Update of the Oklahoma Comprehensive Water Plan 1995

Planning Division
Oklahoma Water Resources Board

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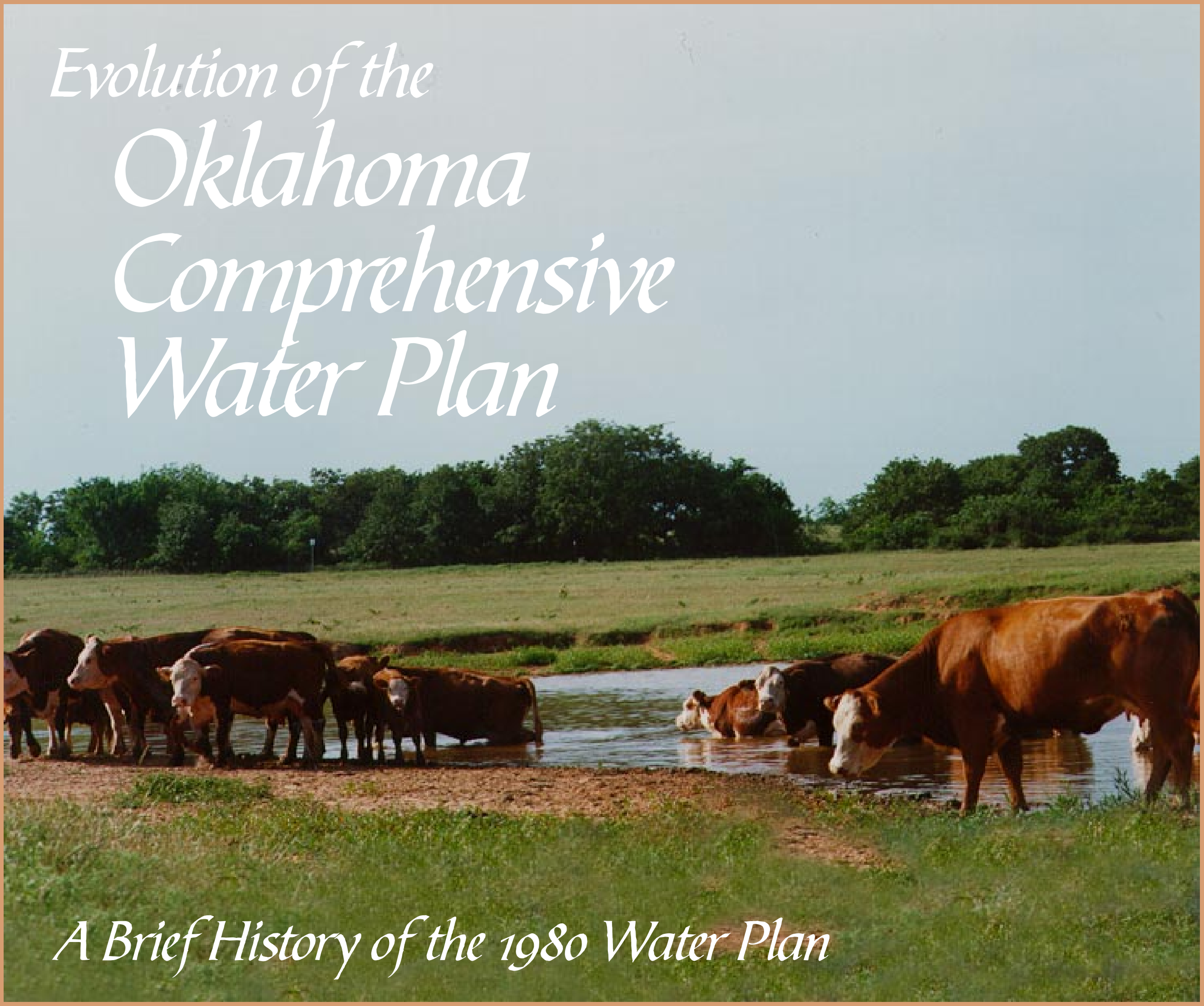
Throughout the past six decades, Oklahoma has experienced tremendous water resource development, primarily through the efforts of the Corps of Engineers, Bureau of Reclamation, Soil Conservation Service, Grand River Dam Authority and numerous other state agencies and municipalities. While only three major reservoirs existed in Oklahoma in the 1920's, the 30's and 40's saw completion of 12 additional projects. Twenty-nine major projects have been constructed since, including the McClellan-Kerr Arkansas River Navigation System, the nation's largest civil works project, in 1971.

In addition to surface supplies, Oklahoma's 23 major groundwater basins store an estimated 320 million acre-feet of water, with smaller amounts available in at least 150 minor basins. Of all the water reportedly used in Oklahoma, more than one-half comes from groundwater sources which provide the vast majority of the state's irrigation needs and supply hundreds of municipalities with drinking water.

Oklahoma is truly blessed with abundant water resources which, perhaps above all other factors, propel the wheels of economic development and growth in the state. However, although generous supplies are available for drinking and domestic use, industry, agriculture, power generation and countless other purposes, state waters are unevenly distributed, sometimes wasted or polluted, and often taken for granted. As a result, planning, management and protection of Oklahoma's water resources is extremely important and complex.

As part of its broad responsibility to enhance the quality of life and general welfare, the state has the specific obligation to plan for and encourage the use of water and natural resources in a manner that will best serve the many needs of the people of Oklahoma. Recognizing that water planning, like the resource itself, is a discipline that must provide for continuous change and periodic revision if it is to accurately reflect dynamic social, political, economic and environmental issues, the Oklahoma Legislature passed House Bill 2036 in 1992. The legislation directs the Oklahoma Water Resources Board (OWRB) to prepare decennial updates of the Oklahoma Comprehensive Water Plan (OCWP), the state's long-range water use and management strategy which was initially completed in 1980. The first update, originally scheduled for completion in September 1995, and each successive revision will employ the most current and dependable socioeconomic data available to meet the constantly evolving water resources needs of Oklahomans. Planning committees consisting of Oklahoma citizens -- as well as representatives of local, state and federal entities -- will guide the update process to ensure that prevailing opinions and policies are properly reflected.

This document, the first update of the OCWP, is submitted to Governor Frank Keating and the 46th Oklahoma State Legislature for their consideration. The authors wish to thank the Governor and legislative members for their patience and indulgence in allowing late submittal of this plan due to complications resulting from the Oklahoma City bombing.



The State Legislature planted the seeds for development of a state water plan through creation of the Governor's Water Study Committee in 1955. Citizen and legislative representatives of the Committee, appointed by Governor Raymond Gary to gather public opinion on the state's critical water problems and recommend appropriate solutions, held meetings throughout the state to obtain first-hand knowledge of Oklahoma's water situation and identify future water resource needs.

A landmark recommendation of the committee led to creation of the OWRB in 1957. The Water Board was initially given the task of managing the state's water supplies and developing a fair, long-range plan to assure the best and most effective use of water to meet the needs of Oklahoma citizens. Despite this legislative authority, limited staff and funding impeded the OWRB's early attempts to create a state water plan.

A major catalyst to the Board's efforts proved to be the federal Water Resources Planning Act of 1965 that provided grants to states to prepare individual water management plans. As part of this preliminary planning effort, the OWRB, in conjunction with other appropriate local, state and federal entities, compiled 11 reports collectively entitled the *Appraisal of Water and Related Land Resources of Oklahoma*. These reports assessed hydrologic, economic, geologic and social characteristics of each of the state's planning regions; identified local water problems; and proposed specific water development projects.

Still, this effort failed to fully incorporate long-range projections of water problems and requirements. In 1974, Senate Bill 510 gave specific statutory authority to the OWRB to expand on the appraisals and construct from them a comprehensive state water plan for submission to the State Legislature.

The initial phase of plan development utilized state agencies, universities and numerous federal agencies which, along with the OWRB, comprised the OCWP's Planning Committee. The Corps of Engineers' Planning Assistance to the States Program, Bureau of Reclamation's Technical Assistance to the States Program, write-in requests from the Congressional Delegation and other cooperative financial agreements were essential in funding plan formation. Substate planning districts assisted in developing population projections and future water requirements and, in an effort to gain broad-based input and public support for the plan, open meetings were held throughout Oklahoma.

Because of central Oklahoma's immediate water needs and the wealth of information already available on the Red River Basin, Phase I of the OCWP addressed the water supply needs of the state's 33 southern counties. Perhaps due to this limited scope, the Legislature failed to take action on the Phase I Water Plan following its submittal in 1975. Instead, the Legislature directed the OWRB to prepare a similar plan for the remaining 44 counties encompassing the Arkansas River Basin.

The final two-phase draft of the OCWP was completed by the OWRB in early 1980 and adopted by the legislature the following year. The primary impetus of the Water Plan was to meet Oklahoma's future demands through regional development and provide additional water to Oklahoma's water deficient areas by transferring surplus water from east to west. This ambitious transfer project was to be accomplished through the construction of separate northern and southern water conveyance systems. However, neither system could be economically justified under federal guidelines.

ACCOMPLISHMENTS

The 1980 OCWP presented a flexible, long-range strategy for managing and developing the state's water resources through the year 2040 and feasible plans to meet projected, future requirements of municipalities, industries and the public. The OCWP offered numerous recommendations that have resulted in stronger water development and management programs.

Probably the most significant recommendation of the 1980 OCWP was an initiative to provide a mechanism for financing community water and sewer system improvements. In 1982, the Oklahoma Legislature appropriated $25 million in seed money to create the Statewide Water Development Revolving Fund (SWDRF). The primary purpose of the SWDRF is to serve as additional security and collateral for revenue bonds issued by the OWRB. Loan monies are generated through the sale and issuance of the bonds; bond sale proceeds are then loaned to eligible applicants who pay back the loans over an extended period of time. Grant funds, derived from interest earned on the Revolving Fund, are available to eligible entities for emergency water and sewer problems. Additional purposes of the SWDRF are to make money available to fulfill cost-sharing requirements of federal water projects, construct state water projects and repay water storage contracts between Oklahoma and the federal government.

The SWDRF program has served as a model for other states while saving the infrastructures of hundreds of Oklahoma cities, towns and rural water districts from potential collapse. The SWDRF has been particularly effective in insulating small communities from the financial crises posed by aging systems, weather-related emergencies, dwindling budgets and increasingly stringent environmental regulations.

The OCWP also laid the groundwork for the Oklahoma Legislature to adopt statewide floodplain management legislation which ensures that every Oklahoma community has access to affordable flood insurance. The OWRB, through the National Flood Insurance Program (NFIP), provides assistance to city, town and county officials in implementing sound management programs aimed at guiding development in floodplain areas, thereby mitigating flood losses and reducing state and federal hazard assistance. The state program has grown enormously since its inception; there are currently 360 Oklahoma communities (including cities, towns and counties) participating in the NFIP.

