annual runoff originating within the region of 6,000,000 acre-feet per year. See Figure II-4. Of this runoff, 2,804,000 acre-feet flows into the Red River within Oklahoma. The main stem of the Red River has an annual average flow of 8,426,000 acre-feet per year at the stream gauge at Index, Arkansas. This also includes runoff from Texas. During drought periods, such as occurred in 1956, this region produced a combined runoff of 1,625,000 acre-feet for the year, while the Index gauging station recorded 4,144,000 acre-feet for the same period. A summary of streamflows at U.S.G.S. gauging stations is included in the following Table IV-1. For location of gauging stations, see Figure IV-4.

TABLE IV-1
SOUTHEAST REGION STREAMFLOW SUMMARY

STREAM	U.S.G.S. STATION	CONTRIBUTING DRAINAGE AREA SQ. MILE	AVERAGE ANNUAL FLOW AF/YR	OBSERVED FLOW (CFS) MAX	MIN
Clear Boggy	3350-near Caney	720	335,400	52,800	0
Muddy Boggy	3340-near Farris	1,087	624,500	61,900	0
Red River	3316-near Denison, TX	33,784	3,410,000	201,000	12
Red River	3370-at Index, AR	42,094	8,426,000	297,000	378
Blue Creek	3325-near Blue	476	207,900	34,400	0
Kiamichi	3365-near Belzoni	1,423	1,231,000	71,400	0
Little River	3375-near Wright City	645	648,400	78,200	0
	3400-near Horatio, AR	2,674	2,676,000	120,000	1
Glover	3379-near Glover	315	284,700	98,600	0

Flooding

Notable floods occurring in this area are the Kiamichi River near Belzoni in October, 1915, with a maximum discharge of 72,000 cfs; Little River near Wright City in 1961, with a maximum discharge of 78,200 cfs; Little River near Idabel in February, 1938, having a maximum discharge of 86,000 cfs and Mountain Fork near Eagletown in 1960, with a maximum discharge of 101,000 cfs.

In more recent times, the Glover River and Little River have gone over their banks and caused severe flooding twice within an 11 month period. These floods occurred on December 10, 1971 and again on October 31, 1972. The gauging 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 covered some 60,000 acres of land, causing in excess of $17.5 million in damages. The 1972 flood repeated the performance by covering some 30,000 to 40,000 acres and causing another $12.6 million in damages to McCurtain County.

Stream Water Quality

All stream water in this eight county region is suitable for municipal and industrial purposes with the exception of the Red River, rated poor because of high total dissolved solids content. The water in this region is also suitable for irrigation, with the exception of the Red River, which is rated fair to poor from Denison Dam to its confluence with the Blue River, and is rated fair from this point to the Arkansas State Line. Suitability is dependent on the type of crops to be irrigated.

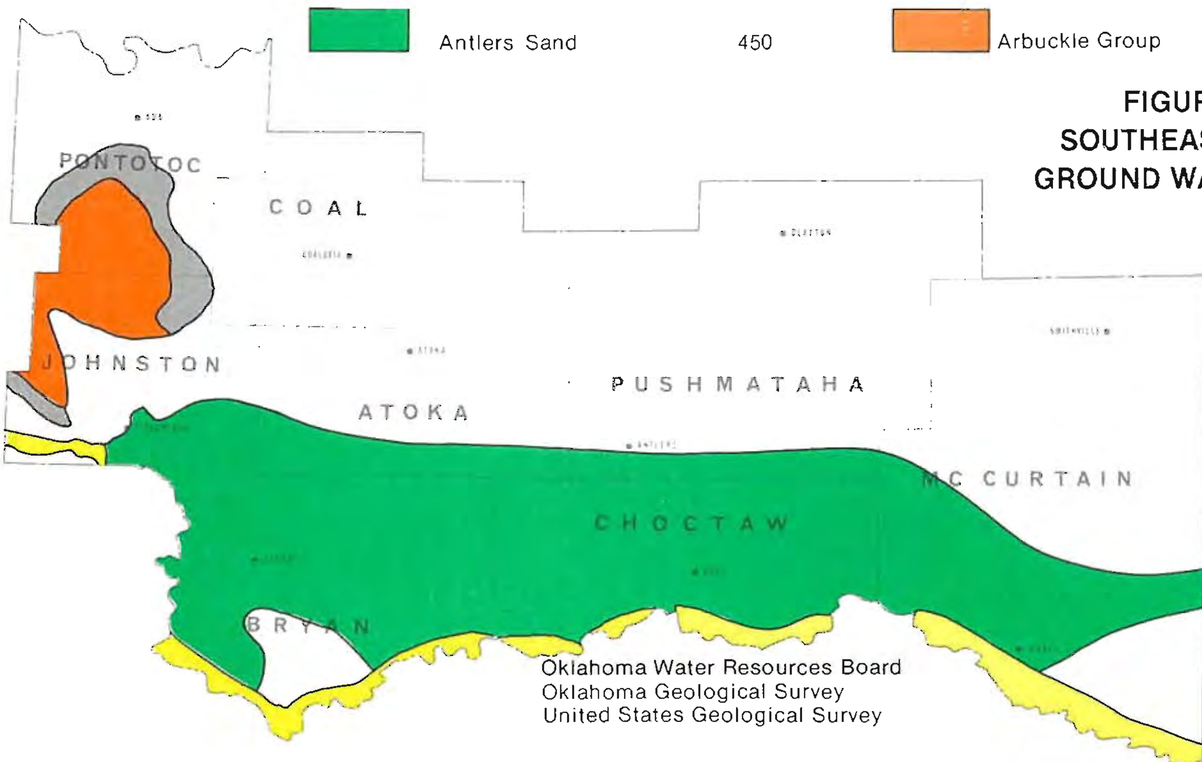
GROUND WATER RESOURCES

Several major ground water basins exist within the boundaries of southeastern Oklahoma. The rock units that comprise the major ground water basins are Arbuckle Group, Sandstones of the Simpson Group, Antlers Sand and alluvium and terrace deposits. The locations of these units are shown on Figure IV-1. The ground water basins supply moderate quantities of water for homes, towns, industries and some irrigation. See Table II-2 for total water in storage and amounts recoverable from ground water basins.

Arbuckle Group (Cambrian-Ordovician in age) 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 have high permeability resulting from fractures, joints and solution channels formed in the rocks. These conditions provide for 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 200-500 gpm, and as much as 2,500 gpm.

GROUND WATER BASIN	MAXIMUM YIELD (Gallons Per Minute)	GROUND WATER BASIN	MAXIMUM YIELD (Gallons Per Minute)
Alluvium and Terrace Deposits	500	Simpson Group	300
Antlers Sand	450	Arbuckle Group	2,500

FIGURE IV-1
SOUTHEAST REGION
GROUND WATER BASINS



Although the water is hard, it is suitable for most uses, because of the small amount of total dissolved solids, consisting mainly of sulfates and chloride concentrations. The water is of a calcium bicarbonate type. Well development is sparse, and the ground water basin is a major potential source of water for the region.

Simpson Group (Ordovician) is a series of sandstone beds totaling 300 feet in thickness and crop 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 gpm up to 500 gpm, averaging 200 gpm. Quality of water is potable in the outcrop area but deteriorates downdip away from the outcrop. Due to small areal extent, this ground water basin is not as significant as the Arbuckle Group.

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

The Antlers Sand ranges in thickness from 190 feet in the west to more than 880 feet in the southeastern part of the region. Water occurs under water table and artesian conditions. Well yields range from 5-50 gpm for water table wells; artesian wells yield 50-650 gpm. An average yield for wells completed in the ground water basin is 100-150gpm.

The quality of the water is good in the outcrop areas, suitable for industrial, municipal and irrigation use. Downdip from the outcrop, quality of the water deteriorates. Dissolved solids range from 130-1,240 mg/l, hardness from 8-580 mg/l, sodium from 1-350 mg/l and bicarbonate from 10-580 mg/l. This ground water basin, with broad areal extent and ample rainfall for recharge, has the most well development at present.

Alluvium and Terrace deposits (Quaternary) are unconsolidated sand and gravel, laid down by streams and rivers. The alluvium underlies the bottom lands along the streams, whereas the terrace deposits are topographically higher and usually adjacent to the stream beds. They are lithologically similar and considered as a hydrologic unit. The deposits have a maximum thickness of 100 feet and average 60 feet. They supply moderate to large quantities of water with maximum yields of 600 gpm, averaging 200 gpm. Most favorable area for development is along the Red River.

MINERAL RESOURCES

The mineral resources of southeastern Oklahoma consists of non-metals and energy fuels. The most important non-metals are stone, including granite, sand and gravel and some clay. Limestone is quarried near the towns of Ada, Bromide, Atoka, Idabel and Hugo for use in the production of cement, building stones, concrete and road metal. Glass sand is produced in Pontotoc County and rockwool in McCurtain County. Sand and gravel is extensively produced from alluvium and terrace deposits for use in cement and road metal. Clay is mined south of Ada and used for the manufacturing of brick. Limonite and iron ore are mined in the Arbuckle Mountains and used for special cements. All these mineral operations require little or no water. See Figure IV-2.

The energy fuels, oil, gas and coal, occur in the western area. Oil and gas is produced from wells in Coal, Pontotoc and Bryan counties. Production in 1973 was an estimated five million barrels of oil and 11 billion cubic feet of gas from 803 wells in 28 fields. Coal deposits occur in Atoka and Coal counties with 1974 resources estimated at 29,619 thousand short tons and 292,875 thousand short tons respectively. These coals have a high sulphur content (4.1 and 5.0 percent respectively) and could be gasified, a process which requires huge amounts of water for production as well as cooling. See Figure IV-3.

LAND RESOURCES

Of the 4,964,900 acre total land area of this eight county group, 1,465,223 acres are utilized for crops and pasture. Present agricultural trends show an increase in production of livestock, livestock feed crops and soybeans, while there is a decline in production of cotton and corn. Peanut production has remained fairly stable for several years. The forested portions of this region total 2,512,468 acres, supporting a thriving commercial lumber and wood products industry. Most commercial timber found in this region is classified as softwood, derived primarily from coniferous trees. Commercial hardwoods here consist of oak, hickory and gum. The 1972 Reported Water Use showed that the southeast region had 16,577 acres under irrigation. This includes only reported acres and does not represent the region total. Oklahoma State University Extension Service in 1973 reported a region total irrigated acres of 20,699 acres.

SOILS

Predominant soil associations located in the southeast region include Hector-Pottsville, Kirvin-Cuthbert-Bowie, Bowie-Caddo-Boswell, Durant-San Saba-Tarrant and the Parsons-Dennis-Bates. Forested and wooded pastures and meadows are the prevailing uses of these soil associations, although cropland exists in cleared wooded areas and along stream channels. Numerous other soil associations exist, but

FIGURE IV-2
SOUTHEAST REGION MINERALS
Oklahoma Geological Survey

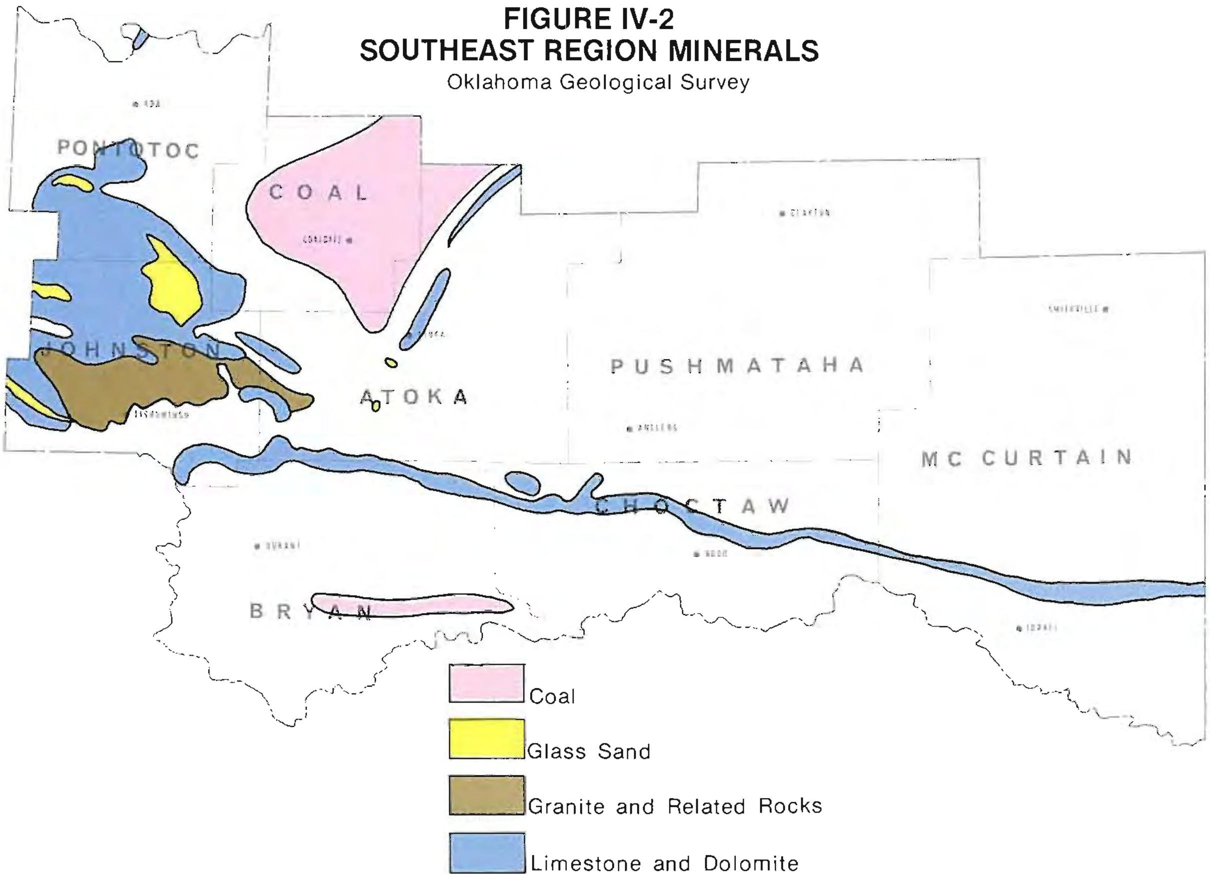
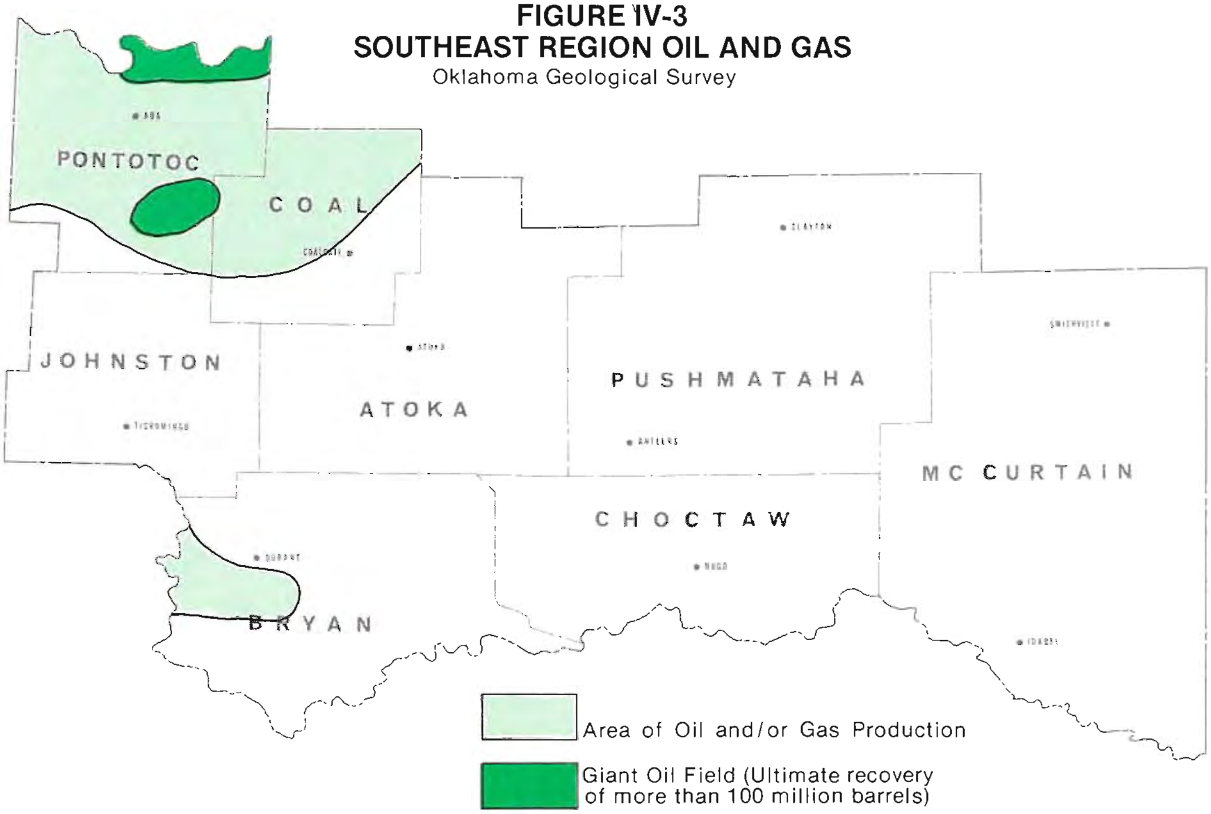


FIGURE IV-3
SOUTHEAST REGION OIL AND GAS
Oklahoma Geological Survey



amount to a small percentage of the land area in the region. These include Enders-Conway-Hector, Miller-Yahola-Teller, Dougherty-Teller-Yahola, Windthorst-Chigley, Darnell-Stephenville, Tarrant-Newtonia, Granitic Mountains-Tishomingo Soils, Tarrant, Yahola-Port-Reinach and Atkins-Pope. Cropland is the dominant usage with pastures, forested land and timber accounting for the remainder. See Figure II-11.

ENVIRONMENTAL RESOURCES

The southeast region has a variety of environmental features not found in other parts of Oklahoma in such abundance. Rivers and clear flowing streams, forest, scenic mountain trails and clean fresh air are large contributors to the importance of this scenic and recreational region.

Under the 1970 Scenic Rivers Act (House Bill 1152), Upper Mountain Fork River in McCurtain County was designated as a scenic stream.

Scenic Areas

Beavers Bend State Park, located in McCurtain County, covers 1,260 acres and features a swift flowing river. The southern portion of the Ouachita National Forest lies in southeastern McCurtain County, providing natural pine forests and mountains. Little River and its tributaries, Glover and Mountain Fork Rivers, along with the Kiamichi River, contribute to the environmental resources of the region. The Talimena (Skyline) Drive is the only national scenic drive in Oklahoma.

Fish, Wildlife and Recreational Activities

The southeast abounds in clear spring-fed rivers and creeks suitable for bass, catfish, sunfish and others.

Hunting for deer, bobwhite quail, eastern turkey, ducks, geese, fox, squirrels and rabbits is popular. Two State game refuges in Atoka County provide 8,660 acres of free public hunting. Many lakes are available for camping, swimming, boating and picnicking. Broken Bow Reservoir, located in McCurtain County, covers 14,200 acres. Lake Raymond Gary covers 390 acres in Choctaw County and Clayton Lake in Pushmataha County covers 75 acres. Atoka Reservoir covers 5,500 acres.

Regional Historical Features

Almost the entire southeast region was once a part of the vast Choctaw Nation. The Choctaws, like the Cherokees, were a highly developed civilization, with a bicameral legislature and a military department. The capitol was located near present-day Tuskahoma in Pushmataha County. The Civil War divided the Choctaws, and the region became a sanctuary for lawless whites. Following the Civil War, white demand for surplus Indian land brought about Indian land allotment.

FIGURE IV-4
SOUTHEAST REGION
STREAM WATER DATA

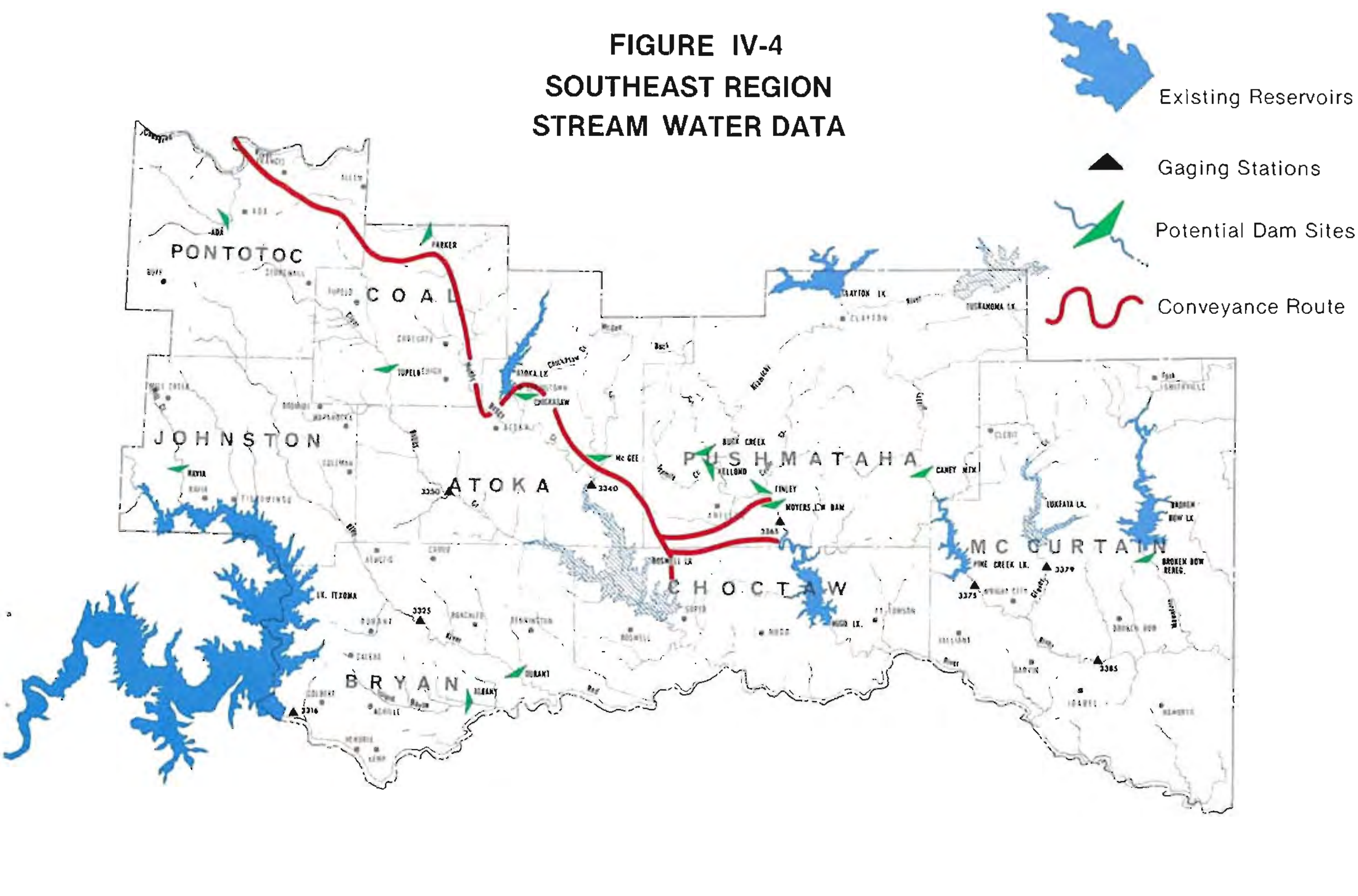


TABLE IV-2

SOUTHEAST REGION PRESENT AND POTENTIAL WATER RESOURCE PROJECTS

NAME OF SOURCE	LOCATION	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	65,000
Broken Bow Lake	Mountain Fork Riv.	WS,FC,P,R,FW	450,000	152,500 [1]	195,900 [1]
Clayton Lake+	Jack Fork Creek	WS,FC,R,FW	128,200	297,200	156,800
Hugo Lake	Kiamichi River	WS,FC,WQ,R,FW	809,200	121,500 [2]	375,100 [2]
Pine Creek Lake	Little River	WS,FC,WQ,FW	388,100	70,500 [3]	134,400 [3]
Sub Total			1,775,500	765,200	927,200
AUTHORIZED					
Boswell Lake	Boggy Creek	WS,FC,R,FW	1,096,000	1,243,800	621,400
Lukfata Lake	Glover Creek	WS,FC,R,FW	171,100	39,400 [4]	67,200 [4]
Tuskahoma Lake	Kiamichi River	WS,FC,R,FW	138,600	231,000	223,900
Sub Total			1,405,700	1,514,200	912,500
TOTAL			3,181,200	2,279,400	1,839,700

NAME OF SOURCE	LOCATION	PURPOSE*	FLOOD CONTROL STORAGE ACRE FT.	CONSERVATION STORAGE	WATER SUPPLY YIELD (AF/YR)
POTENTIAL SITES					
Ada	Sandy Creek	WS,R	0	115,000	23,000
Albany	Island Bayou	WS,FC,R	55,100	85,200	35,800
Broken Bow reregulation structure [5]	Mountain Fork River		-	-	289,000 [5]
Buck Creek	Buck Creek	WS,FC,R	36,300	48,300	56,000
Caney Mountain	Little River	WS,FC,R	105,100	530,000	330,300
Chickasaw	Chickasaw Creek	WS,FC,R	22,000	36,000	17,900
Durant	Blue River	WS,FC,R	232,200	147,000	95,000
Finley	Cedar Creek	WS,FC,R	63,300	210,600	117,600
Kellond	Ten Mile Creek	WS,FC,R	43,300	133,000	72,800
Lukfata Lake Modification	Glover Creek		-	-	145,500 [6]
McGee	McGee Creek	WS,R	-	121,500	60,000
Parker	Muddy Boggy Creek	WS,FC,R	115,400	114,650	47,000
Ravia	Mill Creek	WS,R	0	45,000	19,000
Tupelo	Clear Boggy Creek	WS,FC,R	177,300	302,550	101,000
Sub Total			850,000	1,888,800	1,409,900
TOTAL			4,031,200		3,249,600

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

+Under construction

[1] Includes Water Quality Control Storage of 95,500 acre-feet which yields 123,200 acre-feet per year. Broken Bow Lake also has 317,600 acre-feet of Hydroelectric storage.

[2] Includes Water Quality Control Storage of 73,900 acre-feet which yields 100,800 acre-feet per year. Ultimate stage after Clayton and Tuskahoma are constructed.

[3] Includes Water Quality Control Storage of 21,100 acre-feet which yields 49,320 acre-feet per year.

[4] Includes Water Quality Control Storage of 11,800 acre-feet which yields 20,160 acre-feet per year.

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

[6] Additional yield with modification.

Present and Potential Development

The southeast region is more richly endowed with water and potential dam sites than any other part of the State. With an abundance of stream water, ground water development has been limited. With proper development, if desired, ground water could become one of the prime resources of this region.

STREAM WATER

As shown in Table IV-2, there are existing, under construction or authorized lakes in this region that provide a total of 3,181,200 acre-feet of flood control storage and 1,839,700 acre-feet of water supply. There are additional potential sites having a possible water supply yield of 1,409,900 acre-feet, for a region total of 3,249,600 acre-feet of water supply. Locations of the sites are shown on Figure IV-4.

Watershed Protection and Flood Prevention

The Soil Conservation Service has planned and engineered construction of numerous flood control structures in this region. The purpose of these is to control flooding and silt damage to productive bottom lands and also, in some instances, to provide municipal and irrigation water supplies.

There is a total of 38 small S.C.S. watersheds in this region. Twelve are complete or under construction, 11 more are planned and 15 have potential for development in the next 50 years. To date, a total of 155 structures have been constructed in these watersheds.

With emphasis increasing on development of multiple purpose projects, many cities and towns such as Coalgate, Durant and Antlers are building for dual storage and water control purposes. See Figure I-5 for locations of watersheds and multi-purpose sites.

Stream Water Rights

As of December 31,1973, there was a combined total of 430 vested stream water rights and permits issued in this area. According to Oklahoma Statutes, these are issued to water users on the basis of measurement of acre-feet per calendar year and do not include domestic uses. The tabulation by counties is shown in Table IV-3.

It should be noted that Oklahoma Statutes hold in brief that a permit is reviewed seven years after issue and if the holder has not put the permit amount of water to a beneficial use during this period of time, the water is then considered available for further appropriation.

GROUND WATER

Present ground water development in the southeast region has been small due to the abundance of readily available stream water. Ground water is a natural resource in the region and present development could be expanded. However, there are constraints to water development: small areal extent of the ground water basins (with the exception of the Antlers Sand), topography unfavorable for irrigation development, lack of data concerning hydraulic characteristics of the ground water basins, lack of water quality information, e.g., freshwater/saltwater contact.

Existing Development

Existing ground water development occurs predominantly in two of the four major ground water basins: alluvium and terrace deposits and Antlers Sand. Of the total 221 municipal, industrial and irrigation wells in the region, 111 wells are in the alluvium and terrace deposits. The most favorable area for development of wells is along the Red River where wells yielding several hundred gallons per minute have been completed. The most favorable well sites are those areas with the greatest saturated thickness and the coarsest material.

The Antlers Sand ranks second in importance of development. It has 89 municipal, industrial and irrigation wells in parts of Atoka, Bryan, Choctaw, Johnston, McCurtain and Pushmataha counties. Yields range from a few gpm to more than 650 gpm. The Arbuckle and Simpson Group ground water basins have only a sparse

TABLE IV-3
SOUTHEAST REGION STREAM WATER PERMITS

COUNTY	NUMBER PERMITS ISSUED	AMOUNT ALLOCATED AF/YR
Atoka	46	153,376
Bryan	110	44,212
Choctaw	50	103,631
Coal	20	4,145
Johnston	25	5,286
McCurtain	87	214,729
Pontotoc	26	6,576
Pushmataha	66	22,315
TOTAL	430	554,270

development of 21 municipal, industrial and irrigation wells, although well yields are commonly 200 gpm.

Ground Water Permits

As of July 29, 1974, there was a total of 85 ground water permits issued in this area. These permits allocated ground water to be used as municipal, irrigation, or industrial water. The use of ground water for domestic purposes does not require a permit and therefore is not considered in this section. The tabulation of data from the ground water rights files is shown in Table IV-4.

TABLE IV-4
SOUTHEAST REGION GROUND WATER PERMITS

COUNTY	NUMBER PERMITS ISSUED	NUMBER WELLS	AMOUNT ALLOCATED AF/YR
Atoka	3	14	634
Bryan	28	76	5,135
Choctaw	8	29	2,624
Coal	2	1	565
Johnston	11	27	3,266
McCurtain	5	10	494
Pontotoc	27	62	26,227
Pushmataha	1	2	100
TOTAL	85	221	39,045

Present Uses and Future Requirements

The southeast planning region's population 130,954 (1970 census), is projected to increase to more than 226,000 by the year 2030. Ada has the largest population with 14,859, followed by Durant with 11,118. Other cities with 5,000 or more are Hugo and Idabel. The largest employer in the region is Weyerhaeuser Company with 2,094 employees at their four plant locations.

The municipal and industrial projected water requirements include energy related and rural water district needs. Municipal growth is expected to generally follow growth trends experienced by industry. The vast resources of the southeast will insure the future growth and development within the region.

MUNICIPAL AND INDUSTRIAL

Reported water usage for 1972 was 4,370 acre-feet from ground water and 36,111 acre-feet from stream water, for a total usage of 40,481 acre-feet. Projected requirements for the year 2030 amount to 226,000 acre-feet of water.

RURAL WATER SYSTEMS

There are 38 rural water systems located in the southeast region. Sources of supply include ground water, Boggy and Little Rivers, Coon, San Bois and Mule Creeks. Most of this water is for domestic and household use. However, livestock watering taps have been installed in some areas. The number of rural water systems is expected to increase until the economic limit of service has been reached. Consumer demands of 35,900 people are currently being met, while 97,100 people are presently unserved by any type of public water system. The present number of customers is expected to increase to 39,900 in 1980, 51,900 in 2000 and 65,200 in 2030, based on future projections.

ENERGY RELATED WATER REQUIREMENTS

Energy fuels within the region lie principally in Pontotoc, Coal, Atoka and Bryan counties. Water will be required in varying amounts for production and processing of these energy fuels. For example, new processes for gasification and liquefication are expected to become major consumers of coal within the next decade or so. Secondary and tertiary petroleum recovery processes are expected to require increasing amounts of water. These and other energy related water requirements have been taken in consideration in projecting the municipal and industrial water needs of the region.

IRRIGATION

Total reported water usage for irrigation within this region was 15,795 acre-feet in 1972. Of this, 1,515 acre-feet was from ground water and 14,280 acre-feet was from stream water. By the year 2030, the projected water required for irrigation will be approximately 282,200 acre-feet. This need will be met by individual systems and bank pumping from the Red River mainstem.

OTHER USES AND REQUIREMENTS

Navigation

At present there is no navigation system nor is such development expected in the foreseeable future. The Red River below Denison Dam has been considered as a possible long-range navigable stream. However, power releases from Denison would supply supplemental water required for navigation on the Red River below Denison Dam if it should ever be developed.

Fish, Wildlife and Recreation

The State fish hatchery in Bryan County and the U.S. Fish and Wildlife Service in Johnston County supply fish stocking needs. Water usage was 11,990 acre-feet in 1973, and is projected to increase 7,000 acre-feet in Bryan County.

Water for recreational needs is

considered adequate except for swimming, which will be provided by the individual community.

Hydroelectric Power

The 841,000 acre-feet per year required for hydroelectric power at Broken Bow Reservoir is not included in the proposed water requirements of the southeast region. Water used for hydroelectric power generation is not considered consumptive use of water. This is the only hydroelectric power reservoir in this region and no other hydroelectric power reservoirs are proposed at this time.

Water Quality Control

Water storage for low flow water quality requirements from Broken Bow, Pine Creek, Hugo and Lukfata (authorized) total 202,300 acre-feet per year. This water requirement has been provided for in this region's water requirements. This water is slowly released to prevent stagnant pools of water from forming and lowering water quality in the different streams. The water will be dedicated for this purpose until such time as needed for water supply purposes.

Plan of Development

MAJOR RESERVOIR SYSTEM

Table IV-5 shows the 2030 demand and the recommended supply system of major reservoirs for southeastern Oklahoma. This reservoir system and a portion of the conveyance system is shown on Figure IV-4. The entire water conveyance system is shown on Figure I-2 of Section I. An unallocated surplus of 343,500 acre-feet per year remains after satisfaction of 50-year in-basin needs and inter-basin requirements. The inter-basin requirements are about 45 percent for municipal and industrial and 55 percent for irrigation uses. Reservoir yields shown in Table IV-5 are based on a 50-year dependability. Tolerable shortages for irrigation, on the other hand, can be on a once-in-10-years basis. Thus, the firm yield would be approximately 20 percent larger when used for irrigation.

The Parker and McGee Creek Lakes would be constructed before the conveyance canal and would be independent of the interconnected system. One of these two lakes would be used to supply water to the existing Atoka pipeline, utilizing additional capacity of that line to supply central Oklahoma until the conveyance canal can be constructed. The remaining yield from the two lakes would be available to satisfy basin-of-origin needs. Oklahoma City has expressed an interest in obtaining water from the McGee Lake. Others in central Oklahoma have expressed interest in obtaining water from Parker Lake.

The Albany Lake will provide for the water requirements in the Durant area.

The potential sites shown on Figure III-4 will be utilized after year 2030 and will yield an additional 1,300,000 acre-feet per year.

WATERSHED PROTECTION PROGRAM

For discussion of the proposed watershed protection program, see the Statewide Summary, Section I.

Municipal Needs and Proposed Solutions

Table IV-6 shows the present status and proposed solutions to the water supply needs of towns in the southeast region. Of the 54 communities surveyed, 16 were served by rural water systems. A breakdown of the remaining 38 cities showed that 15 are, or soon will be served by stream water.

The relatively high use of stream water is the result of the high annual rainfall. This high rainfall rate gives a plentiful

TABLE IV-5
SOUTHEAST REGION WATER SUPPLY AND DEMAND IN 1000's OF ACRE-FEET ANNUALLY

ESTIMATED 2030 IN-BASIN REQUIREMENTS

Municipal and Industrial	226.0
Irrigation	282.0[1]
TOTAL	508.0

[1] Irrigation needs to be met by individual systems and bank pumping from Red River Mainstem.

PLANNED 2030 SUPPLY

SOURCE RESERVOIRS	YIELD	INTER-BASIN NEEDS (surplus)	IN-BASIN NEEDS	UNALLOCATED SURPLUS
Broken Bow (E)	195.9	—		
Pine Creek (E)	134.4	—		
Lukfata (A)	67.2	—		
Tuskahoma (A)	223.9	212.7		
Clayton (A)	156.8	145.6		
Hugo (E)	375.1	346.3		
Parker (P)	47.0	—		
McGee Creek (P)	60.0[2]	—		
Boswell (A)	621.4	603.4		
Albany (P)	35.8	—		
Atoka (E)	65.0[3]			
TOTAL	1,877.5[3]	1,308.0	226.0	343.5

(E) Existing or under construction
(A) — Authorized
(P) — Proposed
[2] 40,000 acre-feet to be diverted out of basin before construction of conveyance canal.
[3] Atoka Lake not included in total—now being diverted out-of-basin.

supply of good quality stream water, but it has also hindered the development of ground water in this region.

The ground water basins in the area have the potential to meet a larger part of the regions needs. The Arbuckle Group in particular has not been fully developed.

The problem for the majority of cities in the southeast region is a problem of distribution rather than a supply shortage. This is in contrast to the problems of communities in the southwest region. In the southwest, the main problem associated with municipal supply is a shortage of raw or treatable water.

Distribution systems were proposed for part of Bryan County, small towns near Hugo Reservoir, and part of Coal County. The system in Bryan County will depend upon Durant obtaining a plentiful water supply in the future. The system in Coal County might be implemented by the extension of existing rural water district lines. Currently, 11 cities and towns in the southeast region use stream water and 27 use ground water. Many of these towns will need financial help to develop their long-term sources.

TABLE IV-6
SOUTHEAST REGION MUNICIPAL NEEDS AND PROPOSED SOLUTIONS

COUNTY CITY	PRESENT SOURCE	SHORT TERM NEEDS & PROPOSED SOLUTIONS (Present to 1990)	LONG TERM ALTERNATIVE(S) (From 1990 on)	COMMENTS
ATOKA				
Atoka	Muddy Boggy Creek Water released from Atoka Lake	Support the development of McGee Creek Reservoir and dam site 14 mi. SE of town. City officials feel that Atoka can get by until McGee Creek Res. is built.	Same as short term.	Atoka has expressed an interest in becoming the distribution point for a countywide water system. McGee Creek should provide adequate water for the proposed system.
Stringtown	Ground water- in a minor ground water basin	Obtain water from the city of Atoka. Are in the process of running a water line from the city of Atoka.	Same as short term.	
BRYAN				
Achille	Ground water- Antlers Sand	Additional wells in the Antlers Sand No immediate problems	1) Same as short term. 2) Distribution system from Durant or from proposed Boswell Reservoir and dam site.	City officials say they might use water from Durant if a countywide system develops in the future.
Bennington	Ground water- Bennington Rural Water District	Expand their well system in the Antlers Sand. They should drill at least one additional well immediately.	1) Same as short term. 2) Distribution system from the city of Durant or Hugo Reservoir.	
Bokchito	Ground water- Antlers Sand	1) Expand their well system in the Antlers Sand. 2) Possible dam site on Bokchito Creek E. of town Bokchito has recently added another well to its system. No immediate source problems are anticipated.	1) Same as short term. 2) Distribution system from Durant.	They have trouble with their wells sanding in.
Caddo	Ground water- Antlers Sand	Additional wells in the Antlers Sand. Caddo is planning to drill an additional well. This should ease their water problems.	1) Same as short term. 2) Distribution system from Durant.	
Calera	Ground water- Antlers Sand	1) Additional wells in the Antlers Sand 2) Purchase water from Durant Calera should implement one of these alternatives as swiftly as possible.	Obtain water from Durant.	Rapid growth is anticipated for this community.
Colbert	Ground water- Antlers Sand	Additional wells in the Antlers Sand No immediate problems.	1) Same as short term. 2) Distribution system from Durant	

COUNTY CITY	PRESENT SOURCE	SHORT TERM NEEDS & PROPOSED SOLUTIONS (Present to 1990)	LONG TERM ALTERNATIVE(S) (From 1990 on)	COMMENTS
Durant	Blue River	1) Develop one or more of the proposed SCS sites near town. 2) Proposed Albany Reservoir & dam site, 12 mi. SE of town. 3) The potential for further development in the Antlers Sands also exists. Durant needs to begin the development of one of these alternatives as quickly as possible.	1) Same as short term. 2) Durant Reservoir & dam site 17-18 mi. SE of town	If Durant obtains water from one of these major reservoirs, they should have adequate water to become the distribution point for a countywide distribution system.
Hendrix-Kemp	Ground water-Red River alluvium	Drill additional wells in the Red River alluvium. No immediate problems.	Same as short term.	Since little growth is anticipated for their area, they should not need to utilize the proposed countywide system, except possibly for an emergency source.
Kenefic	Ground water-Antlers Sand	1) Expand their well system 2) Obtain water from the city of Caddo No immediate problems.	1) Same as short term. 2) Utilize water from a countywide distribution system.	This community also expects little or no future growth.
CHOCTAW				
Boswell	Ground water-Antlers Sand	Expand well system in the Antlers Sand. A recently developed 0.1 mgd well should alleviate any short term problem. Another well of 0.1 mgd yield is available if needed.	1) Same as short term. 2) Obtain water from proposed Boswell Reservoir & dam site 3-4 mi. NE of town	Bennington, Unger and Soper could join with Boswell to develop a system utilizing water from the proposed Boswell Res.
Fort Towson	Ground water-Antlers Sand	Expand well system in the Antlers Sand. Ft. Towson will need an additional well in the near future.	Same as short term.	Hugo Reservoir might be a feasible source if enough users can be assembled to lower the cost per gallon price.
Hugo	Ground water-Antlers Sand	Obtain water from Hugo Reservoir. Hugo may have to drill additional wells until Hugo Res. water is implemented.	Same as short term.	Hugo may have to negotiate for more water from Hugo Res. to meet its long term needs.
Soper	Ground water-Antlers Sand	Drill additional wells in the Antlers Sand. Soper should explore the surrounding area to find a dependable location in the Antlers Sand.	1) Same as short term. 2) Obtain water from a distribution system which would get water from Hugo Reservoir.	See comments for Boswell.
COAL				
Coalgate	Coalgate Lake (SCS) and wells in a minor ground water basin	Continue with present sources. No source problems.	1) Same as short term. 2) An additional SCS site is located NE of town. It could be developed if needed in the future.	Coalgate has the water available to meet the long term needs of the entire county if it can be properly distributed.
Lehigh	Ground water-wells in a minor ground water basin	Obtain water from Coalgate by extension of Phillips Rural Water District #1 or laying a line from Coalgate. No immediate problems.	Same as short term.	
Tupelo	Ground water-wells in a minor ground water basin	1) Extension of Rural Water District #2 which serves Centrahoma. 2) Develop a well field in the Arbuckle Group 7-8 mi. W. of town. No immediate problems.	Same as short term.	

COUNTY CITY	PRESENT SOURCE	SHORT TERM NEEDS & PROPOSED SOLUTIONS (Present to 1990)	LONG TERM ALTERNATIVE(S) (From 1990 on)	COMMENTS
JOHNSTON				
Bromide	One spring in the Arbuckle Group	Continue with present system. The spring is adequate.	Continue with present system.	No problems are anticipated with this source in the future.
Coleman	Ground water-Antlers Sand	1) Expand wells system as the demand necessitates. 2) Rural Water District, city needs to begin implementation of one of these alternatives soon.	Same as short term.	Their present system was designed for 100 families. Present population 160 people or 50 families.
Mill Creek	Ground water-Arbuckle Group	Drill additional wells in the Arbuckle Group. No immediate problems.	Same as short term.	There is plenty of good quality ground water available for future expansion for domestic growth.
Ravia	Ground water-Antlers Sand	Expand well system in the Antlers Sand. No immediate problems.	Same as short term.	No problems forseen with their ground water source.
Tishomingo	Pennington Creek	Develop a well field in the Antlers Sand S. and E. of town as it becomes necessary to supplement stream water during low flow periods.	1) Same as short term. 2) Support the development of the proposed Mill Creek Reservoir and dam site W. of town.	
Wapanucka	Wapanucka Lake	1) Utilization of one of the proposed SCS sites near town 2) Develop a well field in the main Arbuckle Group W. and NW of town. No immediate problems.	Same as short term.	
McCURTAIN				
Broken Bow	Mountain Fork River below Broken Bow Reservoir	Continue with present source. No problems with source.	Same as short term.	City officials feel their present source will be adequate unless unexpected growth occurs.
Clebit	Ground water-wells in a minor ground water basin	1) Drill more wells if the demand increases 2) Establish a Rural Water District. Clebit should seek a supplemental source of water in case unexpected growth occurs.	Same as short term.	Little growth is expected for this community. A Rural Water District possibly using water from the Mountain Fork River would provide an adequate dependable source.
Garvin	Ground water-Antlers Sand	1) Expand well system as it becomes necessary. 2) Purchase water from some other source. Garvin should develop an additional well for emergency standby purposes.	Purchase water from some other source.	This community may grow due to its location near Idabel. They might obtain water from either Pine Creek Reservoir, the proposed Lufata Res. & dam site, the city of Idabel or a Rural Water District north of town.
Haworth	Ground water-wells in a minor ground water basin	Obtain Rural Water District water; entirely, or as an emergency standby source. Should develop a dependable good quality source as quickly as possible.	Same as short term.	Haworth needs a more dependable source of water. The Rural Water District would meet this need.
Idabel	Little River	Continue with present source. No short term problems foreseen.	Support the development of Lufata Reservoir & dam site 18-21 mi. N. NW of town.	

COUNTY CITY	PRESENT SOURCE	SHORT TERM NEEDS & PROPOSED SOLUTIONS (Present to 1990)	LONG TERM ALTERNATIVE(S) (From 1990 on)	COMMENTS
Valliant	Little River	Continue with present source. This source should be adequate unless the paper mill expands its operations.	Same as short term.	Valliant gets Little River water from the pipeline which furnishes water to the paper mill west of town.
Wright City	Little River	Continue with present source. No problems are are foreseen with this source.	Same as short term. Might need to apply for a supplemental water appropriation from Little River.	Picks up water from Pine Creek Reservoir water releases. May need to obtain rights to more water from Little River in the future.
PONTOTOC				
Ada	Ground water-Byrd's Mill Spring and wells in the Arbuckle Group	Obtain more water from the springs and drill additional wells in the Arbuckle Group. No short term problems.	1) Same as short term. 2) Have applied for water rights on proposed Parker Reservoir & dam site.	Ada should be able to meet its long term needs by supplementing the yield of Byrd's Mill Spring with additional wells in the same general area.
Allen	Ground water-Canadian alluvium	Drill additional wells in the Canadian alluvium. No immediate problems are anticipated.	1) Same as short term. 2) Have applied for water rights on proposed Parker Reservoir & dam site.	
Francis	Ground water-wells in a minor ground water basin	Francis is developing a well field in the Canadian River alluvium which should solve their short term problems.	Continue development of ground water supply from alluvium deposits.	
Roff	Ground water-Arbuckle Group	Continue to utilize ground water from the Arbuckle Group. Roff should have at least one additional well for a standby source.	Continued expansion of their well system.	City officials feel there is plenty of good quality ground water available by drilling more wells.
Stonewall	Ground water-Arbuckle Group	Continue expansion of well system as requirements increase. Stonewall should have no short term source problems.	Same as short term.	Stonewall's wells in the same general area as Ada's spring can produce plenty of good quality water.
PUSHMATAHA				
Antlers	Kiamichi River	Obtain water from Hugo Reservoir 10 mi. E. of town. Antlers should have sufficient water until Hugo Res. water is utilized.	Antlers should have adequate water from Hugo Res. for its long term needs.	
Clayton	Kiamichi River	City officials feel the city can get by until work is completed on the Clayton Reservoir and dam site.	Clayton Reservoir should provide adequate water for this city's long needs.	

CENTRAL REGION

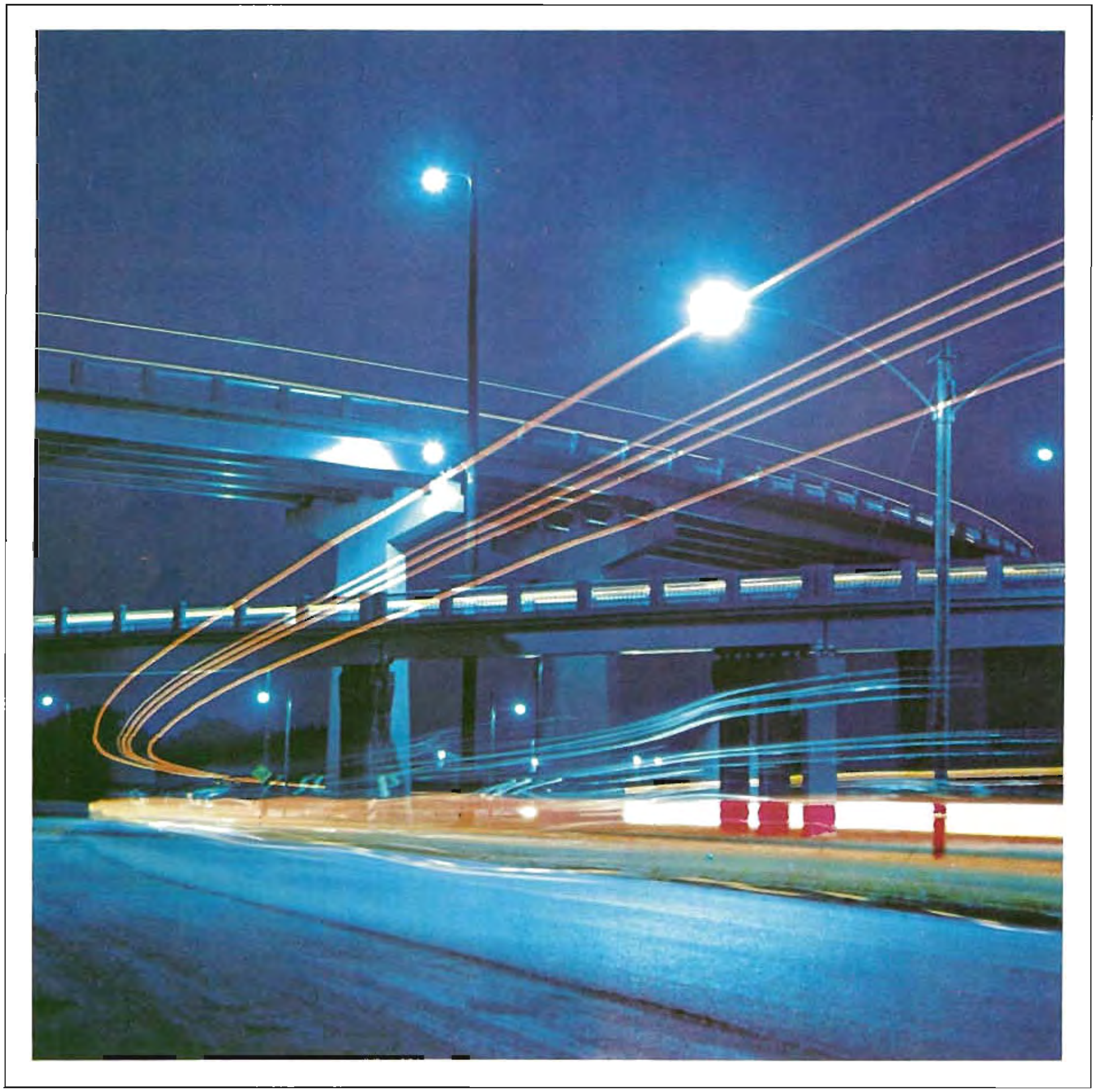


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FIGURE

General Description

The central region, comprised of Canadian, Cleveland, McClain, Oklahoma and Pottawatomie counties, covers an area of 3,544 square miles. Elevations vary from approximately 1,350 feet above mean sea level near Oklahoma City to about 1,150 feet in the south.

The region has a subhumid climate with pronounced day-to-day changes and mild seasonal changes. Short summer droughts occasionally necessitate water rationing for city dwellers and limited use by farmers. The growing season is approximately 200 days per year. The Canadian River cuts through the southern half of the region, and the North Canadian passes through the northern part.

Other major streams include Little River and Upper Deep Fork. Minor streams are Deer, Walnut and Pond Creeks. The region is bounded by Kingfisher, Lincoln and Logan counties on the north and Grady, Garvin and Pontotoc counties on the south.

The 1970 population of the five county region was 941,061, nearly half of the State's two-and-a-half million people. Two-thirds of the region's population is in the metropolitan Oklahoma City area, with 644,083 people. Other cities included in this region are Norman, Midwest City, Edmond, El Reno, Shawnee and Purcell.

Planning Area Resources

PRECIPITATION

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 low intensities over larger areas. As shown in Figure II-1, average annual precipitation ranges from 28 inches in the northwestern part of this region to 38 inches in the southeastern portion.

EVAPORATION AND TEMPERATURE

Figure II-3 shows average annual lake evaporation ranging from 63 inches in the northwest to 57 inches in the southeast. Average annual evaporation greatly exceeds average annual precipitation in this area. High winds and hot temperatures combine to produce a high amount of water loss from lakes. Great storage capacities are required due to this loss. The mean annual temperature is between 60 and 62 degrees throughout the region. See Figure II-2.

STREAM WATER CHARACTERISTICS

This five county region has a combined drainage area of 3,544 square miles. The Deep Fork River and the Little River originate in this area. Deep Fork has its source in northwest Oklahoma City and flows easterly to its confluence with the North Canadian River within Eufaula Reservoir. Approximately two-thirds of the Little River basin is in this region. Its flow is regulated by Lake Thunderbird.

The Canadian and North Canadian Rivers both enter the northwest corner and flow out southeasterly where they later enter Lake Eufaula.

The Cimarron and Washita Rivers do not flow through this region, but 640 square miles of their drainage areas originate here.

Beneficial use of stream water is restricted in some basins because of the quality of the water. It has also been determined that no additional stream water is available for appropriation in the North Canadian basin above the Oklahoma-Pottawatomie County line and above Lake Thunderbird in the Little River basin. Restrictions are applicable to any allocations of stream water from the Washita basin in southwestern McClain County.

Due to increasing demands for high quality water, alternate sources must be sought if this area is to continue to develop.

Runoff

The average annual runoff from precipitation ranges from two inches in the northwest to seven inches in the southeast. See Figure II-4. This is an average annual runoff of approximately 785,000 acre-feet per year.

Discharge may vary widely from the runoff as a result of diversion, consumption, regulation by storage and other factors. Low flows in the North Canadian and the Deep Fork are sustained by Oklahoma City's sewage effluent.

A summary of streamflow records at U.S.G.S. gauging stations inside the region is presented in Table IV-7.

Flooding

Most floods here are caused by intense thunderstorms in which flood waters rise rapidly, but are

TABLE IV-7
CENTRAL REGION STREAMFLOW SUMMARY

STREAM	U.S.G.S. STATION NUMBER	CONTRIBUTING DRAINAGE AREA SQ. MILE	AVERAGE ANNUAL FLOW AF/YR	OBSERVED FLOW (CFS) MAX	MIN
North Canadian	2415.5 - near Harrah	8,602	142,000	5,130	23
Deep Fork	2423.5 - near Arcadia	108	32,000	5,260	16
Canadian	2291 - near Noble	21,110	236,900	35,500	0
Little River	2305 - near Tecumseh	456	38,110	32,400	0

usually back within their banks a few hours after the storm.

Serious flood and drainage problems exist along the Deep Fork basin. Major floods occur on the average of twice yearly. The Little River basin had serious flooding problems until 1965. This flooding problem was reduced considerably with the construction of Lake Thunderbird by the Bureau of Reclamation.

Stream Water Quality

Quality of water considerations restrict the use of several major streams in this area for beneficial use. The water quality of the Canadian River, the North Canadian River below Oklahoma City and the lower part of the Deep Fork River does not meet the accepted standards for municipal and domestic use because of waste water returned to these streams. Most stream water in this region is suitable for irrigation depending on soil type and the crops to be grown.

GROUND WATER RESOURCES

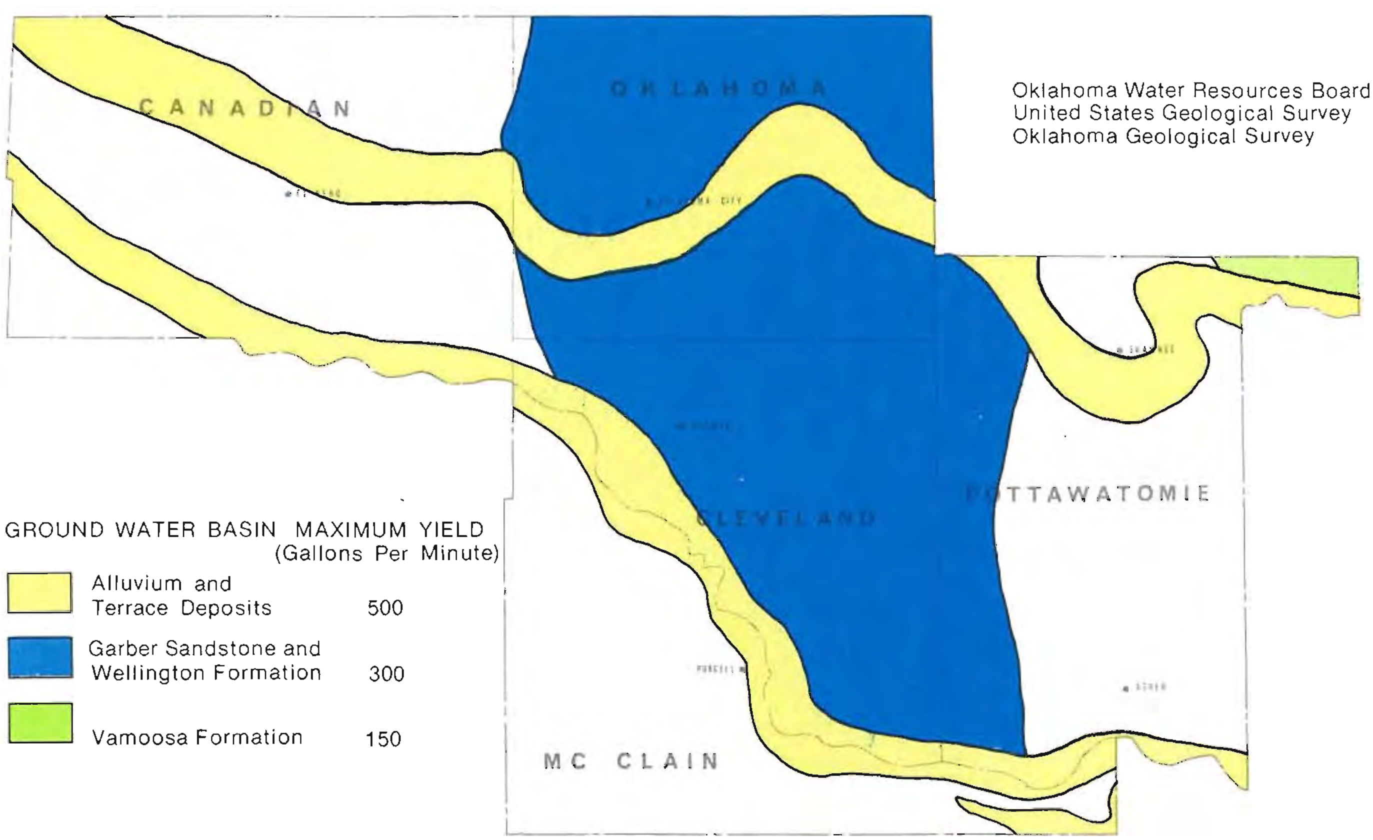
Three major ground water basins are located in central Oklahoma: Vamoosa Formation, Garber-Wellington Formation and alluvium and terrace deposits. For locations of these ground water basins, see Figure IV-5. The Garber-Wellington is a principal source of water for municipal, irrigation and industrial purposes. Oklahoma City, Edmond, Nichols Hills, Del City, Midwest City, Moore, Noble and Norman all have wells in the formation. The alluvium and terrace of the North Canadian River is the source of water supply for the municipalities of El Reno, Yukon, Okarche, Geary and Calumet. Additional users are industries and irrigation farmers. See Table II-2 for total water in storage and amounts recoverable from ground water basins..

Vamoosa Formation - See East Central Planning Region.

Garber-Wellington Formation (Permian in age) 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 as a single water bearing unit.

The total thickness of the combined formations is 800-1,000 feet. Depth to water varies from 100 feet or less in areas of outcrop to 350 feet in structural depressions (for example, Midwest City). Well yields range from 50-450 gpm and average 200 gpm. Water from the Garber-Wellington is suitable for drinking, but locally is high in sulfate, chloride or other mineral constituents. Total dissolved solids range from 109-2,100 mg/l.

FIGURE IV-5
CENTRAL REGION GROUND WATER BASINS



At most places, the water is suitable for irrigation, but in some areas the water contains an excessive amount of sodium.

Alluvium and Terrace deposits (Quaternary) occur in all five counties, along the Canadian and North Canadian Rivers and Deep Fork 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 and gravel in lower parts yield water to wells freely, while the upper part is fine grained, less permeable silt or clay. Maximum thickness of the deposits is 90 feet, but they average 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 more than 500 mg/l. Generally, the water is a calcium magnesium bicarbonate type.

MINERAL RESOURCES

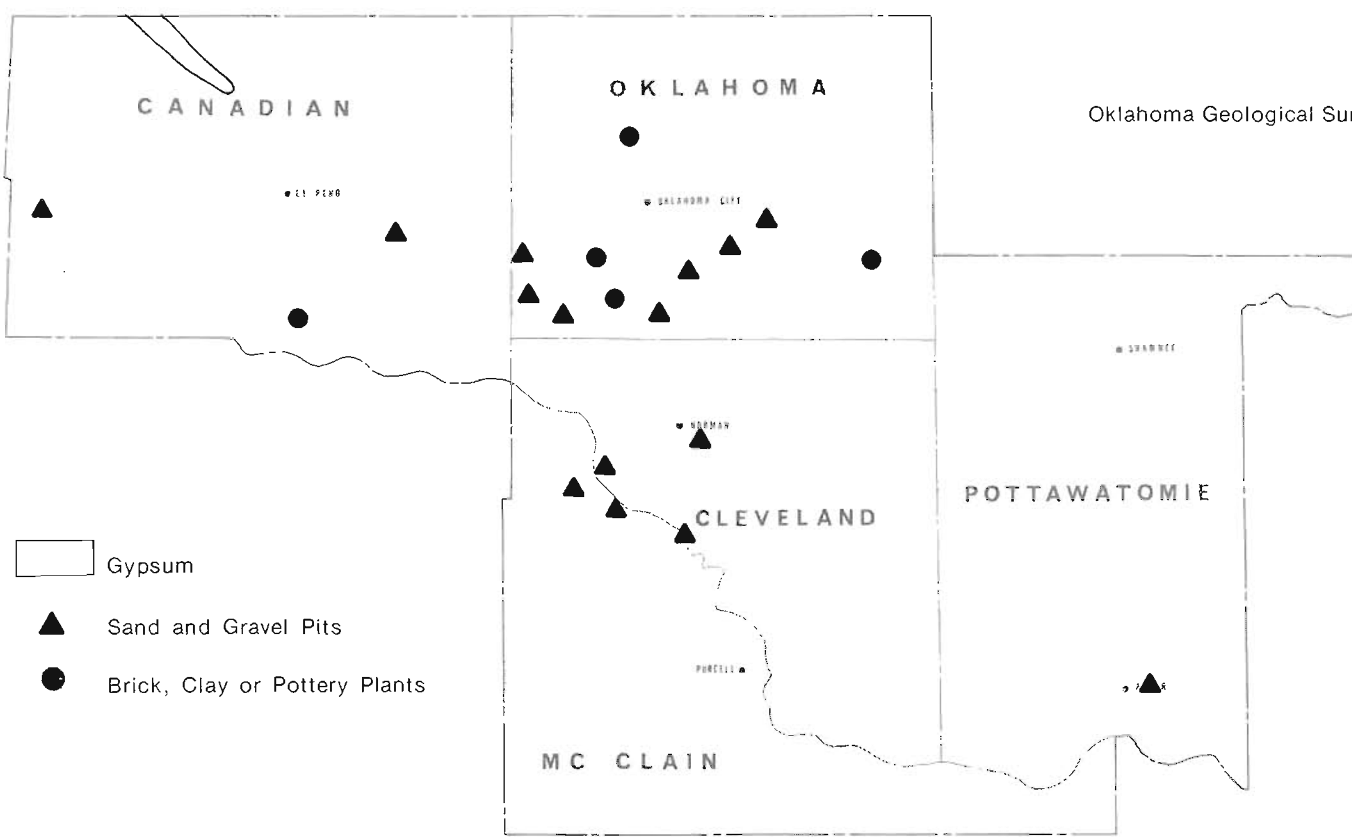
Mineral resources of central Oklahoma consists mostly of oil and gas, with small amounts of non-petroleum products. Four giant oil fields, with ultimate recovery of more than 100 million barrels, occur in the area of Oklahoma City, west Edmond, Earlsboro and St. Louis. Gas processing plants are located in or near Oklahoma City and Edmond. The region has a high rate of oil and gas development and exploration, because of the relatively shallow depths to production and the opportunity for multiple pay zones.

Non-petroleum production consists of asphalt, cement, lime and shale. Numerous sand and gravel pits operate in Oklahoma, Canadian and Cleveland counties. Most production is from the alluvial deposits and the material is used extensively for building purposes. See Figures IV-6 and IV-7.

LAND RESOURCES

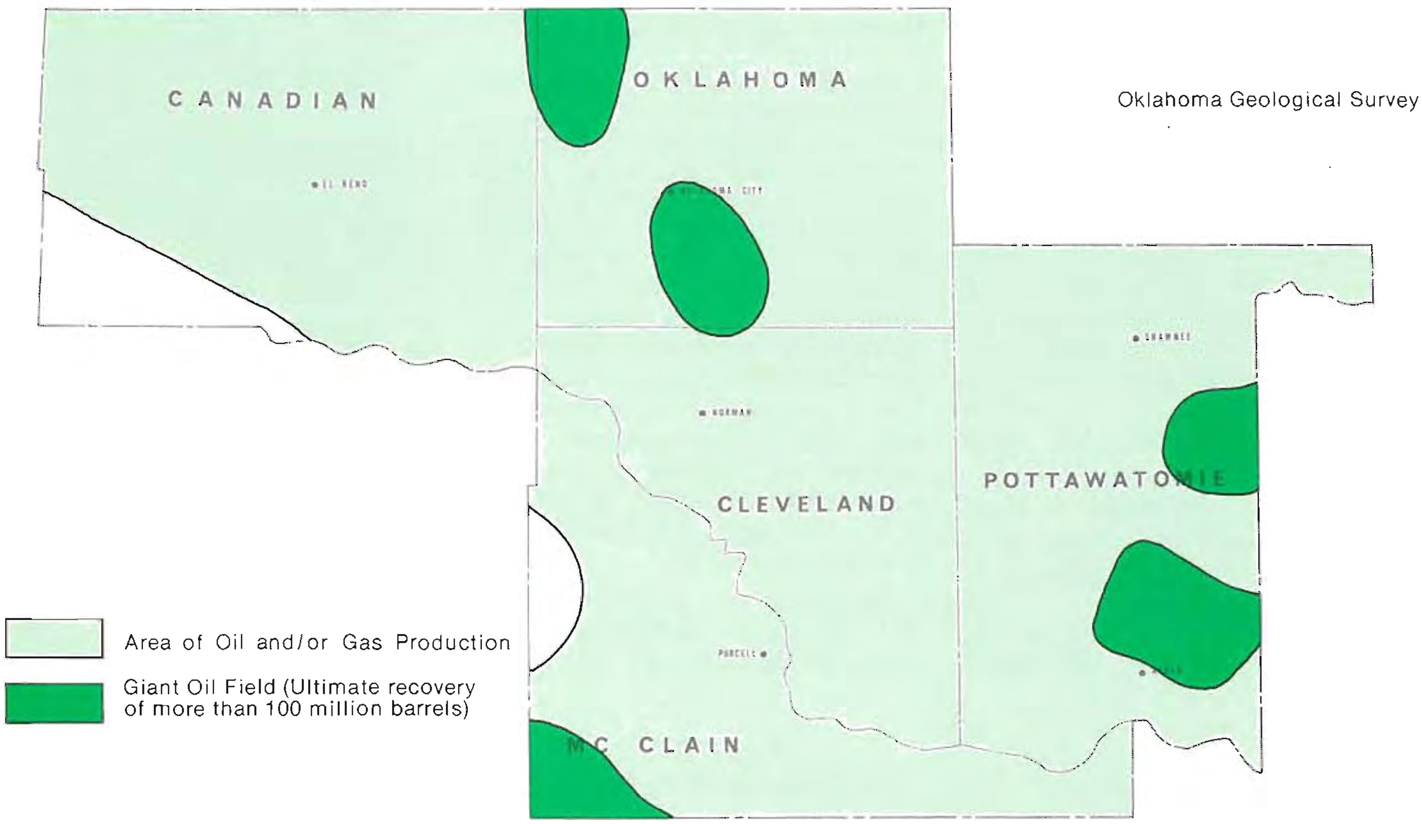
This region contains Oklahoma's largest metropolitan center. Approximately 1,276 square miles are classified as urban and this area is increasing each year. Oklahoma County has become a processing and marketing center of farm produce. Presently, 849,873 acres are in use as crop and pastureland. This area is fast becoming a leading producer of beef and diary cattle and quarter horses. The 1972 Reported Water Use showed that the central region had 20,002 acres under irrigation. This includes only reported acres and does not

FIGURE IV-6
CENTRAL REGION MINERALS



Oklahoma Geological Survey

FIGURE IV-7
CENTRAL REGION OIL AND GAS



represent the region total. Oklahoma State University Extension Service in 1973 reported a region total irrigated acres of 18,495 acres.

SOILS

The central region's soil is divided into two major associations. These are the Renfrow-Zaneis-Vernon and the Darnell-Stephenville associations. Cropland is the primary use with pasture secondary. Dougherty-Teller-Yahola, Yahola-Port-Reinach, Vanoss-Minco-Yahola, Rough Broken Vernon Land and Bethany-Tabler-Kirkland are minor soil associations. Cropland is the primary consumptive use of these soil associations, along with pasture and rangeland. See Figure II-11.

ENVIRONMENTAL RESOURCES

Though largely urban, the central region has an abundance of natural resources. Rivers, reservoirs and recreational areas are plentiful.

Scenic Areas

The central region offers many scenic farmlands and waterways, such as the North Canadian, Canadian and Little Rivers. Broad, sandy river basins have given rise to the new sport of dune-buggy racing. The view of the Canadian River valley from the hills of Purcell in McClain County is spectacular. The Little River near Norman is predominantly covered with post oak and blackjack trees.

Fish, Wildlife and Recreational Activities

Numerous public hunting areas are available. Hunters take approximately one-half million bobwhite quail, over 600 deer and thousands of doves, waterfowl, rabbits, squirrels and other game species annually.

Lexington Public Hunting Area, in Cleveland County, covers 8,780 acres and Thunderbird Public Hunting Areas, on the upper Little River and Hog Creek of Lake Thunderbird, cover approximately 1,200 acres each.

The Oklahoma Department of Conservation Game Farm and Center near El Reno in Canadian County produces over 75,000 quail per year.

The region has many varieties of fish, including largemouth bass, crappie and channel catfish. The numerous lakes, such as Thunderbird, Overholser and Hefner also provide space for motor and sailboat enthusiasts.

Regional Historical Features

The central region, where the State capitol, Oklahoma City, is located, contained most of the "unassigned lands" which were opened to settlers in April, 1889.

Over 50,000 people participated in the run. A large number of settlers called "Sooners" entered early, staking land claims, and thus earning their name. Oklahoma, with 1,500,000 people in 1907, became a state.

Three major universities, the University of Oklahoma, Central State University and Oklahoma City University, are located within the region. The National Cowboy Hall of Fame is also located in Oklahoma City.

Present and Potential Development

Very few suitable sites are left for development of large lakes due to terrain, lack of adequate stream flow and limited drainage areas in the tributaries.

Oklahoma City's municipal and industrial water demand has forced it to obtain water from outside the region. The city has bought storage in Canton Reservoir in Blaine and Dewey counties and receives this water through releases down the North Canadian River. It has also constructed Lake Atoka in Atoka County, and pumps water 100 miles through a 60 inch diameter pipeline.

At present, the principal source of ground water in this region is the Garber-Wellington Formation. There are possibilities for additional development in this ground water basin as well as in the terrace deposits and alluvium of the Canadian, North Canadian and Deep Fork Rivers.

STREAM WATER

As shown in Table IV-8, there are existing, under construction or authorized lakes in this region that provide a total of 147,300 acre-feet of flood control storage and 101,200 acre-feet of water supply. There are additional potential sites having a possible water supply yield of 30,000 acre-feet, for a region total of 131,200 acre-feet. Locations of the sites are shown on Figure IV-8.

Sites not included in the potential resource table are Hog Creek and West Elm Creek, each with a conservation storage capacity of 100,000 and 170,000 acre-feet respectively, for a total of 270,000 acre-feet. These storage reservoirs are designed to hold transported water and develop no yield of their own.

Watershed Protection and Flood Prevention

The Soil Conservation Service has planned and engineered construction of numerous flood control structures in the five county area. The purpose of these structures is watershed protection and flood prevention. They are also used for irrigation and recreation. The city of El Reno is provided excellent recreation facilities from one of these multi-purpose flood prevention structures. There are a total of 31 small S.C.S. watersheds in this region. Fifteen of these are complete or under construction, 5 are planned and 11 have potential for development in the next 50 years. To date, a total of 133 structures have been constructed in these watersheds. For location of these watersheds, see Figure I-5.

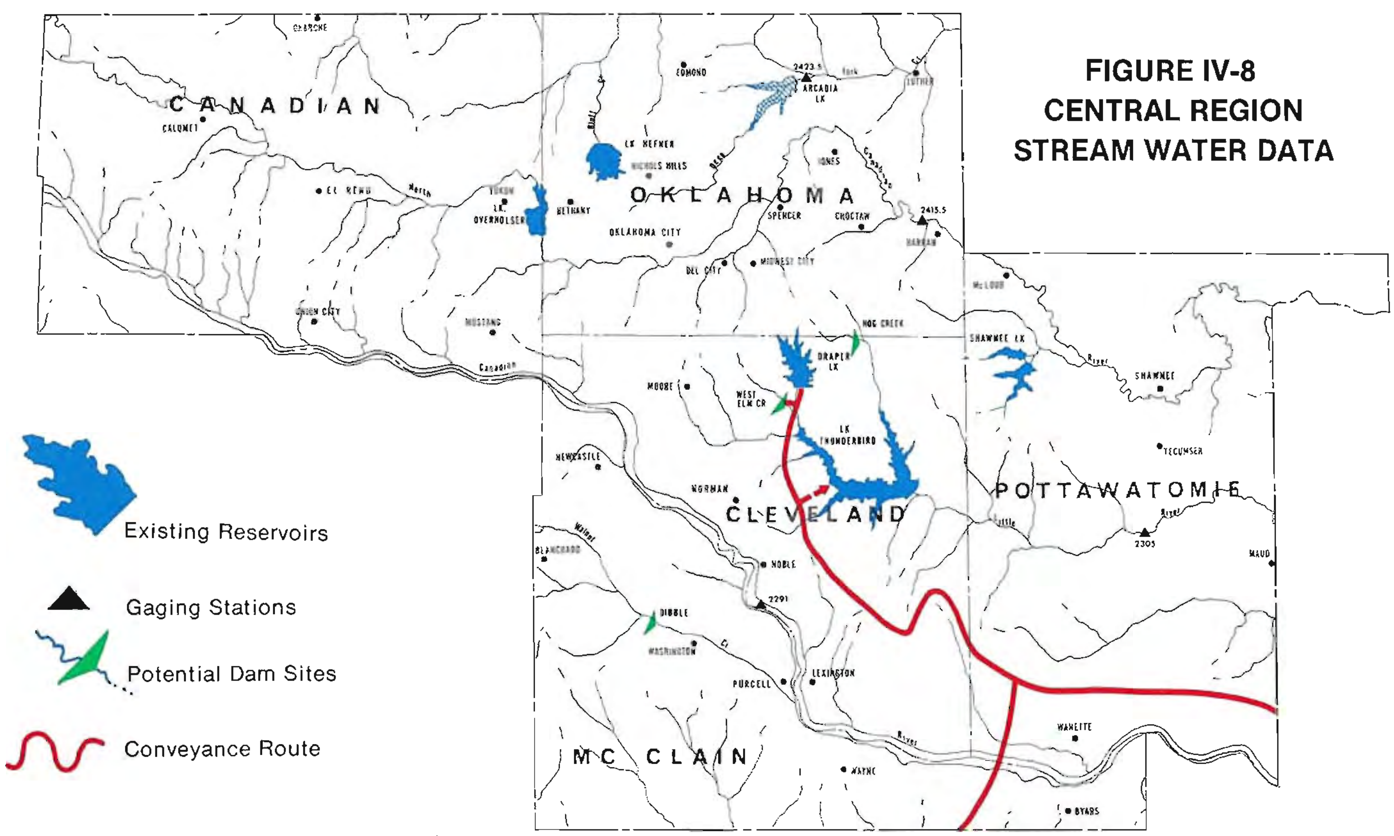


FIGURE IV-8
CENTRAL REGION
STREAM WATER DATA

TABLE IV-8
CENTRAL REGION PRESENT AND POTENTIAL WATER RESOURCE PROJECTS

NAME OF SOURCE	LOCATION	PURPOSE*	FLOOD CONTROL STORAGE ACRE FT.	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
		EXISTING OR UNDER CONSTRUCTION			
Draper Lake	E. Elm Creek	WS,R	0	100,000	41,000 [1]
Lake Hefner	Bluff Creek	WS,R	0	75,000	17,000 [2]
Lake Overholser	N. Canadian River	WS,R	0	17,000	5,000 [2]
Lake Thunderbird	Little River	WS,FC,R	76,600	105,900	21,700
Shawnee Lake	S. Deer Creek	WS,R	0	34,000	4,400
Sub Total			76,600	331,900	89,100
		AUTHORIZED			
Arcadia Lake	Deep Fork Ck.	WS,FC,R	70,700	63,000	12,100
TOTAL			147,300	394,900	101,200
		POTENTIAL		CONSERVATION STORAGE	
Dibble	Walnut Creek	WS,FC,R	25,200	161,000	30,000
TOTAL			172,500		131,200

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

[1] Draper Lake is a terminalstorage lake for which water is pumped from Lake Atoka in Atoka County. Average yield of Lake Atoka is 65,000 acre-feet per year. There is (37mgd) 41,000 acre-feet per year available for water supply out of Draper Lake.

[2] Yield from North Canadian, deducting losses from Lake Hefner and Lake Overholser, is 22,000 acre-feet per year (19.6mgd). This does not include releases from Canton Reservoir.

Stream Water Rights

As of July 17, 1974, there was a combined total of 194 vested stream water rights and permits issued for the appropriation of 102,158 acre-feet of water per year from rivers, streams and lakes. The tabulation by counties is shown in Table IV-9.

GROUND WATER

Development in the ground water basins of the central region is extensive. Ground water withdrawals from the Garber-Wellington Formation began before 1900. At present, this ground water basin is the principal source of water for municipal and industrial purposes. The alluvium and terrace deposits, in contrast, supply ground water mainly for domestic and stock use. There are possibilities for additional development in both ground water basins.

Existing Development

At present, development of ground water in the central region consists of 825 municipal, industrial and irrigation wells. Of this total, 368 are in the Garber-Wellington Formation and 457 are in the alluvium and terrace deposits.

Development in the Garber-Wellington and alluvium and terrace deposits has been extensive. The Garber-Wellington yields large quantities of water to wells. In Oklahoma and Cleveland counties, wells are reported to yield as much as 450 gpm, averaging 200 gpm. The alluvium and terrace deposits similarly yield from less than 100 gpm to as much as 600 gpm, with an average of 200 gpm. Both ground water basins contain water to be developed.

Ground Water Permits

As of July 31, 1974, there was a total of 352 ground water permits issued in this area. These permits allocate fresh ground water to be

TABLE IV-9
CENTRAL REGION STREAM WATER PERMITS

COUNTY	NUMBER PERMITS ISSUED	AMOUNT ALLOCATED AF/YR
Canadian	30	6,948
Cleveland	16	4,108
McClain	54	9,916
Oklahoma	44	59,984
Pottawatomie	50	21,202
TOTAL	194	102,158

used as municipal, irrigation or industrial water. The use of ground water for domestic purposes does not require a permit and therefore is not considered in this section. The tabulation of data from ground water files is shown in Table IV-10.

Present Uses and Future Requirements

The central planning region's population of 941,061 (1970 census), is projected to rise to 1,429,700 by the year 2030. At the present time, the largest water use in the central region is for municipal and industrial needs. This includes energy related water requirements and rural water system needs. Future projections for the region show that municipal and industrial needs will continue to require the most water usage.

MUNICIPAL AND INDUSTRIAL

Municipal and industrial reported water usage for 1972 was 29,303 acre-feet from ground water and 126,534 acre-feet from stream water, making a total usage of 155,837 acre-feet. Projected requirements for 2030 is 705,000 acre-feet.

RURAL WATER SYSTEMS

Presently there are 13 rural water systems serving 9,000 customers. Sources are ground water, Beaver Creek and Little River located in McClain County. Some 60,200 citizens of the central region are unserved by any type of public water system. Using projected future population figures, there will be some 10,400 additional customers by 1980, 13,800 by 2000 and 16,600 by 2030, reached by public water systems.

ENERGY RELATED WATER REQUIREMENTS

Northeastern Canadian, northern Cleveland and southern Pottawatomie counties hold the greatest amounts of energy fuels. Although little coal comes from this area, large supplies of gas and oil do. This will require greater amounts of water for future refinement and processing. Industrial and municipal needs for energy related water requirements are also expected to increase drastically based on projected population figures.

IRRIGATION

Total reported water usage for irrigation in 1972 was 27,596 acre-feet. Ground water accounted for 19,306 acre-feet and 8,290 acre-feet came from stream water. The projected water required for irrigation by the year 2030 will be 71,500 acre-feet for the central region. The 71,500 acre-feet for 2030 will be met by individual systems.

OTHER USES AND REQUIREMENTS

Navigation

At present, there are no navigable works in the central region nor are there any immediate plans for such a system. However, long-range plans for a navigation system in this area could be developed and supplemental water for navigation would be needed.

Fish, Wildlife and Recreation

The Department of Wildlife Conservation Game Farm and Center is located in Canadian County, along with fish hatcheries at Lakes Hefner, Overholser and Draper. The aggregate water usage was 160 acre-feet in 1973, and is anticipated to remain stable.

Water for recreational purposes is considered adequate except for swimming, which will be handled by the individual community.

Hydroelectric Power

At present, there are no hydroelectric power plants in the central region nor are any planned in the foreseeable future.

Water Quality Control

At this time, there are no lakes or authorized lakes for water quality control in the central region. If water quality control storage is needed in the future, water requirements would have to be reviewed.

Plan of Development

MAJOR RESERVOIR SYSTEM

Table IV-11 shows the 2030 demand and the recommended supply system for reservoirs in central Oklahoma. The reservoir system and a portion of the conveyance system are shown on Figure IV-8. The entire water supply system is shown on Figure I-2 of Section I, Summary. To satisfy the deficit of demand over supply, an inter-basin requirement of 487,000 acre-feet per year will be

TABLE IV-10
CENTRAL REGION GROUND WATER PERMITS

COUNTY	NUMBER PERMITS ISSUED	NUMBER WELLS	AMOUNT ALLOCATED AF/YR
Canadian	149	357	58,286
Cleveland	48	108	37,099
McClain	29	48	8,021
Oklahoma	89	246	83,783
Pottawatomie	37	66	9,324
TOTAL	352	825	196,513

required in central Oklahoma by year 2030. The conveyance system will have an emergency diversion stub located upstream of Lake Thunderbird to permit flexibility in future operations. As shown, transported water will be solely for municipal and industrial purposes in central Oklahoma as irrigation requirements are expected to be met by individual systems. Should project-type irrigation be needed prior to year 2030, such needs can be supplied from the interconnected system .

WATERSHED PROTECTION PROGRAM

For discussion of the proposed watershed protection program, see the Statewide Summary, Section I.

Municipal Needs and Proposed Solutions

Information relating to the present condition of most municipal systems and proposed solutions to future municipal needs in the central region are tabulated in Table IV-12. Such information for Oklahoma City is furnished herein in narrative form.

Although a few of the larger cities in the region rely entirely on stream water, the majority use both stream and ground water.

Most large cities in the region presently have an adequate water supply; however, continued development will be necessary to meet rapidly increasing municipal demands.

The smaller communities generally use ground water or purchase water from a nearby city. Several small towns are having supply as well as quality problems. Immediate action is needed in these cases.

Most small communities currently using ground water are expected to either continue expanding their well systems or obtain water from neighboring cities. The larger cities now using ground water are expected to continue using ground water for their short term needs to develop supplemental stream water to meet their long term needs. Two exceptions are: El Reno, which is considering long term ground water use and Edmond, which is encouraging short term stream water development for municipal use.

The additional water to be provided for the central region by the Oklahoma Comprehensive Water Plan is expected to induce the development of various distribution systems such as regional and countywide systems, rural water districts, and larger cities selling water to smaller neighboring communities.

TABLE IV-11
CENTRAL REGION WATER SUPPLY AND DEMAND IN 1000's OF ACRE-FEET ANNUALLY

ESTIMATED 2030 IN-BASIN REQUIREMENTS

Municipal and Industrial	705.0
Irrigation	71.5[1]
TOTAL	776.5

[1]Will be met by individual systems.

PLANNED 2030 SUPPLY

SOURCE	SUPPLY	IN-BASIN NEEDS	INTER-BASIN NEEDS (deficit)
Lakes Hefner & Overholser (E)	22.0[2]		
Draper (E)	86.0[3]		
Lake Thunderbird (E)	21.7		
Arcadia Lake (A)	12.1		
Shawnee Lakes (E)	4.4		
West Elm (P)[4]	0		
Ground water (E)	71.8		
TOTAL	218.0	705.0	487.0

(E) —Existing or under construction
(A) —Authorized
(P) —Proposed
[2]North Canadian River water—no releases from Canton.
[3]Full yield (90 mgd) from Atoka pipeline minus evaporation losses.
[4]Potential Storage 170,000 acre-feet.

Oklahoma City

Oklahoma City is currently using stream water from Lakes Hefner, Overholser and Atoka and ground water from the Garber-Wellington Formation. Lake Stanley Draper is being utilized as a terminal storage reservoir for water from Lake Atoka. Ground water is used mainly as an emergency standby source.

Current estimates indicate that Oklahoma City will need additional water by, or shortly after 1980. Oklahoma City has plans for providing this additional water by increasing the flow of the Atoka-Draper Lake pipeline through development of an additional reservoir in southeast Oklahoma and by increasing pumping capacity along the pipeline. Oklahoma City has indicated a preference for McGee Reservoir as the next supply source. The additional pumps and reservoir will develop the pipeline to its full capacity.

The Garber-Wellington Formation which underlies Oklahoma City has the potential to provide significant quantities of water on a short term, and possibly a long term basis. Plans currently underway for detailed study of this ground water basin should provide further information relating to its development potential.

The increased supply should meet Oklahoma City's needs until at least 1985, and possible until 1990, at which time the interconnected system is expected to be completed.