Another major recommendation put forth by the OCWP was that the Governor, State Legislature and Oklahoma Congressional Delegation continue to support the Red River Chloride Control Project. Natural salt pollution within the Red River Basin makes this water virtually unusable as a source for irrigation, industries or municipalities. To free-up additional sources of fresh water in the basin, the Corps of Engineers embarked on a project in the Red River Basin to remove or bypass 10 major salt sources in southwest Oklahoma and northwest Texas. The initial pilot project, just across the Red River border in Texas, was deemed successful, removing an estimated 86 percent of the chlorides contributed from the South Fork of the Wichita River.

State weather modification ("cloud seeding") efforts, initiated under the Oklahoma Weather Modification Act in 1972, also gained significant momentum as a result of a 1980 OCWP recommendation. The OWRB now regulates all cloud seeding activities in the state through oversight of a comprehensive program of licensing, permitting and reporting. Also, the OWRB encourages scientific research and development of weather modification strategies and has prepared a flexible, long-term plan to utilize and develop weather modification technology to augment Oklahoma's water resource needs.

Recommendations offered in the 1980 OCWP also stressed the need for conservation among municipalities, industry and agriculture. Many of these issues and suggested options -- i.e., water reuse and recycling, conjunctive use of stream water and groundwater, water management districts, and water rate structuring that encourages conservation -- are also a focus of this update. To create public awareness of the need for conservation practices, the state has developed numerous education programs and related materials tailored to elementary and high school students. Although more comprehensive measures are likely required, conservation represents a promising and realistic method to alleviate Oklahoma's present and future water supply problems.

UPDATE OF THE WATER PLAN

The stark contrast of climate and resources from western to eastern Oklahoma compels water agencies to deal with many conflicting issues. Frequent water supply and drought problems in the west prevail upon the minds of water planners while water quality and flooding are primary concerns in the east. Meanwhile, some 34 million acre-feet of water flows unused out of Oklahoma each year. While these irrefutable characteristics will undoubtedly provide the foundation for upcoming water planning efforts in Oklahoma, just as they have guided efforts in years past, new and evolving issues will complicate implementation of future state and federal water policy.

Long-range planning to protect and maximize the benefits of the state's surface and groundwater resources has been a continuing mission of the state since the 1950's, as demonstrated through such planning milestones as the *Appraisal of Water and Related Land Resources of Oklahoma* and, of course, creation of the 1980 *Oklahoma Comprehensive Water Plan*. Although the OCWP spawned numerous achievements related to improved management of state water resources, the 15-year interim since its issuance has seen profound changes in Oklahoma's social, political and economic conditions. The most notable event occurred in the early 1980's with the sudden and unanticipated collapse of the world oil market. That occurrence -- mirrored by a decline in the U.S. agricultural industry -- devastated Oklahoma's economy, significantly reducing projected growth patterns of population, industry, water use and virtually all other factors related to economic well-being.

Another monumental change is the federal government's declining role in state funding which will likely dictate that the expansion or more efficient use of existing projects, rather than the development of new ones, will dominant the 21st Century. Other major issues that are receiving increased federal and state attention include nonpoint source pollution control; development of watershed management strategies; improvements in groundwater quality and protection; and improved management and protection of wetlands resources.

Recognizing that update of the Water Plan is crucial if the state is to move forward into the next century with confidence that its water supplies are sufficiently protected and capable of keeping pace with the demands of Oklahoma's industry and populace, the State Legislature has directed the OWRB to continuously update the OCWP. As stated in HB 2036, this first update, along with future decennial revisions, will provide for the continuous management, protection, conservation, development (both structural and nonstructural) and utilization of state water resources in accordance with the following principles which also guided development of the original plan:

- Multipurpose dams and reservoirs, both existing and planned, should be utilized to the maximum extent possible;
- Water should be stored in the area of usage during periods of surplus supply for use during periods of short supply;
- Water within the state should be developed to the maximum extent feasible for the benefit of Oklahomans, rather than for the benefit of out-of-state, downstream users;
- Only excess or surplus water should be utilized outside the areas of origin and citizens within the area of origin possess a prior right to the water originating therein;
- All citizens, municipalities and other entities in need of water for beneficial use shall be entitled to appropriate water and vest rights in accordance with state and federal law in the most feasible manner; and
- The statutory power of the OWRB in the granting of water rights to water users shall be preserved.

Furthermore, HB 2036 emphasized that the powers granted by the legislation be utilized "for the benefit of the people of the state, for the increase of their commerce and prosperity and for the improvement of their health and living conditions." In reality, this credo directs all basic planning disciplines.

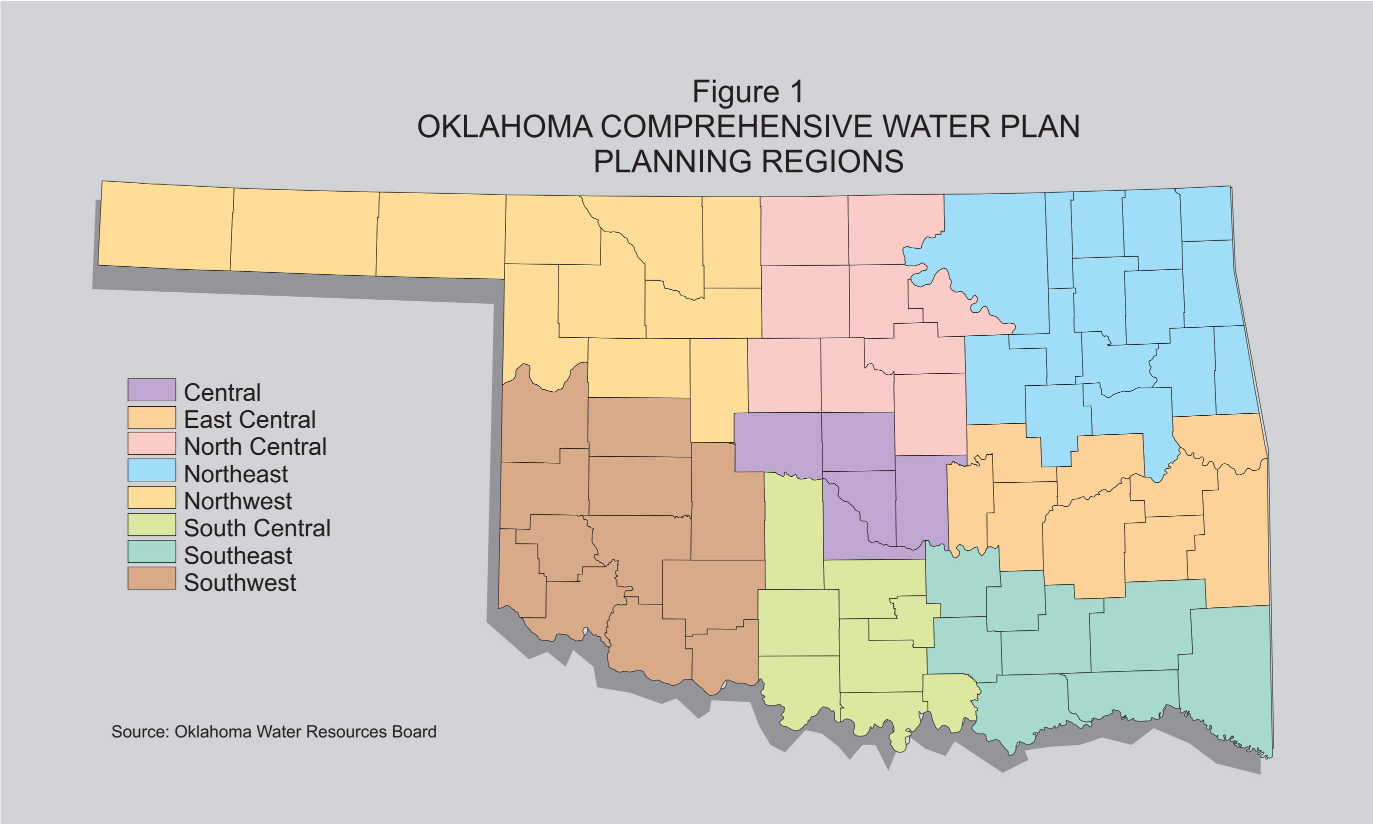
In development of the plan update, the OWRB participated with representatives of the following federal and state agencies and organizations who contributed their collective knowledge and expertise: the U.S. Army Corps of Engineers, Bureau of Reclamation, Natural Resources Conservation Service, U.S. Fish and Wildlife Service, U.S. Geological Survey, National Weather Service, Oklahoma Tourism and Recreation Department, Oklahoma Department of Wildlife Conservation, Oklahoma Conservation Commission, Oklahoma State Department of Health, Oklahoma Department of Agriculture, Oklahoma Department of Commerce, Office of the State Secretary of Environment, Oklahoma Corporation Commission, Oklahoma Department of Environmental Quality, Oklahoma Department of Transportation, Oklahoma Climatological Survey, Oklahoma Geological Survey, Grand River Dam Authority and Southwestern Power Administration.

These organizations did not collaborate to replace or significantly alter the state's current water resource planning strategy. Instead, their intent was to build upon the successes of the 1980 OCWP and modify it to reflect changing water resource philosophies and trends of water use. The recommendations contained within this and future OCWP updates and interim reports, as necessary, are submitted to the Oklahoma State Legislature for their consideration in providing to Oklahoma citizens, as the need develops, additional flood control, water supply, recreation, navigation, hydropower and other water resource opportunities.

GOALS AND OBJECTIVES

To encourage development of optimum water resource management and protection strategies, especially in absence of sufficient funding sources, the Water Plan must be made more realistic, responsive and implementable. While it is recognized that structural and related alternatives must be implemented to resolve many of Oklahoma's water resource problems, the primary objective of the OCWP update is to explore solutions from a policy perspective. The policy approach for each water resource issue will focus on assessing general needs, identifying problem areas and opportunities, establishing objectives, and recommending specific and appropriate policy choices to achieve desired goals. The update of the OCWP addresses the following 11 categories of water resource policy issues:

- water rights;
- water quality;
- water and wastewater systems;
- reservoir operations;
- water marketing;
- water supply augmentation;



- water conservation;
- water resource planning;
- floodplain management;
- problem mediation and arbitration; and
- data collection and management.

By addressing important policy issues from new local, state and federal perspectives, it is envisioned that the following specific objectives, which are restated from the original OCWP, can and will continue to be realized:

- promotion of economic opportunity and development;
- preservation and enhancement of the environment;
- protection of lives and property from floods;
- expansion of agricultural production and agribusiness activity;
- development of recreational opportunities;
- maintenance and improvement of water quality;
- encouragement of water conservation;
- placement of excess and surplus water to beneficial use; and
- encouragement of public participation in water resource planning.