TABLE IV-12
CENTRAL REGION MUNICIPAL NEEDS AND PROPOSED SOLUTIONS

COUNTY CITY	PRESENT SOURCE	SHORT TERM NEEDS & PROPOSED SOLUTIONS (Present to 1990)	LONG TERM ALTERNATIVE(S) (From 1990 on)	COMMENTS
CANADIAN				
Calumet	Ground water-N. Canadian River alluvium deposits	Their system is presently adequate and their water table is stable. Calumet will be able to meet its 1990 needs with their pre-ent system. The water may need to be treated to lower the sulfate content.	Calumet should have sufficient ground water available to meet its long term needs by drilling additional wells in the N. Canadian River terrace or alluvium deposits.	If Calumet's water quality deteriorates they might consider buying supplemental water from the City of El Reno.
El Reno	Ground water-N. Canadian River alluvium deposits	Their supply is adequate and the N. Canadian alluvium deposits should provide enough additional water to meet El Reno's short term needs. If current estimates are accurate, El Reno's demand will exceed the alluvial yield between 1985 and 1990. A supplemental source may be needed by then.	City officials indicate they would prefer to continue to use ground water. They may be able to meet long term needs by obtaining more land for well development and good ground water management. If not, El Reno should consider obtaining supplemental water from the proposed conveyance system. Another alternative would be to utilize a portion of the yield of the proposed Arcadia and/or Seward Reservoir.	If El Reno develops a dependable long term supply, they could sell water to outlying towns such as Union City, Okarche and Calumet.
Mustang	Buying water from Oklahoma City and Ground water-Canadian River alluvium and terrace deposits	They will probably continue to use Oklahoma City water for their future needs.	Same as short term.	
Okarche	Ground water-North Canadian River terrace deposits	Although Okarche's supply is adequate, the water quality is poor. The water has high concentrations of sulfates and dissolved solids. Okarche should consider purchasing water from El Reno or Kingfisher as an alternate source.	Same as short term.	
Union City	Ground water-Canadian River alluvium deposits	Union City will be able to obtain sufficient water from the alluvium deposits by drilling more wells. Unfortunately, the water quality is poor. It may be more economical to seek an alternate source than to treat water from their present source. A possible alternative would be to negotiate to obtain water from the city of El Reno.	The long term alternatives are the same as their short term alternatives. They need to treat their well water or purchase water from a nearby city.	
Yukon	Ground water-North Canadian River alluvium deposits and buy treated water from Oklahoma City	Yukon will probably continue to use ground water and obtain supplemental water from Oklahoma City. They are considering the possibility of drilling additional wells to increase their supply.	As a long term alternative, Yukon might negotiate to obtain additional water from Oklahoma City, obtain water from one of the proposed reservoirs in the area, or utilize a portion of the water to be developed as part of the Oklahoma Comprehensive Water Plan.	

COUNTY CITY	PRESENT SOURCE	SHORT TERM NEEDS & PROPOSED SOLUTIONS (Present to 1990)	LONG TERM ALTERNATIVE(S) (From 1990 on)	COMMENTS
CLEVELAND				
Lexington	Ground water-Canadian River alluvium deposits	Lexington's water supply is adequate, their water table is stable and their water quality is good. Lexington should have no trouble meeting their short term needs by drilling additional wells as their demand increases.	Although no signs of serious overdraft are evident with their present source, the continued increase in upstream and local well development could cause future problems. The Garber-Wellington formation which lies E of town could be a long term source, although specific data on this portion of the formation is scarce.	A secondary long term alternative would be to use transported water from the system which will pass near town.
Moore	Ground water-Garber-Wellington Formation	The present supply is sufficient for Moore's present needs. They should be able to meet their short term needs by drilling additional wells in the immediate area.	Moore should continue to expand their well system until the proposed conveyance system is built. Once the conveyance system is completed, Moore could obtain supplemental water from it to meet their long term needs.	
Noble	Ground water-Garber-Wellington Formation	Noble needs to begin a program of well expansion to adequately provide for the towns water supply needs. They had to ration water in the summer of 1974.	Noble could meet their long term needs by drilling additional wells and obtaining supplemental water from either the transport system or from Norman if it becomes necessary.	The town has recently obtained another well which should ease their problems somewhat.
Norman	Ground water-Garber-Wellington and Lake Thunderbird	Continued expansion of the city's well field should provide adequate water until the conveyance system is developed. Once the conveyance system is built, it would provide enough supplemental water to meet Norman's future needs.	Norman should continue with their present sources and obtain supplemental transport water to meet the city's long term needs.	
McCLAIN				
Blanchard	Ground water-wells in a minor ground water basin	Blanchard badly needs a dependable source of supply. Alternatives considered include obtaining water from Oklahoma City, developing an SCS site W. of town and drilling wells in the Canadian River alluvium deposits E. of town. One of these alternatives should be initiated immediately. Their most economical solution will probably be to develop wells in the Canadian River alluvium deposits. The SCS site or use of water from Oklahoma City would be more expensive, but should provide sufficient water to meet the town's future needs.	Their long term needs could be met by the development of the SCS site, using water from Oklahoma City, or obtaining water from the conveyance system.	In the past they have had to haul water from Norman to meet their peak summertime demands. They have "looked over the entire local area for ground water with no luck."

COUNTY CITY	PRESENT SOURCE	SHORT TERM NEEDS & PROPOSED SOLUTIONS (Present to 1990)	LONG TERM ALTERNATIVE(S) (From 1990 on)	COMMENTS
Byars	Ground water-Canadian River terrace deposits	According to city officials, this town has an adequate water supply. The Canadian River terrace and alluvium deposits should meet the communities short term needs. The water may need to be treated to lower the iron content.	Their best long term source would be to obtain water from the Rural Water District from Wynnewood or obtain water from the proposed conveyance system which would pass near town.	
Newcastle	Ground water-Canadian River alluvium deposits	The wells provide sufficient water to meet their present needs and drilling more wells in the Canadian River alluvium should provide adequate water for their short term needs.	As a long term source, Newcastle should negotiate to obtain water from Oklahoma City or Norman.	
Purcell	Ground water-Canadian River alluvium deposits and Purcell Lake (as standby)	Their wells provide an adequate supply of good quality water. The water table in their wells is stable and they should be able to meet their short term needs by drilling more wells into these deposits.	A long term alternative could be conjunctive use of ground water and transported water. They might utilize Purcell Lake as a terminal storage for transported water.	
Washington	Ground water-Local terrace deposits	They have not had to ration water, but they need to drill at least one more well to meet their short term needs. A Rural Water District line which runs 1.5 mi N. of town might provide water to the town at a higher cost.	As a long term source, they should obtain water from the Rural Water District N. of town or develop a R.W.D. on their own.	
Wayne	Ground water-Canadian River terrace deposits	No immediate problems are anticipated with Wayne's water supply. Their water quality is fair, their water table is stable and their supply is adequate. A new deep well near the Canadian River has recently been added to the system. City officials indicate they will expand their well system as it becomes necessary.	This community will probably stay with ground water as long as sufficient quantities are available to meet their needs. If the terrace deposits become dewatered, Wayne could obtain water from the proposed conveyance system which passes near the town.	
OKLAHOMA				
Bethany	Ground water-North Canadian River terrace deposits	Bethany's wells are presently adequate. They can meet their short term needs by drilling additional wells.	As long as ground water is available in sufficient quantities, it is the most economical alternative for Bethany. If it becomes necessary to seek a supplemental source, Bethany should investigate the possibility of using water from the proposed Seward or Arcadia Reservoir or from the proposed transport system	
Choctaw	Ground water-North Canadian River terrace deposits	Choctaw needs to immediately begin a well expansion program to meet its short term needs. The Garber-Wellington formation S. of town should provide adequate water for their short term needs.	Choctaw should continue to use ground water unless the ground water basin becomes overdeveloped. An alternative for Choctaw would be to obtain water from Oklahoma City or Midwest City.	

COUNTY CITY	PRESENT SOURCE	SHORT TERM NEEDS & PROPOSED SOLUTIONS (Present to 1990)	LONG TERM ALTERNATIVE(S) (From 1990 on)	COMMENTS
Del City	Lake Thunderbird and Ground water-Garber-Wellington Formation	By fully utilizing their allocation from Lake Thunderbird and developing additional wells in the Garber-Wellington Formation, Del City should have adequate water to meet their 1990 needs.	Continued development in the Garber-Wellington Formation plus water from the conveyance system when it becomes available should meet Del City's long term needs.	
Edmond	Ground water-Garber-Wellington Formation	Edmond needs to drill additional wells and also continue to actively encourage the development of Arcadia Reservoir as a short term source.	If Edmond utilizes the major part of the water supply yield of the proposed Arcadia Reservoir, the reservoir in conjunction with their ground water supply should meet the city's long term needs. If Arcadia is utilized as a supply source for a regional distribution systems, Edmond may need additional water for their long term needs. The additional water could come from the proposed Seward Reservoir or from the proposed conveyance system.	
Harrah	Ground water-North Canadian River terrace deposits	This community's supply is adequate. No immediate problems are foreseen. This community can meet its future needs by drilling more wells as it becomes necessary.	Same as short term.	
Jones	Ground water-Garber-Wellington Formation	Jones presently has a sufficient water supply. The most economical alternative to meet their future needs is to develop supplemental wells in the Garber-Wellington Formation.	1) Drill supplemental wells as it becomes necessary. 2) If rapid growth in this area continues, it may be necessary to seek a supplemental source. Purchasing water from Oklahoma City would insure an adequate long term supply.	
Luther	Ground water-Garber-Wellington Formation	Luther needs to begin a well development program to augment their present supply. Continued use of ground water is the most economical alternative for this community.	If the ground water in the local area becomes insufficient, they should develop wells in the main Garber-Wellington Formation W. of town.	
Midwest City	Lake Thunderbird and Ground water-Garber-Wellington Formation	Ground water from the Garber-Wellington Formation augmented by water from Lake Thunderbird should meet Midwest City's short term needs.	Their present sources plus utilization of a portion of the water which is to be transported in conjunction with the Oklahoma Comprehensive Water Plan should meet Midwest City's long term needs.	
Nichols Hills	Ground water-Garber-Wellington Formation	Nichols Hills should be able to meet their future needs by drilling more wells as it becomes necessary.	No long term problems are anticipated with their present source. Obtaining supplemental water from Oklahoma City should be considered if ground water problems develop in the future.	

COUNTY CITY	PRESENT SOURCE	SHORT TERM NEEDS & PROPOSED SOLUTIONS (Present to 1990)	LONG TERM ALTERNATIVE(S) (From 1990 on)	COMMENTS
Spencer	Ground water-Garber-Wellington Formation	Spencer's wells provide an adequate supply of good quality ground water. They should have no difficulty meeting their 1990 needs by developing wells in the Garber-Wellington Formation.	Spencer will probably continue to use ground water since it is their most economical source. If it becomes necessary to seek an alternate source, negotiating to purchase water from Oklahoma City should be considered.	
POTTAWATOMIE				
McLoud	Ground water-North Canadian River alluvium deposits	McLoud has recently drilled an additional well. The increased well capacity should meet their short term needs. If Shawnee develops the proposed reservoir S. of town on North Deer Creek, McLoud should obtain a portion of this water to meet their future needs.	1) Utilize water from the proposed reservoir on North Deer Creek. 2) A countywide distribution utilizing transported water would provide a-dependable long term supply. 3) Continued use of ground water.	
Maud	Ground water-wells in a minor ground water basin	Their water quality is poor due to the high sulfates and total dissolved solids. Maud could develop a well field in the Vamoosa Formation which is located E. of town.	1) Develop wells in the Vamoosa Formation 2) Obtain water from Seminole or Wewoka.	
Shawnee	Shawnee Reservoir	Shawnee's comprehensive plan indicates the present supply will become inadequate "about" 1985. The most promising future alternative appears to be the development of a dam site NW of town on North Deer Creek. This proposed reservoir could meet the short term needs of Shawnee, McLoud and Tecumseh.	The long term alternatives for Shawnee include: 1) A distribution system using water from the proposed conveyance system, or 2) Obtaining water from the Atoka-Draper Lake pipeline once its pumping capacity is increased.	
Tecumseh	Tecumseh City Lake Ground water-N. Canadian River alluvium deposits	The city lake provides an adequate supply of good quality water. To insure adequate water for the town's short term needs, Tecumseh should work with Shawnee to develop a supplemental source. One potential source is the proposed reservoir on North Deer Creek.	Same as the long term alternatives for Shawnee.	Tecumseh also has wells which are used for emergency standby purposes.
Wanette	Ground water-Canadian River alluvium deposits	Wanette's water requires iron removal but is acceptable otherwise. Ground water in the area should meet Wanette's short term needs.	To meet the town's long term needs, Wanette should either drill additional wells or obtain water from the proposed conveyance system which would pass near the town.	If Wanette obtains water from the proposed conveyance system, they may need to build a terminal storage area for the water.

SOUTH CENTRAL REGION

General Description

The south central region possesses a wealth of natural resources. This region, totaling 5,799 square miles, contains the counties of Grady, Garvin, Stephens, Murray, Carter, Jefferson, Love and Marshall. The region possesses both rugged foothills and rich pastures, with elevations ranging from approximately 1,100 feet above mean sea level in the northwest to about 650 feet near Lake Texoma.

This region experiences long hot summers and short mild winters. However, the area has excellent water resources, such as Arbuckle Lake , with a surface area of 2,350 acres, Lake Murray, with a surface area of 5,728 acres and Lake Texoma, with a surface area of 93,500 acres. There is also fertile, productive land and the growing season extends for more than 200 days per year. Almost the entire northern half of the eight county region is drained by the Washita River, while the southern part is drained by Beaver and Mud Creeks and Walnut Bayou.

Population of the south central region, based on the 1970 census, was 158,592. The two largest cities are Ardmore, with 20,881 people and Duncan, with 19,718 people.

Planning Area Resources

PRECIPITATION

Annual precipitation increases eastward ranging from 30 inches to 39 inches as shown in Figure II-1.

Rainfall is usually adequate, but drought of severe to extreme intensity is present about one year in ten.

EVAPORATION AND TEMPERATURE

Figure II-3 shows average annual evaporation ranging from 55 inches in the eastern section to 63 inches in the west. Mean annual temperature varies from 61 degrees to 64 degrees from north to south across the region. See Figure II-2.

STREAM WATER CHARACTERISTICS

The south central region is drained by the Washita River, Beaver Creek, Mud Creek, Walnut Bayou and the main stem of the Red River. These have a combined drainage area of appoximately 5,559 square miles inside the region. The Canadian River and Cache Creek do not flow through this region, but 240 square miles of their drainage area originate here.

Beneficial use of stream water is restricted in some areas because no additional water is available for appropriation. All stream water in the drainage areas of Waurika Lake and Arbuckle Lake has been fully appropriated and no additional water supplies can be developed within those areas. Also, restrictions are applicable to any allocations made on the main stem of the Washita River and its tributaries to Pauls Valley. These restrictions specify that water can be captured or diverted only during periods of high flow or during certain periods of the year.

Runoff

Average annual runoff ranges from three inches in Grady County to seven inches in Marshall County. See Figure II-4. The average annual runoff originating from the six main stream basins is estimated at 1,500,000 acre-feet per year.

The flows of Beaver Creek, Mud Creek and Walnut Bayou are derived almost entirely from rainfall and are very erratic. At times each year, no flows are recorded on these streams.

Most of the streams that flow through this region eventually enter Lake Texoma. This combined flow is recorded at the U.S.G.S. gauging station at Denison Dam. The average annual flow at this gauging station for a period of 49 years is 3,410,000 acre-feet.

Average annual discharges at U.S.G.S. gauging stations inside the region are presented in Table IV-13. For location of gauging stations see Figure IV-12.

Flooding

Flooding, principally in the Washita basin and its tributaries, follows a pattern of several years of little or no streamflow followed by damaging floods. The most damaging flood occurred from May 17-21,1949, between Clinton and Pauls Valley. This flood caused $12,892,830 in direct or related damages. The possibility of future flooding on the Washita

TABLE IV-13
SOUTH CENTRAL REGION STREAMFLOW SUMMARY

STREAM	U.S.G.S. STATION	CONTRIBUTING DRAINAGE AREA SQ. MILE	AVERAGE ANNUAL FLOW AF/YR	OBSERVED FLOW (CFS) MAX	MIN.
Beaver	3135-near Waurika	563	71,070	32,200	0
Mud Creek	3157-near Courtney	572	57,670	10,900	0
Washita River	3310-near Durwood	7,202	973,700	98,000	0
Walnut Bayou	3159-near Burneyville	314	28,110	3,860	0
Red River	3160-near Gainesville, TX	24,846	1,956,000	168,000	48
Red River	3316-at Denison Dam	33,784	3,410,000	201,000	12

and its tributaries has been decreased by numerous flood control structures erected by the U.S. Soil Conservation Service and the Bureau of Reclamation.

Stream Water Quality

In parts of this region, water quality restricts the use of water for beneficial purposes.

The waters of the Red River are too mineralized for municipal and industrial uses, although some irrigation is done from the Red River by using special irrigation management practices. The high chloride content of the water is caused by natural salt seeps and springs in the upper reaches of the Red River basin.

Water from the Washita entering this region is highly mineralized due to gypsum outcroppings in its upper drainage basin. The relatively good quality of many of the tributary streams in this region improves the water quality of the Washita. Therefore, when the Washita reaches Lake Texoma, it is a relatively good quality water but mixes with the poor quality water of the Red River leaving Lake Texoma unusable most of the time for municipal and domestic purposes.

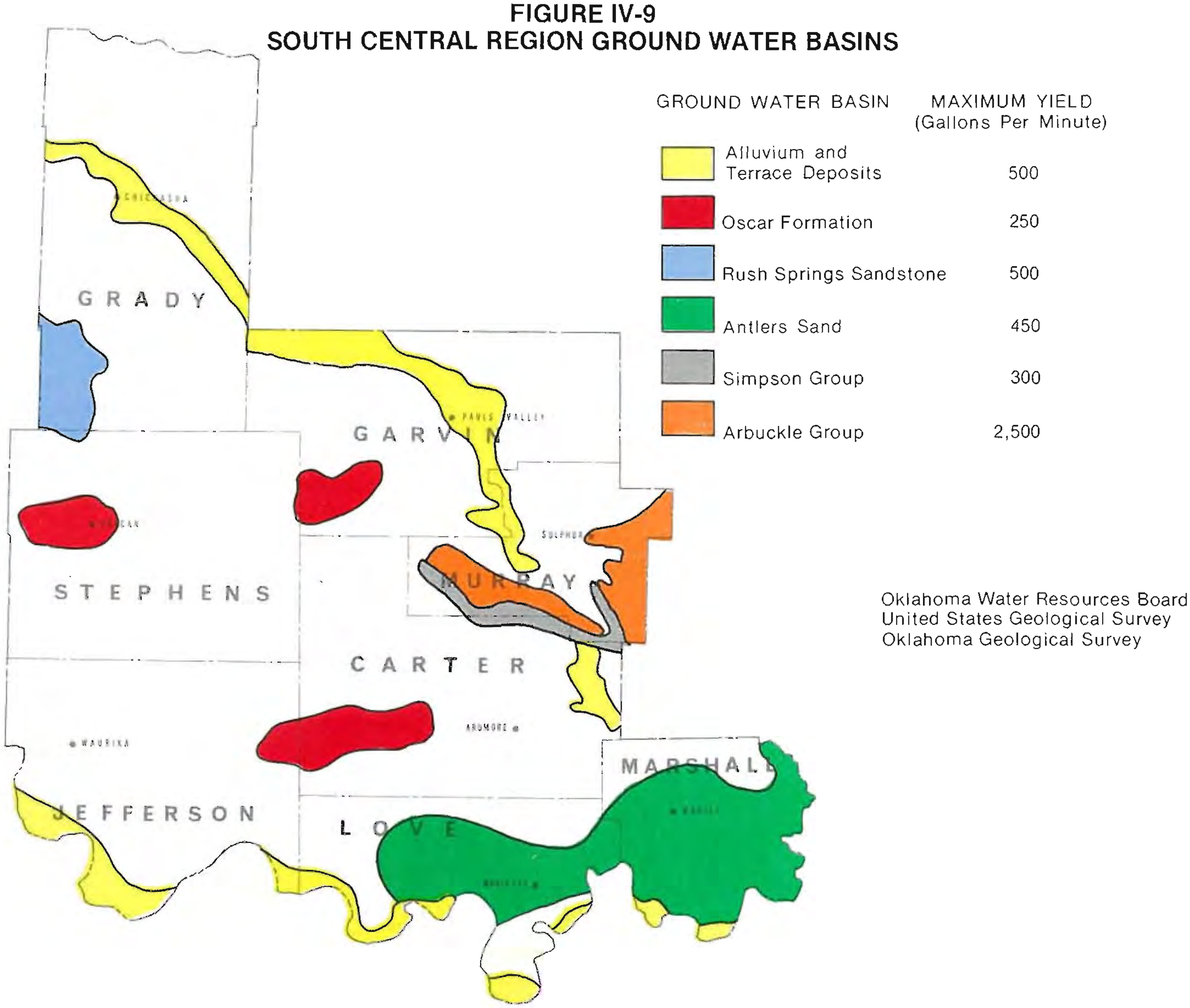
The waters of Walnut Bayou and Mud Creek are also high in chloride content resulting from improper disposal of oil field brines in the early days of the oil industry.

The waters of Beaver Creek, the other major stream in this region, are rated fair to good for municipal and domestic purposes.

GROUND WATER RESOURCES

Five major ground water basins are located here, the Arbuckle Group, Simpson Group, Oscar Formation, Rush Springs Sandstone, Antlers Sand and alluvium and terrace deposits. See Figure

FIGURE IV-9
SOUTH CENTRAL REGION GROUND WATER BASINS



IV-9. Ground Water resources serve the needs of most rural homes and smaller towns and communities, as well as irrigation farmers in the region. See Table II-2 for total water in storage and amounts recoverable from ground water basins.

Arbuckle Group (Cambrian-Ordovician in age) is limestone and dolomite, 5,000-6,000 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 200-500 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 100-200 gpm commonly. Water from the 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 300-400 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 150-180 gpm are reported. Ardmore, Healdton,

FIGURE IV-10
SOUTH CENTRAL REGION MINERALS

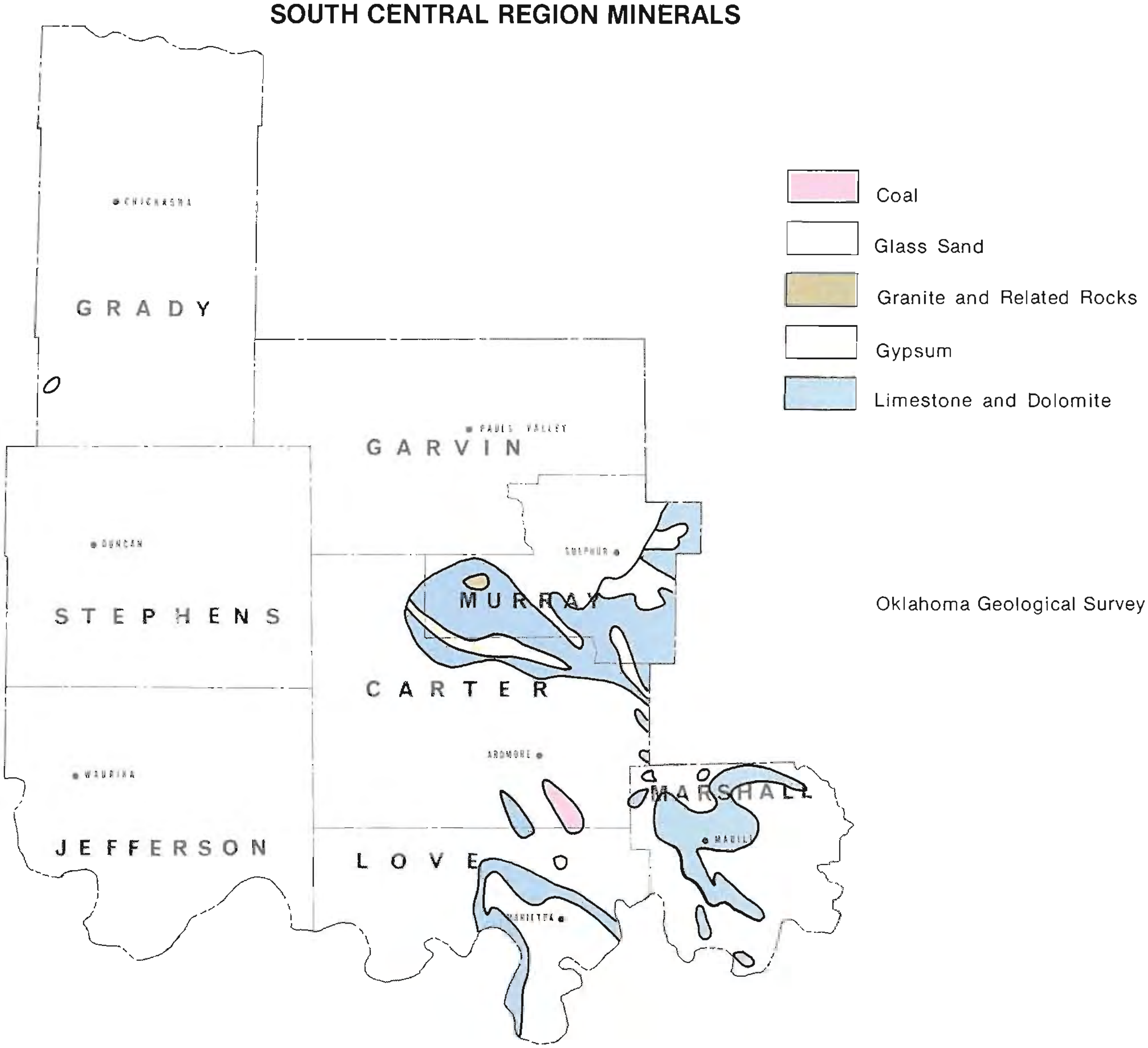
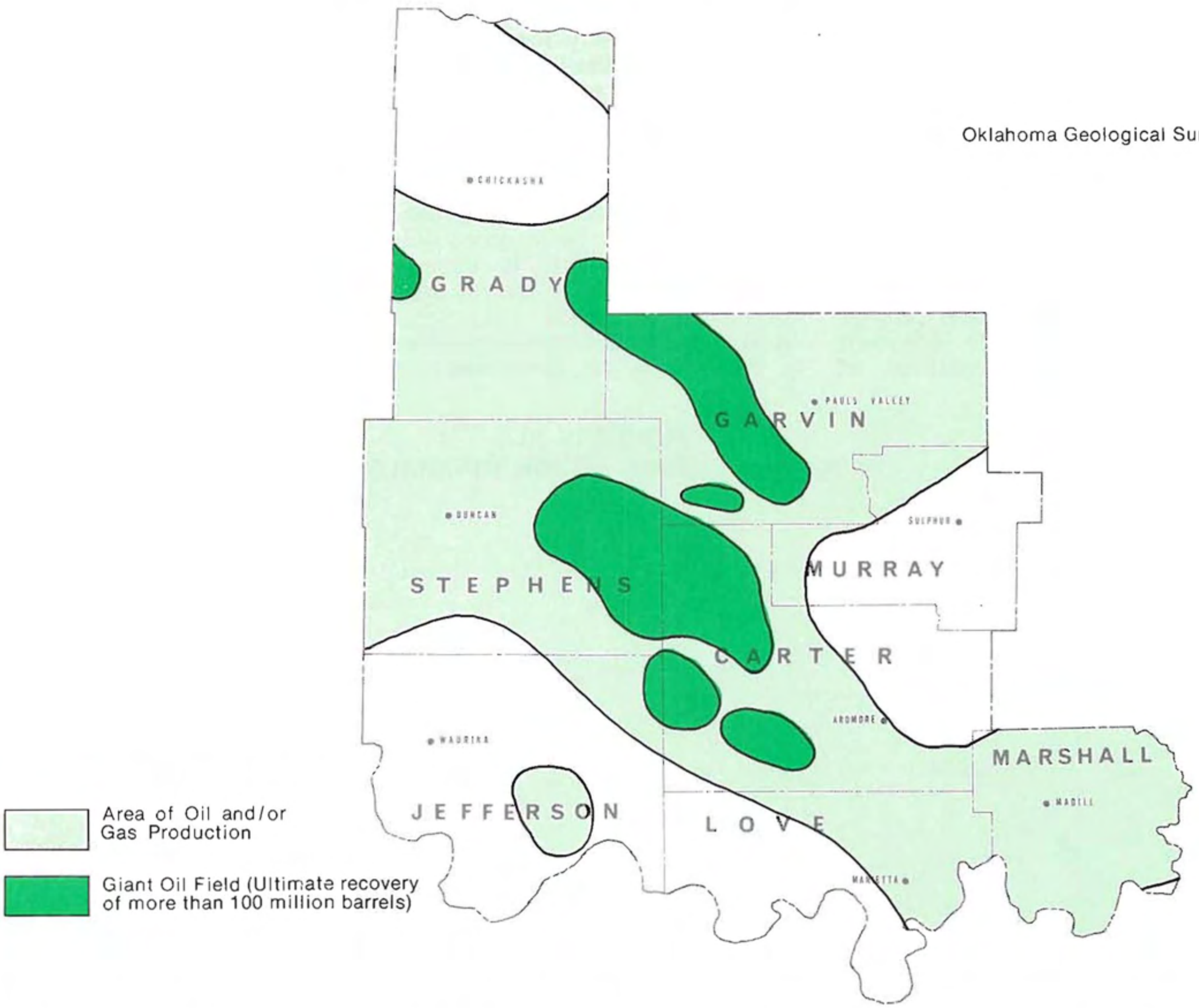


FIGURE IV-11
SOUTH CENTRAL REGION OIL AND GAS



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 - See Southwest Planning Region.

Antlers Sand (Cretaceous) consists mostly of loosely cemented, fine grained sand. 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. Water quality is good in the outcrop area but deteriorates downdip.

Alluvium and Terrace deposits (Quaternary) were laid down by stream 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 20-100 gpm, owing to fine grain sediments in the alluvial fill. Overall water quality is good although water is better in the terrace than the alluvium because the terrace deposits generally receive less water from the adjacent bedrock basin and are not affected by influent seepage of river water which may be mineralized. Total dissolved solids range from 477-1,050 mg/l.

MINERAL RESOURCES

The mineral resources of the south central region consist of oil, gas and non-metals. The non-metals are limestone, produced from the Arbuckle Mountains and used as crushed stone for concrete and road metal; sand and gravel, produced mainly from alluvial deposits along the Washita River Valley and used for concrete and construction work; dolomite, produced near Mill Creek and utilized for agricultural and other high purity materials and glass sand, produced in the region and used for high purity glass and also ground for fine abrasive.

The oil and gas is mostly in four giant oil fields (estimated ultimate recovery of more than 100 million barrels each): Eola-Robberson in Garvin County, Golden Trend in Garvin County, Hewitt in Carter County and Sho-Vel-Tum in Carter and Stephens counties. Production in 1973 was 81 million barrels of oil and 72 billion cubic feet of gas. See Figures IV-10 and IV-11.

LAND RESOURCES

Much of this region is characterized by lush grasslands and pastures which provide good grazing for cattle ranches. Beef cattle production is the major farm commodity and pasture acreage has increased steadily.

Approximately 3,072,000 acres of the 3,613,900 acre total is classified as crop and pasture land. The 1972 Reported Water Use reported that the south central region had 24,810 acres under irrigation. This includes only reported acres and does not represent the region total. Oklahoma State University Extension Service in 1973 reported a region total irrigated acres of 20,699 acres.

Major crops produced include wheat, hay and sorghum, with peanuts and watermelons being grown in the sandier soils of the southern part of the region. Also, some of the most productive pecan orchards in the State are located here.

SOILS

In the south central region, Renfrow-Zaneis-Vernon and Darnell-Stephenville are the predominate soil associations. Cropland is the typical land use, with varying amounts allocated to forested and wooded pastures. Other soil associations are Windthorst-Chigley, Tarrant, Tarrant-Newtonia, Dougherty-Teller-Yahola, Rough Broken Vernon Land, Vanoss-Minco-Yahola, Durant-San Saba-Tarrant and Yahola-Port-Reinach. These minor soil associations allow for varied land usage from rangeland and pastureland to vegetable and fruit cropland. See Figure II-11.

ENVIRONMENTAL RESOURCES

The south central region has a wealth of environmental resources for the outdoorsman, from well-stocked scenic lakes to rugged mountain foothills.

Scenic Areas

Oklahoma's only and the nation's smallest national park, Platt National Park at Sulphur provides fine camping, picnicking and hiking around beautiful hills and running streams. The area has many mineral springs, which the Indians believed had medicinal powers.

The Arbuckle Mountains in Murray County greatly contribute to the study of geologic formations. Turner Falls, the State's only major waterfall, is located in the Arbuckles and is surrounded by rugged, scenic hills.

Fish, Wildlife and Recreational Activities

Much of the south central region is devoted to recreation. Lake Texoma covers 93,000 acres and provides water-skiing, boating and fine sand bass fishing. Lake Texoma State Park has an area of 1,884 acres with free camping grounds, trailer parks, picnic tables and grills. Lake Murray covers 5,728 acres and the surrounding park contains 15,265 acres. This park has a luxury lodge, cottages, cabins and a 2,500 foot air strip. Lake of the Arbuckles, built by the Bureau of Reclamation, has a surface area of 2,350 acres. These lakes have large stocks of bass. Arbuckle contains northern pike. The Washita River, which drains a major portion of the region, offers sand bass fishing that attracts people from many states. Several State and Federal game refuges, such as the Hickory Creek Game Management Area near Marietta and the Arbuckle Public Hunting and Fishing Area near Sulphur, offer excellent duck, goose, deer and wild turkey hunting. Several private organized camping areas are located near Davis in the Arbuckle Mountains.

Regional Historical Features

The history of the Chickasaw Nation is the history of the south central region. The Chickasaws received their land in 1855, established a government with judicial, legislative and executive departments and enjoyed great economic growth.

At Boyd Springs near present-day Ardmore, natural gas spewed from subterranean crevices. The Indians used the spot as a council ground, lighting the area with the natural gas. In 1893, the Chickasaws were allotted 320 acres each because of white pressure for surplus Indian land.

Present and Potential Development

Stream water provides most of the requirements of this region. The four major reservoirs yield over 67,000 acre-feet of water supply annually. Stream water development is continuing and at this time there is minimal ground water development.

TABLE IV-14
SOUTH CENTRAL REGION PRESENT AND POTENTIAL WATER RESOURCE PROJECTS

EXISTING OR UNDER CONSTRUCTION

NAME OF SOURCE	LOCATION	PURPOSE *	FLOOD CONTROL STORAGE ACRE FT.	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
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,FC,R	1,600	2,600	700
Ardmore SCS Site 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	2,660,000	38,900	23,700[3]
Waurika Lake+	Beaver Creek	WS,FC,WQ,R,FW,I	140,400	170,200	46,500[4]
Sub Total			2,863,200	338,600	107,700

POTENTIAL SITES

NAME OF SOURCE	LOCATION	PURPOSE *	FLOOD CONTROL STORAGE ACRE FT.	CONSERVATION STORAGE	WATER SUPPLY YIELD (AF/YR)
Burneyville	Walnut Bayou	WS,R	0	150,000	25,000
Caddo	Caddo Creek	WS,FC,R	53,000	260,000	40,000
Courtney	Mud Creek	WS,R	0	261,000	53,000
Hennepin	Wildhorse Creek	WS,R	0	330,000	60,000
Kechi	Little Washita River	WS,FC,R	33,100	58,900	8,000
Purdy	Rush Creek	WS,FC,R	45,000	140,000	20,000
Lake Texoma Power Releases	Red River		-	-	1,332,200[5]
Sub Total			131,100	1,199,900	1,538,200
TOTAL			2,994,300		1,645,900

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

+Under construction

[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. There is no water supply storage included in this.

[3] Lake Texoma is an inter-state lake and all plans for utilization are subject to compacts between the States of Oklahoma, Texas, Arkansas and Louisiana. It is presently being restudied to modify the existing project to include recreation and irrigation storage. Present dead storage for power head and hydroelectric storage is 1,008,900 acre-feet and 1,673,000 acre-feet respectively. Although Lake Texoma has storage for water supply, water is generally too mineralized for use.

[4] Waurika Lake has irrigation storage to provide 5,040 acre-feet per year for irrigation. This yield is included in the water supply yield above.

[5] This is the approximate yield that could be developed from hydropower releases from Lake Texoma. All plans for utilization are subject to compacts between the States of Texas, Oklahoma, Arkansas and Louisiana.

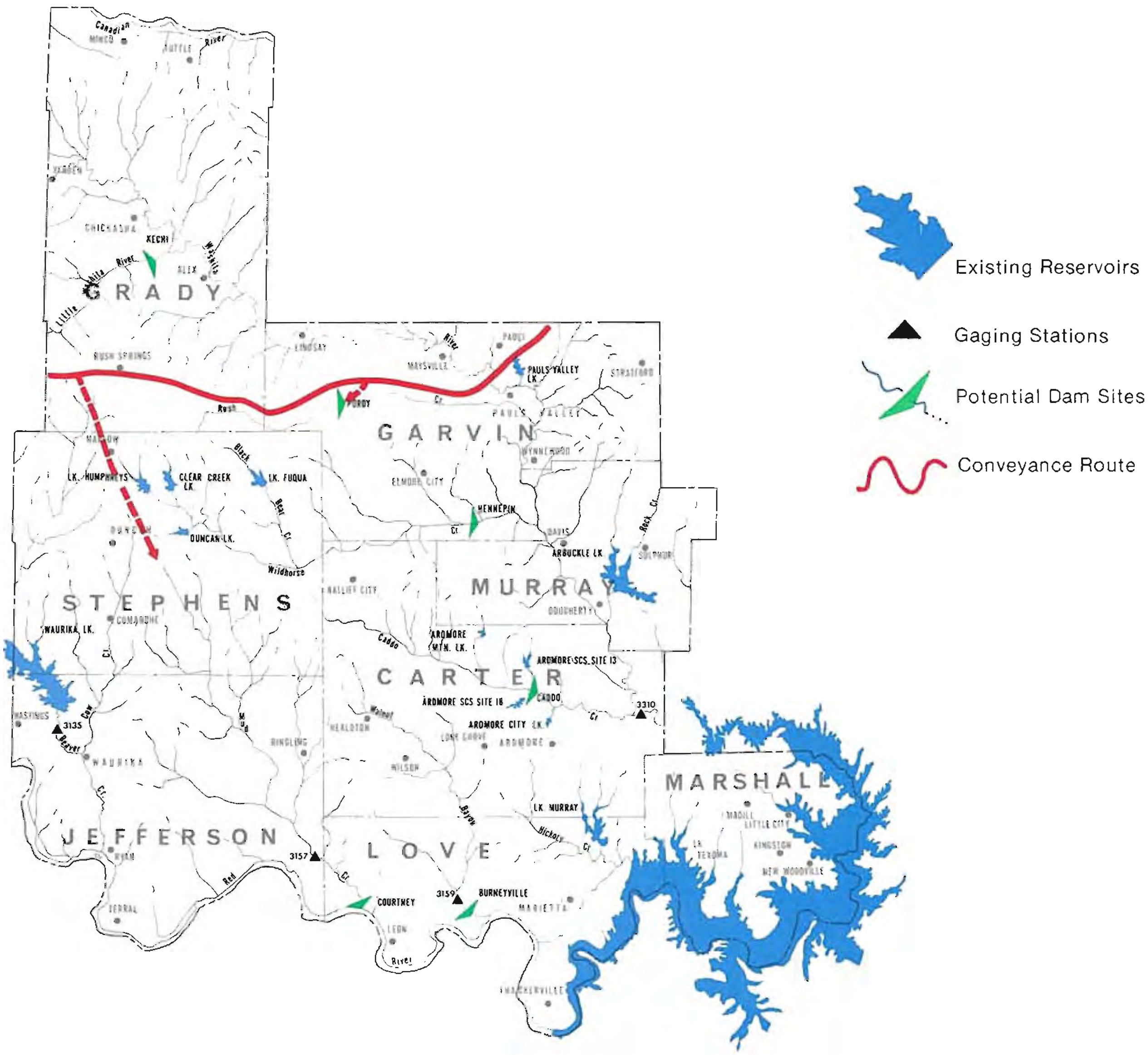
STREAM WATER

As shown in Table IV-14, there are existing and under construction lakes 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. There are additional potential sites having a possible water supply yield of 1,538,200 acre-feet, for a region total of 1,645,900 acre-feet of water supply. Locations of the sites are shown on Figure IV-12.

Watershed Protection and Flood Prevention

The Soil Conservation Service has planned and engineered construction of numerous flood control structures in this region.

FIGURE IV-12
SOUTH CENTRAL REGION STREAM WATER DATA



Many are designed as multi-purpose reservoirs used for irrigation, recreation and municipal water supplies. The cities of Ardmore, Chickasha, Duncan, Elmore City, Lindsay, Marlow and Maysville are provided municipal and recreation water from these multi-purpose sites. One multi-purpose structure with recreation and municipal water is planned for the city of Healdton.

There is a total of 46 small S.C.S. watersheds in this region. Twenty-five of these are complete or under construction, 13 are planned and 8 have potential for development in the next 50 years. To date, a total of 380 structures have been constructed in these watersheds. For locations of these watersheds and multi-purpose sites, see Figure I-5.

Stream Water Rights

As of August 22, 1974, there was a combined total of 443 vested stream water rights and permits issued for the appropriation of 357,282 acre-feet of water per year from rivers, streams and lakes. The tabulation by counties is shown in Table IV-15.

GROUND WATER

Present development of ground water resources in the south central region is minimal. Although there are five major ground water basins, they are generally of small areal extent and little information has been collected concerning recharge, drawdown, static water level, transmissivity, etc.

Existing Development

Well development is sparse in all major ground water basins in the south central region. Of the

TABLE IV-15
SOUTH CENTRAL REGION STREAM WATER PERMITS

COUNTY	NUMBER PERMITS ISSUED	AMOUNT ALLOCATED AF/YR
Carter	38	38,839
Garvin	87	23,194
Grady	169	33,745
Jefferson	43	172,432
Love	14	3,056
Marshall	18	8,742
Murray	37	46,893
Stephens	37	30,381
TOTAL	443	357,282

total 555 municipal, industrial and irrigation wells, 260 are in the alluvium and terrace deposits. These wells are predominately in Jefferson and Love counties along the Red River. The alluvium and terrace yield from 200 gpm to as much as 600 gpm in places where sufficient saturated thickness exists. The remaining 295 municipal, industrial and irrigation wells are divided among the Antlers Sand, Oscar Formation, Simpson and Arbuckle Groups and other minor ground water basins. Potential for increased ground water development exists within the region, but more hydrogeologic data need to be collected in order to make precise determinations.

Ground Water Permits

As of August, 1974, there was a total of 285 ground water permits issued in the south central planning region. These permits allocate fresh ground water to be used for municipal, irrigation or industrial purposes. The use of ground water for domestic purposes does not require a permit and therefore is not considered in this section. The tabulation of data from the Oklahoma Water Resources Board files is shown in Table IV-16.

Present Uses and Future Requirements

The population of the south central region, according to the 1970 census, was 158,592. By the year 2030, this figure is projected to 194,400. At the present, the largest use of water in the south central region is for municipal and industrial needs. This includes water for energy related water requirements and rural water systems needs. Future projections for the region show that irrigation will require the most water usage.

MUNICIPAL AND INDUSTRIAL

Reported water usage for municipal and industrial purposes in 1972 totalled 47,961 acre-feet, with 6,529 acre-feet coming from ground water and 41,432 from stream water. By 2030, the projected requirements will call for 81,400 acre-feet.

RURAL WATER SYSTEMS

There are 35 rural systems located throughout the region serving 30,600 people. Ground water is the main source of water supply. At present, there are 47,900 people not served in this region. Predictions estimate that public water systems will be used by 32,200 customers by 1980, 35,400 by 2000 and 38,500 by 2030.