The public participation objective -- especially involvement of two Water Plan Advisory Committees representing various water uses -- was perhaps the most vital component of the recently completed OCWP update process. The Citizens Advisory Committee brought an invaluable grass-roots perspective to the planning table while the Technical Advisory Sub-Committee allowed state and federal water agencies to contribute their knowledge and experience. Committee members identified 31 water-related issues and offered recommendations to guide legislative efforts in addressing each issue or problem. In addition, public meetings held throughout the state in conjunction with OWRB rules hearings provided an opportunity for Oklahoma citizens to shape the final Water Plan document through comment on the state's current and future water requirements as well as water issue recommendations offered to the State Legislature.

PLANNING HORIZON AND STUDY AREA DELINEATIONS

The OWRB, Corps of Engineers and Bureau of Reclamation based OCWP statewide water demand projections on 50 years (the year 2000 through 2050) because it represents a reasonable, foreseeable time period and encompasses the minimum life span of most large water resources projects in Oklahoma. In addition, it provides consistency in that it is the standard reach of time used by many other state and federal planning agencies.

As in the original OCWP, the state is divided into eight planning regions to better facilitate water planning for the upcoming 50-year period. The counties in each region, shown in Figure 1, exhibit common characteristics -- such as homogeneity of climate, geography, hydrology, economics and demography -- that meld them into functional planning units. Each region is unique in its water resources and requirements.

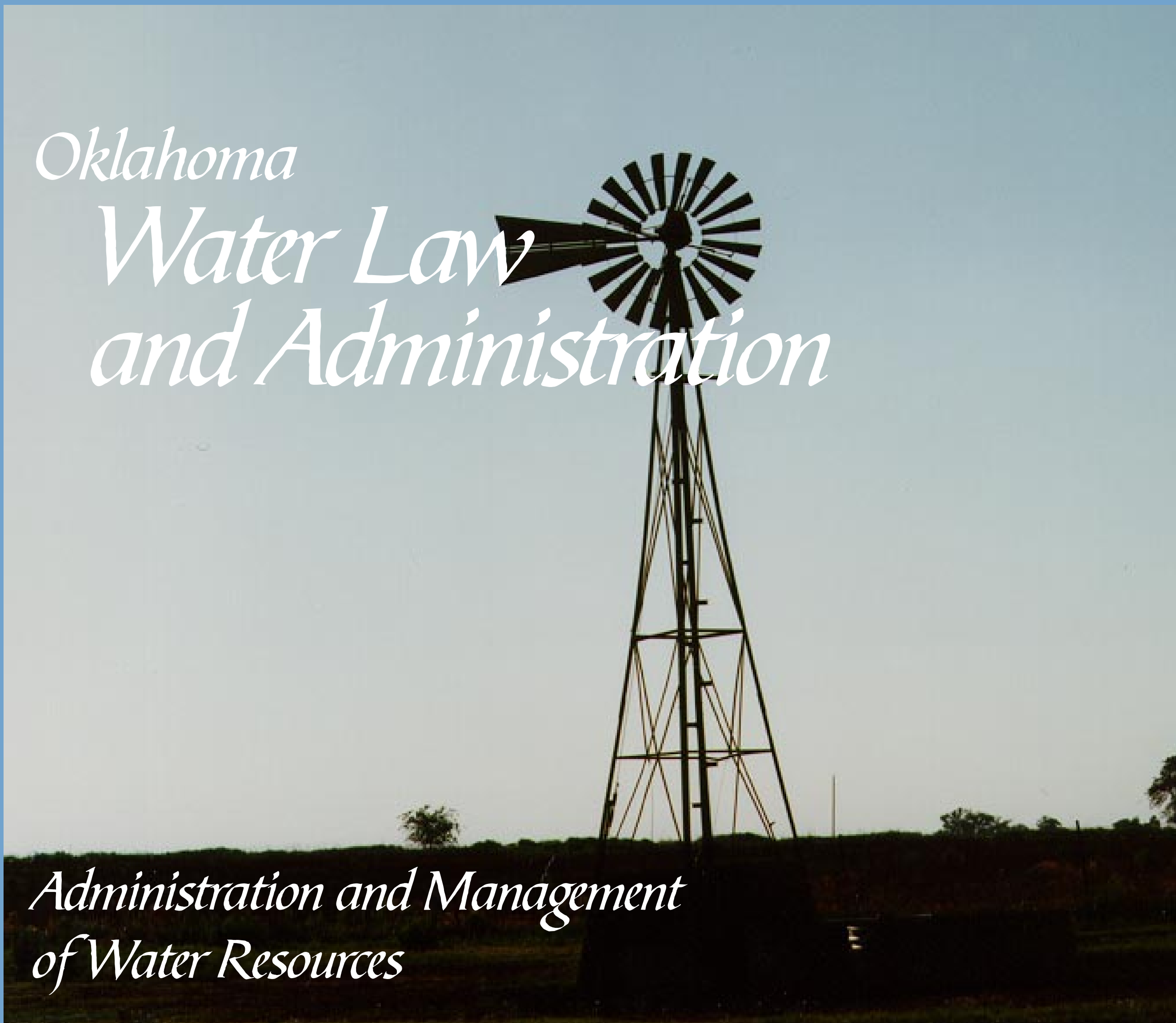
PLAN ORGANIZATION

In order to develop plans and policies to effectively manage Oklahoma's water resources, it is necessary to have broad knowledge of the resources and their use. This includes detailed information which characterizes the state's major rivers, lakes and reservoirs, major and minor groundwater basins, surface and groundwater quality, the amount of available supplies, current and projected rates of use for various purposes, and the size of the population served. Over four years, authors of the update of the *Oklahoma Comprehensive Water Plan* meticulously collected this data for use by state and federal agencies, municipalities, industry, water planners, citizens, students and others interested in the status and future of Oklahoma's water resources.

The initial section of the OCWP update, *Evolution of the OCWP*, details development of the 1980 OCWP, specific accomplishments of the original plan's recommendations and an overview of the philosophy, objectives and procedures that guided development of the updated plan. *Oklahoma Water Law and Administration* provides a general overview of state water law and agencies empowered to administer water and environmental laws in Oklahoma. *Overview of Water and Related Resources,* which revises a similar section of the original OCWP, includes a brief history of water resource development in Oklahoma, an inventory of surface and groundwater water resources in the state and an overview of various natural resource and socioeconomic conditions that affect the availability and use of water.

The section entitled *Statewide Water Use Projections* includes not only an analysis of various categories of future water use in Oklahoma through the year 2050, but also the methodology utilized in development of those projected figures. *Evaluation of Surface and Groundwater Supplies* consists of a detailed evaluation of current and projected surface and groundwater supplies and usage for each planning region. The final two sections, *Water-Related Issues and Problems* and *Recommendations*, present Oklahoma's most pressing water-related policy issues and problems (including the general principles and objectives that guided their development) as well as specific options recommended to address those issues.

Oklahoma Water Law and Administration



Administration and Management of Water Resources

Oklahoma's water resources -- with the sole exception of surface supplies in the Grand River Basin, which are under the jurisdiction of the Grand River Dam Authority (GRDA) -- are administered by the Oklahoma Water Resources Board. The agency's nine-member decision-making body, appointed by the Governor, is responsible for the appropriation, distribution and management of waters in the state. Any person who intends to acquire a water right must file a permit application which is considered for approval by the Board. Stream water is considered to be public water subject to appropriation while groundwater is private property that belongs to the overlying surface owner but is subject to regulation by the OWRB.

A fundamental requirement in the administration of water rights is that the permit holder put the allocated water to beneficial use. Beneficial uses of water include agriculture, irrigation, water supply, hydroelectric power generation, municipal, industrial, navigation, recreation, and fish and wildlife propagation. While state law recognizes no priority among these uses, water needed for public supply (including drinking and domestic use) and vital economic activities generally receives precedence during drought and related local water emergencies. Permits are not required for household or domestic purposes, defined as the use of water "for household purposes, for farm and domestic animals up to the normal grazing capacity of the land and for the irrigation of land not exceeding a total of three acres in area for the growing of gardens, orchards and lawns." Oklahoma stream and groundwater law are discussed more in depth in their respective sections.

To most efficiently manage the state's abundant water resources -- and to determine the amount of water available for appropriation to users in Oklahoma -- the OWRB has divided the state into distinct hydrologic units, including 49 stream systems and 46 groundwater basins. Results from studies of these recognized subsystems and subbasins dictate the reasonable withdrawal of water resources while generally reserving supplies for future use.

Hydrologic studies of Oklahoma's stream systems depend, to a great degree, upon data gathered at streamflow gages and water quality gaging stations operated throughout the state. This monitoring effort not only facilitates the adjudication of water rights, it also assists in prediction of flooding events, protection of water resources in the areas of origin, development of reservoir operation plans and related planning and management strategies. Hydrologic studies have been completed on 48 of the state's 49 subbasins (23 in the Red River Basin and 26 in the Arkansas River Basin). The Grand River Basin is subject to administration by the GRDA.

The OWRB also conducts or supervises studies of reservoir yield which are critical in determining the amount of water supply available for use by municipalities, rural water districts and industries. An estimate of the amount of water (normally depicted in millions of gallons per day) which can be dependably appropriated from a specific source, yield is determined by inflow, evaporation and related factors.

Hydrogeologic investigations, also conducted by the OWRB, accurately determine how much water can be safely withdrawn from Oklahoma's 46 identified groundwater basins (26 "major" alluvial and terrace basins producing in excess of 150 gallons per minute, or more than 50 gpm for bedrock aquifers; 13 minor bedrock formations; and 10 minor alluvial and terrace formations). This figure, called the maximum annual yield, is considered to be the amount of water that can be withdrawn from an aquifer without entirely depleting its supply throughout the minimum basin life which, in Oklahoma, is considered to be a period of 20 years.

To arrive at a basin's maximum annual yield, investigators map the total land overlying the basin and estimate the amount of water in storage (utilizing data obtained from hundreds of wells through the OWRB's annual well measurement program), rate of natural recharge and total discharge (including that amount currently allocated to water right holders), transmissibility (the rate at which water moves through the formation) and potential for pollution from natural sources. The balance of the available water is then allocated proportionately to each acre of land overlying the basin. Hearings are held to allow public input into the determinations prior to final consideration of the prorated amount by the Water Board.

As mentioned, Grand River Dam Authority, established by the State Legislature in 1935, is responsible for administering water resources in the Grand River Basin, including portions of 24 counties in northeast Oklahoma. Expressly, the agency is a public corporation created to control, store, preserve and distribute waters of the Grand River and its tributaries for any useful purpose. The entity is self-sustaining with revenue derived from the sale of power and water. Instead of actual appropriation of waters, the agency enters into repayment contracts for the use of surface water resources in the basin. Groundwater use in the basin remains under jurisdiction of the OWRB. In addition to general control and management of river/tributary waters and hydropower projects at Grand Lake and Lake Hudson, GRDA operates and maintains an integrated electric transmission system, including some 2,090 miles of line and related switching stations and transformer substations.