ENERGY RELATED WATER REQUIREMENTS

Garvin, Stephens, Carter and Jefferson counties contain great quantities of oil and gas. This area contributes approximately 26 percent of the State's oil and 15 percent of natural gas. If this level is to be maintained, greater amounts of water will be required in recovery and refinement. Industrial and municipal energy related water requirements will rise with population and industrial growth as projected.

IRRIGATION

The 1972 water usage for irrigation from ground water was 8,885 acre-feet and 20,355 from stream water, totalling 29,240 acre-feet. Projected water usage for irrigation by the year 2030 will be 147,400 acre-feet for this region.

OTHER USES AND REQUIREMENTS

Navigation

There are no navigation systems in the south central region and none are planned for the future.

Fish, Wildlife and Recreation

Although other public fish and wildlife facilities are located here, game management is provided solely by the Hickory Creek Management Area near Marietta. Demand for water is not expected to increase significantly in the future. At present, approximately 700 acre-feet are used each year.

Recreational water is consider-

TABLE IV-16
SOUTH CENTRAL REGION GROUND WATER PERMITS

COUNTY	NUMBER PERMITS ISSUED	NUMBER WELLS	AMOUNT ALLOCATED AF/YR
Carter	16	33	9,876
Garvin	83	140	39,602
Grady	102	163	27,981
Jefferson	21	78	4,976
Love	20	41	12,562
Marshall	6	16	2,016
Murray	15	37	15,718
Stephens	23	48	4,346
TOTAL	286	556	117,877

ed adequate except for swimming, a community responsibility.

Hydroelectric Power

The 2,953,000 acre-feet per year required for hydroelectric power at Texoma reservoir is not included in the proposed water requirements. Water used for power generation is not considered consumptive use of water. This is the only hydroelectric power reservoir in this region. At present, no other power projects are proposed.

Water Quality Control

Only Waurika Lake in Jefferson County provides water quality storage. Water quality storage in the lake provides 18,600 acre-feet per year for interim water quality control. This water is let out slowly over a period of time to prevent stagnant pools of water from forming and lowering water quality in the different streams.

No other water quality storage areas exist in the region, and water requirements would have to be reviewed if plans for additional areas were implemented.

Plan of Development

MAJOR RESERVOIR SYSTEM

Table IV-17 shows the 2030 demand and the recommended supply system of major reservoirs for south central Oklahoma. These reservoirs and a portion of the interconnected system are shown on Figure IV-12. The entire water supply system is shown on Figure I-2 of Section I, Summary. Verden project, located in the southwest region serves as a source reservoir for the south central region. The system will have emergency diversion stubs located upstream of Courtney and Purdy Reservoirs to permit flexibility in future operations. The transport water will be divided between irrigation and municipal and industrial needs. An undetermined amount of water will also be available from Lake Texoma and the Red River when this stream is compacted.

TABLE IV-17
SOUTH CENTRAL REGION WATER SUPPLY AND DEMAND IN 1000's OF ACRE-FEET ANNUALLY

ESTIMATED 2030 IN-BASIN REQUIREMENTS

Municipal and Industrial	81.4
Irrigation	147.4
TOTAL	228.8
To be met by ground water, SCS structures, farm ponds and Lake Texoma	105.2
NET REQUIREMENT	123.6

PLANNED 2030 SUPPLY

SOURCE RESERVOIR	YIELD	IN-BASIN NEEDS	INTER-BASIN NEEDS (deficit)
Verden (P)	7.5[1]		28.0
Courtney (P)	45.4[2]		—
Purdy (P)	20.0		—
Arbuckle (E)	22.7		—
TOTAL	95.6[1]	123.6	28.0

(E) — Existing or under construction
(A) — Authorized
(P) — Proposed

[1] Diverted from Verden Reservoir in southwest region—yield efficiency increases with imported water.

[2] Total yield of Courtney is 56,000 acre-feet. The additional 7,600 acre-feet will not be needed until after 2030.

WATERSHED PROTECTION PROGRAM

For discussion of the proposed watershed protection program, see the Statewide Summary, Section I.

Municipal Needs and Proposed Solutions

The present adequacy and suggested solutions to the water supply needs for communities in the south central region are compiled in Table IV-18. Surveys were conducted with officials of 44 areas. The surveys showed 14 communities were served by rural water systems or some other type of distribution system. A check of the remaining 30 towns showed that 13 communities are or will soon be using stream water. The remaining towns are generally small communities, or cities located near one of the main ground water basins. Well development in the region is more extensive than in the southeast; however, the potential for further development exists, especially in the Arbuckle Group.

The south central region, like the southeast, has the ground and stream water potential to meet its long term needs if their sources are properly developed and distributed. Several distribution systems are proposed for the region. Each system will depend on a reservoir which is proposed or under construction for its supply. These reservoirs are Courtney and/or Burneyville, Purdy, Hennipen and Waurika.

The proposed systems will be flexible in that no community will be compelled to participate in the systems. Also, each reservoir should have sufficient water to serve areas not mentioned. Such areas would include rural water districts and county water cooperatives.

TABLE IV-18
SOUTH CENTRAL REGION MUNICIPAL NEEDS AND PROPOSED SOLUTIONS

COUNTY CITY	PRESENT SOURCE	SHORT TERM NEEDS & PROPOSED SOLUTIONS (Present to 1990)	LONG TERM ALTERNATIVE(S) (From 1990 on)	COMMENTS
CARTER				
Ardmore	Mountain Lake City Lake SCS Sites No. 13 & 18 Arbuckle Lake 11 mgd Ground water- Oscar Formation	Proposed Courtney Reservoir and dam site 28 mi. SW of town No immediate problems are anticipated.	Proposed Caddo Creek or Courtney Reservoir	
Healdton	Ground water- Oscar Formation	SCS Site 2-3 mi. E. of town. Extra wells may need to be drilled until lake is built.	Same as short term.	City has purchased the land for the site and construction should begin soon.
Lone Grove	Ground water- wells in the edge of Oscar Formation	Additional wells in other sections of the Oscar Formation. Additional water will be needed in the very near future.	1) Purchase water from Ardmore 2) Obtain water from proposed Courtney Reservoir.	If Ardmore obtains water from the proposed Courtney Res., Lone Grove & Wilson should look into obtaining water from the resulting pipeline. Rapid growth is anticipated for this town.
Ratliff City	Ground water- minor ground water basin	Rural Water District from Fox. They plan to initially use R.W.D. water for an emergency standby source.	Same as short term.	Little or no growth is expected for this community. If growth occurs, the Oscar Formation or the Arbuckle Group would be a logical source of ground water.
Wilson	Ground water- Oscar Formation	Expanded well system in the Oscar Formation. A new well has just been completed; this should provide for their immediate needs.	1) Continued expansion of well system 2) Obtain water from Courtney Reservoir via pipeline to Ardmore	Lone Grove and one or more Rural Water Districts could be included in the distribution system to increase its feasibility.
GARVIN				
Elmore City	City Lake	City Lake. Present source should meet their short term needs.	Distribution system utilizing water from proposed Hennipen or Purdy Reservoir	A distribution system from Hennipen Res. could include Elmore City, Pauls Valley, Maysville, Davis, & possibly Wynnewood.
Lindsay	Ground water- Washita River alluvium	Expand their well system in the Washita River alluvium until Purdy Res. is built. An interim source may be needed for the city. SCS site N. of town might be utilized.	Purdy Reservoir 11-12 mi. S. of town	
Maysville	Wiley Post Memorial Lake	Wiley Post Memorial Lake; this source should be adequate for all short term needs.	Distribution system utilizing water from proposed Hennipen or Purdy Reservoir.	See comments for Elmore City.
Paoli	Ground water- Washita River alluvium	SCS Site E. of town (Paoli) may need supplemental wells until the reservoir is built.	Same as short term.	Paoli is now working with the SCS to develop the site near their town. This site should meet their long term needs.
Pauls Valley	City Lake NE of town. Ground water- Washita River alluvium deposits	Develop supplemental wells in the Washita River alluvium until Purdy Reservoir is built. This should be utilized as soon as possible.	Obtain water from Purdy or Hennipen Reservoirs	See comments on Elmore City.

COUNTY CITY	PRESENT SOURCE	SHORT TERM NEEDS & PROPOSED SOLUTIONS (Present to 1990)	LONG TERM ALTERNATIVE(S) (From 1990 on)	COMMENTS
Stratford	Ground water-Canadian River terrace deposits	Expand well system in terrace deposits No source problems anticipated	Same as short term.	City officials feel that there is a plentiful supply of good quality ground water in the area.
Wynnewood	Lake of the Arbuckles Ground water-Washita River alluvium deposits	Lake of the Arbuckles; this source should be adequate for the city's future needs.	1) Lake of the Arbuckles 2) Hennipen or Purdy Reservoirs (proposed)	Their Lake of the Arbuckles allotment should meet the city's long term needs. If unexpected growth occurs they should seek water from the proposed Hennipen Reservoir.
GRADY				
Alex	Ground water-Washita River alluvium	They should expand their well system as it becomes necessary.	Same as short term.	Their water table is stable & the quality is acceptable. They should be able to meet future needs by drilling more wells.
Chickasha	Fort Cobb Reservoir	1) Fort Cobb Reservoir. An alternate source will be probably required after their short term contract expires. 2) Develop wells in the Washita River alluvium deposits	1) Use water from the proposed Verden Reservoir once its yield is supplemented by water from the conveyance system. 2) Potential exists for further development of the Washita River alluvium deposits.	Chickasha's contract to use the short term yield of Ft. Cobb will expire around 1990, so an alternate source may be needed.
Minco	Canadian River alluvium	Continue expansion of their present well system.	Wells in the Rush Springs Sandstone, 15-17 mi. W. of town	
Rush Springs	Ground water-Rush Springs Sandstone	Continue well expansion in Rush Springs Sandstone. No problems.	Same as short term.	Plentiful supply of good quality ground water.
Tuttle	Ground water-Canadian River terrace deposits	Canadian River terrace deposits. Tuttle should immediately start a steady. expansion program in anticipation of rapid growth.	1) Canadian River terrace deposits 2) Purchase water from Oklahoma City	Water table is stable and quality is good. This city will probably grow rapidly due to its location close to the Oklahoma City area.
Verden	Ground water-Washita River alluvium and water from Chickasha	Obtain water from Chickasha. Adequacy is directly tied to Chickasha's supply adequacy	Same as short term.	Verden buys water from Chickasha when its wells will not meet the city's needs.
JEFFERSON				
Hastings	Rural Water District obtaining water from city of Waurika.	Continue using water from the city of Waurika. No problems.	Same as short term.	Plans are underway to enlarge the system which serves Hastings.
Ringling	Ground water-Oscar Formation	Expanded well system. Present wells are adequate for the next few years.	1) Expanded well system 2) 4 potential multi-purpose SCS sites in the area 3) Courtney Reservoir	The city foresees no water shortage problems, but one of the SCS sites could be developed in the future if needed.
Ryan	Ground water-Red River terrace deposits	1) Development of potential SCS 7 mi. E. of town 2) Purchase water from city of Waurika or from the Hastings R.W.D. which is being expanded to serve several rural areas. Need to implement one of these.	Same as short term.	Ryan should seek an alternate source due to the low yield of its 29 wells. Waurika should have extra water once Waurika Reservoir is built.
Terral	Ground water-Red River terrace deposits	Additional wells into the Red River terrace deposits. Additional wells needed to meet peak summertime demand.	1) Continue with terrace ground water 2) Develop SCS site 4 mi. E. of town	If the quality and/or yield of the terrace deposits becomes undesirable, Terral should utilize the SCS site E. of town.

COUNTY CITY	PRESENT SOURCE	SHORT TERM NEEDS & PROPOSED SOLUTIONS (Present to 1990)	LONG TERM ALTERNATIVE(S) (From 1990 on)	COMMENTS
Waurika	Ground water-Beaver and Cow Creek alluvium	Well renovation currently under way should provide sufficient water for Waurika, Hastings and the large Rural Water District which is being developed until Waurika obtains water from Waurika Reservoir.	1) Same as short term. 2) There is a potential SCS site NE of town which could provide supplemental water if needed.	
LOVE				
Leon	Ground water-Red River terrace deposits	Continued development of the yield of the Red River terrace deposits.	1) Same as short term. 2) Cookietown Reservoir would provide a dependable long term source.	No short term problems.
Marietta	Ground water-Antlers Sands	Expanded well system in the Antlers Sands.	Same as short term.	No short term problems.
Thackerville	Ground water-Red River terrace deposits	Continue well expansion as the citys demand increases. No short term problems.	Same as short term.	
MARSHALL				
Kingston	Ground water-Antlers Sands	Continued development of ground water from Antlers Sands	Same as short term.	No immediate problems.
Little City	Ground water-Antlers Sands	1) Continued use of present wells 2) Rural Water District which passes next to the town No immediate problems.	Same as short term.	The owner of the present wells has a contract to provide water for the town "as long as his wells are adequate". Rural Water District water may be needed after this point is reached.
Madill	Carter Lake City Lake	1) Develop wells in the Antlers Sands 2) Obtain water from the Glasses Creek arm of Lake Texoma No immediate problems are anticipated	1) Same as short term. 2) Potential SCS site SW of town	With present treatment methods and costs, water from Texoma Lake would be feasible only if a pickup point could be located which would not be affected by lake level fluctuations, and still be able to remove the water before it becomes mixed with water from the Red River arm of the lake.
Woodville (New)	Ground water-Antlers Sands	1) Continue with present source 2) Join a Rural Water District An additional well is needed for emergency standby.	Join the Rural Water District which passes near town, either for emergency standby or for their entire supply	
MURRAY				
Davis	Lake of the Arbuckles	1) Lake of the Arbuckles 2) Wells in the Washita River alluvium	1) Lake of the Arbuckles 2) Hennipen or Purdy Reservoir 3) Wells in the Washita River alluvium	If no large industry utilizes the 0.5 - 1.0 mgd the city has available for industrial use, their supply will be adequate. If a large industry does utilize this water, then a supplemental source will be needed.
Dougherty	Lake of the Arbuckles	Lake of the Arbuckles	Same as short term.	Dougherty needs to negotiate for more water from Lake of the Arbuckles for its future needs.
Sulphur	Ground water-Arbuckle Group	Expand their well system in the Arbuckle Group No problems with their present source.	1) Same as short term. 2) Utilize their allotment from Lake of the Arbuckles	

COUNTY CITY	PRESENT SOURCE	SHORT TERMS NEEDS & PROPOSED SOLUTIONS (Present to 1990)	LONG TERM ALTERNATIVE(S) (From 1990 on)	COMMENTS
STEPHENS				
Comanche	Comanche Lake	Comanche plans to obtain water from Waurika Reservoir upon its completion. Comanche's present system may become inadequate before Waurika Reservoir is finished. So an interim supply may be needed. Possibly supplemental wells could be drilled or Rural Water District water might become available.	Same as short term.	Should have no problems with water supply once Waurika Reservoir is built.
Duncan	Lake Humpreys Clear Creek Lake Duncan Lake Ground water-Oscar Formation	1) Present source supplemented by water from Waurika Reservoir 2) SCS site 3-4 mi. NE of town No immediate problems are foreseen.	1) Same as short term. 2) Proposed Hennipen or Courtney Reservoir	
Marlow	Ground water-Rush Springs Sandstone	1) Continued development of wells in Rush Springs Sandstone 2) Use of city owned lake E. of town (Taylor Lake) No problems are foreseen.	Same as short term.	

SOUTHWEST REGION

LIST OF TABLES AND FIGURES

TABLE

FIGURE

General Description

The southwest region, covering the 12 counties of Roger Mills, Custer, Beckham, Washita, Caddo, Greer, Kiowa, Harmon, Jackson, Comanche, Tillman and Cotton, extends over an area of 11,006 square miles. The western part of the region has gentle plains, with large expanses of rich agricultural land. The area also has more land under irrigation than any other area of similar size in the State. The eastern portion contains the Wichita Mountains.

Elevations vary from about 2,200 feet above mean sea level in Roger Mills County to approximately 800 feet near the Red River in Cotton County.

The region is bounded on the north by Ellis, Dewey and Blaine counties and on the south by the Red River. The southern section is drained by the Red River and the North, Salt and Prairie Dog Town Forks. The northern portion is drained by the Washita River and its tributaries.

Population was 268,369, according to the 1970 census. The largest city is Lawton, with 74,740 people. Other large communities include Altus, Anadarko, Frederick and Hobart.

Planning Area Resources

PRECIPITATION

Average annual rainfall increases easterly across the region, ranging from 22-32 inches as shown in Figure II-1. The variability of precipitation and the high evaporation rate cause a tendency toward severe drought. Ground water irrigation has saved many crops from drought.

EVAPORATION AND TEMPERATURE

The evaporation rate ranks highest in the State, averaging 64 inches annually as a result of strong winds and high temperatures. See Figure II-3. Mean annual temperature ranges from 59 degrees in the north to 65 degrees in the south. See Figure II-2.

STREAM WATER CHARACTERISTICS

Runoff

Average annual runoff from precipitation ranges from one inch in the west to three and one-half inches in the southeast corner, for a total of 1,225,000 acre-feet per year. See Figure II-4.

All streams, with the exception of the Washita River, enter into the main stem of the Red River and their combined flow is recorded at the U.S.G.S. gauging station at Burkburnett, Texas. The average flow at this station for a period of twelve years is 498,500 acre-feet.

Records disclose prolonged periods of drought on the Washita River followed by years of devastating floods. These wide fluctuations in flow have been regulated by numerous flood retarding structures and by Foss and Fort Cobb reservoirs. There has been a decline in the average annual flows since closure of these structures. For location of these structures see Figure IV-16.

No flows at times have been recorded on all major streams in the region and no flows have been recorded each year on the Salt Fork and North Fork of Red River.

A summary of streamflow records at U.S.G.S. gauging stations inside the region is presented in Table IV-19.

Flooding

This area is subject to frequent flooding, with large severe floods occurring on an average of more than once a year. However, flooding has been reduced through the combined efforts of the U.S. Soil Conservation Service and the Corps of Engineers through construction of numerous flood control structures.

Stream Water Quality

A large quantity of poor quality water flows out of the region annually. The major water quality problem is the high mineral load carried by the streams.

The Washita River, like most of its tributaries, is rather gyppy and carries moderate to large amounts of dissolved minerals throughout most of its length. Total dissolved mineral concentrations at times exceed 2,000 mg/l. The Washita is used for irrigation because soils usually accept the high sulfate load, but this water does not meet public health standards on a dependable basis.

The Elm Fork arm of the Red River contains excessive amounts of chlorides due to natural salt

TABLE IV-19
SOUTHWEST REGION STREAMFLOW SUMMARY

STREAM	U.S.G.S. STATION	CONTRIBUTING DRAINAGE AREA SQ. MILE	AVERAGE ANNUAL FLOW AF/YR	OBSERVED FLOW (CFS) MAX	MIN.
Elm Fork of Red River	3035-near Mangum	838	72,020	30,600	0
North Fork of Red River	3050-near Headrick	3,845	216,600	30,700	0
Red River	3085-near Burkburnett TX	14,634	498,500	62,800	0
Cache Creek	3110-near Walters	675	133,200	28,200	0
Salt Fork	3005-at Mangum	1,357	63,680	72,000	0
Washita	3265-at Anadarko	3,656	284,000	29,000	0

seeps and springs originating in its drainage basin and therefore, is generally unusable for any purpose. The flow of the North Fork of the Red River below the mouth of the Elm Fork is not suitable for municipal and industrial or irrigation purposes because of the chloride load of the Elm Fork. The water of the Salt Fork of the Red River is contaminated with sulfates and chlorides to such an extent that it is also not suitable for municipal and industrial uses and would not be suitable for irrigation unless mixed with water of higher quality.

The highest quality water in this region is found in the Cache Creek basin. Water quality records indicate that water impounded on Cache Creek would be suitable for most beneficial uses.

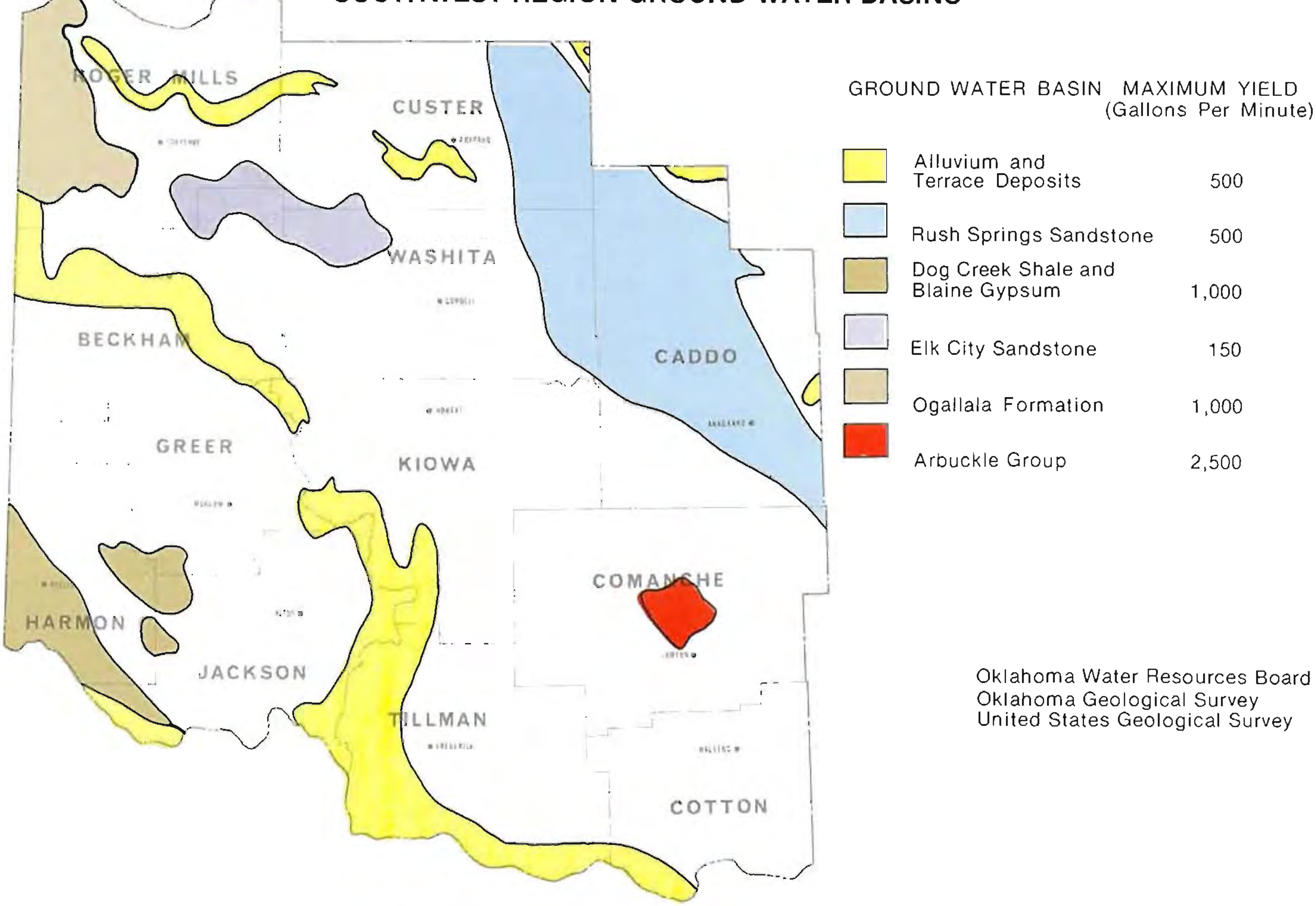
GROUND WATER RESOURCES

Six major ground water basins, of differing extent and storage potentials, exist in the southwestern region: the Arbuckle Group, Dog Creek Shale and Blaine Gypsum, Rush Springs Sandstone, Elk City Sandstone, Ogallala Formation and alluvium and terrace deposits. See Figure IV-13. Ground water serves the needs of most rural homes, towns and communities in the southwest region. See Table II-2 for total water in storage and amounts recoverable from region ground water basins.

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, locally has high porosity and wells yield 25-500 gpm. Where permeabilities are high, water may be suitable for industrial use; however, before used as a public water supply, the quality should be checked for excessive concentrations of fluoride.

Dog Creek Shale and Blaine Gypsum (Permian) occurs in Harmon, and parts of Jackson, Greer and Beckham counties. The ground water basin consists of interbedded shale, gypsum, anhydrite, dolomite and limestone, which in places are characterized by solution channels and zones of

FIGURE IV-13
SOUTHWEST REGION GROUND WATER BASINS



secondary porosity. The yield from wells tapping the Dog Creek Shale and Blaine Gypsum range from less than 10 to as much as 2,000 gpm. For a well to yield enough water for irrigation, it must tap a water-filled solution cavity.

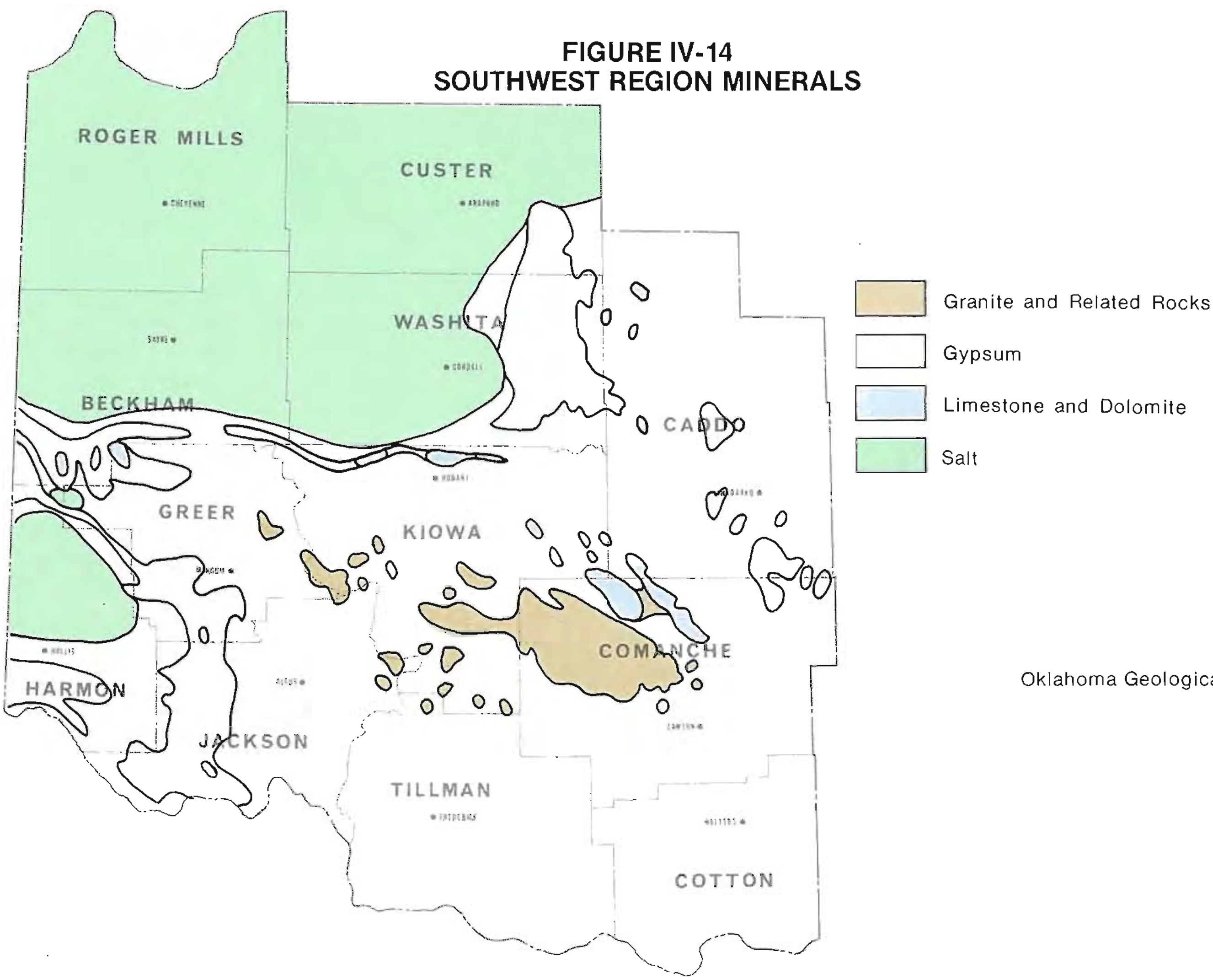
Water levels in the ground water basin respond rapidly to infiltration of precipitation, and also to the effects of pumping. Due to the erratic nature of solution channels and cavities, it is difficult to predict yields or estimate amounts in storage. Water quality is poor because of hardness and very high calcium sulfate concentrations. Locally, 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) is an extensive ground water basin outcropping over an area of about 1,900 square miles in Caddo, Custer, Washita and small parts of Comanche, Dewey and Grady counties. It is a fine grained, cross-bedded sandstone, containing irregular silty lenses. Thickness ranges from less than 200 feet in the south to about 330 feet in the northern part of the region. Depth to water below land surfaces ranges from 0-150 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. Dissolved solids concentration in 38 samples ranged from 179-2,270 mg/l with the median concentration at 296 mg/l. Seventy-five percent of the wells sampled showed less than 450 mg/l dissolved solids, which is within the recommended (500 mg/l) level for drinking water. Median hardness is 179 mg/l.

Elk City Sandstone (Permian) occurs in western Washita and eastern Beckham counties. It is similar to the Rush Springs ground water basin in being a fine-grained sandstone with little or no shale; however, it differs from the Rush Springs in being of smaller areal extent and considerably thinner. Well yields range from 60-200 gpm. The ground water basin supplies water to the towns of Clinton, Cordell, Canute and Dill City. 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 and its thickness ranges greatly. The proportions of the different rock types comprising the Ogallala

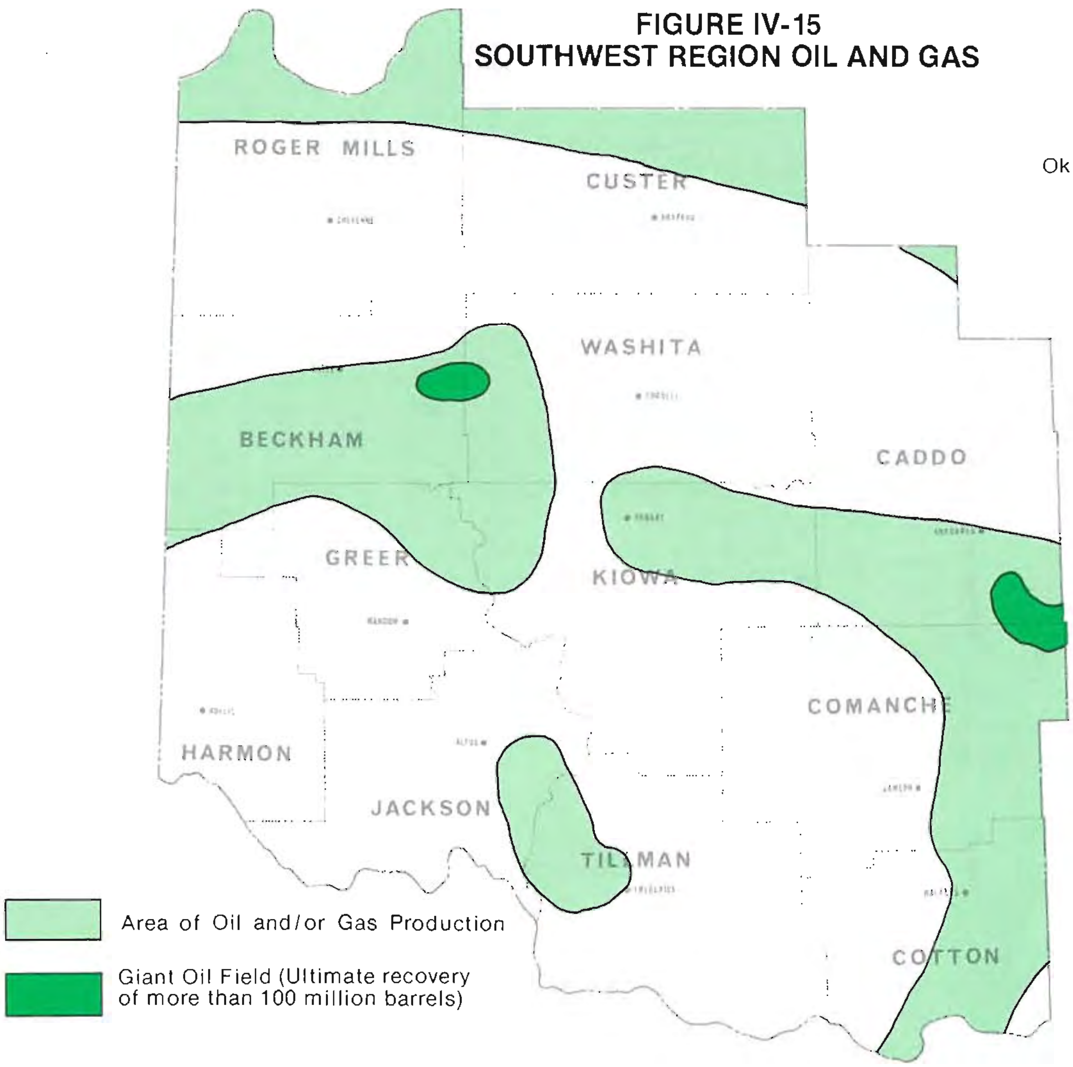
FIGURE IV-14
SOUTHWEST REGION MINERALS



Oklahoma Geological Survey

FIGURE IV-15
SOUTHWEST REGION OIL AND GAS

Oklahoma Geological Survey



change rapidly from place to place, but sand generally predominates. In the southwest region, the Ogallala occurs in western Roger Mills County where it is partly eroded and thins to the east. Yields are as much as 800 gpm, but more commonly, because of thinning and erosion of the ground water basin, yields are 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 terrace deposits are topographically higher than the alluvium, but hydrologically the alluvium and terrace constitute a single water-bearing unit. The deposits provide water in the areas adjacent to the Washita River, and North Fork of the Red River in Roger Mills, Custer, Beckham, Greer, Kiowa, Jackson, Tillman and Cotton counties. Total thickness of the alluvium and terrace deposits average 70 feet, but saturated thickness is 0-50 feet. Wells can be expected to yield from 200-300 gpm, but locally they may yield more than 500 gpm. Water quality is good and, except for hardness, the water can be used for domestic, irrigation, industrial and municipal supplies.

MINERAL RESOURCES

Most mineral production of the southwestern 12 counties consists of oil and gas, with the remainder being non-metallic minerals and some metals. During 1973, the region produced six million barrels of oil and 63 billion cubic feet of gas. Two giant oil fields exist in the region: the Elk City field and the Cement field, each with an ultimate recovery of more than 100 million barrels.

Oil and gas is produced in the region from rocks ranging in depth from 230-24,000 feet. The world's deepest production comes from a gas well in Beckham County, with a total depth of 24,548 feet. The greatest number of oil and gas wells are in Caddo and Kiowa counties.

The non-metals and metals produced in the region are mainly clay, gypsum, sand and gravel, stone, copper and silver. Clay is used for building bricks and gypsum is used mostly for land plaster, portland cement retarder and wall board. The alluvial and terrace deposits yield sand and gravel used for construction, concrete aggregate and road metal.

Dolomite is quarried to produce crushed stone. Limestone is quarried from the Arbuckle Limestone near Richards Spur north of Lawton, crushed and used for concrete and road metal. Granite is quarried and produced near Snyder and Granite for monuments and dimension stone.

Salt is presently produced in northern Harmon County, with deposits occurring in most of western Oklahoma at depths of 30-3,000 feet. Small amounts of silver are recovered from smelting operations in Jackson County. See Figures IV-14 and IV-15.

LAND RESOURCES

This region contains vast amounts of deep, rich agricultural land and fine pasture lands. Approximately 3,632,000 acres of the total 6,923,000 land acres are utilized as cropland and pastureland. Principal crops are cotton, wheat and sorghum. Caddo County, in the northeastern part of the region, produces more peanuts than any other county in the State.

The 1972 Reported Water Use showed that the southwest region had 183,687 acres under irrigation. This includes only reported acres and does not represent the region total. Oklahoma State University Extension Service in 1973 reported a region total of 199,210 irrigated acres.

The Altus-Lugert Irrigation District, authorized by Congress in 1938, was the first of its kind and started a trend to irrigate where water could be made available. It is located in Jackson County below Altus Reservoir. Irrigation water is released and gravity-flowed through canals to the 47,000 acres of land that make up the district.

Livestock is also an important contributor to the economy, with all counties showing substantial cattle production.

The southwest region has two important defense installations which contribute to the economy of the area: Altus Air Force Base in Jackson County and the U. S. Army Artillery and Missile Center at Fort Sill in Comanche County. Fort Sill utilizes 98,560 acres of land in the Wichita Mountains.

SOILS

Six major soil associations dominate the southwest region. These associations include Tillman-Vernon, Enterprise-Tillman-Yahola, Woodward-Carey-Quinton, Nobscott-Brownfield-Miles, Foard-Hollister-Tillster and Woodward-Dill-Quinlan. Most of the area is cropland with the remainder devoted to pasture and rangeland. Minor soil associations are numerous and include Tarrant, Granitic Mountains-Tishomingo soils, Rough Broken Land, both Vernon and Quinlan, Darnell-Stephenville, Yahola-Port-Reinach, Cobb-Quinlan, Vanoss-Minco-Yahola, Renfrow-Zaneis-Vernon, Pratt-Tivola and Carey-St. Paul. Typical land usage is crop, pasture and rangeland for these associations. See Figure II-11.

ENVIRONMENTAL RESOURCES

From canyons and rolling prairies to large lakes and mountain ranges, this area offers much for fishermen, hunters or vacationers.

Scenic Areas

In northern Caddo County, canyons caused by erosion of the soft sandstone make up Red Rock Canyon State Park. The area has many large cottonwood and cedar trees protected by the canyon walls. The Wichita Mountains near Lawton offer rugged terrain for the experienced hiker. Steep cliffs and large boulders provide an opportunity to enjoy a true wilderness. The Washita River in the north and the Red River in the south, along with their tributaries, offer miles of scenic and often untouched landscape.

Fish, Wildlife and Recreational Activities

The southwest region has many reservoirs well-stocked with channel catfish, bluegill and largemouth bass. The 8,800 acre Foss Reservoir in Custer County offers camping, boating, fishing and swimming. Quartz Mountain State Park, surrounding Lake Altus-Lugert in Kiowa County covers 6,791 acres. Fort Cobb Reservoir in Caddo County has some 43 miles of shoreline. The Washita National Wildlife Refuge, settled on 8,200 acres, offers hunters rabbits, raccoon, squirrels, beaver and 20 species of waterfowl. The Wichita Mountain Wildlife Refuge near Lawton, contains 59,020 acres and has fox, squirrels, beaver, wild turkey and many other game species. This area is one of four national refuges for buffalo, housing nearly one thousand animals.

Regional Historical Features

The southwest region is steeped in history. The lands were originally the hunting grounds of the Kiowas, Apaches and Comanches. After the Civil War, the Indians were allotted lands and forced to move. In 1868, General George A. Custer launched a surprise attack on a sleeping Cheyenne Indian camp near what is now Cheyenne, Oklahoma. This massacre became known as "The Battle of the Washita." Fort Sill Military Reservation, one of the nation's largest, is located near Lawton. Annually, the American Indian Exposition is held in Anadarko.

Present and Potential Development

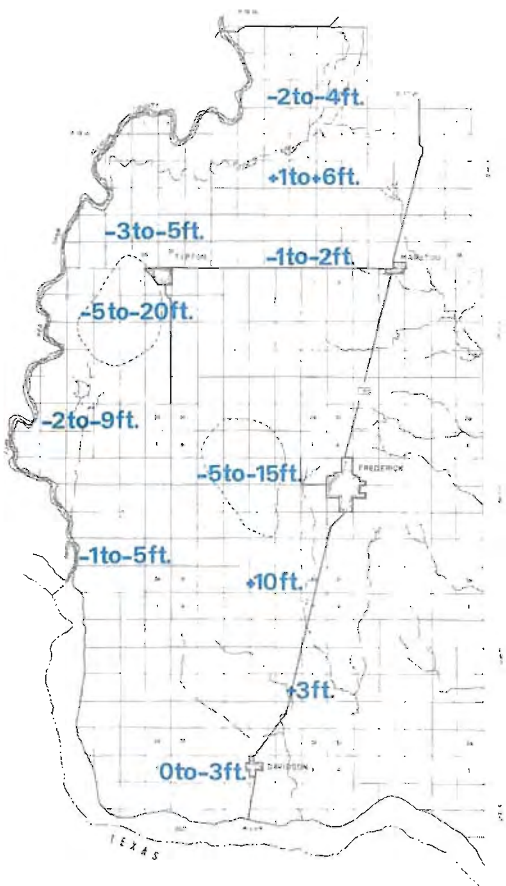
This area is drained by the main stem of the Red River, the North Fork and the Salt Fork of the Red River, The Washita River and their tributaries. Ground water provides a significant portion of this area's needs and overdevelopment is taking place.

TABLE IV-21
SOUTHWEST REGION STREAM WATER PERMITS

COUNTY	NUMBER PERMITS ISSUES	AMOUNT ALLOCATED AF/YR
Beckham	51	9,058
Caddo	261	64,669
Comanche	59	54,932
Cotton	73	10,775
Custer	105	84,780
Greer	15	2,148
Harmon	11	1,330
Jackson	118	104,656
Kiowa	76	109,186
Roger Mills	83	9,399
Tillman	45	12,600
Washita	190	29,666
TOTAL	1,087	493,199

water level declines have occurred in the Rush Springs Sandstone of Caddo County. The greatest change is in the Sickles area where a decline of 11-40 feet was reported between 1956-1974. See Figures IV-19 and IV-20. At present, the Dog Creek Shale and Blaine Gypsum may also be overdeveloped with wells pumping more water than is recharged annually from rainfall. Resulting problems in ground water mining areas are declining water levels, higher pumping costs, lower well yields and saline water encroachment.

FIGURE IV-17
WATER LEVEL CHANGES IN TILLMAN TERRACE DEPOSITS, TILLMAN COUNTY



Ground Water Permits

As of February, 1975, there was a total of 2,141 ground water permits issued. These permits allocate fresh ground water to be used as municipal, irrigation, or industrial water. The use of ground water for domestic purposes does not require a permit and therefore is not considered in this section. The tabulation of data from Oklahoma Water Resources Board files is as shown in Table IV-22.

Present Uses and Future Requirements

According to the 1970 census, the population of the southwest region was 268,369. This figure is expected to rise to 346,500 by the year 2030. At the present time the largest use of water in the southwest region is for irrigation. Future projections for the region show that irrigation will continue to require the most water usage.

MUNICIPAL AND INDUSTRIAL

Reported water usage in 1972 was 81,483 acre-feet, with 16,325 acre-feet coming from ground water and 65,158 from stream water. By 2030 this figure is projected at 173,700 acre-feet.

RURAL WATER SYSTEMS

Twenty-seven rural water systems exist in the southwest eight counties. Although the main source of water is ground water, minor amounts for Comanche County are extracted from Lawton's water supply.

The number of systems is increasing and this trend will continue in order to meet maximum water needs to all areas in the region. Currently 20,500 people are served by public water systems. At present 55,500 people are unserved by any type of water system. Projections indicate service accounts will increase by 1980 to 23,600, by 2000 to 32,700 and by the year 2030 to 42,100.

ENERGY RELATED WATER REQUIREMENTS

Large gypsum and minor silver mining operations are located in Greer, Harmon, Kiowa, Jackson and Tillman counties. Water is an important part of the mining operation and greater amounts of water will be needed in the future for expanding operations. Some oil and gas production further extends future water requirements.

IRRIGATION

In 1972, ground water irrigation accounted for 155,597 acre-feet and stream water accounted for 50,772 acre-feet, totalling 206,369 acre-feet. This figure is projected at 1,219,100 acre-feet by the year 2030.

FIGURE IV-18
WELL LEVEL DECLINE, TILLMAN COUNTY
NW 1/4 , NW 1/4 , NW 1/4 Sec. 2, T1S, R19W , 1953-1972

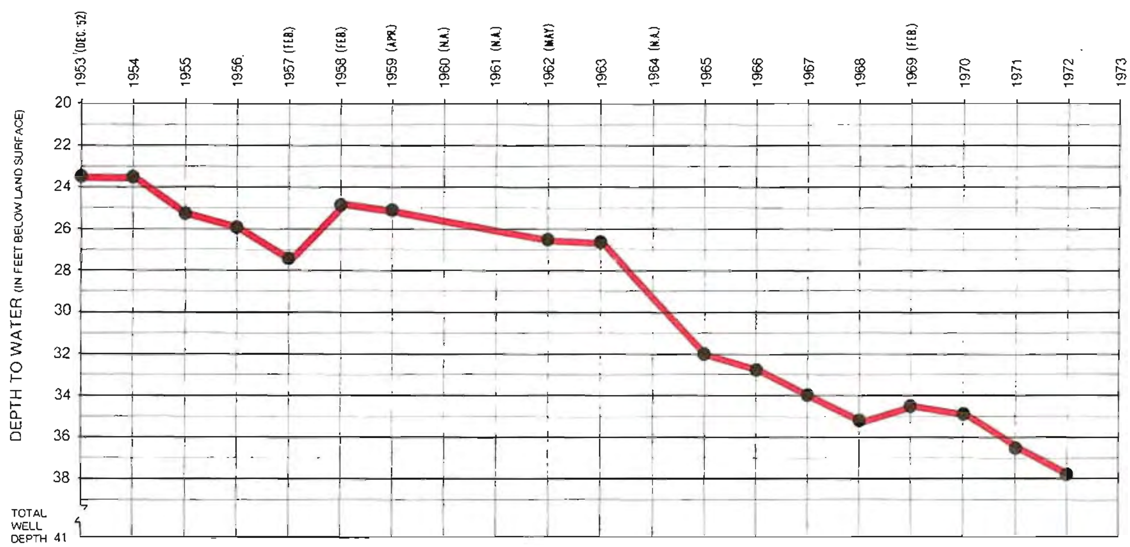


FIGURE IV-19
WELL LEVEL DECLINE, RUSH SPRINGS SANDSTONE
NW 1/4, NW 1/4, Sec. 3, T10N, R12W, 1956-1974

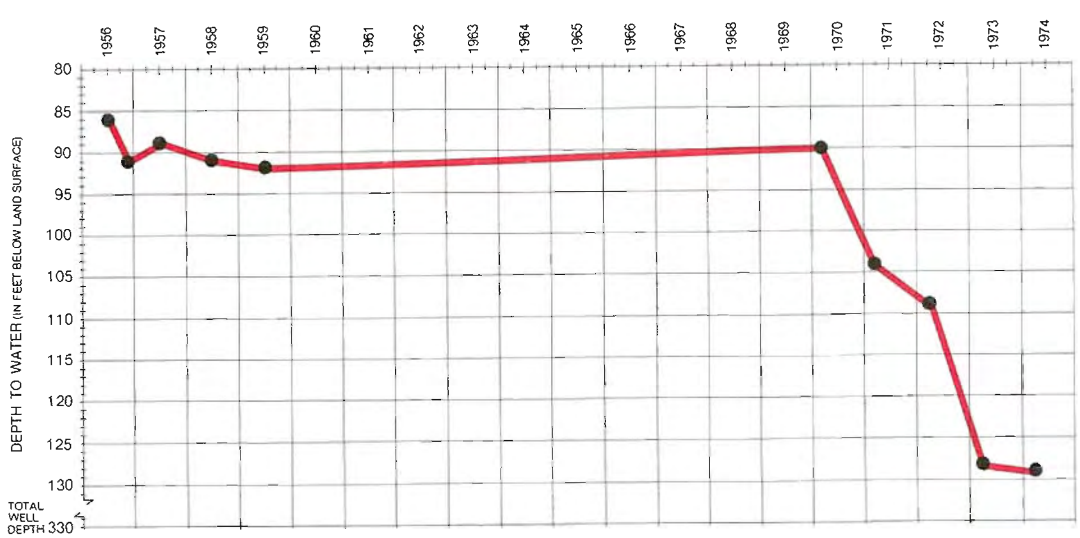
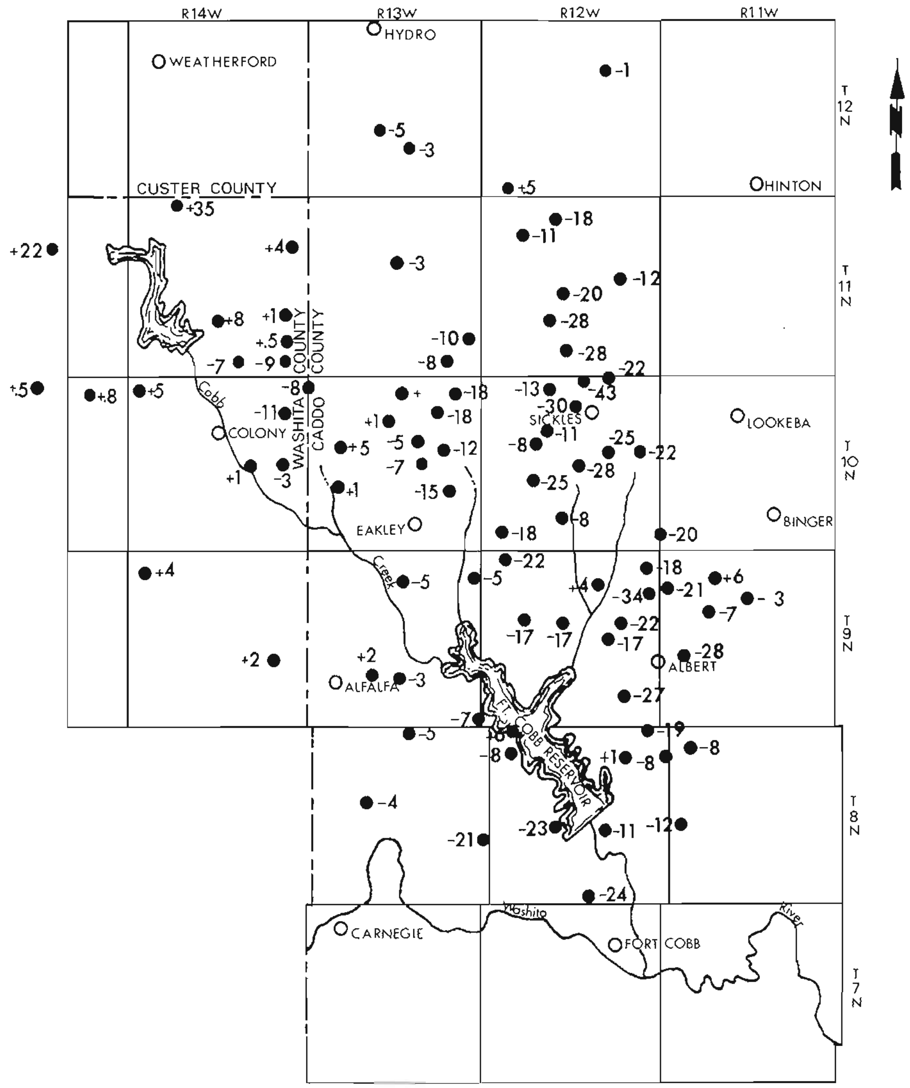


FIGURE IV-20
WATER LEVEL CHANGES IN CADDO AND WASHITA COUNTIES, 1956-1973 (In Feet)



OTHER USES AND REQUIREMENTS

Navigation

There are no navigation systems in the southwest region at present and it is unlikely that any will be planned for the future. If such a plan were established, water requirements would need review to provide the surplus water necessary for navigation.

Fish, Wildlife and Recreation

With 67,200 acres of wildlife refuges, water usage requirements were 612 acre-feet in 1973. The only projected increase was for the Medicine Park State Fish Hatchery in Comanche County. This increase was to be 1,709 acre-feet in 1974.

Water for recreation purposes is adequate except for swimming which will be provided by the individual community.

Hydroelectric Power

Inadequate streamflow and unfavorable terrain make hydroelectric power generation impractical in this area of the State.

Water Quality Control

There are no water quality storage areas other than the proposed chloride control project, nor are any planned in the foreseeable future. If such plans are implemented, water requirements will need adjustment and review.

The water stored in Foss Reservoir is of such quality that conventional treatment will not produce a potable water supply that meets the Public Health Service standards. However, this water is now being treated by an electrodialysis desalting plant and is producing 3 mgd (3,360 AF/YR) of good quality water. The facility is designed for a maximum output of 4 mgd (4,480 AF/YR).

The proposed chloride control project mentioned above is located on the Elm Fork of the

TABLE IV-22
SOUTHWEST REGION GROUND WATER PERMITS

COUNTY	NUMBER PERMITS ISSUED	NUMBER WELLS	AMOUNT ALLOCATED AF/YR
Beckham	105	235	30,092
Caddo	795	966	159,807
Comanche	39	94	10,325
Cotton	26	106	9,587
Custer	136	187	38,616
Greer	145	308	53,979
Harmon	51	64	11,796
Jackson	213	403	47,157
Kiowa	104	242	23,261
Roger Mills	98	148	21,140
Tillman	289	608	53,632
Washita	140	239	36,659
TOTAL	2,141	3,600	496,051

Red River in Harmon County. The Corps of Engineers has done extensive studies in this area where a large daily chloride load emerges from salt springs. Control of chlorides by the proposed project would help provide a better quality water downstream.

Plan of Development

MAJOR RESERVOIR SYSTEM

Table IV-23 shows the 2030 demand and the recommended supply system of major reservoirs for the 12 counties in southwest Oklahoma. These reservoirs and a portion of the conveyance system are shown on Figure IV-16. The entire water supply system is shown on Figure I of Section I, Summary. Water uses in the region will be approximately 11 percent for municipal and industrial use and 89 percent for irrigation. Reservoirs receiving imported water will be Altus, Fort Cobb, Foss, Mountain Park, Mangum and Snyder. Reservoirs independent of the canal system will be Ellsworth, Lawtonka, Waurika, Cookietown, Courtney, Hydro, Purdy, Weatherford and Carnegie Diversion Dam. Emergency canal diversion stubs will be placed upstream of Waurika, Ellsworth and Lawtonka to permit flexibility in future operations. The potential sites shown on Figure IV-16 could be utilized after the year 2030 for inter-basin storage as well as local supply.

TABLE IV-23
SOUTHWEST REGION WATER SUPPLY AND DEMAND IN 1000's OF ACRE-FEET ANNUALLY

ESTIMATED 2030 IN-BASIN REQUIREMENTS

Municipal and Industrial	173.7
Irrigation	1,219.1
TOTAL	1,392.8
To be met by ground water, SCS Structures and farm ponds	374.8
NET REQUIREMENT	1,018.0

PLANNED 2030 SUPPLY

SOURCE RESERVOIR	YIELD	IN-BASIN NEEDS	INTER-BASIN REQUIREMENTS (deficit)
Foss (E)	68.0[1]		48.0
Mangum (P)	15.0		84.0
Weatherford (P)	12.0		—
Fort Cobb (E)	13.3		97.9
Mountain Park (E)	16.0		90.0
Cookietown (P)	27.0		—
Hydro (P)	44.2[2]		—
Ellsworth (E)	9.5		—
Lawtonka (E)	8.5		—
Waurika (E)	46.5		—
Snyder (P)	0[5]		348.6
Altus (Mod)	25.0[3]		50.0
TOTAL	285.0[4]	1,018.0	718.5

(E) — Existing or under construction
(A) — Authorized
(P) — Proposed

[1] 50,000 AF/YR Diverted from Carnegie Division Dam.
[2] Diverted from Hydro project in northwest region.
[3] Modification will increase present yield of Altus Lake from 16.8 to 25.0 acre-feet.
[4] Yield efficiency increases 14,500 acre-feet with imported water.
[5] Potential storage 380,000 acre-feet.

WATERSHED PROTECTION PROGRAM

For discussion of the proposed watershed protection program, see the Statewide Summary, Section I.

Municipal Needs and Proposed Solutions

The proposed solutions to the short and long term municipal needs for the southwest region are shown in Table IV-24. The table also includes a brief statement relating to the present condition of each community's supply.

A total of 86 areas were contacted. Of these, 22 are or soon will be served by rural water districts or other types of distribution systems. Fifty-five are presently using ground water, three are using stream water, and six are using both ground and stream water.

As the previous figures indicate, ground water is the major supply source for this region. The lack of stream water development is due primarily to the scarcity of good quality streamflow.

The rural water districts in the region depend almost entirely on ground water from alluvium and terrace deposits. The districts distribute water of generally good quality to areas which would otherwise have an inadequate and/or poor quality supply. As overdevelopment of the alluvium and terrace deposits continues, a supply problem is expected to develop. This future need has been considered in the determination of future water needs for the region.

Several communities in the southwest region are using water which exceeds the U.S. Public Health Service Drinking Water Standards of 1962. Other communities suffer water shortage during the summer months. These communities need an expeditious solution to their present problems.

TABLE IV-24
SOUTHWEST REGION MUNICIPAL NEEDS AND PROPOSED SOLUTIONS

COUNTY CITY	PRESENT SOURCE	SHORT TERM NEEDS & PROPOSED SOLUTIONS (Present to 1990)	LONG TERM ALTERNATIVE(S)(From 1990 on)	COMMENTS
BECKHAM Carter	Rural Water District	Continue with present source. No problems are anticipated.	Same as short term.	Carter has recently joined a Rural Water District which provides relatively good quality water.
Elk City	Ground water- N. Fork of Red River terrace deposits	1) Development of wells in the Elk City sandstone 2) Additional wells in the North Fork Red River terrace deposits No immediate problems are expected.	1) SCS site S. of town 2) Utilize the yield of Foss Reservoir which is to be supplemented by transported water.	The Elk City Sandstone has a definite local potential. A combination of these alternatives may be needed to meet Elk City's future needs.
Erick	Ground Water- N. Fork of Red River terrace deposits	1) Drill additional wells in the N. Fork Red River terrace deposits 2) Develop a Rural Water District with Texola Have recently developed some new wells which should be adequate for several years.	Same as short term.	City officials indicate their water table has declined slightly. Little growth is anticipated for this community.
Sayre	Ground water- N. Fork of Red River terrace deposits	1) Drill additional wells in the present terrace deposits 2) Develop the SCS site near town. Will need additional wells in the near future.	1) Develop the potential SCS site near town 2) Obtain Foss Reservoir water once it is supplemented by transport water.	The SCS site is 9 mi SW of town. City officials indicate their water table is lowering a little each year.
Texola	Ground water- Blaine Gypsum	Develop Rural Water District either with Erick, or independently. Need another well for emergency standby until R.W.D. is formed.	Same as short term.	Water quality of present system is poor due to high total dissolved solids and sulfates. Plan to form R.W.D. in 2 to 3 years if funding becomes available.
CADDO Anadarko	Fort Cobb Reservoir and emergency wells in the Rush Springs Sandstone	Fort Cobb Reservoir No short term problems are foreseen.	1) Reallocation of Ft. Cobb Res. water previously allocated to irrigation. 2) Utilize supplemental water from the Rush Springs Sandstone.	The irrigation water which reverted to the Master Conservancy District if allocated proportionally between Anadarko and the Western Farmers Electric Cooperative should meet the city's long term needs.
Apache	Ground water- Marlow Formation	Drill additional wells in the Rush Springs Sandstone. Present system is adequate but their water table is dropping.	Same as short term.	
Binger	Ground water- Rush Springs Sandstone	Drill additional wells as it becomes necessary. No problems are foreseen with the present source.	Same as short term.	The addition of a new well and the repair of the water supply line have resulted in a more than adequate water supply for Binger.
Bridgeport	Ground water- Canadian River alluvium	Formation of a Rural Water District. They have adequate water, but the quality is poor.	Same as short term.	A dependable source of water would be the Rush Springs Sandstone 4-5 mi SW of town.

COUNTY CITY	PRESENT SOURCE	SHORT TERM NEEDS & PROPOSED SOLUTIONS (Present to 1990)	LONG TERM ALTERNATIVE(S) (From 1990 on)	COMMENTS
Carnegie	Ground water-Rush Springs Sandstone	Continued development of the yield of the Rush Springs Sandstone. No problems are anticipated for the next few years.	Same as short term	City officials feel that plenty of good quality water can be obtained by drilling more wells.
Cement	Ground water-Rush Springs Sandstone	Develop deeper wells N. of town in the Rush Springs Sand stone. Their present supply is inadequate and the quality is poor.	1) Same as short term. 2) Develop a Rural Water District, possibly with Cyril, utilizing Ft. Cobb Reservoir water once Ft. Cobb's yield is increased by import water.	Recent tests of a well N. of town indicate a good yield, and acceptable quality. Further development in this area is a logical alternative.
CADDO cont. **Cyril**	Ground water-Rush Springs Sandstone	Supply is inadequate and the quality is deteriorating. 1) Exploration of the surrounding area to locate a high yield and high quality area in the Rush Springs Sandstone. 2) Obtain water from a Rural Water District.	1) Same as short term. 2) Develop a Rural Water District to obtain water from Ft. Cobb Reservoir after transport water is supplied to Ft. Cobb.	Cyril could join with Cement in developing a Rural Water District.
Eakly	Ground water-Rush Springs Sandstone	The present wells should meet their long term need unless the yield declines due to sanding in. Drilling additional wells in the Rush Springs Sandstone is their most economical alternative.	Same as short term.	
Fort Cobb	Ground water-Rush Springs Sandstone	No immediate problems exist, & plenty of good quality ground water is available by drilling more wells if needed.	Same as short term.	
Gracemont	Ground water-Rush Springs Sandstone	Their wells are presently adequate, and drilling more wells in the future is their most economical alternative.	Same as short term.	
Hinton	Ground water-Rush Springs Sandstone	No immediate problems exist with this source. The best future source for Hinton, as well as most of the other small towns in Caddo County, is to drill more wells in the Rush Springs Sandstone.	Same as short term.	
Hydro	Ground water-Rush Springs Sandstone	Their present system is adequate. Their most economical future alternative is to drill supplemental wells as it becomes necessary.	Same as short term.	
COMANCHE **Cache**	Ground water-Arbuckle Group	Their present supply is adequate, but they may need to drill additional wells to meet their short term needs. Water quality is fair.	1) Drilling additional wells. 2) Development of SCS site on Beaver Creek. Approx. 5 mi. SE of Cache.	The most economical alternative is drilling wells and should be considered first. But development of the SCS site should not be ignored, especially if the rapid growth of Lawton swells out to Cache, thus affecting it also.

COUNTY CITY	PRESENT SOURCE	SHORT TERM NEEDS & PROPOSED SOLUTIONS (Present to 1990)	LONG TERM ALTERNATIVE(S) (From 1990 on)	COMMENTS
Clinton	Clinton Lake and wells in the Elk City Sandstone	Their present system is adequate and the addition of Foss Reservoir water to their system should easily meet Clinton's short term needs. Further well development in the Elk City Sandstone also appears to be a promising alternative.	As a long term source Clinton might obtain water from the proposed Weatherford Reservoir 3-4 mi. NE of the city of Weatherford.	Clinton will also sell up to 70,000 gpd to the city of Butler.
Custer City	Ground water-Rush Springs Sandstone	Custer City has located a relatively good source of ground water E of town. Their new wells should provide adequate water for the town.	Continue with present source.	Negotiations are underway to form a Rural Water District which would obtain water for Custer City's wells, or from wells in the same general area. This R.W.D. would also serve Arapaho.
Thomas	Ground water-Rush Springs Sandstone	Their supply is adequate and their quality is relatively good. They will probably drill more wells as it becomes necessary.	Same as short term.	
Weatherford	Ground water-Rush Springs Sandstone	Their present system should meet the city's needs for the foreseeable future.	If properly developed the Rush Springs Sands should yield sufficient water to meet their long term needs. If Weatherford Reservoir or the Site #11 on Deer Creek is developed, use of a portion of their yield would insure a plentiful long term supply.	
GREER Granite	Ground water-North Fork of Red River terrace deposits	Although the quality is good their supply is inadequate and the water table is falling in their wells. Indications are that water is more abundant in the terrace deposits N. of town where the wells have reportedly had less trouble with declining water tables.	Utilize supplemental water from Altus Lake once its yield is supplemented by transport water.	a) The water table of their present wells has dropped rapidly in the last 5 years. b) Proper well spacing and ground water management will be necessary if the terrace deposits are to remain a dependable source.
Mangum	Ground water-North Fork of Red River terrace deposits	Their supply is presently adequate and city officials feel that they have plenty of water rights to drill more wells as it becomes necessary	Obtain supplemental water from the proposed Mangum Reservoir once it is constructed and its yield is supplemented by imported water.	See comments for Granite (b). Mangum also provides water to three Rural Water Districts in the area.
Willow	Ground water-North Fork of Red River terrace deposits	Their supply is presently adequate and future well expansion should meet their short term needs.	1) Same as long term alternatives for the city of Mangum. 2) A Rural Water District line near town might be utilized to provide supplemental water to the town.	See comments for Granite (b).
HARMON Hollis	Ground water-Salt Fork of Red River alluvium and terrace deposits	Their system will meet their present needs easily. Develop additional wells in the Salt Fork of Red River alluvium as it becomes necessary.	1) Same as short term. 2) Obtain water from the proposed Mangum Reservoir which is to be used as a terminal storage for transport water.	
Gould	Harmon County Rural Water District Salt Fork of Red River terrace deposits	Gould's present source is adequate & they will probably continue with it in the future.	Same as short term.	

COUNTY CITY	PRESENT SOURCE	SHORT TERM NEEDS & PROPOSED SOLUTIONS (Present to 1990)	LONG TERM ALTERNATIVE(S) (From 1990 on)	COMMENTS
JACKSON				
Altus	Altus Lake and in Texas Red River terrace deposits	The quality of the Altus Reservoir water now being used is poor and has to be diluted with good quality ground water which is piped from across Red River. Their allocation from the Mountain Park Reservoir which is under construction should meet the cities future needs.	Same as short term.	Altus' supply after it obtains Mountain Park Res. water should be sufficient for the city to supply the needs of surrounding towns such as Duke, Olustee, and Blair.
Blair	Ground water-North Fork of Red River terrace deposits	City officials feel they can get by on ground water until they obtain water from Altus in the near future. This should provide them with a dependable good quality source once Altus begins to utilize Mountain Park Reservoir water.	Continue to utilize water purchased from the city of Altus.	
Duke	Ground water-Dog Creek Shale & Salt Fork of Red River terrace deposits	Duke badly needs a different source since their wells in the Dog Creek Shale are inadequate, the quality is very poor, & this source is being rapidly depleted. They should try to obtain water from the city of Altus. It is noted that this would be expensive & if water of even fair quality could be located in the area, it might be more economical to develop it. The Salt Fork terrace deposits could be explored for further development.	Duke should plan to purchase water from Altus or some other source for its long term needs.	
Eldorado	Harmon County Water Corporation Salt Fork of Red River terrace deposits	Continue using water from Harmon County Water Corp.	Same as short term.	Ran short of water last year, but officials feel they have "bugs" worked out of the system.
Olustee	Ground water-Salt Fork of Red River terrace deposits	They have never had to ration water, but their quality is poor. They should locate a better quality source as quickly as possible. Apparently the best short term solution to their problems would be to obtain water from Jackson County Water Company.	If Rural Water District can not be obtained, Olustee should try to negotiate to obtain water from the city of Altus.	
KIOWA				
Gotebo	Ground water-Local Terrace deposits	Their quality is poor & the supply is inadequate. They hope to obtain water from a Rural Water District in the near future.	The Rural Water District which they anticipate joining should meet their long term needs.	
Hobart	Ground water-Rush Springs Sandstone and Hobart (Rocky) Lake	Once their present supply is supplemented by water from Foss Reservoir they should have sufficient water for their short term needs.	If Foss Reservoir's yield is supplemented by transport water Hobart should have enough water to meet its needs plus the needs of some of the small surrounding towns.	Hobart might pump water directly from the proposed conveyance project which would pass just south of Hobart.

COUNTY CITY	PRESENT SOURCE	SHORT TERM NEEDS & PROPOSED SOLUTIONS (Present to 1990)	LONG TERM ALTERNATIVE(S) (From 1990 on)	COMMENTS
Lone Wolf	Ground water-North Fork of Red River terrace deposits	Their quality is relatively good, but the city officials indicate their water table has dropped 19 feet in 20 years. More ground water can be developed by proper ground water management & obtaining land for more wells. Lone Wolf should investigate the development of the potential SCS site SE of town. They could also serve the rural areas nearby to lower the per capita cost.	1) Same as short term. 2) Use water from a distribution system or Rural Water District. Hobart could be the distribution point for such a system if sufficient water becomes available from Foss Reservoir.	
Mountain Park	Ground water-North Fork of Red River terrace deposits	Their quality is fair and the water table of their wells is not dropping. City officials indicate they plan to buy water from Snyder in the future. Additional ground water can be developed if needed.	Utilize the water from the city of Snyder.	
Mountain View	Ground water-wells in the west edge of the Rush Springs Sandstone	Their water quality is good and their present supply is adequate. City officials say their water table has dropped 10-15 feet in 10 years. Thus, they may need supplemental water in the future. They could drill wells in an area of the Rush Springs Sandstone which is not as densely developed locally, or develop a Rural Water District utilizing water from the main Rush Springs Sandstone.	This community's close proximity to the main Rush Springs Sandstone formation tends to favor ground water as a future alternative. With proper development the Rush Springs Sandstone should meet their long term needs.	
Roosevelt	Ground water-Local Terrace deposits	Roosevelt's present wells are barely adequate and will be flooded when Mountain Park Reservoir is completed. The Bureau of Reclamation has agreed to develop wells for the town to replace the ones to be flooded by the reservoir.	Ground water in this area probably will not meet this towns long term needs. They should consider the possibility of sponsoring a Rural Water District using water which would be transported to Mountain Park Reservoir under the proposed conveyance project.	
Snyder	Ground water-North Fork of Red River terrace deposits	They may need to develop supplemental wells until the Mt. Park Reservoir is completed. Snyder's allotment from Mountain Park Res. plus its current ground water supply should meet the city's short term needs.	A portion of the water plan would provide supplemental water to Mountain Park Res. for municipal, industrial, and irrigation. A portion of this supplemental water will be needed by Snyder to meet its long term needs.	
ROGER MILLS				
Cheyenne	Cheyenne Lake	This community's water supply is adequate and their quality is fair. No short term problems are anticipated for this town.	If additional water is needed for their long term needs, the potential Casady dam site NW of town would impound good quality run-off for municipal use. City officials also indicate there is a second SCS lake about the same size as Cheyenne Lake which might be developed as a future municipal source.	

COUNTY CITY	PRESENT SOURCE	SHORT TERM NEEDS & PROPOSED SOLUTIONS (Present to 1990)	LONG TERM ALTERNATIVE(S) (From 1990 on)	COMMENTS
Hammon	Ground water-Washita River alluvium deposits	Hammon's present source is adequate and their water table is stable, but the water is high in sulfate content. City officials indicate they hope to join a Rural Water District as an emergency standby source. If the R.W.D. water could be utilized to dilute their ground water it would produce a relatively good supply.	A Rural Water District using either ground water or water from one or more SCS sites would provide a dependable long term source. The ground or surface water could be developed by the town or by a Rural Water District to serve the town.	
Reydon	Ground water-Ogallala Formation	Although Reydon has plenty of water, their source is high in chlorides. Reydon should explore the Ogallala formation to locate an area of better quality water, or use water from the Washita River alluvium deposits.	1) Same as short term 2) Obtain water from the potential Casady dam site E. of town.	
TILLMAN				
Davidson	Ground water-North Fork of Red River alluvium and terrace deposits	Davidson may need to drill additional wells to meet their peak summertime demand.	1) Purchase water from Frederick once Frederick secures water from Mountain Park Reservoir 2) Obtain water from proposed Cookietown Reservoir.	Better ground water management could increase the dependability of wells in this area. Water for lawns is already rationed during summer months.
Frederick	Ground water-North Fork of Red River terrace deposits	Will soon obtain water from SCS project on Deep Red Run Creek (Lake Frederick). They have been allocated water from Mountain Park Reservoir.	1) Utilize Cookietown Reservoir 2) Develop the SCS reservoir on Coffin Creek for municipal use.	
Grandfield	Ground water-Red River terrace deposits	If the Red River terrace deposits become overdeveloped, new wells could be drilled in the alluvium S. of present field, as temporary measure.	The proposed Cookietown Reservoir should provide for any future needs.	A further problem may arise if the increased pressure to produce domestic oil forces a re-opening of the Grandfield Oil Refinery.
Hollister	Ground water-Local alluvium deposits	Might purchase Rural Water District water or irrigation well water is available to the town.	1) Same as short term. 2) Obtain water from the proposed Cookietown Reservoir.	Little growth is anticipated for this community. Existing supplies should be adequate for the future.
Manitou	Ground water-North Fork of Red River terrace deposits	Terrace deposits are thin in this area and are only a small resource. Manitou should negotiate to obtain water from the city of Frederick.	1) Purchase water from Frederick 2) Obtain water from a regional system based on Mountain Park and/or Cookietown Reservoirs	Same as Davidson
Tipton	Ground water-North Fork of Red River terrace deposits	Terrace deposits are being overdeveloped. Should negotiate to obtain water from the city of Frederick.	Obtain water from a regional system based on Mountain Park Reservoir or the proposed Cookietown Reservoir.	Improved ground water management techniques should be implemented to decrease or halt the water table decline in the area.

COUNTY CITY	PRESENT SOURCE	SHORT TERM NEEDS & PROPOSED SOLUTIONS (Present to 1990)	LONG TERM ALTERNATIVE(S) (From 1990 on)	COMMENTS
WASHITA				
Bessie	Ground water-minor ground water basin	Bessie's ground water is not potable, and they have to haul drinking water to individual cisterns. They plan to use Foss Reservoir water in near future. City officials estimate that the Foss Reservoir supply will only be adequate for 5 years. By that time they hope to have developed a Rural Water District which will obtain ground water from the Rush Springs Sandstone E. of town.	1) Development of a Rural Water District to use ground water from the Rush Springs Sandstone E. of town. 2) Obtain additional water from the Foss Reservoir pipeline when Foss Reservoir's yield is increased by transport water.	
Canute	Ground water-Elk City Sandstone	A consulting engineer recently reported that Canute has adequate water, and their main problem is a lack of storage capacity. Canute's water quality is fair and the potential for further ground water development exists.	Obtain a portion of the water to be imported to Foss Reservoir.	
Cordell	Ground water-Elk City Sandstone and Lake Cordell	Cordell's wells supply adequate water and their quality is fair. They plan to obtain supplemental water from Foss Reservoir in the near future. Their present supply plus Foss Res. water should meet their needs for several years.	Cordell's best long term alternative will probably be to use additional water from Foss Res. once Foss Res.' yield is supplemented by transport water.	They use Lake Cordell as an emergency source only. There are several wells in the area of Cordell's present well field which furnished water to Clinton-Sherman AFB while it was active. Since the base closed, only a fraction of the 1.4 mgd capacity of these wells is used. If Cordell could negotiate for a portion of this water, it would be an inexpensive supplemental source.
Corn	Ground water-Rush Springs Sandstone	Corn's present well provides adequate water and the city plans to drill another well to use on a standby basis. No problems are foreseen with this community's source.	Drill additional wells if it becomes necessary.	
Dill City	Ground water-Elk City Sandstone	Dill City's water quality is fair, they presently have adequate water and their water table is reportedly stable. They can drill additional wells when it becomes necessary.	They should either develop a Rural Water District using water from Cordell or continue well development in the Elk City Sandstone.	Dill City's water use is influenced by the Clinton-Sherman AFB NW of town. If the base were to reopen, or a large industry was to locate on the base, it would increase Dill City's population and water use.
Foss	Ground water-Local alluvium deposits	Foss' quality is fair. Due to Foss' small size and declining population, they will probably continue with their present system, and drill another well if it becomes necessary in the future.	1) Drill another well if it becomes necessary. 2) Obtain Foss Reservoir water once transport water becomes available.	

COUNTY CITY	PRESENT SOURCE	SHORT TERM NEEDS & PROPOSED SOLUTIONS (Present to 1990)	LONG TERM ALTERNATIVE(S) (From 1990 on)	COMMENTS
Rocky	Ground water-Rush Springs Sandstone	Rocky's supply is presently adequate, but their quality is poor. Rocky's best solution to their short term needs would be to obtain water from the Rural Water District which passes near town.	As a long term source Rocky should negotiate to obtain water from the Foss Reservoir to Hobart pipeline. There should be sufficient water for this purpose once Foss Res.' yield is supplemented by transport water.	Rocky could try to negotiate with Hobart or the Foss Master Conservancy District to obtain a portion of the Foss Res. water which should soon be supplying Hobart. Although this alternative exists, it will probably cost more than Rural Water District water.
Sentinel	Ground water-Rush Springs Sandstone	Sentinel should be able to meet their short term needs by drilling more wells as it becomes necessary.	They should consider using a Rural Water District as a supplemental or emergency standby source. Foss Res. water from the Foss Reservoir-Hobart pipeline might be utilized once transport water is provided to Foss Res. or water might be obtained directly from the conveyance system canal which will be located S. of Hobart.	

EAST CENTRAL REGION

LIST OF TABLES AND FIGURES

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FIGURE

General Description

The east central region lies in an area surrounded by the Ouachita National Forest in the southern part and Robert S. Kerr Lake and Lake Eufaula in the north. Comprised of Haskell, Hughes, Latimer, LeFlore, McIntosh, Okfuskee, Pittsburg, Seminole and Sequoyah counties, the area covers 7,829 square miles. The foothills of the Ozarks cross the northern section and the Arkansas and Canadian Rivers cross the central portion, providing wide alluvial plains for cultivation. The elevation ranges from approximately 2,700 feet above mean sea level in the southeastern Kiamichi Mountains to about 900 feet in the west.

This nine county region has a warm, moist subtropical climate, with gradual seasonal changes and moderately high humidity. The growing season averages about 212 days a year, but sometimes extends as long as 231 days. The region is drained by the Canadian River and the Poteau River, as well as the Arkansas.

The region's population in 1970 was 172,734. The largest city is McAlester, with 18,802 people. Other towns such as Seminole, Wewoka and Poteau are smaller and provide pleasant country living.

Planning Area Resources

PRECIPITATION

Spring is the wettest season, with May being the wettest month. Average annual precipitation varies from 37 inches in the northwestern section to 56 inches in southern LeFlore County. This is illustrated on Figure II-1. Winter is the driest season of the year. Most rainfall comes from thunderstorms, which occur frequently during the spring. These occasionally produce great variations in daily or seasonal amounts.

EVAPORATION AND TEMPERATURE

Annual average lake evaporation only slightly exceeds and in some cases, is less than the annual precipitation levels. As shown in Figure II-3, evaporation rates vary from 56 inches in the west to 48 inches in the east. Compared to other parts of the State, this is low and due to lower summer temperatures and wind velocities. This makes this region ideal for reservoirs and water storage areas. Mean annual temperature varies from 51-63 degrees across the region, as shown in Figure II-2.

STREAM WATER CHARACTERISTICS

This area is drained by four major streams. These are the North Canadian, Canadian, Poteau and Arkansas Rivers. These have a combined drainage of 191,165 square miles. In parts of the region, water quality considerations restrict utilization of some streams for domestic and municipal use.

Runoff

The average annual runoff from precipitation ranges from seven inches in the west to 20 inches in the southeast corner. This amounts to approximately 4,885,000 acre-feet per year of runoff originating in this region.

Runoff from mountainous drainage areas is rapid and results in high peak rates during storm conditions, causing floods of short duration. This runoff, plus the flows originating outside the region, constitute a tremendous amount of water flowing through this area. See Figure II-4.

A summary of streamflow records at U.S.G.S. gauging stations inside the region is presented below. For locations of gauging stations see Figure IV-24.

Flooding

Considering the amount of stream water development in this region, flooding should be minimal. However, rapid runoff from mountainous drainage areas results in high peak rates during storm conditions causing floods of short duration.

Stream Water Quality

In parts of this region, quality considerations restrict water use. Most of the time water quality of the Canadian River above Eufaula Reservoir and of the Arkansas River does not meet public health standards for municipal or domestic use. This water usually contains excessive amounts of dissolved minerals because of soluble material in the mantle rocks upstream or improper disposal of waste brines in early development of the oil industry. These minerals also impair the chemical suitability of the water for irrigation.

With a few exceptions, tributary streams of the Arkansas and

TABLE IV-25
EAST CENTRAL REGION STREAMFLOW SUMMARY

STREAM	U.S.G.S. STATION	CONTRIBUTING DRAINAGE AREA SQ. MILE	AVERAGE ANNUAL FLOW AF/YR	OBSERVED FLOW MAX (CFS)	OBSERVED FLOW MIN (CFS)
N. Canadian River	2420 - near Wetumka	14,290	473,100	66,000	0
Canadian River	2450 - near Whitefield	47,576	3,821,000	281,000	.4
Poteau River	2485 - near Wister	993	798,400	78,600	0
Arkansas River	2505 - at Van Buren, Ark.	128,306	21,520,000	850,000	16
Kiamichi	3357 - near Big Cedar	40.1	51,510	21,500	0

Canadian Rivers contain water of suitable quality for most uses. Generally the eastern tributaries of the Arkansas are of highest quality, although parts have been damaged by the mining activities in the area.

Of the two major lakes, Wister and Eufaula, Wister contains high quality water, while Eufaula contains fair to good quality water in the lower reaches.

GROUND WATER RESOURCES

Ground water is available in the east central region from two major ground water basins: the Vamoosa Formation and alluvium deposits. Wells in these basins provide water for most rural homes, for towns and industries and some irrigation. For location of ground water basins see Figure IV-21. See Table II-2 for total water in storage and amounts recoverable from ground water basins.

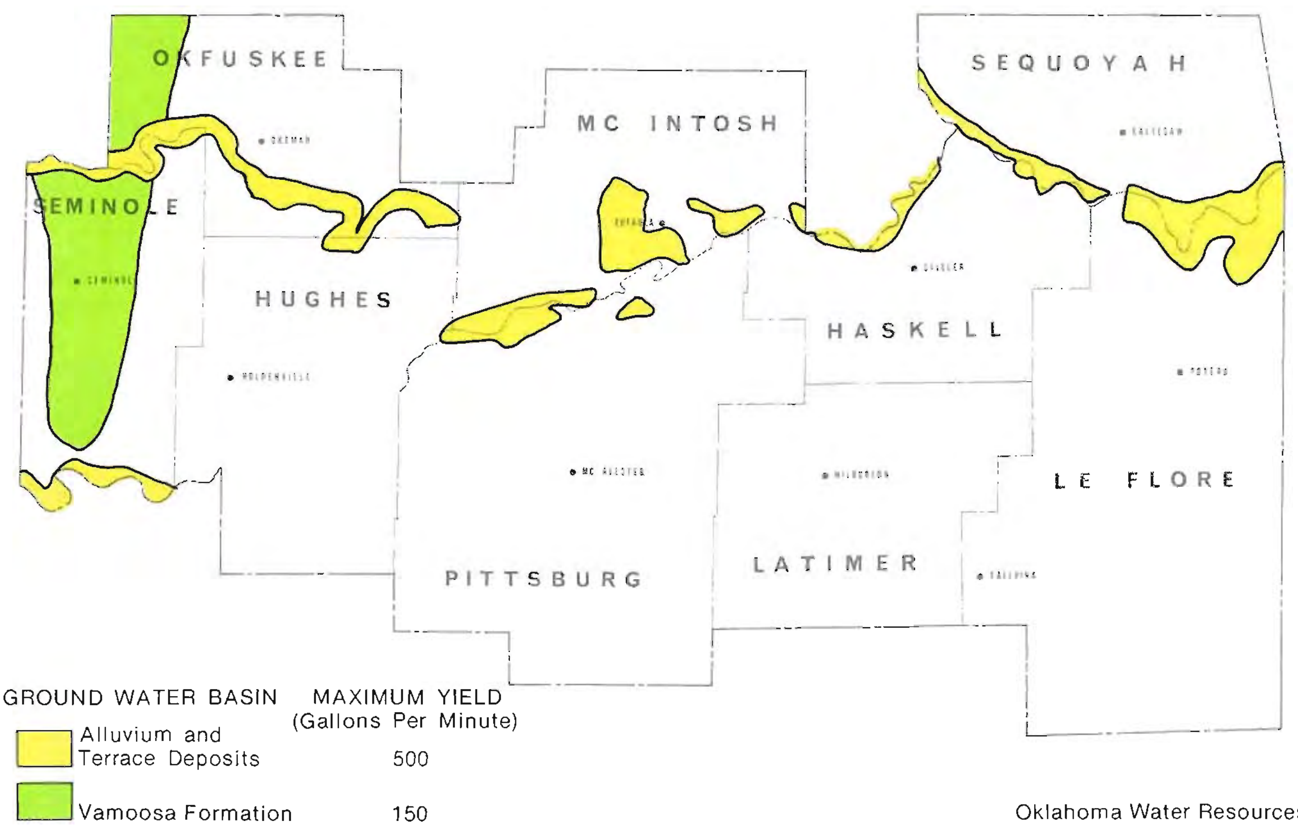
Vamoosa Formation (Upper Pennsylvanian in age) is composed of 125-1,000 feet of interbedded sandstone, shale and conglomerate. It has an outcrop area of about 600 square miles in Seminole, Okfuskee and Pottawatomie counties. The formation supplies water for municipal and industrial uses along its outcrop and several miles downdip to the west. The best wells are in the Seminole area where wells produce a maximum of 500 gpm. Yields change northward, decreasing from 250 gpm to 10-20 gpm. Although water quality is generally good, salt contamination and hardness are problems.

Alluvium Deposits (Quaternary) occurs along the Arkansas and Canadian Rivers. The deposits consist of silt, clay, sand and gravel. The total thickness of the deposits averages 42 feet and the saturated thickness is about 25 feet. Reported well yields range from 200-1,000 gpm. Along the Canadian River, the alluvium is known to be 35 feet thick locally. Yields up to 200 gpm can be obtained in most areas. The ground water in the alluvium is predominantly of a calcium, magnesium bicarbonate type, variable in dissolved solids content and hard. The water is suitable for irrigation and domestic, stock and limited industrial purposes.