The 1980 Oklahoma Comprehensive Water Plan recognized the concept of federal reserved rights as well as the Winters Doctrine, derived from Winters v. U.S. That 1908 federal court case declared that when the federal government reserved lands from the public domain for the nation's Indian populations, sufficient waters were also reserved, by implication, to allow the Indians to live on those lands. Several areas in western Oklahoma were reserved for various Indian tribes, but most of that land was allotted -- i.e., transferred out of tribal ownership -- to individuals before statehood and, therefore, no reservations exist today in the state. In the eastern portion of Oklahoma ("Indian Territory," prior to statehood), several large areas of land were granted to Indian tribes by the federal government. While most of these areas have been allotted, a question has arisen regarding original tribal ownership of appurtenant waters and rights to the use of water within original boundaries of those lands. The federal court case, U.S. v. GRDA, indicated that the state did not obtain rights to use water for hydroelectric power in an area that had been transferred prior to statehood from the federal government to the Cherokee Nation. Obviously, recognition of tribal sovereignty will be a key element in addressing future Native American water rights claims.

To resolve and prevent disputes over waters shared with neighboring states, Oklahoma participates in four interstate stream compacts: the Arkansas River Compact with Arkansas; the Arkansas River Compact with Kansas; the Red River Compact with Arkansas, Louisiana and Texas; and the Canadian River Compact with New Mexico and Texas. Compacts clearly spell out how much water a signatory state is allowed to develop or store on an interstate stream. Although the compacts continue to address problems concerning quantities and equitable development of river waters, annual meetings of the compact commissions deal increasingly with quality and pollution problems.

Stream Water Law

As defined by state law, stream water is that which occurs in a "definite stream," meaning "a watercourse in a definite, natural channel, with defined beds and banks, originating from a definite source or sources of supply." Although appropriative rights are fundamental to the use of stream water in Oklahoma, exceptions are made for domestic uses by the riparian landowner and the capture and storage of diffused surface water on the landowner's property, provided the natural flow of the stream as it enters his land is maintained. "Diffused" surface water -- which, according to OWRB rules and regulations, is "water that occurs, in its natural state, in places on the surface of the ground other than in a definite stream or lake or pond" -- is not subject to state regulation or use.

The basic principle of the appropriation doctrine is that the first person to exercise a water right establishes a right that is superior to later appropriators. Developed to resolve competing claims to the use of water for mining purposes during expansion of the western U.S., appropriation is defined as "the right to use water in a definite stream or impoundment thereon for a beneficial use with priority in time giving the better right."

In an attempt to more fairly allocate waters of the state and simplify existing water right laws, the State Legislature passed major amendments to state stream water law in 1963. An important provision of the new law required the OWRB to accurately determine the amount of available water in Oklahoma's rivers, streams and lakes for appropriation to prospective users. In fairness to existing stream water rights holders, the OWRB was also required to determine those with "vested" rights -- i.e., those in effect before enactment of the 1963 law. Vested right holders were allowed to continue use of their previously appropriated amount of water.

Under existing Oklahoma water law, as set forth in the Stream Water Use Act (as amended in 1991), a permit application for any use of water must be filed prior to the applicant's commencement of construction of facilities needed to put the water to use and/or actual diversion of water. The Act also requires that notice of the application be published in newspapers in the county where the diversion is to take place and in the adjacent downstream county. Any interested party, especially those whose interests could be affected by the proposed use of water, may appear at the required hearing to protest issuance of the permit. The applicant must establish that unappropriated water is available in the amount applied for; there is a present or future need for the water and the intended use is beneficial; the use of water will not interfere with domestic or existing appropriative uses; and, if the application is for the transportation of water for use outside the area where the water originates, the use must not interfere with existing or proposed beneficial uses within the stream system and the needs of the area's water users.

If the four elements are satisfied, the permit is approved. However, certain conditions may be placed upon the permit to protect existing rights and uses, current stream flows and to address other issues of importance. The permit is also usually conditioned upon timely construction of works and commencement of use (normally two years) and upon full use of the annually authorized amount within the seven-year period following permit issuance and at least once in a continuous seven-year period thereafter. If water authorized by regular permit is not put to beneficial use within the specified time, the OWRB may reduce or cancel the unused amount and return the water to the public domain for appropriation to others. However, when full use of the permitted water is contingent upon a pending project, the permit can be conditioned upon a schedule allowing phased-in use over a longer period of time.

The Board may issue five types of permits for stream water use: regular, authorizing the holder to appropriate water year around; seasonal, allowing diversion of water for specified periods; temporary, authorizing water use for up to three months; term, spelling out water use for a given number of years; and provisional temporary, which is nonrenewable, allowing appropriation for up to 90 days. The provisional temporary permit is the only one that does not require a public hearing and subsequent approval by the Board. Permits for the use of stream water may be transferred or assigned, although those authorized for irrigation purposes remain appurtenant to the lands irrigated.

In addition to stream water appropriation law, the state also recognizes a second precept of water use called the "riparian" doctrine. This doctrine recognizes that owners of land bordering a stream have rights to the "reasonable" use of water flowing in the stream. The date that a riparian right claim is made is irrelevant and the right is not lost if the use is discontinued.

Generally, riparian rights are followed in water-rich states in the eastern U.S. while appropriative rights are recognized in water-short western states. Conflicts between the two doctrine have arisen in states, such as Oklahoma, which possess divergent geographic and climatic characteristics. Prior to 1963, Oklahoma recognized both the appropriation and riparian doctrines and two theories were employed to resolve controversies between conflicting riparian and appropriative uses of water. One was that the riparian landowner could use the water as long as the natural flow of the stream was not diminished; the other theory espoused that the landowner could use a "reasonable" amount of the water while also considering other prospective users along the stream.

In 1963, as a result of a study committee recommendation, the Legislature amended statutes which implied that the appropriation doctrine would prevail in Oklahoma. In 1993, the Supreme Court finalized its ruling in Franco-American Charolaise, Ltd. v. OWRB and City of Ada, a landmark case. The Court's opinion was interpreted by many to give riparian rights priority over appropriative rights. Immediately after issuance of that final opinion, corrective legislation was adopted to express directly that riparian rights were abolished by the 1963 statutes. That legislation has been challenged in court.

Groundwater Law

Groundwater use and regulation in Oklahoma is heavily steeped in state property statutes which provide that "the owner of the land owns water standing thereon, or flowing over or under its surface but not forming a definite stream." However, to more fully preserve future supplies, groundwater resources are subject to reasonable regulation. Like stream water, use for domestic purposes is exempt from permit requirements, although prohibitions against waste still apply. Early laws impacting the use of groundwater -- defined in Oklahoma as "water under the surface of the earth regardless of the geologic structure in which it is standing or moving outside the cut bank of any definite stream" -- followed the appropriation doctrine of "first in time is first in right."

Current Oklahoma groundwater law, originally passed in 1972 (with latest amendments in 1995), removed any reference to priority in time and changed the regulatory scheme from the appropriation process to an allocation system tied directly to the amount of land overlying a groundwater basin. The allocation system provides that landowners or their lessees may obtain a permit from the OWRB for the use of water from a common basin, the amount of which is based upon the number of acres of the applicant's land that overlies the basin.

As with the state's stream water law, the 1972 Oklahoma Groundwater Law acknowledged that uses established under previous laws relating to groundwater use should be recognized as valid. The new law determined that existing water right holders or applicants seeking rights before enactment of the current law should be allowed to continue use of their previously authorized amount. These earlier claims are referred to as "prior rights."

Due to the length of time necessary to determine the amount of water available in the state's many groundwater basins and subbasins through maximum annual yield studies, the 1972 law allows the issuance of "temporary" permits. These permits -- granted in basins where maximum annual yield determinations have not yet been completed and approved and the amount of water available for use reliably prorated -- are for two acre-feet of water for each acre of land owned or leased by the applicant and dedicated to the application. This figure is presumed to be maximum amount needed by Oklahoma irrigators.

Before commencement of drilling or actual use of the water for any purpose other than domestic, persons intending to use groundwater must submit a permit application to the OWRB. Normally, the applicant must publish notice of the hearing on the application in a newspaper in the county where the well(s) is to be located and give notice by certified mail to all adjacent landowners having wells within a ¼-mile radius of the proposed well site. At the hearing, the Board must determine that the applicant owns or leases the land; the land overlies a fresh groundwater basin or subbasin; the proposed use is beneficial; and waste by depletion or pollution will not occur.

If the four elements are satisfied, the Board will issue one of four types of groundwater permits: regular, temporary, special and provisional temporary. A regular permit is approved for a proportionate amount of water determined by the maximum annual yield of the basin and the percentage of the land overlying the basin which is owned or leased by the applicant. As mentioned previously, for basins in which no hydrologic survey has been conducted and no maximum annual yield determined, the OWRB issues a temporary permit allowing the withdrawal of two acre-feet of water per acre owned or leased; a regular permit may then be issued upon determination of the basin's yield. Special permits, renewable three times, allow six-month water use in excess of that allocated under a regular or temporary permit. Provisional temporary permits, frequently sought by oil companies requiring water for the drilling of oil and gas wells, allow use for up to 60 days. Provisional temporary permits may be approved by the executive director of the OWRB and do not require public notice and hearing. Like with stream water, groundwater permits may be either transferred or assigned.

WATER QUALITY AND POLLUTION CONTROL

Because the right to ownership and use of water does not include the right to pollute or degrade fresh water resources, numerous agencies and organizations have responsibilities related to the enforcement of state and federal pollution laws. The quality of surface and groundwaters is of enormous importance to public health and prosperity in Oklahoma and, as a result, potentially harmful pollutants from both point and nonpoint sources are closely monitored to ensure that Oklahoma rivers, streams and lakes receive at least adequate protection.

While the state originally passed laws to curb water pollution in the 1920's, it was through passage of the 1955 Pollution Remedies Act that Oklahoma made monumental strides toward public health and environmental protection. That law -- which was more fully enacted with passage of the federal Clean Water Act in 1977 -- required regulation of discharges to state waters, provided for the protection of certain beneficial uses of stream water, and spawned adoption of Oklahoma's first standards for water quality in 1968.

Today, municipalities and industries must acquire waste discharge permits and adequately treat their wastewaters prior to release to ensure that the quality of receiving waters is not impaired. Oklahoma Water Quality Standards (OWQS), maintained by the OWRB and revised at least every three years, are the cornerstone of this regulation. Standards serve to enhance water quality, protect beneficial uses and aid in the prevention, control and abatement of water pollution. In particular, standards are critical to the development of water quality-based discharge permits which specify treatment levels required of industrial and municipal wastewaters.

Identification and protection of beneficial uses -- similar in concept, though separate from the strategy utilized in state water management and use programs -- is vital to water quality standards implementation. Currently recognized beneficial uses include water supply, fish and wildlife propagation, agriculture, industrial and municipal cooling water, recreation, aesthetics, navigation and hydropower. Physical, chemical and biological data on Oklahoma's rivers, streams and lakes are used to ascertain the condition of individual waters, determine appropriate present and future beneficial uses and thus set realistic water quality standards to protect them. Through assignment of as many beneficial uses as are attainable, standards assure that existing water quality is not unduly impacted. Narrative and numerical criteria imposed in the OWQS ensure attainment of beneficial uses as well as limit waste and pollution of state waters. All uses receive equal protection, for each has its unique environmental and economic importance to Oklahoma. Although all of Oklahoma's surface waters receive protection through the OWQS, specific protection is afforded to approximately 27,000 stream and river miles and 5,000 lakes. Beneficial uses have also been assigned to the state's major groundwater basins.

Through the efforts of numerous agencies and organizations, the state has made great strides in limiting pollution from point sources, including municipal and industrial stormwaters. Now the state has turned its attention to minimizing impacts from agriculture, silviculture, urban areas and various other nonpoint source related activities. Efforts have been undertaken to encourage owners and operators of lands to adopt practices which minimize the likelihood of nonpoint source problems. While these primarily voluntary efforts have met with some success, water quality degradation continues to occur in many state waterbodies.

A major ongoing state effort to address pollution reduction is development and implementation of the "whole basin planning approach." This comprehensive, or holistic, strategy takes into account all threats to human health and ecological integrity within a specific watershed. Greater emphasis is placed on all aspects of water quality, including chemical quality (toxic and conventional pollutants), physical quality (such as temperature, flow and circulation), habitat quality (such as channel morphology, composition and health of biotic communities) and biodiversity (i.e., species number and range). Using this information, flexible mitigation strategies for a specific watershed can be developed to address problem areas in a prioritized, cost-effective manner.

The current manner in which state and federal agencies approach water quality regulation in Oklahoma has been greatly affected by passage of House Bill 2227, a measure passed in 1993 to mend the state's fragmented environmental regulatory structure and better utilize limited financial and workforce resources. Through realignment of the responsibilities of eight agencies into one primary agency, the Oklahoma Department of Environmental Quality (ODEQ), the goal of HB 2227 was to eliminate the jurisdictional overlap and duplication of effort of state environmental agencies, provide for consistency of regulation between agencies and improve the way in which citizen pollution complaints are addressed.

Specifically, HB 2227 consolidated air quality, solid and hazardous waste, and certain water quality functions into the ODEQ and established jurisdictional powers among state environmental support agencies. The measure also directed the Oklahoma Conservation Commission to supervise the management of pollution complaints through local conservation districts and created an all-citizen rulemaking and appellate board for complaint, permit or penalty matters.

STATE AND FEDERAL WATER AGENCIES

The major water and water quality related duties and programs of state and federal agencies are summarized below.

The Oklahoma State Department of Agriculture enforces rules and regulations relating to the state's agricultural industry. The agency has specific duties and responsibilities in the areas of pesticide use, storage, registration and application; fertilizer use and storage; confined animal feeding operations; and forestry operations.

The Oklahoma Biological Survey, under direction of the University of Oklahoma, identifies and surveys biological resources of the state. The agency also administers the state's Natural Heritage Program.

The Oklahoma Department of Civil Emergency Management implements and coordinates the development of programs and plans to minimize the effects of natural disasters upon the people of Oklahoma.

The Oklahoma Climatological Survey, which is under the direction of the University of Oklahoma, is responsible for the accumulation and dissemination of climatological data collected throughout the state and determines state policy regarding climate-related issues. The agency also serves as the data collection and dissemination center for the Oklahoma Mesonetwork.

The Oklahoma Department of Commerce, the state's lead agency for the creation of jobs and the promotion of economic development, administers federal funds for planning assistance to state agencies, substate districts and local communities. The Community Development Block Grant Program is the major funding source administered by the ODOC for improvements to water supply systems. Oklahoma's 11 substate planning districts, regional entities funded by the federal government through the Economic Development Administration and state through the ODOC, encourage and coordinate social and economic development at the local level.

The Oklahoma Conservation Commission develops and administers programs to control and prevent soil erosion; prevent floodwater and sediment damage; reduce nonpoint source pollution; promote implementation of Geographic Information System (GIS) technology in Oklahoma; protect state wetlands; and further the conservation, development and utilization of the state's renewable resources. With assistance from Oklahoma's 88 conservation districts, the agency is involved in land use planning, reclamation of abandoned mine lands, water quality monitoring and in the overall conservation of soil, water, wildlife and forestry resources.

The Oklahoma Corporation Commission regulates oil and gas activities in the state to prevent pollution of Oklahoma's surface and groundwater resources. The Commission has jurisdiction over salt water, mineral brines, waste oil, and other deleterious substances produced from, obtained or used in connection with the drilling, development, production and procession of oil and gas. The Commission also regulates transportation and transmission companies, public utilities, motor carriers and pipeline safety.

The Oklahoma Department of Environmental Quality supervises the majority of the state's environmental protection and management programs. The ODEQ has jurisdiction over a number of water-related, environmental areas, including treatment and discharge of industrial and municipal wastewaters and stormwaters; nonpoint source discharges and pollution (excluding those associated with agricultural or oil and gas related activities); public and private water supplies; underground injection control (excluding brine recovery, saltwater disposal or secondary/tertiary oil recovery); fresh water wellhead protection; enforcement of Oklahoma's Water Quality Standards; and development and update of the state's Water Quality Management Plan. In addition, the ODEQ has jurisdiction over air quality, hazardous and solid waste, radioactive waste, Superfund program activities and emergency response.

The Oklahoma Geological Survey collects and disseminates information on the geology, mineral, energy and water resources of the state.

The Grand River Dam Authority controls the waters of the Grand River and its tributaries.

The Oklahoma State Department of Health administers programs to promote health and prevent disease throughout the state. The agency, assisted by 69 county health departments, is responsible for all municipal drinking water and sewer systems in Oklahoma.

The Oklahoma Department of Mines is the environmental regulatory authority empowered to execute, enforce and implement provisions of state and federally mandated programs in the area of health, safety, mining and land reclamation practices associated with surface and subsurface mining.

The Oklahoma Scenic Rivers Commission fosters programs to develop and protect the state's scenic river areas and adjacent lands.

The Oklahoma Department of Tourism and Recreation promotes tourism and recreation in the state and develops, operates and maintains state parks, recreation areas and lodges.

The Oklahoma Department of Transportation is the coordinating agency for the state's transportation systems, including the McClellan-Kerr Arkansas River Navigation System. Under the agency's jurisdiction are the Port Authority and Oklahoma Waterways Advisory Board.

The University Center For Water Research at Oklahoma State University promotes and coordinates research of state and national interest to help decision-makers plan for the availability of water in adequate quality and quantity for all citizens. The UCWR is comprised of the Oklahoma Water Research Institute, the State Water Research Center, and the National Center for Groundwater Research.

The Oklahoma Water Resources Board promulgates and adopts water quality standards and related implementation documents for the state as well as directs programs to assess and improve lake water quality. The agency also administers state water laws through the issuance of stream and groundwater permits; investigates stream and groundwater resources; approves and assists irrigation district organization; ensures the safety of water works projects; administers the state dam safety program; supervises state weather modification activities; establishes water well construction standards; and licenses water well drillers. The OWRB also administers the Financial Assistance Program for water/wastewater projects; coordinates the National Flood Insurance Program in Oklahoma; negotiates and administers interstate stream compacts; and updates the state water plan.

The Oklahoma Department of Wildlife Conservation enforces state fishing and hunting laws and, in general, protects and manages the state's wildlife resources. The agency ensures that water resource projects and programs -- such as reservoir construction and management, water quality standards development, Section 404 permits and pollution related activities -- properly consider and provide for Oklahoma's fish and wildlife.

Federal agencies active in Oklahoma which are also involved in water quality matters include the following:

The federal Agricultural Stabilization and Conservation Service (Consolidated Farm Service Agency) administers the Conservation Reserve Program (CRP), Agricultural Conservation Program (ACP) and Swampbuster and Sodbuster provisions of the Food Security Act of 1985. The objective of the CRP is to conserve and improve soil and water resources on highly erodible cropland while the ACP provides cost-sharing with farmers to carry out farm-related conservation and environmental measures.

The U.S. Army Corps of Engineers has major responsibilities in flood protection, navigation and the planning and development of multipurpose water resource projects. The Corps also regulates the disposal of dredge and fill material in navigable waters under the Section 404 (Clean Water Act) permit program.

The Bureau of Reclamation assists in the development and conservation of water, power and related land resources throughout the western United States. Bureau projects are operated to serve municipal and industrial, irrigation, water quality improvement and flood control purposes.

The Department of Civil Emergency Management prepares, implements and coordinates disaster plans and operations relating to droughts, floods, storms etc.

The Federal Emergency Management Agency administers the National Flood Insurance Program which provides low-cost insurance for residents in flood-prone areas to encourage community floodplain management and land use measures. FEMA also provides assistance to states, local entities and ordinances in response to flood, drought and other natural disasters.

The Federal Energy Regulatory Commission provides technical assistance and review of water resource development projects in which hydroelectric power generation is among the project purposes. FERC, an agency of the U.S. Department of Energy, also licenses hydropower projects developed by nonfederal entities.

The U.S. Environmental Protection Agency administers numerous federal environmental laws regulating water quality, such as the Clean Water Act, Safe Drinking Water Act, Resource Conservation and Recovery Act, Superfund program and National Environmental Policy Act. EPA accomplishes this duty by setting national water quality standards used to develop site-specific waste discharge permits, enforcing those permits, and providing technical, emergency, and grant assistance to state and local governments. In addition, EPA is the lead federal agency for administering the Wastewater Facility Construction Loan Account-State Revolving Fund.

The U.S. Fish and Wildlife Service assists states in the planning and development of projects to restore and manage fish and wildlife resources.

The U.S. Geological Survey investigates the occurrence, quantity, quality, distribution, use and movement of the nation's surface and groundwater resources. Oklahoma cooperates with the USGS in maintaining stream gaging stations throughout the state.