MINERAL RESOURCES

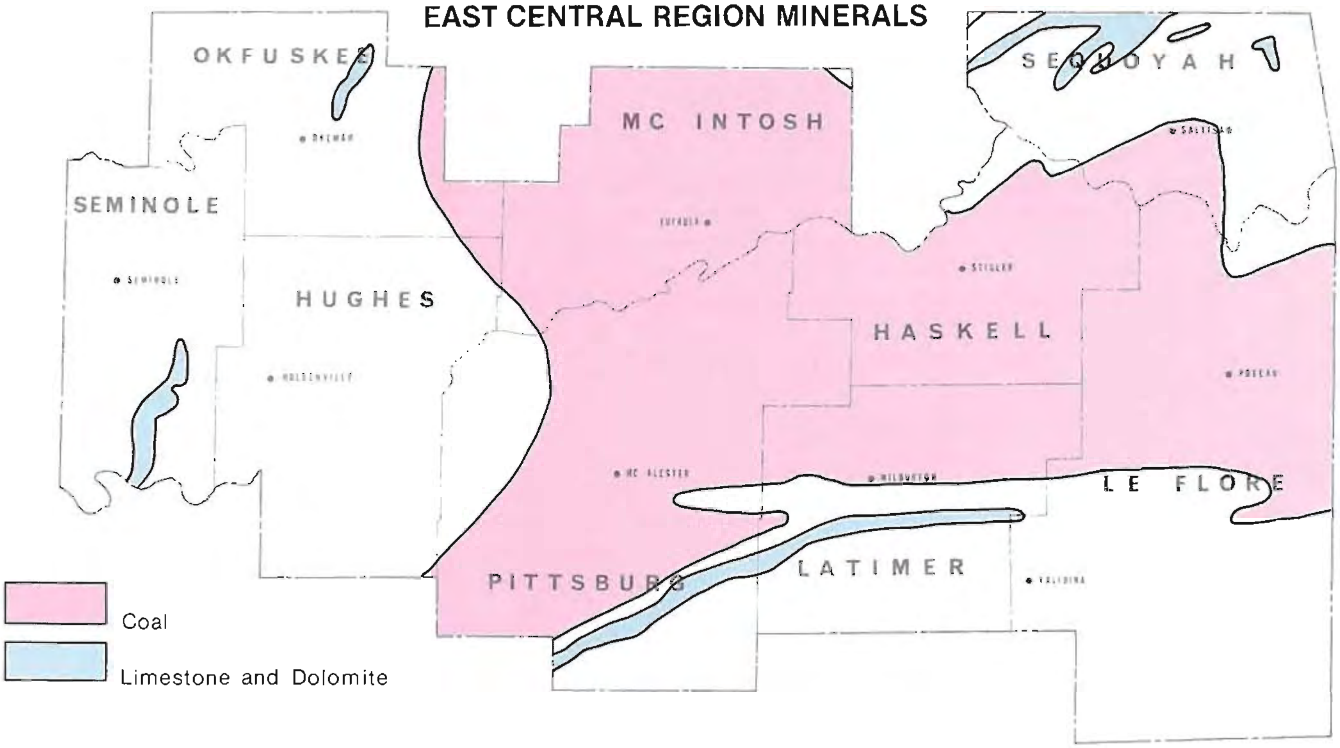
Mineral resources of the east central region consist predominantly of oil, gas and coal, with minor amounts of limestone, sand and gravel, and clay deposits. The region contains three large oil fields: Seminole, Bowlegs and Little River. Oil production in 1973 was nine million barrels for the nine county region. Natural gas is abundant. Also produced are nitrogen, carbon dioxide, ethane,

FIGURE IV-21
EAST CENTRAL REGION GROUND WATER BASINS



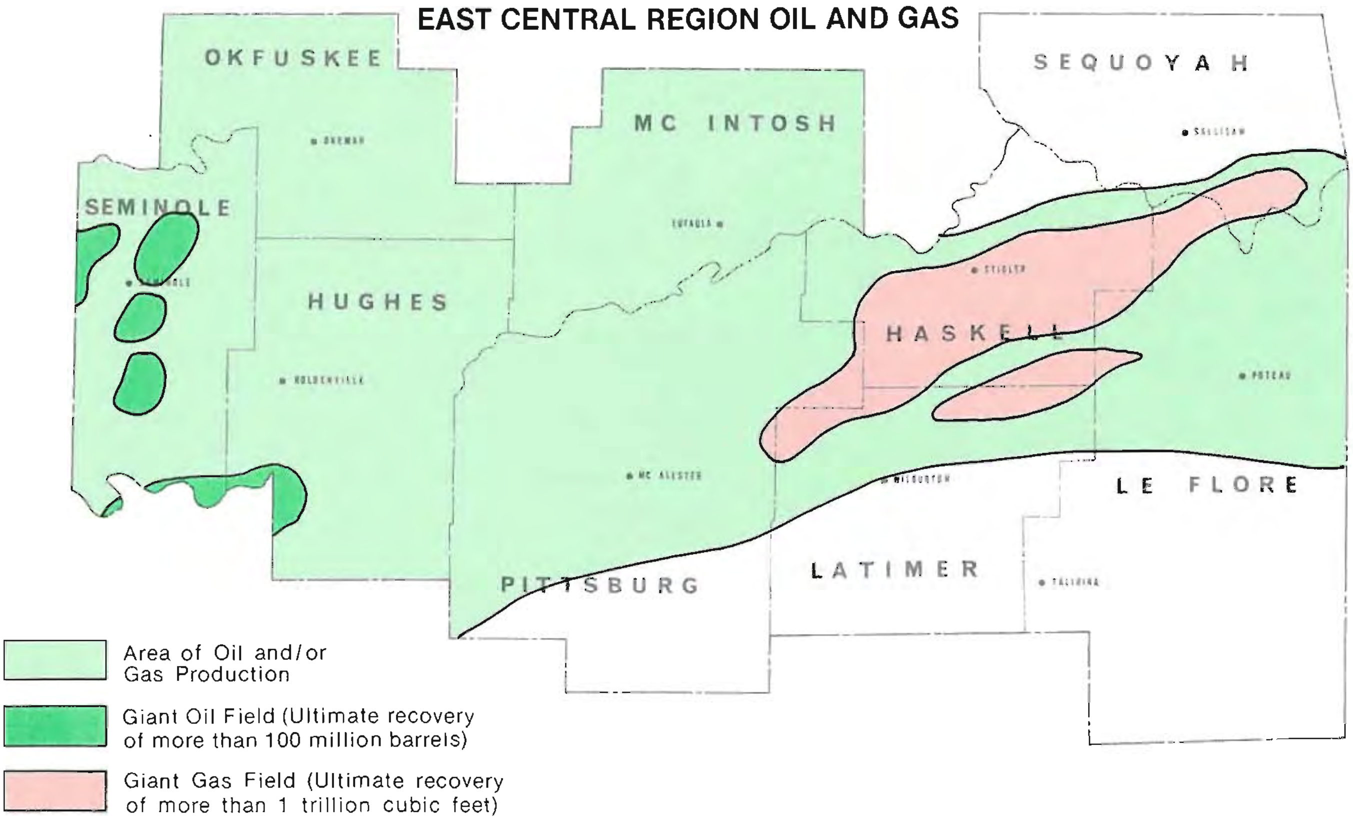
Oklahoma Water Resources Board
Oklahoma Geological Survey
United States Geological Survey

FIGURE IV-22
EAST CENTRAL REGION MINERALS



Oklahoma Geological Survey

FIGURE IV-23
EAST CENTRAL REGION OIL AND GAS



Oklahoma Geological Survey

propane and isobutane. Most of the oil and gas production is from the Pennsylvanian sands found at depths ranging from 500-12,000 feet. In 1973, natural gas production was 244 billion cubic feet. Coal deposits are found in Pittsburg, McIntosh, Haskell, Latimer, LeFlore and Sequoyah counties. As of January 1974, these six counties contained six billion short tons of remaining coal resources. Most of this coal is of low sulphur content. See Figures IV-22 and IV-23.

LAND RESOURCES

This region has 1,282,632 acres of cropland and pasture. Beef and dairy cattle and soybeans are increasing in production. A once dormant swine industry is now making a comeback due to a pork deficit in Oklahoma. Peanut, cotton, grain, sorghum and fruit production have declined in recent years and wheat and alfalfa have remained steady. There are 1,699,200 acres in forestland in this region, mostly oak and hickory. There is one military installation, the 45,000 acre U.S. Naval Ammunition depot near Savanna, nine miles southwest of McAlester. The 1972 Reported Water Use showed that the east central region had 13,812 acres under irrigation. This includes only reported acres and does not represent the region total. Oklahoma State University Extension Service in 1973 reported a region total of 12,582 irrigated acres.

SOILS

Soil associations located in the east central region are used as meadows, forest and rangeland pastures. Major soil associations include Parsons-Dennis-Bates, Hector-Pottsville and the Darnell-Stephenville association. Minor soil associations include Dougherty-Teller-Yahola, Yahola-Port-Reinach, Atkins-Pope, Enders-Conway-Hector and Renfrow-Zaneis-Vernon. Cropland, timber, fruits and vegetables are commodities grown on these soil associations. See Figure II-11.

ENVIRONMENTAL RESOURCES

The east central region, by far, contains the largest amounts of natural environmental resources. Green, rolling hills, abundant rainfall and mild climate make the area an ideal location from an environmental standpoint.

Scenic Areas

The entire eastern half of the region is dominated by the Ouachita Mountains, and the western half by oak forests and wide cattle ranges. Robbers Cave State Park in Latimer County provides large rocks and hills for the adventurous. Ouachita National Forest in southern LeFlore County possesses thousands of acres of tall pines and clear mountain streams. Three major streams, the Poteau, Canadian and Arkansas Rivers offer plenty of water for fishing and recreation. Big Lee Creek in Sequoyah County was designated a State scenic river under House Bill 1639, passed in 1974.

Fish, Wildlife and Recreational Activities

The 102,000 acre Lake Eufaula, located in McIntosh County, is a sportsman's paradise, offering boating, waterskiing and fishing. Several species of fish are stocked in region lakes, including rainbow trout, white and largemouth bass and crappie. Robert S. Kerr Lake covers 42,000 acres in Haskell County, while Lake Wister, in LeFlore County, covers 4,000 acres. Hunting is another popular sport. White-tailed deer are abundant, as well as bobwhite quail, eastern turkey, ducks, geese and squirrels. Public hunting areas include Choctaw and Wister Public Hunting Areas in LeFlore County and three areas near Lake Eufaula.

Regional Historical Features

The east central region history extends further back than any other region because of two discoveries there. The Spiro Mound and prehistoric Indian burial ground in Sequoyah County dates back to 500-1500 A.D., along with stone carvings in LeFlore County, which are believed to be of Nordic origin. The entire Seminole Nation and portions of the Choctaw and Creek Nations are located in the region. The early 1800's brought prosperity and growth to the Indians following their disastrous removal to Oklahoma. The Civil War once again divided the tribes. The region was once a haven for now famous outlaws, including the Daltons, the James Gang and Belle Starr. The home of the famous Cherokee, Sequoyah, is located in Sequoyah County.

Present and Potential Development

Developed stream water in this area consists of four major projects: Wister Reservoir, W. D. Mayo Reservoir (Lock and Dam No. 14), Robert S. Kerr Lake (Lock and Dam No. 15) and Lake Eufaula. The lower end of Tenkiller Lake is in this region. The subhumid climate, along with the large drainage area controlled by these projects, contributes so large a volume of water that adequate storage to develop the full potential of the streams is unlikely. This is an area of high rainfall and runoff averages and a naturally rough surface topography. The combination of these natural factors makes it possible to develop extensive stream water storages for both in-basin and out-of-basin needs. Ground water development is limited to two major basins and information is unavailable to accurately assess the potential for further ground water development.

STREAM WATER

As shown in Table IV-26, there

TABLE IV-26

EAST CENTRAL REGION PRESENT AND POTENTIAL WATER RESOURCE PROJECTS

NAME OF SOURCE	LOCATION	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	Illinois River	WS,FC,P,R[2]	576,700	25,400[2]	17,900[2]
Wister Lake	Poteau River	WS,FC,R,FW	400,000	9,600	6,700
Sub Total			2,471,700	115,300	91,100
POTENTIAL SITES				CONSERVATION STORAGE	
Brazil	Brazil Creek	WS,FC,R	108,000	190,000	87,400
Eufaula Power Releases[3]	Canadian River		-	-	1,250,000[3]
Higgins	Gaines Creek	WS,R	0	195,000	68,000
Sasakwa	Little River	WS,FC,R	150,000	600,000	135,000
Tenkiller Power Releases[3]	Illinois River		-	-	392,000[3]
Wetumka	Wewoka Creek	WS,FC,R	36,700	70,000	24,000
Wister Lake Modification	Poteau River	WS,FC,R,FW	400,000[4]	835,000[4]	473,700[4]
Sub Total			694,700	1,890,000	2,430,100
TOTAL			3,166,400		2,521,200

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

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

[2]A restudy is underway to consider water supply, recreation, etc., and reduce fluctuations in the power pool.

[3]This is the approximate yield that could be developed from Hydropower releases.

[4]Water supply yield is based on first and second stage modifications or ultimate development. First stage modification will yield 68,800 acre-feet per year.

are existing and under construction lakes in this region that provide a total of 2,471,700 acre-feet of flood control storage and 91,100 acre-feet of water supply. There are additional potential sites having a possible water supply yield of 2,430,100 acre-feet, for a region total of 2,521,200 acre-feet. Locations of the sites are shown on Figure IV-24.

Watershed Protection and Flood Prevention

The Soil Conservation Service has planned and engineered construction of numerous flood control structures for the purpose of watershed protection and flood prevention.

There is a total of 32 small S.C.S. watersheds in this region. Ten of these are complete or under construction, 6 are planned and 16 have potential for development in the next 50 years. To date, a total of 106 structures have been constructed in these watersheds.

Increased emphasis has been given in recent years to multiple uses of these flood retarding structures. In addition, to widespread recreation use, many local sponsors have added water storage for municipal purposes. The cities of Wilburton, Sallisaw and Talihina are presently using these structures for water supply purposes. There are two multipurpose structures planned for the city of McAlester and three for the city of Okemah. For location of these structures, see Figure I-5.

Stream Water Rights

As of August 30, 1974, there was a combined total of 346 vested stream water rights and permits issued for the appropriation of 397,069 acre-feet of water from streams in this region. The tabulation by counties is shown in Table IV-27.

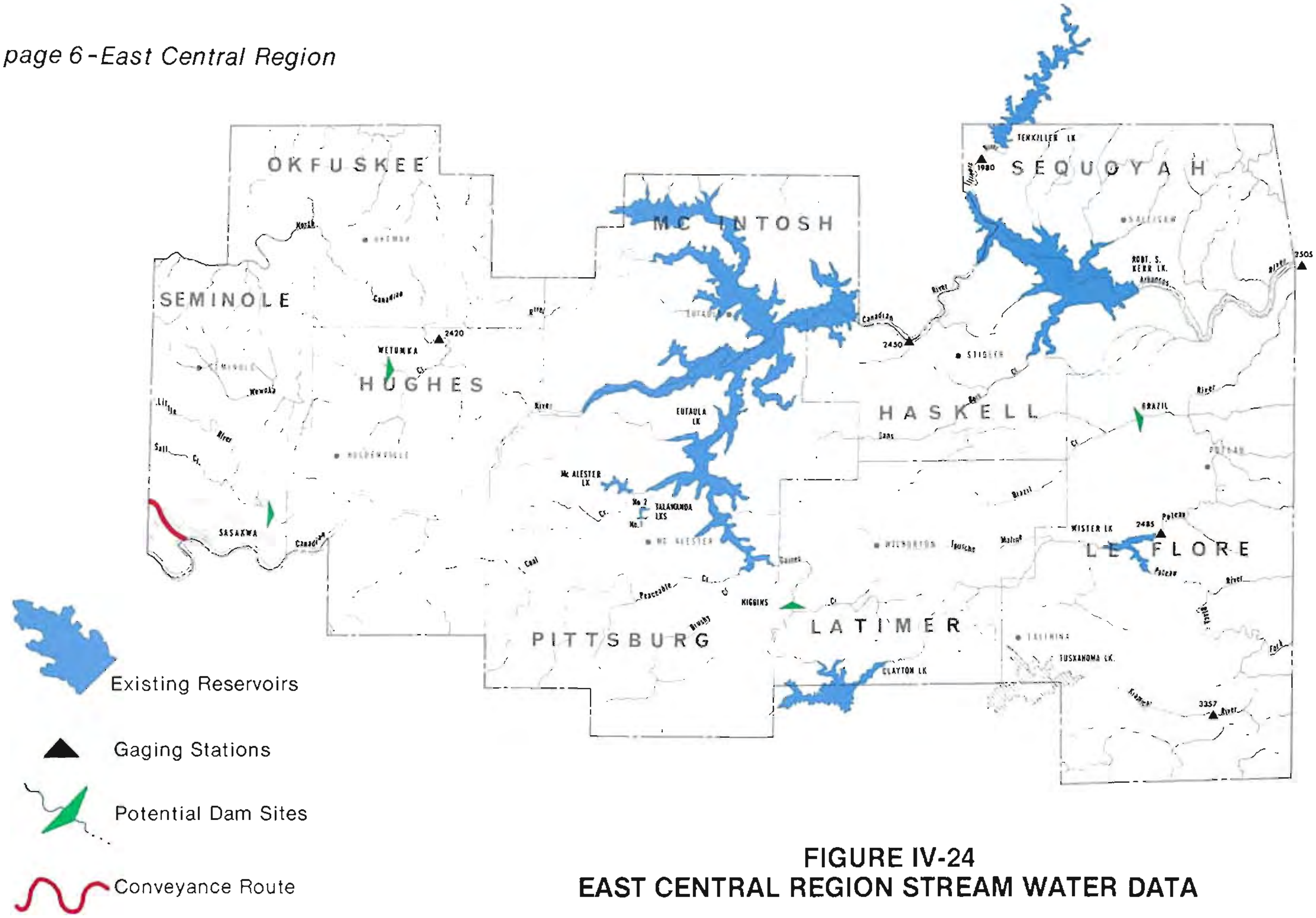


FIGURE IV-24
EAST CENTRAL REGION STREAM WATER DATA

GROUND WATER

Ground water development in the east central region is limited to the Vamoosa Formation and the alluvium deposits along major streams. Wells provide water for most rural homes and some towns and industries. Detailed and accurate ground water information is meager, and considerable work is needed to assess the potential development of the east central ground water basins.

Existing Development

The existing development of ground water supplies occurs in areas underlain by alluvium and by the Vamoosa Formation. The most favorable areas of development in the alluvium is along the Canadian and Arkansas Rivers. The alluvium supplies moderate to large quantities of water at rates of 100-1,000 gpm, averaging 250 gpm. The Vamoosa Formation yields about 200 gpm to wells supplying towns and industries. Most of the existing development in the Vamoosa occurs in Seminole and Okfuskee counties.

The total number of wells in the east central region, as obtained from Oklahoma Water Resources Board files, is 189. Most of these wells are in Seminole County, with the remaining portion of wells in Hughes, Okfuskee, Sequoyah and LeFlore counties.

TABLE IV-27
EAST CENTRAL REGION STREAM WATER PERMITS

COUNTY	NUMBER PERMITS ISSUED	AMOUNT ALLOCATED AF/YR
Haskell	14	4,791
Hughes	99	17,224
Latimer	21	3,962
LeFlore	64	40,262
McIntosh	17	5,586
Okfuskee	19	185,046
Pittsburg	41	59,918
Seminole	25	32,307
Sequoyah	46	47,973
TOTAL	346	397,069

Ground Water Permits

As of September 1974, there were 77 ground water permits issued. These permits allocate fresh ground water to be used as municipal, irrigation and industrial water.

The tabulation of data from the Oklahoma Water Resources Board files is shown in Table IV-28.

Present Uses and Future Requirements

The population of the east

TABLE IV-28
EAST CENTRAL REGION GROUND WATER PERMITS

COUNTY	NUMBER PERMITS ISSUED	NUMBER WELLS	AMOUNT ALLOCATED AF/YR
Haskell	2	2	882
Hughes	24	36	11,764
Latimer	1	1	134
LeFlore	9	23	8,062
McIntosh	0	0	0
Okfuskee	7	36	4,743
Pittsburg	4	7	659
Seminole	18	56	10,642
Sequoyah	12	28	5,223
TOTAL	77	189	42,109

central region is 172,734 (1970 census), and by the year 2030 that figure is projected to be 255,700. At the present time, the largest use of water in the east central region is for municipal and industrial needs. This includes water for energy related requirements and rural water systems needs. Future projections for the region show that municipal and industrial needs will continue to require the most water usage.

MUNICIPAL AND INDUSTRIAL

In 1972, reported water usage by municipalities and industries was 69,405 acre-feet. Ground water usage was 1,788 acre-feet and stream water was 67,617 acre-feet. By the year 2030, this figure is projected at 382,000 acre-feet.

RURAL WATER SYSTEMS

There are 45 rural water systems in the east central region. Water sources for the systems are Lakes Eufaula, Checotah, Wetumka and McAlester. Other sources consist of San Bois, Deep Fork, Mule and Bushy Creeks and ground water. Although 81,900 people are currently unserved by any type of public water system, 44,100 people are receiving services. Using projected figures, in 1980, 50,400 customers will be served. In 2000, there will be 63,000 customers and in 2030, that amount will increase to 75,600.

ENERGY RELATED WATER REQUIREMENTS

Oil and gas fields cover much of Okfuskee, Seminole, Hughes, Haskell, Latimer and Sequoyah counties. Water plays an important part in the recovery and refinement. Future water requirements have been considered in order to maintain and expand oil and gas operations.

IRRIGATION

Reported water usage for irrigation totalled 13,296 acre-feet in 1972. Ground water irrigation took 4,530 acre-feet and stream water took 8,766 acre-feet. The projected total for the year 2030 is 215,000 acre-feet.

OTHER USES AND REQUIREMENTS

Navigation

The east central region contains part of the McClellan-Kerr Arkansas River Navigation System and studies are under way for navigation from the McClellan-Kerr waterway to central Oklahoma. Water requirements for the McClellan-Kerr Navigation System are not included in this report. Further detailed analyses will be required before such analyses can be incorporated in a later report.

Fish, Wildlife and Recreation

The Wister State Waterfowl Refuge, Holder State Fish Hatchery and the Robert S. Kerr Federal Waterfowl Refuge Area are located here. Water usage was 190 acre-feet in 1973, with projected future demand to increase by 1,285 acre-feet.

Water is considered adequate for recreational purposes, except for swimming, which will be provided by the individual community.

Hydroelectric Power

Water requirements for hydroelectric power generation are not included in this report. Further detailed hydrologic system analyses will be made in a later report spelling out these hydropower requirements.

Water Quality Control

There is no water quality storage included in any of the east central region lakes, nor is any planned for the future. Water requirements would have to be reviewed if plans were ever established.

Plan of Development

MAJOR RESERVOIR SYSTEM

Table IV-28 shows the estimated 2030 demand and the possible supply system of major reservoirs in east central Oklahoma. The demand does not include the navigation water requirements for the McClellan-Kerr Arkansas River Navigation System, nor does the resource tabulation contain waters

TABLE IV-29
EAST CENTRAL REGION WATER SUPPLY AND DEMAND IN 1000's OF ACRE-FEET ANNUALLY

ESTIMATED 2030 IN-BASIN REQUIREMENTS

Municipal and Industrial	382.0[1]
Irrigation	215.0
TOTAL	597.0[2]

[1]Irrigation needs to be met by individual systems and stream bank pumping units.

[2]Does not include navigation water requirements.

POSSIBLE 2030 SUPPLY

SOURCE RESERVOIR	YIELD	IN-BASIN NEEDS	DEFICIT	SURPLUS
Eufaula (E)	56.0			
McAlester Lakes (E)	10.5			
Tenkiller (E)	17.9			
Wister (E-P)	68.8[3]			
Brazil (P)	87.4			
Higgins (P)	68.0			
Sub-Total	308.6	382.0	73.4	
Tenkiller Power Releases (E)	392.0			
TOTAL	700.6	382.0		318.6

(A) — Authorized
(E) — Existing or under construction.
(P) — Proposed

[3]First Stage modification proposed by Corps of Engineers

of the Arkansas River main stem. Detailed system hydrologic studies are needed to determine the quantity of water available on the Arkansas River, with the appropriate reservoir system operated according to the terms of the interstate compacts affecting that stream. Further detailed economic studies are needed to update and refine projections of water use within this region.

As shown, the estimated 2030 in-basin needs will exceed the resources. Tenkiller power releases could satisfy this deficit if the demand can be physically served. An additional potential supply of 1,650,000 acre-feet per year can be obtained from power releases of the Eufaula Reservoir and by the second stage modification of Wister Reservoir. These and other alternatives would be considered when more detailed studies are made for the 44 northern counties of Oklahoma. The proposed system studies should consider the effects of withdrawal from any of these sources upon the flow regime on the Arkansas River main stem. Figure IV-24 shows existing reservoirs and potential sites in east central Oklahoma.

WATERSHED PROTECTION PROGRAM

For discussion of the potential watershed protection program, see the Statewide Summary, Section I.

NORTHEAST REGION

LIST OF TABLES AND FIGURES

TABLE

FIGURE

General Description

Bordered by Kansas on the north and on the east by Arkansas and Missouri, the northeast region is comprised of Adair, Cherokee, Craig, Creek, Delaware, Mayes, Muskogee, Nowata, Okmulgee, Osage, Ottawa, Rogers, Tulsa, Wagoner and Washington counties.

The eastern section of the region consists of low mountains covered with dense vegetation. The southern part features wide alluvial plains along both banks of the Arkansas River. The northwestern portion is predominantly low, flat, rolling hills. Elevations range from about 1,750 feet above mean sea level in Adair County to approximately 400 feet near the Arkansas River. This region covers 11,794 square miles.

The climate in the northeast region varies from a moist humid climate in the east to a moist subhumid climate in the west. Spring and autumn months are mild and summers are not unusually hot. The growing season ranges from 210 days in the southwestern portion to 190 days in Delaware and Adair counties. The region is drained by the Arkansas, Caney, Verdigris, Deep Fork and Grand Rivers.

The 1970 population of the 15 county region was 798,389, with nearly half located in the metropolitan Tulsa area. Other relatively large communities are Muskogee, Bartlesville and Sapulpa.

Planning Area Resources

PRECIPITATION

As shown in Figure II-1, the average annual precipitation varies from 34 inches in the extreme west to 44 inches in Adair County. Maximum precipitation occurs in late spring and early summer, with May being the wettest month of the year. Most of this precipitation occurs in the form of scattered thunderstorms, compared to light, widespread precipitation during the fall and winter. Winter is the driest season.

EVAPORATION AND TEMPERATURE

Average annual lake evaporation only slightly exceeds precipitation levels, ranging from 56 inches in the west to 46 inches in the extreme northeastern corner of the region. This is illustrated in Figure II-3. Since this evaporation inevitably extracts a portion of the water supply from northeast region reservoirs, the loss must be compensated through larger water storage areas in these reservoirs. Strong southerly winds contribute to this evaporation level. Mean annual temperature in the region varies from 59 degrees in the east to 61 degrees in the west. See Figure II-2.

STREAM WATER CHARACTERISTICS

This region has a combined drainage area of 11,794 square miles. It is richly blessed with stream water, however, many streams in the western part of the region do not meet quality standards for domestic and municipal use.

Runoff

Average annual runoff ranges from five inches in the northwest corner to 13 inches in the southeast corner. This amounts to approximately 5,445,000 acre-feet per year of runoff originating in this area. See Figure II-4.

A summary of streamflow records from U.S.G.S. gauging stations inside the region is presented in Table IV-30. For location of gauging stations see Figure IV-28.

Flooding

The U. S. Army Corps of Engineers has made a sizable contribution to main stem flood control through storages in reservoirs throughout the region.

Stream Water Quality

The water of a number of streams in this region is of good quality and is suitable for most uses. Two such streams, Grand (Neosho) and Illinois Rivers, produce nearly six million acre-feet of usable water annually.

Although water from the Verdigris and Caney Rivers and some of their tributaries does not meet accepted water quality standards because of excessive oil brines and soluble material in rocks upstream, any impoundments will provide water of adequate quality for most uses.

The Arkansas River does not meet accepted standards for

TABLE IV-30
NORTHEAST REGION STREAMFLOW SUMMARY

STREAM	U.S.G.S. STATION	CONTRIBUTING DRAINAGE AREA SQ. MILE	AVERAGE ANNUAL FLOW AF/YR	OBSERVED FLOW (CFS) MAX	OBSERVED FLOW (CFS) MIN.
Arkansas River	1525-at Ralston	54,465	3,239,000	179,000	14
Arkansas River	1645-at Tulsa	63,274	4,545,000	246,000	27
Verdigris River	1710-near Lenapah	3,639	1,490,000	137,000	0
Verdigris River	1760-near Claremore	6,534	2,449,000	182,000	0
Grand River	1935-near Fort Gibson	12,495	4,836,000	223,000	12
Illinois River	1965-near Tahlequah	959	610,000	150,000	.1
Illinois River	1980-near Gore	1,626	1,052,000	180,000	2.0

municipal or domestic use, but can generally be used for industrial water supply.

GROUND WATER RESOURCES

Major ground water basins in the northeast region are the Roubidoux, Vamoosa Formation and alluvium deposits. The alluvium is a shallow ground water basin, exposed at the surface. The Vamoosa Formation outcrops at the surface or is present in the shallow subsurface. In contrast, the Roubidoux is a deeply buried ground water basin.

Other basins occur, such as the Noxie Sandstone, Keokuk and Reeds Springs formations; however, they are considered of minor importance because of low yields, sufficient only for domestic and stock use and thus not mentioned in detail in this section.

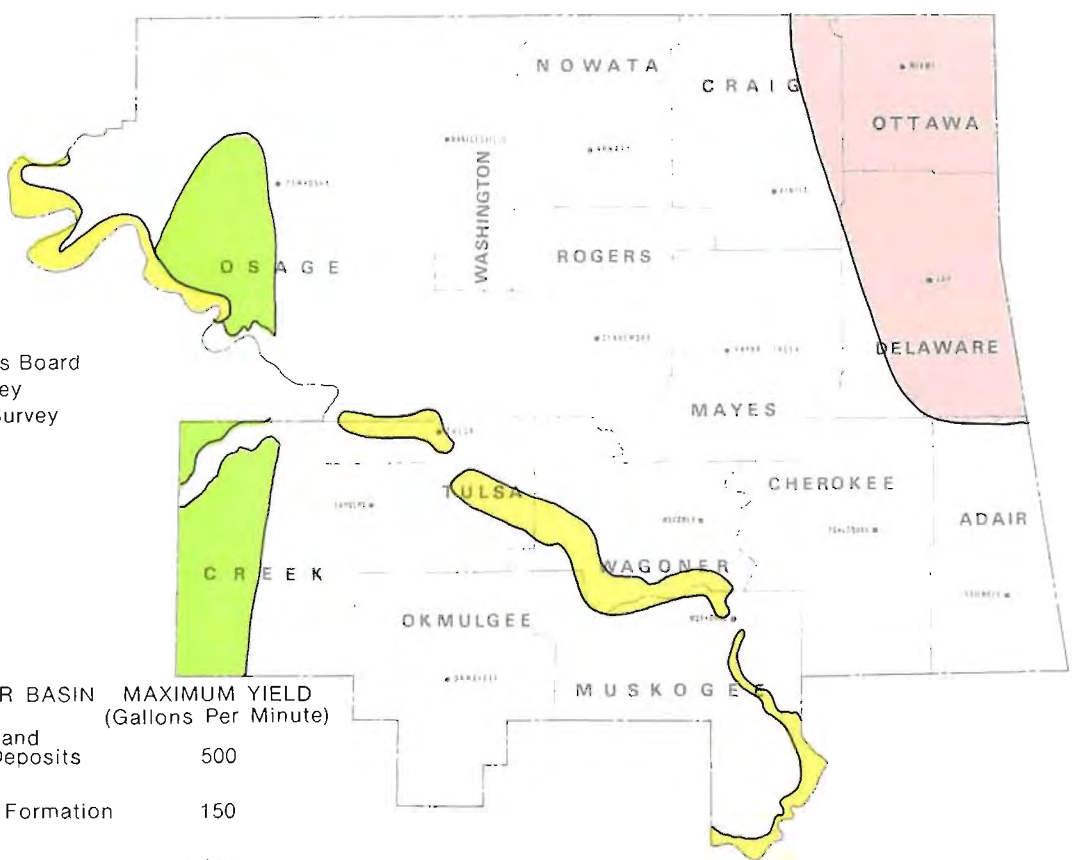
Major ground water basins supply water for both public and industrial use. For location of basins see Figure IV-25.

See Table II-2 for total water in storage and amounts recoverable from ground water basins.

Roubidoux (Upper Cambrian-Lower Ordovician in age) consists mainly of sandy and cherty dolomite. The Roubidoux basin shall, in this discussion, include the Roubidoux, Gasconade and Eminence-Potosi formations of which the Roubidoux formation is the principal water bearing unit. The Roubidoux does not outcrop on the surface, but is deeply buried beneath Ottawa and Delaware counties, and small parts of Craig and Adair counties, at depths of 450-1,700 feet. 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 and presently the water is being lifted more than 500 feet to the surface in some wells. Yields are as much as 1,000 gpm and average 200 gpm. Although the water is hard, it has a low total mineral content. In Ottawa County, the water quality is suitable for most purposes and characterized as a calcium bicarbonate type, but it changes to sodium chloride farther west and becomes unusable.

Vamoosa Formation (Upper Pennsylvanian in age) outcrops in a band four to nine miles wide across Osage and Creek counties. It consists of interbedded sandstone, shale and conglomerate and proportions of shale increase northward. The formation ranges from about 300 to more than 630 feet thick. Because of the large amount of shale, the Vamoosa is not as good a ground water basin as it is farther south. Wells yield only about 60 gpm. Major use of the water is for secondary oil recovery operations. The cities of Oilton and Bristow

FIGURE IV-25
NORTHEAST REGION GROUND WATER BASINS



Oklahoma Water Resources Board
Oklahoma Geological Survey
United States Geological Survey

GROUND WATER BASIN	MAXIMUM YIELD (Gallons Per Minute)
Alluvium and Terrace Deposits	500
Vamoosa Formation	150
Roubidoux	1,200

also use the basin for municipal water supply. The major water quality problem is brine infiltration.

Alluvium deposits (Quaternary) are stream laid deposits of interfingering sand, silt and clay. The most favorable deposits are along the Arkansas River in a band ranging in width from about one to six miles. In the vicinity of Tulsa, the alluvium is about 30 feet thick, whereas downstream in the area of Webbers Falls, thickness is about 55 feet. Yields range from 20-400 gpm. Wells penetrating the sand layers obtain the largest yields. Yield variations depend on well depth, and size and method of well construction. Water in the alluvium is hard or very hard, with dissolved solids content greater than 500 mg/l in some places. The water is typically of a sodium or calcium bicarbonate type.

MINERAL RESOURCES

Mineral production consists mostly of oil and gas, with additional production in asphalt, cement, chemicals, clay, coal, dimension stone, dolomite, germanium, glass sand, granite, limestone, lead, sand and gravel, tripoli, volcanic ash and zinc.

Coal beds produced 2.52 million short tons of high volatile bituminous coal in 1970. About 80-90 percent of the coal is recovered by strip mining and about 50 percent is recovered by underground mining of less than 1,000 feet deep. As of January, 1974, over one billion short tons of coal resources remained in the area.

Oil and gas in this region provided the State, in 1970, with a revenue of $65.5 million, or 6.8 percent of the total pertroleum income. In 1970, 21 million barrels of oil and 5.1 trillion cubic feet of gas were produced from the area. The Glenn pool field in Creek and Tulsa counties is the most prolific field in this region, having produced more than 300 million barrels of oil and expected to produce an additional 19 million barrels of oil in its lifetime. See Figures IV-26 and IV-27.

LAND RESOURCES

With 1,236,727 acres in crop production, the major crops in this region are corn, hay, sorghum and soybeans. Other crops are barley and oats. Cattle and calves, milk cows, swine and chickens are important to agriculture. Land cultivated in soybeans has more than doubled every ten years since 1940. Seven out of the State's ten top soybean producing counties are in this region. The 1972 Reported Water Use showed that the northeast region had 11,522

FIGURE IV-26
NORTHEAST REGION MINERALS

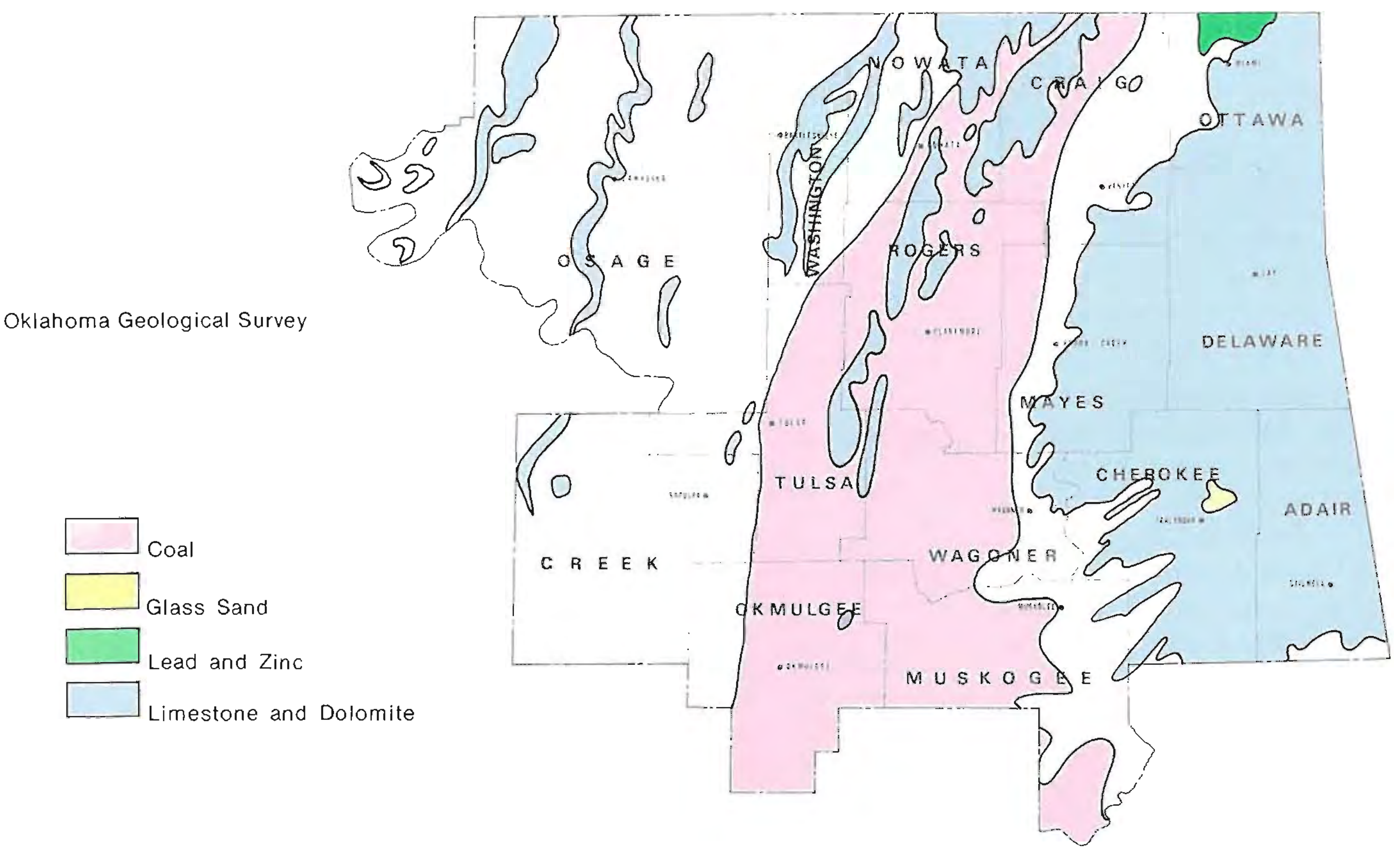
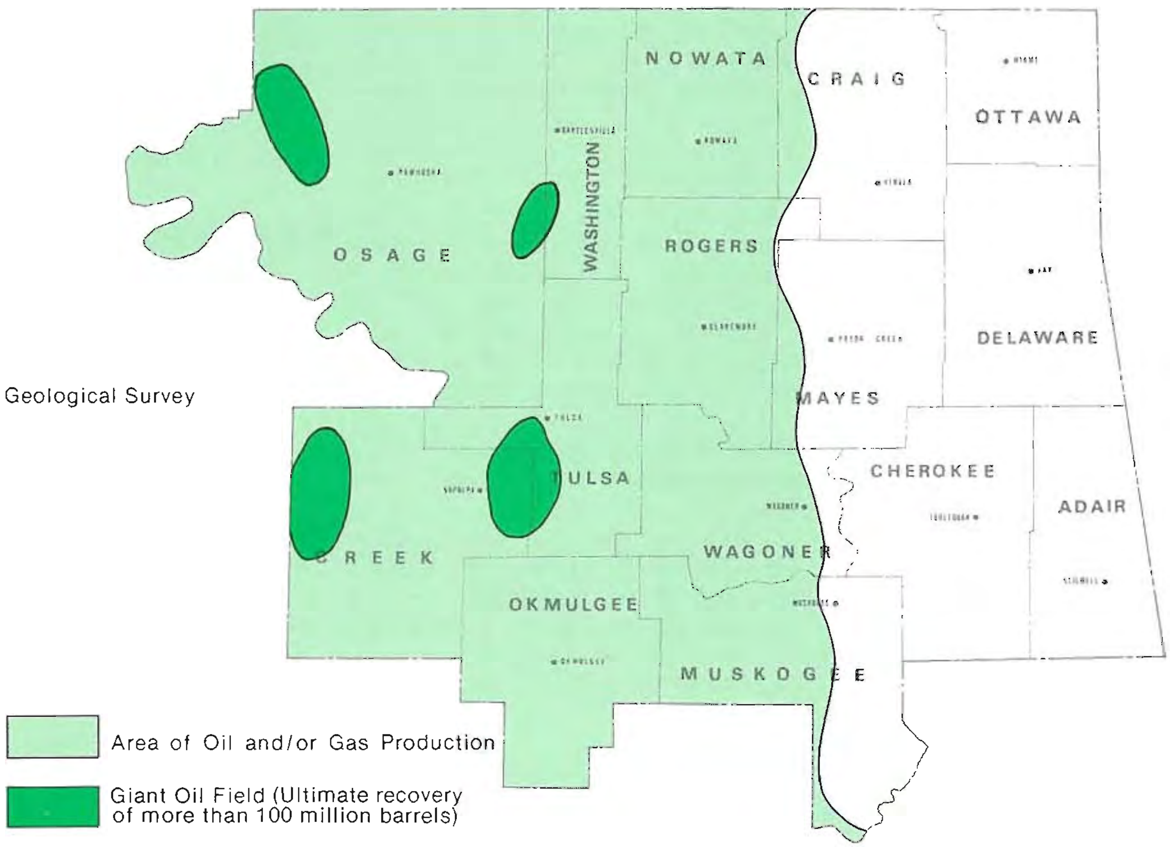


FIGURE IV-27
NORTHEAST REGION OIL AND GAS



Oklahoma Geological Survey

acres under irrigation. This includes only reported acres and does not represent the region total. Oklahoma State University Extension Service in 1973 reported a region total of 5,301 irrigated acres.

SOILS

Major soil associations in the northeast region include Parsons-Dennis-Bates, Bodine-Baxter and Darnell-Stephenville. Land usage varies from cropland producing fruits, vegetables, farm and field crops to forest and woodland pastures. Minor soil groups are Labette-Summit-Soga, Verdigris-Osage, Hector-Pottsville, Soga-Summit, Yahola-Port-Reinach and the Dougherty-Teller-Yahola association. Land usage is cropland, meadows, pastures and forested pastureland. See Figure II-11.

ENVIRONMENTAL RESOURCES

The northeast region constitutes most of "Green Country," and is rich in Indian and territorial history and natural beauty. It is a region of contrasts, ranging from free-flowing rivers to rolling plains, scattered with oil derricks.

Scenic Areas

The eastern portion of the region has pine-covered mountains, while the west is marked by grassy prairies and scrub timber. The area is drained by the Arkansas, Verdigris, Grand and Deep Fork Rivers. The 1970 Scenic Rivers Act (House Bill 1152) established the Illinois River and Barren Fork and Flint Creeks as State scenic streams. State parks and recreation areas are plentiful. The McClellan-Kerr Arkansas River Navigation System, finished in December, 1970, is a remarkable engineering feat.

Fish, Wildlife and Recreational Activities

White bass, crappie, channel catfish and flathead catfish are highly prized species taken from northeast region reservoirs. Rainbow trout is frequently stocked in the Illinois River. The most popular lakes include Grand Lake, covering 46,500 acres; Fort Gibson, covering 19,000 acres and Tenkiller, covering 12,650 acres. All offer camping, boating and swimming. All species of waterfowl and big and small game are available for hunters. Okmulgee Game Management Area in Okmulgee County contains 7,719 acres. Deer, squirrel and quail are the primary game species.

The 4,000 acre Fort Gibson and the 1,800 acre Hulah Waterfowl

Refuges enjoy excellent mallard and blue-winged teal hunting. Popular recreation areas, such as Tsa-La-Gi Cherokee Indian Village in Tahlequah, the Will Rogers Memorial in Claremore and the Creek Council House in Okmulgee draw thousands of visitors each year.