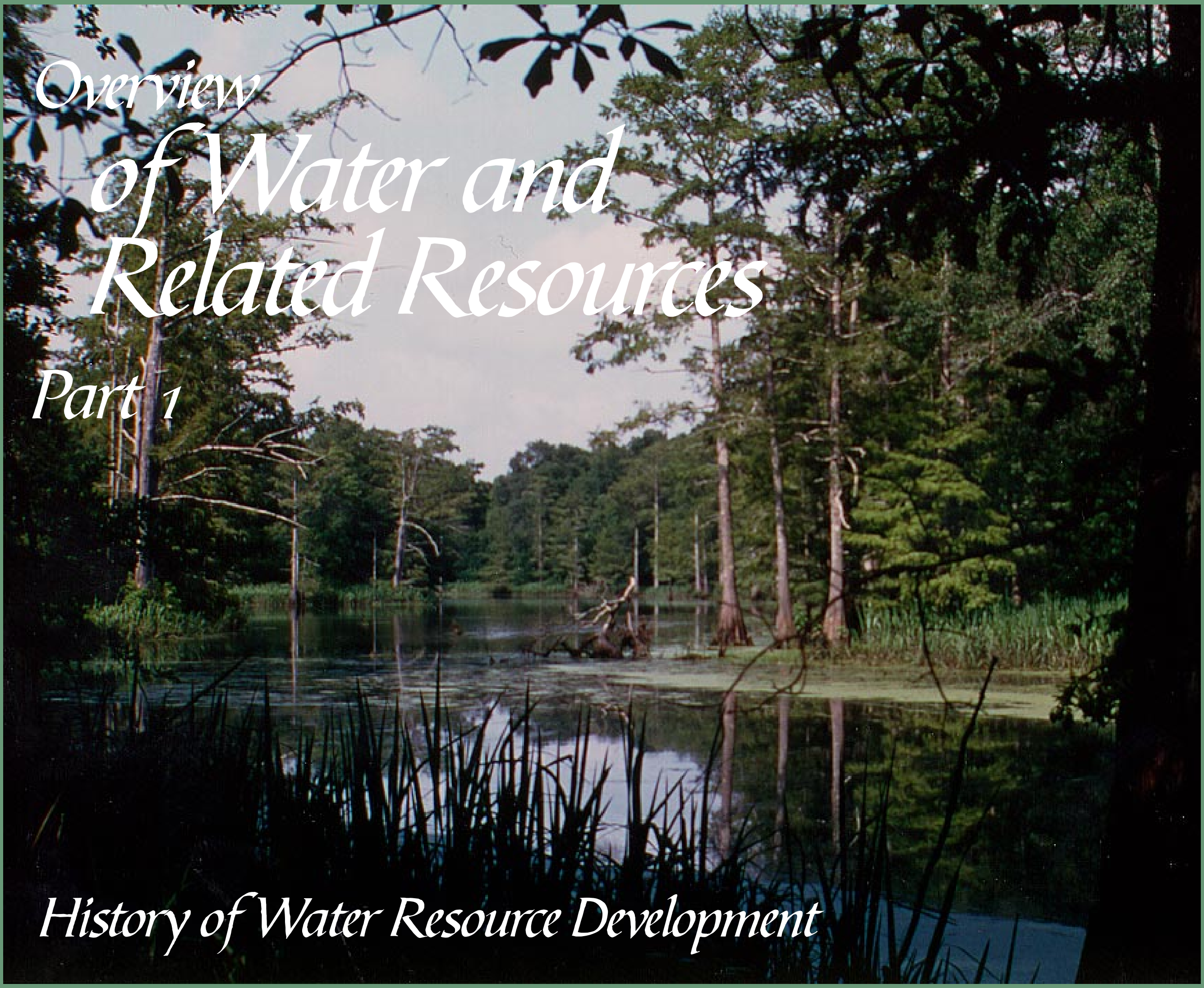
The Bureau of Indian Affairs represents Native American water rights interests throughout the U.S. and Oklahoma.

The Natural Resources Conservation Service, formally the Soil Conservation Service, is responsible for developing and implementing soil and water conservation programs in cooperation with landowners, community planning agencies, and federal, state and local agencies. The NRCS assists in agricultural pollution control, environmental improvement and rural community development. The agency also provides technical help to local conservation districts and consultation to individuals and organizations.

Rural Development, formerly Farmers Home Administration, provides grants to farmers and local entities of government for irrigation and drainage systems, watershed protection and flood prevention projects and community waste disposal and water supply systems for rural communities with a population of 10,000 or less.

The Southwestern Power Administration, an arm of the Department of Energy, markets power produced at federal dams in the southwest U.S.

The National Weather Service supervises meteorological activities, develops hydrologic forecasts and provides climatological services throughout the U.S.



Acute interest in water and water development began before statehood. The oldest right for the use of stream water (a water right that is still valid) was issued to a farm family near Boise City in 1899. Their claim entitled them to a prior right of 52 acre-feet per year from Marcelus Canyon Creek, a tributary of the Cimarron River, for the irrigation of 26 acres of land. The water right is numbered 99-1, signifying the year 1899, permit number one. The oldest right to the use of groundwater is that of the City of Norman, claiming a prior right to 12 acre-feet of water per year from the Garber-Wellington Aquifer, based on municipal use dating back to 1894.

In 1902, President Theodore Roosevelt signed into law the Reclamation Act to aid arid western states, and the following year investigations were begun in Oklahoma Territory to determine how water supplies could be beneficially used. The Eighth Legislative Assembly of Oklahoma Territory enacted the first water law in 1905, outlining the procedure for acquiring water rights, regulating the use of water and creating the post of territorial engineer.

With the coming of statehood, the office of territorial engineer became state engineer, responsibilities of that post were expanded and new water laws were enacted. Many of those original laws, which primarily spelled out water ownership and irrigation rights, remain in effect and have since been extended to include municipal and industrial water supply, streamflow regulation, water resource planning, water quality regulation and data collection. Of course, as the population increased, so did the number of water users and problems related to water use. In the 1920's, the Conservation Commission was created to deal with the state's expanding water issues. Also at that time, Oklahoma citizens were drinking water for the first time from new Lake Overholser and Tulsa had just completed its water supply, Spavinaw Lake.

As the seeds of the Great Depression were being sown, the attention of the nation turned to flooding on the Mississippi River. The river mocked and devastated the people of its valley. Although the Corps of Engineers built levees higher and higher and invested $300 million along the lower Mississippi between 1886 and 1926, they met with little success in controlling the river and its tributaries which again left their banks in the catastrophic floods of the 1920's. Finally, a plan emerged to hold back floods by constructing upstream storage basins in the veins pouring into the Mississippi -- a revolutionary strategy originating from similar problems in Oklahoma City.

The North Canadian River regularly washed over the flat capital city in the spring while, in late summer, streams dried up and water supplies diminished. In the 1923 record flood, the rampaging river broke the Lake Overholser municipal water dam and washed out nearly every wagon and railroad bridge in the central part of the state. This made a powerful case for holding more water in upstream reservoirs. In the flood of 1927, water levels on the Arkansas River were the highest in 99 years. The entire Mississippi Valley was an enormous muddy reservoir a thousand miles long and 50 to 150 miles wide.

By the early 1930's, rural Oklahoma farm families, burned out by drought and hot, dry winds, retreated from their tortured lands to regroup farther west. Meanwhile, dry fields piled up in high sand dunes while lighter silt rose in dust clouds, some five miles high, and swept east to the Atlantic in "black blizzards." During a single day in 1934, it is estimated that some 300 million tons of soil were swept from the Great Plains. Armies of Civilian Conservation Corps (CCC) and Soil Conservation Service (SCS) workers moved over the land, healing it with plantings of grass and shelter belts, filling in deep gullies and coaching farmers in conservation practices.

In response to widespread water problems, the Oklahoma Legislature created the State Planning and Resources Board in 1935 and included in its jurisdiction parks, forestry and water resources. In 1937, Lake Murray was completed in Murray County as a project of the state while the CCC and Works Progress Administration continued to work on bank stabilization and other water-related tasks. Lake Carl Blackwell, a project of the SCS, was completed as a water supply for Oklahoma A&M College, and soon after, Grand River Dam Authority completed Grand Lake O' the Cherokees on the Grand (Neosho) River in northeastern Oklahoma. In addition, two Corps of Engineers lakes authorized by the Flood Control Act, Great Salt Plains and Fort Supply, were completed early in the 1940's.

The years of searing drought in the west and devastating floods in the east outraged Oklahomans and called conservationists, flood control advocates and navigation interests to march, but not before the Arkansas River had again rampaged in 1943. Beginning May 7, rain fell for days on end; skies cleared only to succumb to faint and faraway rumbles of thunder heralding still more storms. Ninety percent of the crops over hundreds of square miles were destroyed. In some places, 15 inches of rain fell in two days; Tulsa had 16 inches of almost continual rainfall. The Arkansas climbed to six feet over flood stage at Muskogee and, in a 500-mile swath of reckless anger, the river rolled on, plunging fertile farms to the bottom of a deep, mud-stained lake.

Three years later, a comprehensive plan of development for the Arkansas River -- uniting advocates of soil and water conservation, hydropower, flood control and navigation -- was authorized by Congress through the River and Harbor Act.

While eastern Oklahoma was waterlogged with repeated floods, the arid west had focused on developing a reservoir for irrigation, with the added benefits of flood control and water supply. The W.C. Austin Project (Lugert-Altus Reservoir), a project of the Bureau of Reclamation, was completed in 1948.

Spurred by a Congressional appropriation in 1949, the U.S. Army Corps of Engineers began construction in Oklahoma on the largest civil works project it had ever undertaken. Completed in 1971, some 63 years after the last of the river steamers had climbed the Arkansas River from Fort Smith to Muskogee, the McClellan-Kerr Arkansas River Navigation System was named in tribute to two far-sighted statesmen who had labored to see the vast inland waterway project become a reality.

One of these "water boomers," Senator Robert S. Kerr -- elected governor in 1943, U.S. Senator in 1948, then appointed to the powerful Public Works Committee -- was also instrumental in setting in motion an enormous program of water development throughout the 1950's and 60's. In Oklahoma, the first four years of the fifties produced four major reservoirs: Heyburn in 1950, Hulah in 1951, and Tenkiller and Fort Gibson in 1953 – all projects of the Corps of Engineers.

In 1955, House Joint Resolution 520 created a water study committee composed of legislators and citizens, and chaired by Dr. Lloyd E. Church, of Wilburton. The committee surveyed Oklahoma's water problems and recommended the establishment of a separate water authority with responsibilities in water rights administration, federal contracts negotiation and the development of state and local projects to assure the most efficient use of all water resources. In 1957, the Twenty-Sixth Oklahoma Legislature authorized creation of the Oklahoma Water Resources Board, a panel of seven chaired by Guy H. James. In 1972, two at-large seats were added to the Board.

Most of the state's major reservoir construction has occurred since 1959, with that year seeing completion of Fort Cobb, followed by Foss Reservoir in 1961; Oologah's initial phase in 1963; Keystone, Eufaula, and Hudson in 1964; Thunderbird in 1965; Lake of the Arbuckles in 1967; Pine Creek in 1969; and Broken Bow in 1970. The seventies brought to completion Robert S. Kerr and Webbers Falls Reservoirs in 1970; Hugo in 1974; Tom Steed in 1975; Kaw in 1976; Waurika and Birch in 1977; and Optima in 1978. Prior to 1990, five more reservoirs had been completed: Sardis in 1982; Copan in 1983; Skiatook in 1984; Arcadia in 1986; and McGee Creek in 1987. Although construction of Candy Lake, in Osage County, was partially complete in 1990, a dispute concerning petroleum/mineral rights at the site forced abandonment of the project.

Seven lakes authorized for federal construction, but not yet funded, could add to Oklahoma's future surface water supply. They are Candy (still authorized); Lukfata, on the Glover River in McCurtain County; Boswell, on Boggy Creek in Choctaw County; Sand, on Sand Creek in Osage County; Shidler, on Salt Creek in Osage County; Tuskahoma, on the Kiamichi River in Pushmataha County; and Parker, on Muddy Boggy Creek in Coal County.

Water Resources

Oklahoma is blessed with abundant water resources, both on the surface and underground, that provide ample supply for various uses. The amount of water withdrawn from groundwater sources slightly exceeds that of surface water; however, on an annual basis, use of the two sources is virtually even. In 1994, almost 1.4 million acre-feet of water was withdrawn for agricultural, municipal and industrial, and power purposes. Irrigation is the number one use of water in Oklahoma; water supply is a close second, followed distantly by livestock.

The three Panhandle counties of Texas, Cimarron and Beaver are the largest irrigation water users, respectively. Rogers, Mayes and Oklahoma Counties withdrew the most under the water supply category while livestock use was greatest in Grady, Caddo and Bryan Counties. Muskogee, Pawnee and Seminole Counties account for approximately three-fourths of the state's total water used for thermoelectric power generation.

Except for domestic purposes, the Oklahoma Water Resources Board permits the use of state waters. As of August 1995, the agency had on file a total of 11,699 permits for the use of 5,675,652 acre-feet per year (ac-ft) of surface and groundwaters in Oklahoma, mostly allocated for irrigation, the state's leading water use, and municipal needs. Seventy-five percent of public water supply comes from the major federal reservoirs in Oklahoma and their smaller municipal lake counterparts.

The majority of the state's surface water (approximately 60 percent) is used for public water supply, especially in the Oklahoma City and Tulsa metropolitan areas, followed by thermoelectric power generation and irrigation. As of August 1995, the OWRB had on file 2,515 permits for the allocated use of 2,603,661 ac-ft of stream water.

Groundwater is the prevalent source of water in the western half of the state, accounting for almost 90 percent of total irrigation water use in Oklahoma. More than 700 million gallons are withdrawn for use each day. As of August 1995, the OWRB had on file 9,184 permits for the use of 3,071,991 ac-ft of groundwater.

STREAM WATER RESOURCES

Oklahoma's terrain is dominated by two major river basins, the Arkansas and Red, which were generally established within the last one million years during the Pleistocene Epoch, a time characterized by significant erosion. The Red River drains the southern one-third of the state while the Arkansas River drains the remaining two-thirds of Oklahoma's northern land area. Considering those two rivers and their tributaries (including rivers, streams and creeks with a length of 20 miles or more), the state has a combined stream length of 12, 294 miles.

The Arkansas and Red Rivers and their countless tributaries flow into Oklahoma from the state's six neighbors, but this water leaves through only four watercourses (the Red, Arkansas and Little Rivers and Lee Creek) into the State of Arkansas. The rivers and tributaries flow in a predominantly southeasterly direction, often winding in and out of Oklahoma on their long, arduous journey to the Mississippi River and Gulf of Mexico. The Red River forms the state's southern border with Texas but small sections of three other rivers and streams also mark Oklahoma's eastern border with Arkansas: 1.6 miles of the Poteau River, .5 mile of the Arkansas River and .12 mile of Mill Creek -- all near Ft. Smith, Arkansas. An overview of the state's major river basins, reservoirs, streams and their principal tributaries is provided in the following section.

Thirty-four major reservoirs dot the Oklahoma landscape, primarily in the east with its relatively high precipitation rate and advantageous topography for dam building (Figure 2). These important sources of water for the public, industry, power, recreation and various other uses have a combined surface area of 543,450 acres and collectively store well in excess of 13 million acre-feet of water (Table 1). Most were constructed by the U.S. Army Corps of Engineers and Bureau of Reclamation during the federal water development boom from the 1930's through the 60's. Two projects, Grand Lake and Hudson, were constructed by the Grand River Dam Authority, a state agency responsible for the general operation and management of waters in the Grand (Neosho) River Basin. (Flood control is the statewide responsibility of the Corps of Engineers.) Few major projects have been established in western Oklahoma where flat lands, low runoff and high evaporation make it poorly-suited to reservoir construction.

The state's largest reservoir, in terms of conservation storage, is Lake Texoma which holds 2,580,386 ac-ft of water under normal conditions. The next largest are Eufaula and Grand Lake O' the Cherokees. By surface area, the largest lake is Eufaula, covering approximately 105,500 acres, followed by Texoma and Grand Lake.

To satisfy the enormous construction costs associated with large water development projects and to provide the maximum benefit to users, major reservoirs are designed to accommodate multiple purposes. Sufficient storage space is reserved in multipurpose projects to fulfill each pre-ordained project benefit -- i.e., flood control, water supply, irrigation, hydroelectric power generation, water quality control and/or navigation. While projects are frequently authorized for recreation and fish and wildlife uses, storage space is rarely set aside expressly for those purposes.

The flood control pool of a multipurpose reservoir is designed to accommodate the most severe potential flood and is based upon the project's drainage basin, historical hydrologic information and related factors. Oklahoma's major reservoirs, which have prevented billions of dollars in potential flooding damages, are built with sufficient space to contain and safely release a collective 13.6 million acre-feet of floodwaters. Lake Texoma, among the nation's largest, contains more than 2.6 million ac-ft of flood storage. Eufaula, Keystone and Oologah all have sufficient capacity to hold in excess of one million ac-ft of floodwaters.

Water supply storage in federal reservoirs is normally purchased by water users through repayment contracts with the construction agency. This storage is reserved for hundreds of municipalities and industries across the state whose very existence depends upon timely water releases for drinking and domestic use and various industrial and manufacturing processes. In western Oklahoma, the irrigation component of several large water supply projects is relied upon by farmers who supplement relatively modest rainfall with reservoir supplies, groundwater sources and direct diversions from streams. Water supply storage in Oklahoma's major reservoirs amounts to approximately 2.9 million acre-feet; the yield of those reservoirs, that water which may be safely relied upon in the event of a drought of record, amounts to almost 1.8 million ac-ft. The three largest water supply projects in Oklahoma are Kaw Lake (230,720 ac-ft of yield), Broken Bow (196,000 ac-ft) and Oologah (172,480 ac-ft).

Though incidental to water supply, recreation is an important and common component of reservoir projects, attracting millions of visitors to the state each year and boosting local economies from Woodward to Idabel. While recreation benefits, as well as those associated with fish and wildlife, are normally unprotected from lake fluctuations caused by increased water supply usage and/or drought conditions, contractual provisions are allowed for non-consumptive water storage. In addition, periodic releases from fish and wildlife storage may be made to supplement downstream flows upon which certain species may depend. Though seldom authorized or used, water quality storage is utilized in much the same way. Water quality releases are normally made in response to emergency conditions downstream, such as fish kills, increased pollution loading during drought conditions, or aesthetics problems.

Many federal projects in Oklahoma have set aside space for hydroelectric power generation; 12 currently support power facilities. GRDA and Southwestern Power Administration market all hydroelectric power produced in Oklahoma. The navigation benefit of Oklahoma reservoirs is realized primarily through channel maintenance of the McClellan-Kerr Arkansas River Navigation System.

In addition to the 34 major projects, numerous smaller lakes play a vital role in water supply, recreation and other uses of water in Oklahoma. Throughout the state, there are more than 2,300 public and private lakes many constructed for municipal use, and almost 2,000 watershed protection structures covering some 144,000 acres and impounding 2.2 million acre-feet of water. (Table 2 shows the major municipal and private lakes in Oklahoma.) The combined shoreline length of state lakes with a surface area of 100 acres or more totals almost 7,000 miles. In addition, it is estimated that Oklahoma contains more than 220,000 farm ponds with a combined surface area of approximately 33,000 acres.

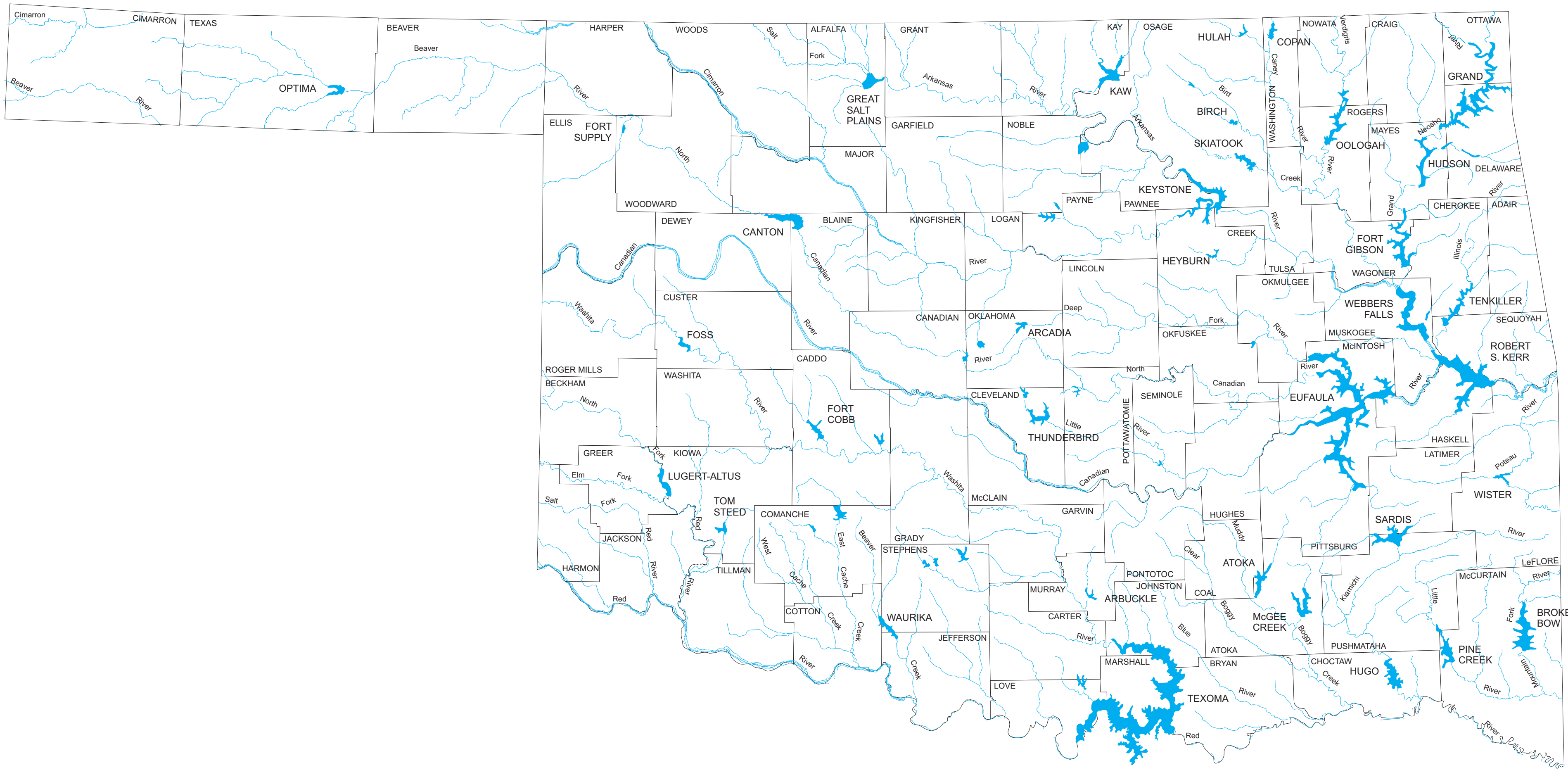
Relatively insignificant, though still important, state water resources include playa and oxbow lakes. Playas, shallow depressions formed by wind erosion up to 17,000 years ago, are transient water supplies which hold water only during and following the state's rainy seasons, unless nourished by irrigation runoff. Primarily a feature of the Panhandle region, playas vary in diameter from a few hundred feet to one mile; in depth, from a few feet to as much as 40 feet. During their brief lifespan, they primarily serve the three-fold purpose of irrigation supply, livestock watering and habitat for migratory waterfowl. The state's largest playa is 34-acre Wildhorse Lake, in Texas County, which has been deepened by lo-