Regional Historical Features

The major portion of the northeast region consists of the Cherokee Indian Nation. Other Indian groups include the Creek and Osage. The Cherokees had a highly developed civilization, which included an alphabet and newspaper, an elected bicameral legislature and a police force. The Cherokees were forcibly removed to Oklahoma in 1835-1838, a misery that became known as "the Trail of Tears." During the Civil War, Stand Watie, a Cherokee and the only Indian to achieve the rank of Brigadier General, led Indian soldiers for the Confederate cause.

Many famous outlaws roamed the region, which was under the jurisdiction of the "hanging judge," Isaac Parker.

Perhaps the most famous Oklahoman, Will Rogers, was born near Claremore, in Rogers County. A columnist, humorist and actor, Rogers became a symbol of the warmth and hospitality of Oklahomans.

Present and Potential Development

The combined stream basins of this area consist of Bird Creek, main stem of the Arkansas above Keystone Reservoir to the mouth of the Canadian, Verdigris, Grand (Neosho), Illinois and Caney Rivers.

Developed stream water resources include nine large reservoirs, more than 100 smaller lakes and approximately 30,000 flood detention and stock ponds with less than ten surface acres. Six more lakes have been authorized for construction by Congress and another five sites have been considered potential locations for dams.

Despite the large use of ground water in many local areas, it is not as widely used as stream water in this area.

STREAM WATER

As shown in Table IV-31, there are existing, under construction and authorized lakes in this region that provide 3,366,600 acre-feet of flood control storage and 390,500 acre-feet of water supply. There are additional potential sites having a possible water supply yield of 1,907,000 acre-feet, for a region total of 2,336,700 acre-feet. Locations of the sites are shown on Figure IV-28.

FIGURE IV-28
NORTHEAST REGION STREAM WATER DATA

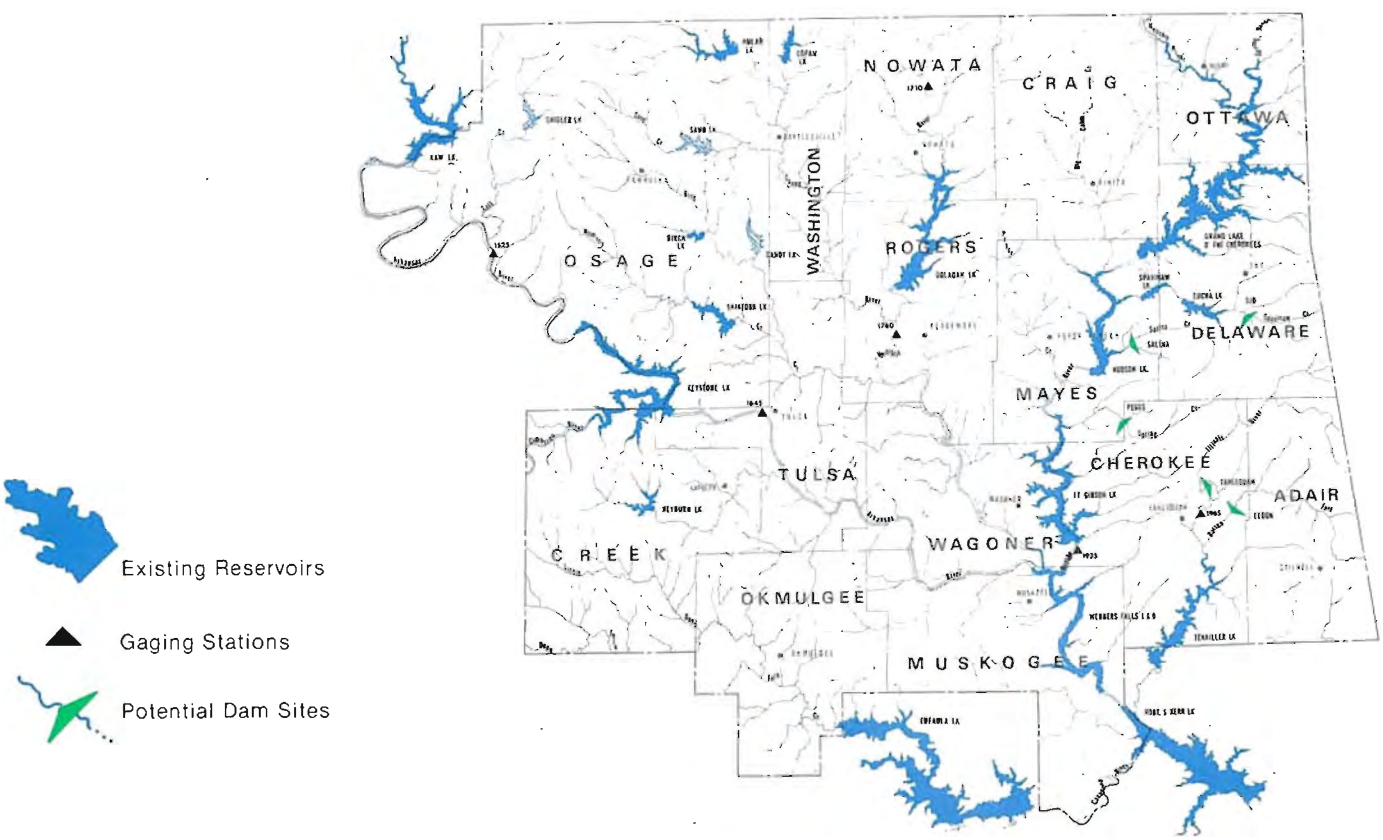


TABLE IV-31

NORTHEAST REGION PRESENT AND POTENTIAL WATER RESOURCE PROJECTS

EXISTING OR UNDER CONSTRUCTION

NAME OF SOURCE	LOCATION	PURPOSE *	FLOOD CONTROL STORAGE ACRE FT.	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
Birch Lake+	Birch Creek	WS,FC,WQ,R,FW	39,000	15,200	6,700[1]
Copan Lake+	Little Caney River	WS,FC,WQ,R,FW	184,300	33,600	21,300[2]
Eucha Lake	Spavinaw Creek	WS,R	0	79,600	84,000[3]
Fort Gibson Lake[4]	Grand (Neosho) River	FC,P	919,200	0	0
Grand Lake O' the Cherokees[4]	Grand (Neosho) River	FC,P	525,000	0	0
Heyburn Lake	Pole Cat Creek	WS,FC	49,100	1,900	1,900
Hudson Lake[4]	Butler Creek	FC,P	244,200	0	0
Hulah Lake	Caney River	WS,FC, lowflow regulation	257,900	27,000[5]	19,000
Oologah Lake	Verdegris River	WS,FC,N	965,600	544,100[6]	172,500
Skiatook Lake+	Hominy Creek	WS,FC,WQ,R,FW	182,300	304,800	85,100[7]
Spavinaw Lake	Spavinaw Creek	WS,R	0	30,600	-[3]
Webbers Falls Lock & Dam	Arkansas River	N,P,R,FW	0	0	0
Sub Total			3,366,600	1,036,800	390,500

AUTHORIZED

NAME OF SOURCE	LOCATION	PURPOSE *	FLOOD CONTROL STORAGE ACRE FT.	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
Candy Lake	Candy Creek	WS,FC,WQ,R,FW	31,250	43,100	8,950[8]
Sand Lake	Sand Creek	WS,FC,WQ,R,FW	51,700	35,000	13,450[9]
Shidler Lake	Salt Creek	WS,FC,WQ,R	49,050	54,900	16,800[10]
Sub Total			132,000	133,000	39,200
TOTAL			3,498,600	1,169,800	429,700

POTENTIAL SITES

NAME OF SOURCE	LOCATION	PURPOSE *	FLOOD CONTROL STORAGE ACRE FT.	CONSERVATION STORAGE	WATER SUPPLY YIELD (AF/YR)
Eldon[11]	Barren Fork Creek	WS,R	0	280,000	158,000
Fort Gibson Power Release[12]	Grand (Neosho) River		-	-	771,000[12]
Keystone Power Releases[13]	Arkansas River		-	-	572,000[13]
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
Sub Total			200,000	2,036,000	1,907,000
TOTAL			3,698,600		2,336,700

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

+Under construction

[1] Includes Water Quality Control Storage of 7,600 acre-feet which yields 3,360 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] These lakes are under the jurisdiction of the Grand River Dam Authority and are exempt from this study by provisions in Senate Bill 510. They have been included in this tabulation to give the total water resources of this region.

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

[6] This includes 168,000 acre-feet for navigation and 33,500 acre-feet for 50 years sediment.

[7] Includes Water Quality Control Storage of 240,000 acre-feet which yields 69,440 acre-feet per year.

[8] Includes Water Quality Control Storage that will yield 2,240 acre-feet per year.

[9] Includes Water Quality Control Storage of 12,200 acre-feet which yields 4,704 acre-feet per year.

[10]Includes Water Quality Control Storage that will yield 1,790 acre-feet per year.

[11]These potential sites are located on scenic rivers designated by Legislative action. The Scenic Rivers Act prohibits the impoundment of a stream designated as a scenic river by any large dam or structure except as specifically authorized by the State Legislature.

[12]This is the approximate yield that could be developed from hydropower releases from Fort Gibson.

[13]This is the approximate yield that could be developed from hydropower releases from Keystone.

Watershed Protection and Flood Prevention

The Soil Conservation Service has planned and engineered the construction of numerous flood control structures for the purpose of watershed protection and flood prevention.

There is a total of 39 small S.C.S. watersheds in this region. Ten of these are complete or under construction, 8 are planned and 21 have potential for development in the next 50 years. To date, a total of 103 structures have been constructed in these watersheds.

Stilwell and Okmulgee utilize watershed structures for added municipal water storage purposes. Other facilities are being planned with multi-purpose usage for the cities of Dewey and Wann. See Figure I-5 for watershed location and multi-purpose sites.

Stream Water Rights

As of Aug. 31, 1974, a combined total of 416 vested stream water rights and permits were issued for the appropriation of 974,337 acre-ft. of water from streams and lakes in this region. The tabulation by counties is shown in Table IV-32.

GROUND WATER

Despite the large use of ground water in many local areas, it is not as widely utilized as stream water in the northeast region. Usefulness of ground water in the region is restricted by low yields, thinness of potable water zone and presence of salt water at shallow depths.

Due to the dependency on stream water, it is difficult to assess the potential for future ground water development.

Existing Development

Present development occurs primarily in the three major ground water basins. The Roubidoux is a source for public and industrial water supplies. Overdevelopment of the Roubidoux has occurred through too close well spacing. The cluster of wells in the area of Miami has caused overpumping. This has resulted in interference between wells, producing a reduction in artesian head. In the past, water flowed at the surface, but now needs to be lifted up about 500 feet.

Development in the alluvium is mainly along the Arkansas River. Wells along the river can yield up to 100 gpm when properly constructed. Most of the development in the Vamoosa is low yield wells for oil field waterflood operations. The formation's potential for development is not good due to the high proportion of shale and resulting low yields, and water quality problems. Also, there is little information available on the hydrology of the Vamoosa in the region.

The best potential for development of ground water is with the springs in the northeast region. Their source is the Boone Formation, a ground water basin consisting of fractured chert which outcrops in the area. The formation is a minor ground water basin, supplying individual wells at yields of only 10-50 gpm. However, where the water table intersects the surface, springs flow at amounts of about 10 million gallons of water per day.

Ground Water Permits

As of October 1974, a total of 151 ground water permits had been issued. These permits allocate fresh ground water to be used as municipal, irrigation or industrial water. The tabulation of

TABLE IV-32
NORTHEAST REGION STREAM WATER PERMITS

COUNTY	NUMBER PERMITS ISSUED	AMOUNT ALLOCATED AF/YR
Adair	95	23,903
Cherokee*	63	12,291
Craig*	0	0
Creek	14	30,457
Delaware	12	13,204
Mayes*	0	0
Muskogee*	28	194,911
Nowata	6	33,751
Okmulgee	13	8,993
Osage	61	98,586
Rogers	46	463,939
Tulsa	25	54,851
Wagoner*	23	27,691
Washington	30	11,760
TOTAL	416	974,337

*This county is located in or partly in the Grand (Neosho) River Basin and all stream water in this basin is under the jurisdiction of the Grand River Dam Authority.

data from the ground water files is shown in Table IV-33.

Present Uses and Future Requirements

Total population for the northeast region, according to 1970 census figures, was 798,389. This figure is projected to reach 2,492,100 by the year 2030. At the present time, the largest use of water in the northeast region is for municipal and industrial needs. This includes energy related water requirements and rural system needs. Future projections for the region show that municipal and industrial needs will continue to require the most water use.

MUNICIPAL AND INDUSTRIAL

Reported ground water usage for municipal and industrial purposes was 9,666 acre-feet and stream water usage was 258,993 acre-feet for a total of 268,659 acre-feet in 1972. By 2030 this total is projected to rise to 822,000 acre-feet.

RURAL WATER SYSTEMS

The northeast region is densely populated with 95 rural water systems. Sources of supply include vast amounts of ground water, reservoirs and rivers.

At present, 87,300 people are served by public water systems, and 125,600 people lack any type of service. Projections show that public water systems will reach 95,800 customers in 1980, 119,200 in 2000 and 144,700 in the year 2030.

Future needs must be evaluated and met to insure maximum service to all people in these system areas.

ENERGY RELATED WATER REQUIREMENTS

Large oil and gas fields are located throughout the eastern half of the region, producing almost 21,000,000 barrels of oil in 1970. Water is an important part of recovery and refinement and if maximum levels are to be maintained and expanded, future water requirements for these fields and operations must be taken into consideration.

IRRIGATION

Total reported water usage for irrigation in 1972 was 12,367 acre-feet, with 3,452 acre-feet coming from ground water and 8,915 taken from stream water. The projected figure for the year 2030 is 521,100 acre-feet.

TABLE IV-33
NORTHEAST REGION GROUND WATER PERMITS

COUNTY	NUMBER PERMITS ISSUED	NUMBER OF WELLS	AMOUNT ALLOCATED AF/YR
Adair	4	4	1,439
Cherokee	3	4	204
Craig	2	2	55
Creek	21	68	4,526
Delaware	5	6	529
Mayes	0	0	0
Muskogee	16	48	4,880
Nowata	0	0	0
Okmulgee	2	2	800
Osage	33	83	16,535
Ottawa	24	27	13,008
Rogers	0	0	0
Tulsa	26	87	22,197
Wagoner	15	103	3,626
Washington	0	0	0
TOTAL	151	434	67,799

OTHER USES AND REQUIREMENTS

Navigation

The McClellan-Kerr Arkansas River Navigation System is located in the northeast region. The system carried over 800,000 tons of traffic in 1973. Oologah Reservoir near Tulsa contains 168,000 acre-feet of water for navigation storage and additional water is obtained from downstream hydro power reserves. Studies are underway for expansion of the system into Wichita, Kansas and central Oklahoma. Future needs and requirements will be determined in these studies.

Hydroelectric Power

Water requirements for hydroelectric power generation are not included in this report. Further detailed hydrologic system analyses will be made in a later report spelling out these requirements.

Water Quality Control

The water storage for low flow water quality requirements of Birch, Copan, Hulah, Sand and Skiatook Lakes total 293,000 acre-feet. This water requirement has been provided for in this region's water requirements. This water is let out slowly over time to prevent stagnant pools of water from forming and lowering water quality in the different streams. The water will be dedicated for this purpose until such time as needed for water supply purposes.

Fish, Wildlife and Recreation

Gruber Game Management Area, Cherokee Refuge, Cookson Hills Refuge, Fort Gibson Public Hunting Area and Waterfowl Refuge, Hulah Public Hunting Area and Waterflow Refuge, Spavinaw Hills Refuge and the Okmulgee Game Management Area are the wildlife refuges in this area. Total acreage of these areas is 112,519 acres. Water demand was 960 acre-feet in 1973. Water requirements are not expected to fluctuate in the future.

Water for recreation is considered adequate except for swimming, which will be provided by the individual community.

Plan of Development

MAJOR RESERVOIR SYSTEM

Table IV-34 shows the 2030 demand and the supply system of major reservoirs in northeast Oklahoma. The demand does not include the navigation water requirements for the McClellan-Kerr Arkansas River Navigation System, nor does the resource tabulation contain waters of the Arkansas River mainstem. Senate Bill 510 specifically excludes the Grand River Basin from provisions of the act. However, for illustration purposes, both the needs and resources of that basin are included within the totals shown herein. Detailed hydrologic and economic studies are needed within the region to accurately determine the needs and resources of the Grand River Basin and of the remainder of the region, including the Arkansas River mainstem.

Without using power releases of Fort Gibson, the region shows a net deficit of 392,000 acre-feet per year. With such power releases, there would be a surplus of about 379,000 acre-feet per year. However, because of the exclusion contained in Senate Bill 510, in this study such releases could be used only in the Grand River Basin when diverted above the confluence of the Arkansas River. After reaching the Arkansas River, such flows could be considered for use outside the Grand River Basin. Figure IV-28 shows existing and potential reservoir sites in northeast Oklahoma.

WATERSHED PROTECTION PROGRAM

For discussion of the potential watershed protection program, see the Statewide Summary, Section I.

TABLE IV-34
NORTHEAST REGION WATER SUPPLY AND DEMAND IN 1000's OF ACRE-FEET ANNUALLY

ESTIMATED 2030 IN-BASIN REQUIREMENTS

Municipal and Industrial	822.0
Irrigation	521.1[1]
TOTAL	1,343.1

[1]Irrigation needs will be met by individual systems and stream bank pumping units.

POSSIBLE 2030 SUPPLY

SOURCE RESERVOIRS	YIELD	IN-BASIN NEEDS	DEFICIT	SURPLUS
Birch (E)	6.7			
Copan (E)	21.3			
Eucha & Spavinaw (E)	84.0			
Heyburn (E)	1.9			
Hulah (E)	19.0			
Oologah (E)	172.5			
Skiatook (E)	85.1			
Candy (A)	9.0			
Sand (A)	13.5			
Shidler (A)	16.8			
	429.8	822.0	392.2	
Power Releases, Fort Gibson	771.0			
	1,200.8	822.0		378.8

(E)—Existing or Under Construction
(P)—Proposed
(A)—Authorized

NORTH CENTRAL REGION

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FIGURE

General Description

The north central region covers an area of 7,689 square miles and consists of Garfield, Grant, Kay, Kingfisher, Lincoln, Logan, Noble, Pawnee and Payne counties. The western section of the region consists primarily of low sand hills with very little cover. The central portion has prairie hills covered by scatterings of scrub timber. The east is somewhat rougher with low hills and dense vegetation. Elevation ranges from 1,100 feet above mean sea level in Grant County to 850 feet in Lincoln County.

The climate of the nine county area is moist and subhumid in the eastern half and dry and subhumid in the western half. Drought is a major problem. The growing season is approximately 200 days per year. The Cimarron River drains the central portion of the area. Minor streams include the Salt Fork and Chikaskia Rivers in the northern section and a portion of the Deep Fork River in the southeastern corner.

The population for the north central region in 1970 was 235,292. The three major cities in the region are Enid, with 44,986 people, Stillwater, with 31,126 people and Ponca City, with 25,940 people.

Planning Area Resources

PRECIPITATION

Maximum precipitation levels occur in the spring and early fall. May is the wettest month of the year with September second. Seventy-five percent of the annual precipitation occurs during the approximate 200 day growing season. Thunderstorms, bringing high winds and hail, occur often. Average annual precipitation varies from 28 inches in the west to 36 inches in the extreme eastern portion, as shown in Figure II-1.

EVAPORATION AND TEMPERATURE

Average annual lake evaporation greatly exceeds average annual precipitation, ranging from 61 inches in the west to 55 inches in the east. Because of this, water storage areas in reservoirs are closely tabulated and adjusted. See Figure II-3. Mean annual temperature ranges from 60-61 degrees across the region. See Figure II-2.

STREAM WATER CHARACTERISTICS

The Cimarron, Chikaskia, Salt Fork of the Arkansas and Arkansas Rivers are located in this nine county region and have a combined drainage area of 7,689 square miles originating in this region. Water quality considerations restrict municipal and domestic utilization in all those basins except the Chikaskia.

Runoff

Average annual runoff ranges from two inches in the western portion of this area to five inches in the east. See Figure II-4. Average annual runoff originating in the region is estimated at 1,475,000 acre-feet per year.

A summary of streamflow records at U.S.G.S. gauging stations inside the region is presented below. For location of gauging stations see Figure IV-32.

Flooding

Some floods occur gradually, when slow but continued rainfall saturates a river or stream basin until almost all precipitation becomes runoff and overflows the natural channel. Others are the result of sudden concentrated areas of high precipitation that occur over the basin during a short period of time.

Stream Water Quality

The water of the Arkansas, Salt Fork of the Arkansas and Cimarron Rivers and some tributaries of these streams does not meet public health standards for municipal and domestic use most of the time. The water usually contains excessive amounts of dissolved minerals originating in the rocks and salt plains drained by the streams. Salt concentrations in some tributaries are due to improper disposal of oil field brines in the early days of the oil industry. These minerals also impair the chemical suitability of water for irrigation.

The waters of the northern tributaries of the Salt Fork of the Arkansas, some of the tributaries in the Cimarron basin and part of the Arkansas River tributaries are of good or fair quality and suitable for use. The water of Keystone Reservoir is of fair or poor quality most of the time and only rarely is it of good quality. The water of Great Salt Plains Reservoir is of poor quality and not suitable for use. The water of Kaw Reservoir will probably be of poor quality part of the time.

TABLE IV-35
NORTH CENTRAL REGION STREAMFLOW SUMMARY

STREAM	U.S.G.S. STATION	CONTRIBUTING DRAINAGE AREA SQ. MILE	AVERAGE ANNUAL FLOW AF/YR	OBSERVED FLOW (CFS) MAX	OBSERVED FLOW (CFS) MIN
Cimarron River	1610 - at Perkins	12,926	783,200	149,000	8
Chikaskia River	1520 - near Blackwell	1,859	326,000	85,000	0
Salt Fork of Arkansas	1510 - at Tonkawa	4,520	448,500	40,800	0
Arkansas River	1525 - at Ralston	46,850	3,239,000	179,000	0

GROUND WATER RESOURCES

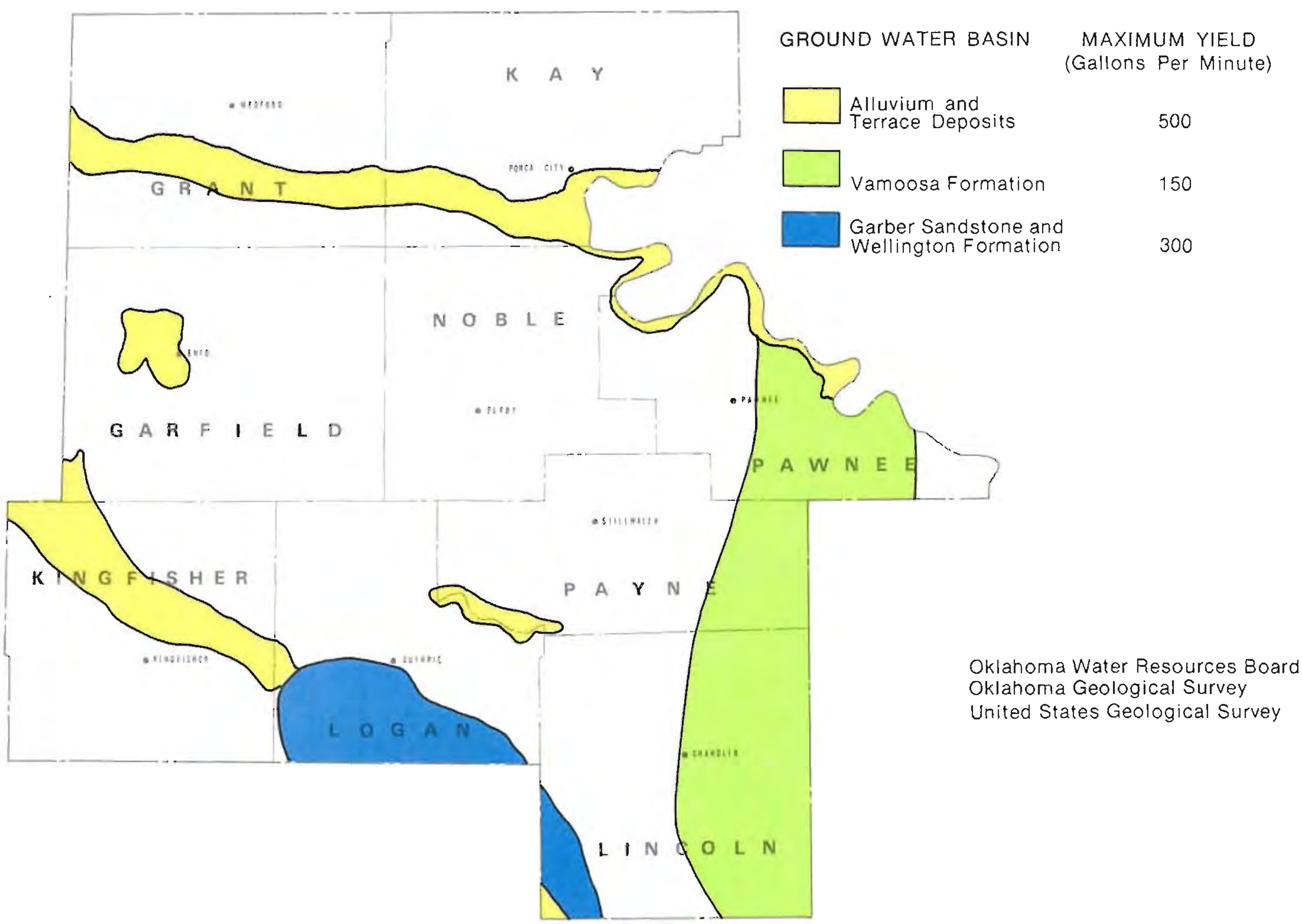
Ground water in north central Oklahoma is found in three major ground water basins: the Vamoosa Formation, Garber-Wellington Formation and the alluvium and terrace deposits. See Figure IV-29. Ground water resources provide water for most rural homes and many municipalities, as well as water for irrigation farming. See Table II-2 for total water in storage and amounts recoverable from ground water basins.

Vamoosa Formation (Pennsylvanian in age) crops out in Pawnee County and in eastern Payne and Lincoln counties. The Vamoosa ranges in thickness from 300-400 feet and consists of interbedded sandstone, shale and conglomerate. The amount of sandstone generally decreases to the north. The rock types in the Vamoosa differ from place to place with a wide range of colors and grain sizes, varying from fine to extremely coarse in clastic rocks. The sandstone of the Vamoosa yields about 100 gpm to wells. Chemical quality of the water ranges widely. Locally, the water has a high concentration of sodium bicarbonate.

Garber-Wellington Formation (Permian in age) consists of two rock units: the Garber Sandstone and the Wellington Formation. The two units were deposited under similar conditions, both containing lenticular beds of red, fine grained sandstone alternating with shale, and are considered a single water bearing zone. The formation is about 300 feet thick near the Oklahoma-Logan County Line. In Logan County, it is shaly and has low permeability and well yields are as low as 10 gpm or less near Guthrie. Generally, water from the Garber is suitable for most purposes, but locally may be hard and high in sulfate, chloride, fluoride, and nitrate concentrations. Dissolved solids range from 100-1,000 mg/l.

Alluvium and Terrace deposits (Quaternary in age) are found in all

FIGURE IV-29
NORTH CENTRAL REGION GROUND WATER BASINS



nine counties, mainly along the Salt Fork of the Arkansas River across Grant and Kay counties with a minor extension into Pawnee County and along the Cimarron River across Kingfisher County into Logan County. The deposits consist of unconsolidated clay, silt, sand and gravel which interfinger and were deposited by streams in an irregular pattern.

The alluvium underlies the bottomlands along the streams, whereas the terrace deposits are topographically higher and usually adjacent to the alluvium. The alluvium and terrace deposits along the Salt Fork of the Arkansas reach a maximum thickness of about 60 feet, while similar deposits along the Cimarron attain a maximum thickness of 120 feet. Maximum saturated thicknesses for the Salt Fork and Cimarron are 35 feet and 50 feet, respectively.

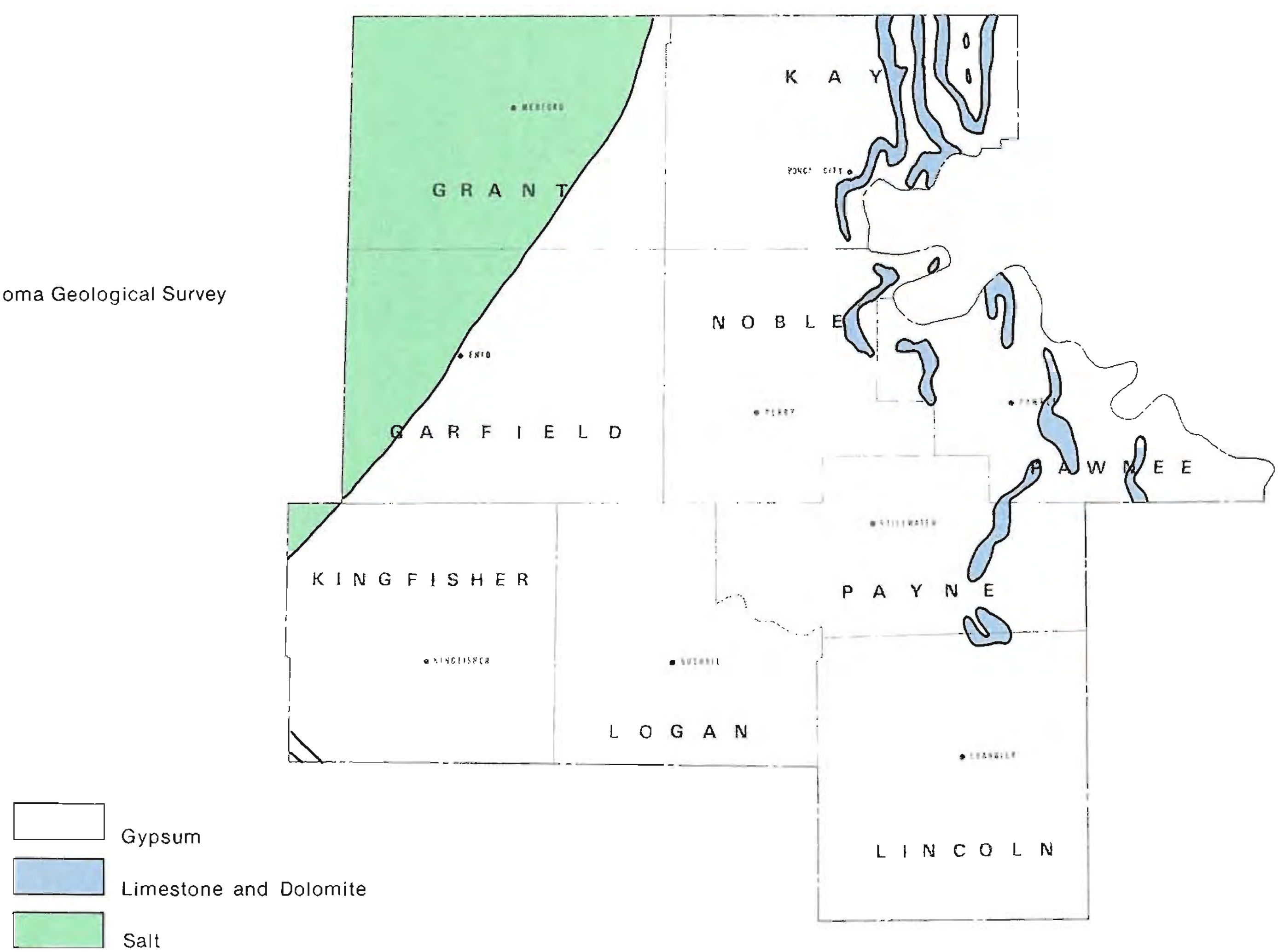
Well yields from the alluvium of the Salt Fork average between 400 and 500 gpm, whereas yields from the terrace of the Salt Fork are about 100-200 gpm. Well yields from the Cimarron range from 1,000 gpm to less than 50 gpm and average between 100 and 300 gpm. Chemically, water quality of the Cimarron River alluvium is poor because of high chloride and sulfate concentrations introduced upstream.

Water quality from the Cimarron terrace deposits generally is 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 about 350 mg/l. Water quality from the alluvium of the Salt Fork is generally poor due to high sulfate and chloride concentrations. Water quality from the Salt Fork terrace deposits is suitable for most uses and is similar in chemical character to ground water from the Cimarron terrace.

MINERAL RESOURCES

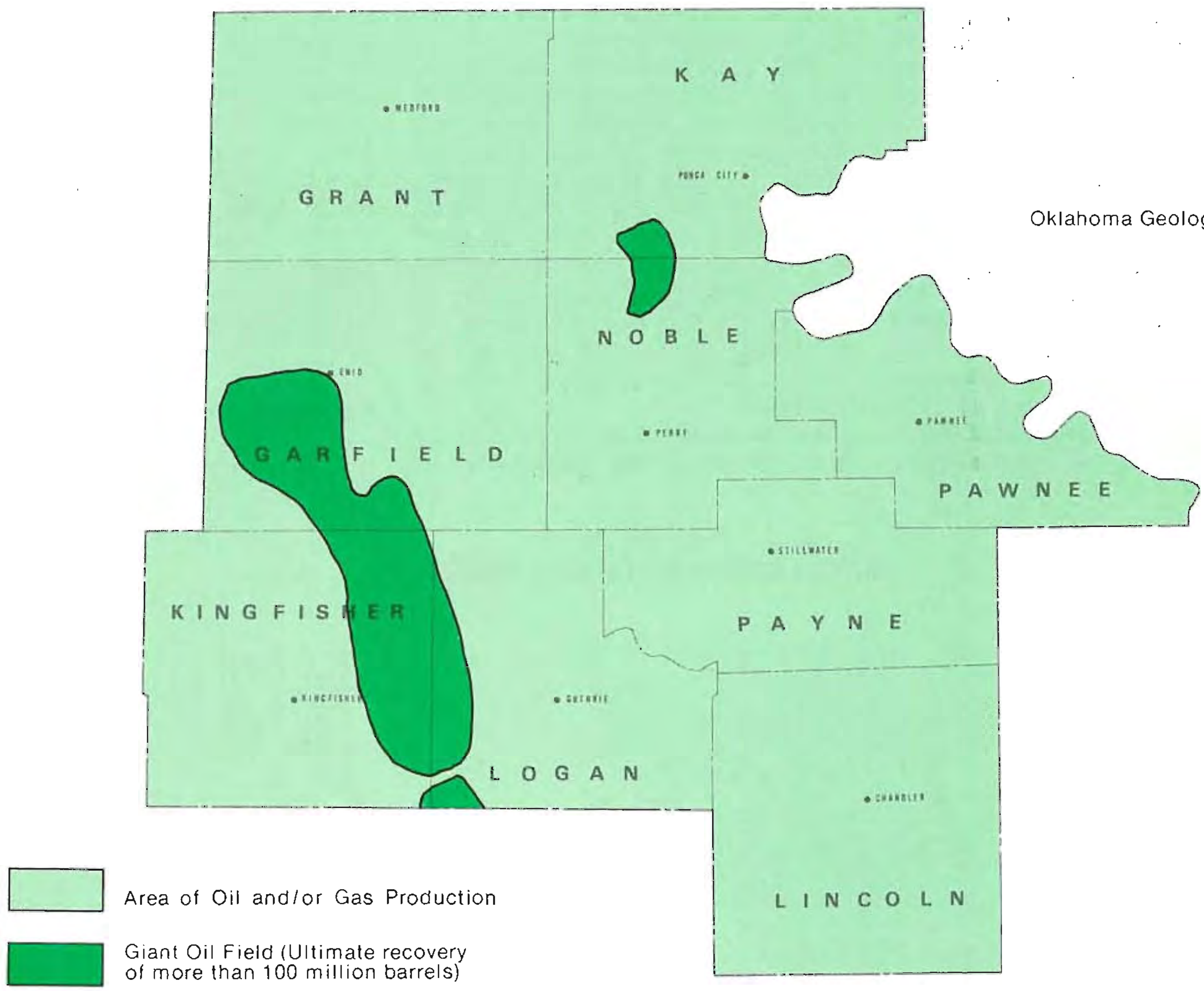
The minerals of the north

FIGURE IV-30
NORTH CENTRAL REGION MINERALS



Oklahoma Geological Survey

FIGURE IV-31
NORTH CENTRAL REGION OIL AND GAS



central region consist of oil, gas and non-metals.

Oil and gas production is mostly in two giant oil fields (estimated ultimate recovery of more than 100 million barrels each): Tonkawa in Kay and Noble counties and Sooner Trend in Garfield, Kingfisher and Logan counties.

Non-metals consist of gypsum, found in the Blaine Formation in southwestern Kingfisher County and useful in the manufacture of building materials; limestone and dolomite, quarried in Kay County, with the limestone used as crushed stone for concrete and road metal and the dolomite used in manufacturing agricultural and other high purity materials and salt, which has many commercial and chemical uses. For location of mineral and oil and gas resources see Figures IV-30 and IV-31.

LAND RESOURCES

This nine county region, containing 4,877,730 acres, has 2,453,346 acres in cropland and pasture. Beef is the major agricultural industry and production has been increasing consistently for some years. Dairy cattle production is also a significant industry, although it has been decreasing for some time. Wheat production is of significance, but decreasing, as is sorghum. Stable crops are barley and oats. The 1972 Reported Water Use showed that the north central region had 13,156 acres under irrigation. This includes only reported acres and does not represent the region total. Oklahoma State University Extension service in 1973 reported a region total of 8,860 irrigated acres.

SOILS

Within the north central region, the Renfrow-Zaneis-Vernon soil association is dominant. Minor soil associations are Pratt-Tivoli, Vanoss-Minco-Yahola, Darnell-Stephenville, Grant-Pond Creek-Nash, Soga-Summit, Parsons-Dennis-Bates, Dougherty-Teller-

Yahola and Bethany-Tabler-Kirkland. Cropland, pasture and rangeland are the uses of these soil associations. See Figure II-11.

ENVIRONMENTAL RESOURCES

The north central region does not have as many lakes and streams as other areas, but there is still a great variety of scenic and recreational facilities.

Scenic Areas

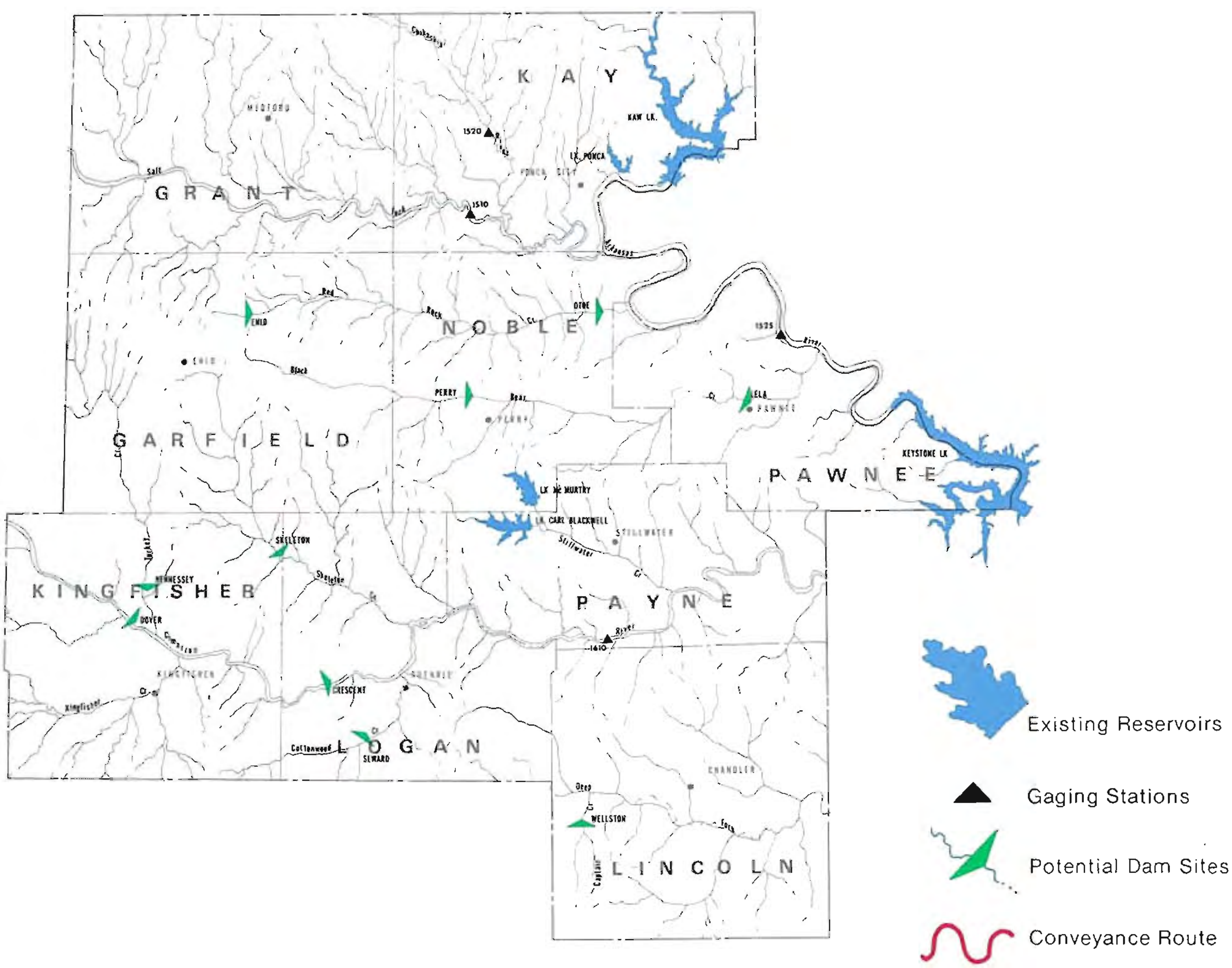
Keystone Lake, in Pawnee County, attracts more than two million visitors each year with boating, fishing, camping and beautiful scenery. The southern portion of the region is drained by the Cimarron River and the northern part is drained by the Salt Fork of the Arkansas and Chikaskia Rivers. These basins provide miles of scenic spots.

Fish, Wildlife and Recreational Activities

Hunting and fishing are popular pastimes in the north central region. Rio Grande turkey does well near streams and upper wooded areas. Deer is becoming increasingly popular, as is quail.

Sandy river bottoms aid in the production and cultivation of minnows. Lake Keystone, covering 26,300 acres, is well-stocked with crappie, channel catfish, white bass, largemouth bass and walleye. Striped bass is also being developed in the area. Lake Carl Blackwell near Stillwater has an area of over 3,000 acres and serves as the city's water supply and research station for Oklahoma State University. Other popular tourist attractions are the Pioneer Woman Statue and Museum at Ponca City, Cherokee Strip Museums at Perry and Enid, Pawnee Bill Museum at Pawnee and Seay Mansion and Chisholm Trail Museum at Kingfisher.

FIGURE IV-32
NORTH CENTRAL REGION STREAM WATER DATA



Regional Historical Features

Most of the north central region is an area designated as the Cherokee Outlet, which was opened for settlement in 1893. Other tribes in the area include the Poncas, Pawnees and Tonkawas. The land became a dumping ground for tribes from all areas of the country. Following the completion of the railroads, cattle became a large industry in Oklahoma. The famous Chisholm Trail, blazed by a mixed blood Cherokee trader, Jesse Chisholm, crosses the heart of the region. The region's first "oil boom town" sprang up at Cleveland, in Pawnee County in 1904.

Present and Potential Development

Although there is a great abundance of stream water moving through the region, the development has been limited to five major lakes due to quality reasons. There is potential for further ground water development, but data are inadequate for an accurate assessment at this time.

STREAM WATER

As shown in Table IV-36, there are existing and under construction lakes in this region that provide a total of 2,087,000 acre-feet of flood control storage and 272,100 acre-feet of water supply. There are additional potential sites having a possible water supply yield of 437,400 acre-feet, for a region total of 709,500 acre-feet.

The only site not included in the potential resource table is Enid, with a conservation storage capacity of 80,000 acre-feet. This storage reservoir is designed to hold possible transported water

TABLE IV-36
NORTH CENTRAL REGION PRESENT AND POTENTIAL WATER RESOURCE PROJECTS

EXISTING OR UNDER CONSTRUCTION

NAME OF SOURCE	LOCATION	PURPOSE *	FLOOD CONTROL STORAGE ACRE FT.	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
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
Keystone Lake +	Arkansas River	WS,FC,P,FW	1,216,000	20,000	22,400
Lake McMurtry	N. 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
Sub Total			2,087,000	306,800	272,100

POTENTIAL SITES

NAME OF SOURCE	LOCATION	PURPOSE *	FLOOD CONTROL STORAGE ACRE FT.	CONSERVATION STORAGE	WATER SUPPLY YIELD (AF/YR)
Crescent	Cimarron River	WS,FC,R,FW	660,000	703,000	150,000
Dover	Cimarron River	WS,FC,R,FW	508,000	388,000	60,000
Hennessey	Turkey Creek	WS,FC,R,FW	105,000	135,000	22,400
Lela	Black Bear Creek	WS,R,FW	0	165,500	47,000
Otoe	Red Rock Creek	WS,FC,R,FW	42,000	162,000	40,000
Perry	Black Bear Creek	WS,FC,R,FW	76,000	170,500	30,000
Seward	Cottonwood Creek	WS,FC,R,FW	51,000	146,000	25,300
Skeleton	Skeleton Creek	WS,R,FW	0	280,000	41,400
Wellston	Captain Creek	WS,FC,R,FW	8,100	95,300	21,300
Sub Total			1,450,100	2,245,300	437,400
TOTAL			3,537,100		709,500

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

+Under construction

[1] Includes Water Quality Control Storage of 31,800 acre-feet which yields 43,680 acre-feet per year.

and will develop no yield of its own. See Figure IV-32 for all locations.

Watershed Protection and Flood Prevention

The Soil Conservation Service has planned and engineered construction of numerous flood control structures for watershed protection and flood prevention.

There is a total of 35 small S.C.S. watersheds in this region. Thirteen of these are complete or under construction, 4 are planned and 18 have potential for development in the next 50 years. To date, a total of 202 structures have been constructed in these watersheds.

With emphasis increasing for development of multiple use projects, seven projects were developed in this region on this basis. In addition to widespread recreational use, many local sponsors have added water storage for municipal purposes, such as Perry, Stroud, Stillwater, Meeker, Sparks, Lucien and Langston. Other multi-purpose structures with recreation and municipal water supplies are planned for the cities of Chandler, Wellston, Prague, Pawnee, Morrison and Glencoe.

Stream Water Rights

As of September 25, 1974, there was a combined total of 230 vested stream water rights and permits issued for the appropriation of 140,539 acre-feet of water per year from streams and lakes in this region. The tabulation by counties is shown in Table IV-37.

TABLE IV-37
NORTH CENTRAL REGION STREAM WATER PERMITS

COUNTY	NUMBER PERMITS ISSUED	AMOUNT ALLOCATED AF/YR
Garfield	33	2,507
Grant	10	685
Kay	19	5,403
Kingfisher	24	3,631
Lincoln	19	4,514
Logan	47	14,380
Noble	25	16,978
Pawnee	20	10,738
Payne	33	81,703
TOTAL	230	140,539

GROUND WATER

Present development of ground water resources in the north central region has been predominantly from the alluvium and terrace deposits, especially in Kingfisher County where the Cimarron Terrace deposits have been extensively developed. Well yields in this area range from 1,000 gpm to less than 50 gpm. Development from the Garber-Wellington Formation and Vamoosa Sandstone is sparse.

Existing Development

There is the potential for greater development of ground water within the region, but more well measurements and data need to be collected in order to make more accurate determinations.

Ground Water Permits

As of October 1974, there was a total of 331 ground water permits issued. These permits allocate fresh ground water to be used as municipal, irrigation or industrial water. The tabulation of data from Oklahoma Water Resources Board files is shown in Table IV-38.

TABLE IV-38
NORTH CENTRAL REGION GROUND WATER PERMITS

COUNTY	NUMBER PERMITS ISSUED	NUMBER WELLS	AMOUNT ALLOCATED AF/YR
Garfield	28	94	18,950
Grant	46	108	15,155
Kay	35	164	61,289
Kingfisher	136	288	41,595
Lincoln	14	32	6,338
Logan	23	58	9,786
Noble	10	26	2,758
Pawnee	6	11	1,447
Payne	33	80	18,762
TOTAL	331	861	176,080

Present Uses and Future Requirements

The population of the north central region is 235,292 (1970 census), and by the year 2030, that figure is projected to be 343,700. At the present time, the largest water use is for municipal and industrial needs. This includes water for energy related water requirements and rural water system needs. Future projections for the region show that municipal and industrial water needs will continue to require the most water use.

MUNICIPAL AND INDUSTRIAL

In 1972, total reported water usage by municipalities and industries was 87,415 acre-feet. Of that, 27,237 acre-feet came from ground water and 60,178 acre-feet came from stream water. By the year 2030 this figure is projected to rise to 247,000 acre-feet.

RURAL WATER SYSTEMS

In the north central region, there are 41 rural water systems. At present, systems are supplying water demands of 27,000 people. Sources consist of ground water, reservoirs and rivers. Public water systems of any type have not yet reached some 90,400 customers. It is estimated that in 1980 some 32,900 customers will be served by public water systems. Service accounts are expected to increase to 44,600 in 2000, and 58,700 in 2030.

ENERGY RELATED WATER REQUIREMENTS

Large portions of Garfield and Kingfisher, as well as parts of Lincoln, Noble and Kay counties contain expansive oil and gas fields, producing almost 26 percent of the State's petroleum. Because water plays an important role in recovery and refinement, future water requirements must be evaluated and adjusted for maximum operation and output.

IRRIGATION

Total reported water usage for irrigation in 1972 was 16,295 acre-feet. Ground water accounted for 12,621 acre-feet and stream water accounted for 3,674 acre-feet. This total is projected to increase 241,000 acre-feet by 2030.

OTHER USES AND REQUIREMENTS

Navigation

There are no navigation systems in the north central region at present. The Central Oklahoma Project, bringing navigation to the central part of the State is under study. Studies are also underway for navigation to Wichita, Kansas, which could affect this area. If plans are ever developed, water requirements would need review to provide the water necessary for navigation.

Fish, Wildlife and Recreation

No Federal or State hatcheries or refuges are located in this region. Estimated water usage was 160 acre-feet in 1973, and is projected to remain stable.

Water for recreational purposes is considered adequate except for swimming, which will be provided by the individual community.

Hydroelectric Power

Water requirements for hydroelectric power generation are not included in this report. Further detailed hydrologic system analyses will be made in a later report spelling out these hydropower requirements.

Water Quality Control

Only Kaw Lake in northern Kay County provides 31,800 acre-feet for water quality storage. This water is let out slowly over a period of time to prevent stagnant pools of water from forming and lowering water quality in various streams. The water will be dedicated for this purpose until such time as needed for water supply purposes. If other storage areas were considered, water requirements for these would have to be reviewed.

Plan of Development

MAJOR RESERVOIR SYSTEM

Table IV-39 shows the estimated 2030 demand and the possible supply system of major reservoirs in north central Oklahoma. Further detailed studies are needed to determine the quantity of flows available on the Arkansas River considering the terms of the Kansas-Oklahoma compact. In addition to the yield shown for the proposed 2030 system, 450,000 acre-feet can be obtained at other potential sites within the region.

Essentially, the problem within the region is one of distribution. Alternatives would be to develop in-basin sources for re-distribution within the region or to transport water into the region. These and other alternatives will be investigated when further, detailed studies are made for the northern 44 counties of Oklahoma. A portion of the water from Seward Lake is expected to be diverted to the central region for municipal use. Figure IV-32 shows existing and potential reservoir sites in north central Oklahoma.

WATERSHED PROTECTION PROGRAM

For discussion of the potential watershed protection program, see the Statewide Summary, Section I.

TABLE IV-39
NORTH CENTRAL REGION WATER SUPPLY AND DEMAND IN 1000's OF ACRE-FEET ANNUALLY

ESTIMATED 2030 IN-BASIN REQUIREMENTS

Municipal and Industrial	247.0
Irrigation	241.0
TOTAL	488.0[1]
To be met by ground water, SCS structures and farm ponds	105.0
NET REQUIREMENT	383.0

POSSIBLE 2030 SUPPLY

SOURCE RESERVOIR	YIELD	IN-BASIN NEEDS	DEFICIT
Carl Blackwell (E)	7.0		
Kaw (E)	230.7		
Keystone (E)	22.4		
McMurtry (E)	3.0		
Ponca (E)	9.0		
Seward (P)	25.3		
Enid (P)	0[1]		
TOTAL	297.4	383.0	85.6

(E)—Existing or under construction
(P)—Proposed
(A)—Authorized
[1] Potential Storage 80,000 acre-feet

NORTHWEST REGION

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General Description

The northwest region includes the three Panhandle counties of Cimarron, Texas and Beaver and the adjoining counties of Alfalfa, Blaine, Dewey, Ellis, Harper, Major, Woodward and Woods. Droughts are a way of life here. Portions of the terrain are very rough with high sand hills and severe erosion. However, the land is flat and dry in the Panhandle counties. The North Canadian River basin west of Guymon provides the only wide alluvial plain in the area.

Elevations vary from 4,973 feet above mean sea level at Black Mesa in extreme western Cimarron County to almost 1,200 feet in Alfalfa County.

The 14,339 square mile region has a climate ranging from semiarid in the Panhandle to dry subhumid in the remainder of the region. The growing season averages 185 days per year, varying from about 170 days in Cimarron County to approximately 200 days in Blaine County. Almost the entire Panhandle, as well as the central portion is drained by the North Canadian River. Another large section is drained by the Cimarron River, with smaller areas drained by the Salt Fork of the Arkansas and the Canadian River.

According to 1970 census figures, the eleven county region has a population of 96,719. The three largest communities are Woodward, with 9,412 people Guymon, with 7,600 and Alva, with 7,440 people.

Planning Area Resources

PRECIPITATION

As shown in Figure II-1, the average annual precipitation varies from 16 inches in the Panhandle to 28 inches in eastern Major and Blaine counties. Most precipitation occurs in the spring, with May being the wettest month of the year. Thunderstorms dominate the rainfall pattern during the growing season, often producing high winds and damaging hailstorms. January is the driest month of the year.

EVAPORATION AND TEMPERATURE

Annual average lake evaporation ranges from 56 inches in the west to 61 inches in the east, as shown in Figure II-3. Evaporation greatly exceeds precipitation. High winds and hot temperatures create this high evaporation rate. Evaporation is a major concern in the design of reservoirs, where additional water storage must be allowed. Mean annual temperature varies from 57 degrees in the Panhandle to 61 degrees in the western portion of the region, as shown in Figure II-2.

STREAM WATER CHARACTERISTICS

There is a combined drainage area of 14,339 square miles within the region. Major streams are the Salt Fork of the Arkansas River, the Cimarron, entering the region from eastern New Mexico, the Canadian, entering from Texas and the North Canadian, entering from the west side of the Oklahoma Panhandle. Available stream water is considered of insufficient quantity and quality for most of the needs of the area. Most needs are met by the use of ground water.

Runoff

Average annual runoff ranges from .2 inches in the western Panhandle to two inches in the eastern edge of the region. See Figure II-4. Average annual runoff originating in this region is estimated at 820,000 acre-feet per year.

A summary of streamflow records at U.S.G.S. gauging stations inside the region is presented below.

Flooding

This region is subjected to prolonged periods of insufficient water, interspersed with brief periods of far too much. To help control this situation, there are two reservoirs, Canton and Fort Supply. Under construction in Texas County is Optima Reservoir, scheduled for completion in 1976.

Stream Water Quality

The beneficial use of all the major streams in the northwest region is restricted because of the water quality. The water of the Canadian, the North Canadian, the Cimarron and the Salt Fork of the Arkansas Rivers do not meet public health standards for municipal or domestic use. All streams contain excessive

TABLE IV-40
NORTHWEST REGION STREAMFLOW SUMMARY

STREAM	U.S.G.S. STATIONS	CONTRIBUTING DRAINAGE AREA SQ. MILE	AVERAGE ANNUAL FLOW AF/YR	OBSERVED FLOW MAX (CFS)	MIN
Salt Fork of Arkansas	1505 - near Jet	3,194	245,600	25,900	0
Canadian River	2285 - at Bridgeport	20,428	307,200	150,000	0
Cimarron River	1545 - near Kenton	1,038	17,530	43,400	0
Cimarron River	1580 - near Waynoka	8,504	251,400	94,500	0
North Canadian River	2325 - near Guymon	1,175	20,000	55,400	0
North Canadian River	2390 - at Canton	7,601	150,000	24,800*	0

*This maximum observed flow is lower than the station above due to Canton Reservoir's flood control storage.

amounts of dissolved minerals primarily derived from soluble material brought into solution as the water moves down its basin.

Natural salt pollution is the major quality problem in the Cimarron and the Salt Fork of the Arkansas Rivers. These rivers contain large amounts of chlorides derived from salt plains and seeps located in northwestern Oklahoma.

The water of the Cimarron River is the most mineralized, with a dissolved solids content occasionally exceeding that of sea water. The two major reservoirs in the area, Canton and Fort Supply are rated as fair in quality and suitable for use.

GROUND WATER RESOURCES

Major ground water basins in the northwest region are the Rush Springs Sandstone, Ogallala Formation and alluvium and terrace deposits. For location of basins, see Figure IV-33. Ground water use, for irrigation, municipal, industrial and other purposes, accounts for more than 50 percent of the State's total reported ground water use. See Table II-2 for total water in storage and amounts recoverable from ground water basins.

Rush Springs Sandstone—See Southwest Planning Region.

Ogallala Formation (Tertiary in age) consists of interbedded sand, siltstone, clay, lenses of gravel, thin limestone and caliche. The Ogallala covers almost entirely the three Panhandle counties (Beaver, Texas and Cimarron) and extends a short distance into parts of adjacent Harper, Ellis, Woodward and Dewey counties. Total thickness ranges from zero to more than 700 feet, due to the irregular surface on which the Ogallala was deposited. Average thickness in the Panhandle area is 300 feet.

The Ogallala is the major source of water in the Oklahoma Panhandle. About 1,800 irrigation wells have been drilled in this area. Most of the wells yield about 500-1,000 gpm, averaging about 700 gpm. The water is generally of a calcium magnesium bicarbonate type, containing between 200 and 500 mg/l of dissolved solids. Although hard, the water is suitable for most uses.

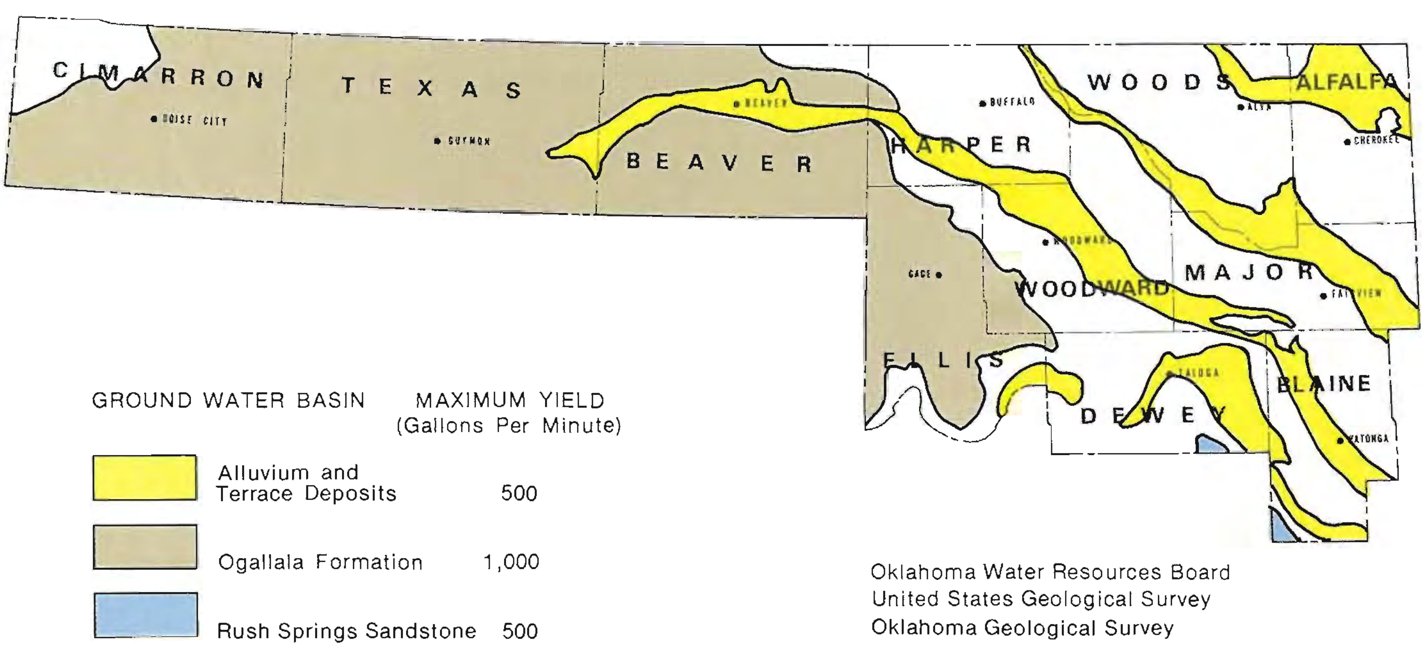
Alluvium and Terrace deposits (Quaternary) were laid down by streams and rivers and consist of poorly sorted, unconsolidated, interfingering lentils of clay, sand and gravel. The alluvium underlies the bottomlands along the streams, whereas the terrace deposits are topographically higher and usually adjacent to the alluvium.

The most favorable deposits are along the North Canadian, 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 100-300 gpm. Water quality is affected by nearby streams. However, generally the water is suitable for most uses where the deposits directly overlie the Ogallala and are not in contact with the Permian redbeds.

MINERAL RESOURCES

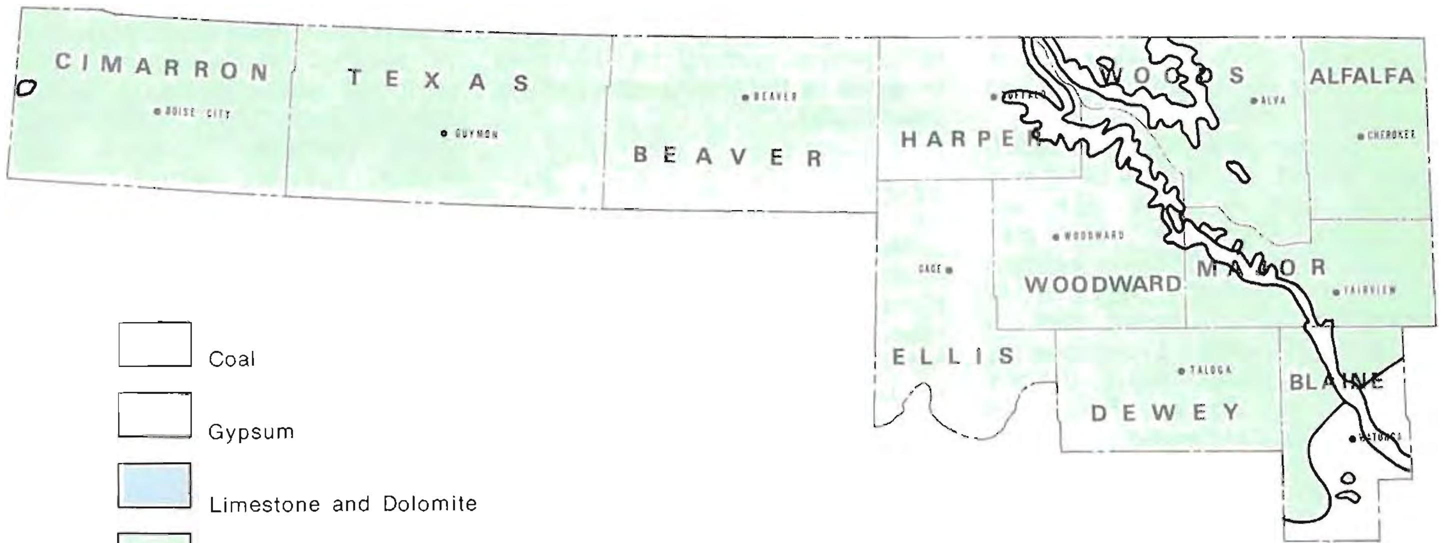
Major mineral production is from oil and gas. The area contains three giant gas fields, each with an ultimate recovery of more than one trillion cubic feet. Gas production is from porous dolomites and limestones at depths of 2,700-3,000 feet.

FIGURE IV-33
NORTHWEST REGION GROUND WATER BASINS



Oklahoma Water Resources Board
United States Geological Survey
Oklahoma Geological Survey

FIGURE IV-34
NORTHWEST REGION MINERALS



Coal

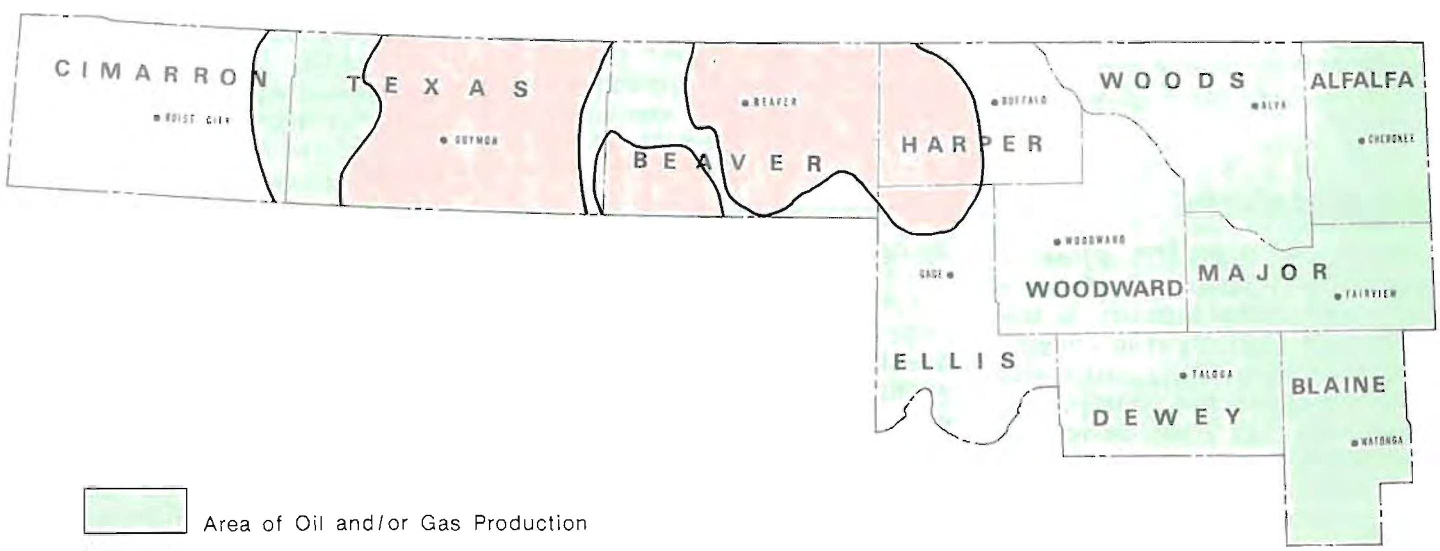
Gypsum

Limestone and Dolomite

Salt

Oklahoma Geological Survey

FIGURE IV-35
NORTHWEST REGION OIL AND GAS



Area of Oil and/or Gas Production

Giant Gas Field (Ultimate recovery of more than 1 trillion cubic feet)

Oklahoma Geological Survey

Production of oil in 1973 was 30 million barrels, with a total value of $117 million. Five secondary recovery projects are in operation and more will be initiated. The increasing need for oil and gas will assure continued drilling and production in the area.

In addition to energy fuels, coal, salt, helium, limestone, sand and gravel and volcanic ash are produced. Coal has been produced since the 1880's in western Cimarron County. Helium is extracted from natural gas in Cimarron County. Limestone is produced locally from caliche beds of the Ogallala Formation and used for road metal.

Thick sequences of rock salt (NaCl) underlie most of the northwest region at depths ranging from 30 feet to more than 3,000 feet. Salt reserves in western Oklahoma, estimated at 20 trillion tons, are virtually untapped. Current production in the northwest is from one solar evaporation plant in Woods County. Uses at present are for stockfeed and in recharging water softeners, but major potential uses include chemical industries (chlorine, caustic soda, soda ash and sodium), human consumption and snow removal. Underground storage facilities are easily and economically made by dissolving salt and forming salt cavities in salt beds. For mineral and oil and gas resources, see Figures IV-34 and IV-35.

LAND RESOURCES

There are 3,995,787 acres in cropland and pasture. Beef is the major agricultural industry in this region and production is consistently increasing. Dairy cattle also provide a significant contribution, but activity has been decreasing for some time. Wheat production is of significance, but decreasing, as is sorghum. Stable crops are barley and oats.

The 1972 Reported Water Use showed that the northwest region had 291,368 acres under irrigation. This includes only reported acres and does not represent the region total. Oklahoma State University Extension Service in 1973 reported a region total of 478,866 irrigated acres. The Panhandle alone contains over 44 percent of the total irrigated land in Oklahoma. Ninety-nine percent of the land irrigated in the Panhandle utilizes ground water.

SOILS

The Panhandle area consists mainly of Potter-Mansker, Richfield-Dalhart-Portales and Pullman-Richfield associations. Typical land use consists of small grains and row crops usually with supplemental irrigation to aid productivity. Less dominant associations are Vona-Dalhart-Tivoli and Travessila-Berthoud-Rough Stoney Land used for rangeland.

The remainder of the northwest region's land area has a large variety of soil associations. Pratt-Tivoli, Rough Broken Land-Vernon, Woodward-Carey, Quinlan and Grant-Pond Creek-Nash are the prevailing soils. Land usage consists of choice cropland, pasture and rangelands. Minor soil associations located within the northwest region include Vanoss-Minco-Yahola, Bethany-Tabler-Kirkland, Enterprise-Tipton-Yahola, Rough Broken Land-Quinton, Renfrow-Zaneis-Vernon, Nobscot-Brownfield-Miles and Carey-St. Paul. Usage is widely diversified, predominantly cropland, along with some pasture and rangeland. See Figure II-11.

ENVIRONMENTAL RESOURCES

Although water is in short supply, the area has many beautiful and unique environmental resources. Alabaster caverns, springs and flat plains are found in the northwest region.

Scenic Areas

Five State parks, each different in appeal, offer visitors many choices. Great Salt Plains State Park in Alfalfa County provides gleaming white sands, a residue from evaporated salt water. Alabaster Caverns State Park, in Woods County, is the world's largest known alabaster cavern and approximately 200 million years old. Roman Nose State Park is nestled in a canyon near Watonga in Blaine County. Boiling Springs State Park, near Woodward, features numerous cold water springs which "boil" through white sands. Black Mesa State Park in Cimarron County is the State's highest point at over 4,000 feet.

Fish, Wildlife and Recreational Activities

Three Department of Wildlife Conservation lakes, Etling, Chambers and Schultz, all in the Panhandle, provide much of the region's fish harvest. Native species include largemouth bass, channel catfish, bluegill and red-ear sunfish.

Hunting is good in the region, with regular game species of bobwhite quail, pheasant, turkey, rabbit, whitetail deer and waterfowl. The area is also the only region in the State that has mule deer and antelope. Public hunting areas include Rita Blanca Public Hunting Areas, Great Salt Plains National Wildlife Refuge and Lake Etling Waterfowl Refuge.

Interesting tourist sights include traces of the old Santa Fe Trail, Fort Nichols, established by Kit Carson in 1865 and No Man's Land Museum.

Regional Historical Features

The northwest region, once called "No Man's Land," shows traces of human habitation as much as 4,000 years ago. During the past 300 years, the flags of five nations have flown over the Panhandle at different times.

The Santa Fe Trail, the link between Independence, Missouri and Santa Fe, New Mexico passes through this region. Ruts from wagon wheels can still be seen in Black Mesa State Park. The region was a haven for outlaws, and vigilante groups were formed to rid the area of the villains.

The settlers who came to the region were a hardy lot, facing drought, blizzard and dust storms. No sturdier or more resourceful people lived anywhere than in No Man's Land.

Present and Potential Development

There are three existing reservoirs and one under construction. In addition, there are seven potential sites available for development. Ground water development in this area occurs primarily in the Ogallala Formation.

STREAM WATER

As shown in Table IV-41, there are existing and under construction lakes in this region that provide a total of 669,300 acre-feet of flood control storage and 32,300 acre-feet of water supply. There are additional potential sites having a possible water supply yield of 308,400 acre-feet, for a region total of 340,700 acre-feet of water supply.

Sites not included in the potential resource table are Boise City, Goodwell and Slapout, each with a conservation storage capacity of 550,000, 510,000 and 600,000 acre-feet respectively, for a total of 1,660,000 acre-feet. These storage reservoirs are designed to hold possible transport water and will develop no yield of their own. See Figure IV-36 for these locations.

Watershed Protection and Flood Prevention

The Soil Conservation Service has planned and engineered construction of flood control structures for the purpose of watershed protection and flood prevention.

There is a total of 30 small S.C.S. watersheds in this region. Five of these are complete or under construction, 1 is planned and 24 have potential for development in the next 50 years. To date, a total of 22 structures have been constructed in these watersheds. As secondary benefits, many towns, such as Laverne, are using watershed structures for recreational purposes. For location of the watershed programs, see Figure I-5.

Stream Water Rights

As of September 25, 1974, there was a combined total of 137 vested stream water rights and permits issued for the appropriation of 39,277 acre-feet of water per year from streams and lakes in this region. The tabulation by counties is shown in Table IV-42.

GROUND WATER

Ground water development occurs primarily in the Ogallala Formation. It is the best ground water basin in Oklahoma because of its areal extent, thickness and high permeability, and thus the most important source of ground water. It contains approximately 70,000,000 acre-feet of water in storage and supplies most of the water requirements of the Panhandle. Ground water from the Ogallala is used to irrigate about 260,000 acres of land and meet the industrial, municipal and domestic needs of the region. However, pumpage from wells exceeds recharge. Only 1.5 percent of the annual rainfall or one-fourth inch reaches the water table. Ground

FIGURE IV-36
NORTHWEST REGION STREAM WATER DATA

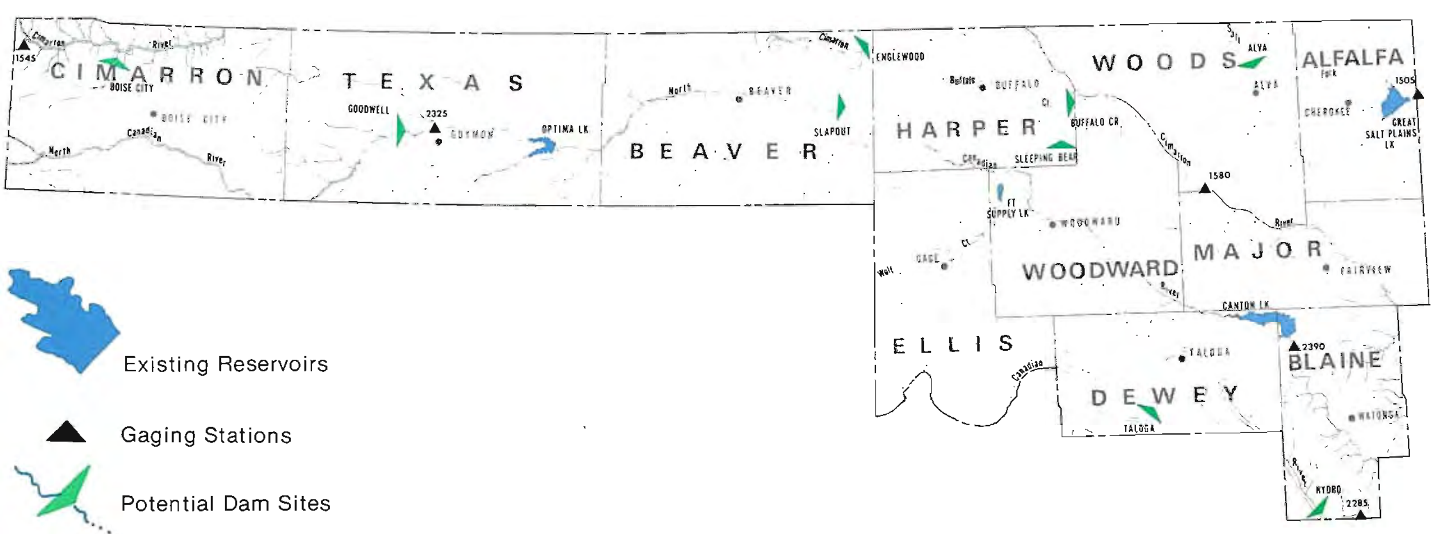


TABLE IV-41
NORTHWEST REGION PRESENT AND POTENTIAL WATER RESOURCE PROJECTS

NAME OF SOURCE	LOCATION	PURPOSE *	FLOOD CONTROL STORAGE ACRE FT.	WATER SUPPLY STORAGE ACRE FT.	WATER SUPPLY YIELD (AF/YR)
EXISTING OR UNDER CONSTRUCTION					
Canton Lake	N. Canadian River	WS,FC,I	267,600	107,000[1]	13,440[1]
Fort Supply Lake	Wolf Creek	WS,FC,R	87,200	400	220[2]
Great Salt Plains Lake	Salt Fork of Arkansas River	FC,R	242,700	0[3]	0[3]
Optima Lake +	N. Canadian River	WS,FC,R,FW	71,800	76,200[1]	18,640[4]
Sub Total			669,300	183,600	32,300
POTENTIAL SITES				CONSERVATION STORAGE	
Alva	Salt Fork of Arkansas River	WS,FC,R,FW,I	98,000	234,000	35,000
Buffalo Creek	Buffalo Creek	WS,FC,R,FW	147,000	61,500	9,000
Englewood	Cimarron River	WS,FC,R,FW,CC	440,000[5]	231,000	49,300
Hydro	Canadian River	WS,R,FW	0	676,300	112,000
Slapout	N. Canadian River	WS,FC	137,000	598,000	10,000
Sleeping Bear	Sleeping Bear Creek	WS,FC	21,000	7,800	1,100
Taloga	Canadian River	WS,FC,I	156,000	620,000	102,000
Sub Total			999,000	2,428,600	308,400
TOTAL			1,668,300		340,700

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

+Under construction

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

[2]Restudy by the Corps of Engineers indicated that Fort Supply Lake would yield 15,680 acre-feet per year of water supply if the water supply storage was increased to 25,000 acre-feet. This would, however, decrease the effectiveness of the flood control storage.

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

[4]This yield includes 7,474 acre-feet per year of water that is released to existing downstream water rights.

[5]Includes flood control storage and chloride control storage.

TABLE IV-42
NORTHWEST REGION STREAM WATER PERMITS

COUNTY	NUMBER PERMITS ISSUED	AMOUNT ALLOCATED AF/YR
Alfalfa	15	3,135
Beaver	18	2,064
Blaine	13	2,729
Cimarron	22	8,633
Dewey	3	384
Ellis	14	1,386
Harper	26	13,514
Major	4	922
Texas	7	950
Woods	5	3,564
Woodward	10	1,996
TOTAL	137	39,277

water in the Ogallala Formation is being mined.

Existing Development

Well development in the Ogallala has increased significantly over the past ten years. In 1960, there were approximately 400 wells in the Panhandle. By 1965, the number had more than doubled to about 975 wells, and in 1974 there were 2,067 wells. The greatest concentration of high capacity wells occurs in the 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.

The increase in development and pumpage of wells has caused adverse effects on water levels. Wells that are closely spaced and pumped for significant periods of time at high rates create a cone of depression around the pumped wells, causing interference between wells, thereby reducing the quantity of water to wells. This situation is common in the heavily developed areas of the Panhandle.

Declines in water levels as much as 75 feet (in a well south of Guymon) have taken place over the past 20 years. See Figure IV-37. This represents a reduction in saturated thickness of the formation and loss of ground water in storage. The results are a decrease in rate at which pumps will deliver water, higher pumping costs and possible water quality problems from saline encroachment. Eventually, pumping of wells will become financially infeasible and a new source of fresh water will be required to meet the needs of northwestern Oklahoma and sustain the economic life of the region.

Ground Water Permits

As of October 1974, a total of 2,303 ground water permits have been issued. These permits allocate fresh ground water to be used as municipal, irrigation or industrial water. The tabulation of data from the Oklahoma Water Resources Board files is shown in Table IV-43.

TABLE IV-43
NORTHWEST REGION GROUND WATER PERMITS

COUNTY	NUMBER PERMITS ISSUED	NUMBER WELLS	AMOUNT ALLOCATED AF/YR
Alfalfa	70	173	19,948
Beaver	325	276	125,365
Blaine	65	130	32,674
Cimarron	457	786	264,595
Dewey	40	69	11,850
Ellis	93	133	40,964
Harper	71	101	29,735
Major	220	443	78,593
Texas	795	1,005	547,666
Woods	56	115	35,423
Woodward	111	179	32,486
TOTAL	2,303	3,410	1,219,299

Present Uses and Future Requirements

The population of the northwest region, according to the 1970 census, is 96,719. The projected figure for the year 2030 is 99,800. At the present time, the largest water use is for irrigation needs. Future projections for the region show that irrigation will continue to require the most water usage.

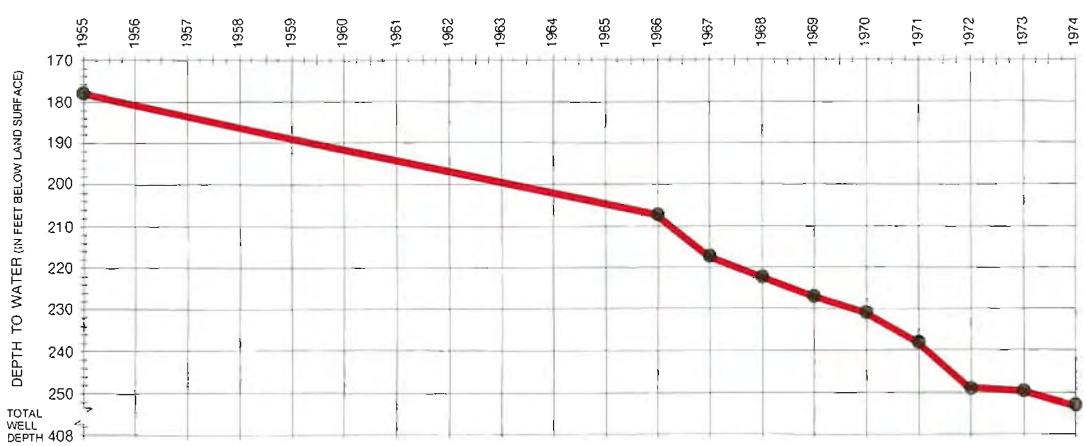
MUNICIPAL AND INDUSTRIAL

The 1972 total reported water usage for municipal and industrial purposes was 25,168 acre-feet. Of this amount, 24,823 acre-feet came from ground water and 345 acre-feet came from stream water. Projected requirements for the year 2030 is 57,000 acre-feet.

RURAL WATER SYSTEMS

There are 16 rural water systems in the northwest region, with sources coming mostly from ground water. In Woods County, however, these sytems draw water from the city of Alva, which currently extracts water from the

FIGURE IV-37
WELL LEVEL DECLINE, OGALLALA FORMATION
NW 1/4, SW 1/4, NW 1/4 Sec. 9, T2N, R15E, 1956-1974



Salt Fork River. These rural water systems serve 7,500 people, while 45,900 are unserved by any type of public system. Based on projections, there will be 8,500 customers in 1980, 11,800 in 2000 and 14,900 in 2030. Requirements must be reviewed to insure maximum service to all systems.

ENERGY RELATED WATER REQUIREMENTS

Almost all of Texas and Beaver counties and portions of Harper, Dewey and Ellis counties hold oil and gas reserves, producing 29 percent of the State's total output. With the increasing demand for natural gas and fuels, water requirements for energy related activities must be reviewed and adjusted in order to maintain maximum production.

IRRIGATION

Ground water irrigation used 416,872 acre-feet and stream water used 8,629 acre-feet in 1972, totaling 425,501 acre-feet. The projected figure for the year 2030 is an unparalleled 1,489,200 acre-feet.

OTHER USES AND REQUIREMENTS

Navigation

At present, there are no navigation systems in the northwest region nor are there any plans for such a system.

Fish, Wildlife and Recreation

Lakes Etling, Schultz and Chambers are owned by the Department of Wildlife Conservation specifically for raising fish. Refuges are the Great Salt Plains Wildlife Refuge and Lake Etling Waterfowl Refuge. Total consumption was 1,970 acre-feet in 1973. Usage is projected to increase by 2000 acre-feet. This increase will be used to expand facilities at the Byron State Fish Hatchery.

Water for recreational purposes is considered adequate except for swimming, which will be provided by the individual community.

Hydroelectric Power

There are, at present, no hydroelectric plants or plans for plants in the northwest.

Water Quality Control

None of the major reservoirs in the northwest region have storage space allocated for water quality control.

The poor quality of the Cimarron, the Salt Fork of the Arkansas, the Arkansas and some of its tributaries (Buffalo Creek) is due primarily to natural salt pollution. The Corps of Engineers has made studies on the natural salt pollution in these basins and has formulated several plans aimed at elimination or abatement of pollution from these natural salt sources. Four sources consisting of salt plains and salt water seeps and springs have been located and chloride control plans have been formulated and proposed to eliminate some of this salt load to make the resources of these streams more useful.

Plan of Development

MAJOR RESERVOIR SYSTEM

Table IV-44 shows the estimated 2030 demand and the possible supply system of major reservoirs in northwest Oklahoma. The ground water estimate shown in the table is based on preliminary and incomplete information, and further detailed studies are needed to accurately quantify this resource. However, a sizeable

TABLE IV-44
NORTHWEST REGION WATER SUPPLY AND DEMAND IN 1,000's OF ACRE-FEET ANNUALLY

ESTIMATED 2030 IN-BASIN REQUIREMENTS

Municipal and Industrial	57.0
Irrigation	1,489.2
TOTAL	1,546.2
To be met by ground water, SCS structures and farm ponds	400.0
NET REQUIREMENT	1,146.2

POSSIBLE 2030 SUPPLY

SOURCE RESERVOIR	YIELD	IN-BASIN NEEDS	DEFICIT
Canton (E)	13.4		
Ft. Supply (E)	0.2		
Optima (E)	18.6		
Hydro (P)	67.8[1]		
Englewood (P)	49.3		
Alva (P)	35.0		
Taloga (P)	102.0		
Buffalo Creek (P)	9.0		
Slapout (P)	10.0[2]		
Boise City (P)	0[3]		
Goodwell (P)	0[4]		
TOTAL	305.3	1,146.2	840.9

(E) Existing or under construction
(A) Authorized
(P) Proposed
[1]Does not include 44,200 acre-feet per year diverted to southwest Oklahoma
[2]Potential Storage 600,000 acre-feet
[3]Potential Storage 550,000 acre-feet
[4]Potential Storage 575,000 acre-feet

deficit appears by the year 2030 based on the present knowledge of the region's resources. Presently, more ground water is being removed than is being replaced by natural recharge. Ground water levels are rapidly declining, and a lack of adquate quantitative information on maximum safe yields and recharge potentials has hampered the development of effective management programs for ground water basins within this region.

A partial solution would, of course, be better management of the resource, including construction of more surface reservoirs. The array of alternative solutions would range from doing nothing as a minimum, to full transportation of water as a maximum. A combination of transportation plus better management will, no doubt, be the most reasonable alternative from an economic standpoint. Phase II of the Oklahoma Comprehensive Water Plan will treat these alternatives in more detail and will propose a definite plan for the region. Figure IV-36 shows existing and potential reservoir sites within the northwest region.

WATERSHED PROTECTION PROGRAM

For discussion of the potential watershed protection program, see the Statewide Summary, Section I.