Table 1
MAJOR FEDERAL & STATE WATER RESOURCE DEVELOPMENT PROJECTS IN OKLAHOMA

Official Name	Source	Purpose	Flood Control Storage (ac-ft)	Normal Operating Capacity (ac-ft)	Water[1] Supply Storage (ac-ft)	Water Supply Yield (ac-ft)	Normal Surface Area (ac-ft)	Construction Agency & Completion Date
Arbuckles	Rock Creek	ws, fc, r, fw	36,400	72,400	62,600	24,000	2,350	BuRec; 1967
Arcadia	Deep Fork	ws, fc, r	64,430	27,520	27,380	12,320	1,820	COE; 1984
Birch	Birch Creek	ws, fc, wq, r, fw	39,805	19,225	15,165	6,700	1,145	COE; 1977
Broken Bow	Mountain Fork River	ws, fc, p, r, fw	450,160	918,070	152,500	196,000	14,200	COE; 1970
Canton	North Canadian River	ws, fc, I	265,790	111,310	97,170	18,480	7,910	COE; 1948
Copan	Little Caney River	ws, fc, r, fw	184,300	43,400	33,600	21,300	4,850	COE; 1981
Eufaula	Canadian River	ws, fc, p, n	1,510,800	2,314,600	56,000	56,000	105,500	COE; 1964
Fort Cobb	Cobb Creek	ws, fc, r, fw	63,730	80,010	78,350	18,000	4,070	BuRec; 1959
Fort Gibson	Grand (Neosho) River	fc, p	919,200	365,200	n/a	n/a	19,900	COE; 1953
Fort Supply	Wolf Creek	ws, fc	86,800	13,900	400	224	1,820	COE; 1942
Foss Reservoir	Washita River	ws, fc, I, r	180,410	165,480	165,480	18,000	6,800	BuRec; 1961
Grand	Grand (Neosho) River	fc, p	525,000	1,672,000	n/a	n/a	46,500	GRDA; 1940
Great Salt Plains	Salt Fork/Arkansas River	ws, fc, r, fw	239,980	31,420	n/a	n/a	8,690	COE; 1941
Heyburn	Polecat Creek	ws, fc, r, fw	48,290	7,105	2,340	1,904	880	COE; 1950
Hudson (Markham Ferry)	Grand (Neosho) River	fc, p	244,200	200,300	n/a	n/a	10,900	GRDA; 1964
Hugo	Kiamichi River	ws, fc, wq, r, fw	808,300	158,617	121,500	165,800	13,144	COE; 1974
Hulah	Caney River	ws, fc, flow	257,900	31,160	26,960	18,928	3,570	COE; 1951
Kaw	Arkansas River	ws, fc, wq, r, fw	867,310	459,850	203,000	230,720	18,775	COE; 1976
Keystone	Arkansas River	ws, fc, p, fw, n	1,167,232	505,381	20,000	22,400	22,420	COE; 1964
Lugert-Altus	North Fork/Red River	ws, fc, I	19,600	132,830	132,830	47,100	6,260	BuRec; 1948
McGee Creek	McGee Creek	ws, fc, r, fw, wq	85,340	113,930	107,980	71,800	3,810	BuRec; 1985
Oologah	Verdigris River	ws, fc, r, fw, n	1,007,060	552,210	342,600	172,480	31,040	COE; 1974
Optima	North Canadian River	ws, fc, r, fw	71,800	129,000	76,200	n/a	5,340	COE; 1978
Pine Creek	Little River	ws, fc, wq, r, fw	388,080	53,750	70,560	134,400	3,750	COE; 1969
Robert S. Kerr	Arkansas River	p, r, n	n/a	525,700	n/a	n/a	32,800	COE; 1970
Sardis	Jackfork Creek	ws, fc, r, fw	121,670	274,330	270,270	156,800	13,610	COE; 1981
Skiatook	Hominy Creek	ws, fc, wq, r, fw	176,100	322,700	280,200	85,130	10,190	COE; 1984
Tenkiller Ferry	Illinois River	fc, p	576,700	654,100	25,400	29,792	12,900	COE; 1953
Texoma	Red River	ws, fc, p, r, n, flow	2,613,777	2,580,386	150,000	168,000 [2]	86,910	COE; 1944
Thunderbird	Little River	ws, fc, r	76,600	119,600	105,900	21,700	6,070	BuRec; 1965
Tom Steed	Otter Creek	ws, fc, r, fw	20,310	88,970	88,970	16,000	6,400	BuRec; 1977
Waurika	Beaver Creek	ws, fc, I, wq, r, fw	131,900	190,200	170,200	45,590	10,100	COE; 1977
Webbers Falls	Arkansas River	p, n	n/a	170,100	n/a	n/a	11,640	COE; 1970
Wister	Poteau River	ws, fc, r, fw	388,399	61,423	39,082	31,400	7,386	COE; 1949
			13,637,373	**13,166,177**	**2,922,637**	**1,790,968**	**543,450**	

[1] Includes water quality storage, where applicable.
[2] Oklahoma portion of total yield.

n/a = not applicable; ws = water supply; fc = flood control; I = irrigation; r = recreation; fw = fish & wildlife; wq = water quality; p = power; n = navigation; flow = low flow regulation.



OKLAHOMA COMPREHENSIVE WATER PLAN

Figure 2
MAJOR WATER RESOURCE DEVELOPMENT PROJECTS

cal landowners to store irrigation water throughout the year. During the rainy season, nearly 600 playa lakes, covering almost 10,000 acres, exist in the High Plains of Oklahoma.

An oxbow lake forms when deposits of sediment fill in the open end of a U-shaped bend in a river, land-locking a small new lake from the river channel. Primarily occurring along the Red River -- especially in McCurtain County, where 26 oxbows exist -- these water resources are nourished only by rainfall, runoff and, in some cases, the underlying alluvium of the old river. Oklahoma is home to 62 oxbow lakes which are 10 acres or larger in size; the largest of these is the 272-acre 1941 Cut-Off in McCurtain County.

Transitional areas between land and water, wetlands are also important water resource components. Though not prolific sources of water, wetlands serve several crucial water-related purposes, including flood control, improved water quality, aquifer recharge, flow stabilization of streams and rivers, and habitat for fish and wildlife. Oklahoma's wetlands fall into three broad classifications (related to size, location, dominant vegetation and related characteristics) under the system used by the U.S. Fish and Wildlife Service's National Wetland Inventory (NWI) -- riverine, lacustrine and palustrine. While often a feature of floodplains statewide, wetlands are more frequently found along river corridors in eastern Oklahoma where approximately 61 percent of the state's 687,000 wetland acres are found.

The following section presents a detailed description of the Red and Arkansas Rivers and their major tributaries (Figure 3), followed by a separate discussion of generalized water quality information for selected stream gages and stream systems.

Red River and Tributaries

The trek of the Red River begins with two small tributaries in eastern New Mexico, about 30 miles south of Tucumcari. The river then flows across the Texas Panhandle, along the Oklahoma/Texas border, through Arkansas and Louisiana, and finally to its confluence with the Atchafalaya River and the mighty Mississippi.

Tierra Blanca and Palo Duro Creeks, in the flatlands of the Texas Panhandle, flow easterly toward their confluence prior to entering scenic Palo Duro Canyon, south of Amarillo. Here begins the Prairie Dog Town Fork of the Red River which flows southeasterly then easterly to begin, more or less, the southern border of Oklahoma at river mile 1,050. Only a few miles downstream, the Prairie Dog Town Fork encounters Buck Creek, where it becomes the Red River proper. In Jackson County, the Red River is united with two of its more significant tributaries, Sandy and Gypsum Creeks. Its two major contributors, the Salt Fork and North Fork of the Red River, join the river south of Altus. As the state's southern border, the Red River spans 517 miles from the Texas Panhandle to southwestern Arkansas. Oklahoma contributes 22,971 square miles of drainage to the Red River. Massive Lake Texoma -- the nations' seventh biggest and Oklahoma's largest reservoir-- is the only major reservoir project on the mainstem of the Red River in Oklahoma.

The Salt Fork of the Red River heads in the High Plains of southern Carson and northern Armstrong Counties, Texas, and flows in a southeasterly direction for 97 miles where it enters Oklahoma in rural Harmon County. It continues in the same general direction for 73 miles to its confluence with the mainstem of the Red River near Elmer, Oklahoma -- a total of 167

Table 2
MAJOR MUNICIPAL AND PRIVATE WATER RESOURCE DEVELOPMENT PROJECTS IN OKLAHOMA

Official Name	Source	Purpose	Normal Operating Capacity (ac-ft)	Water Supply Storage (ac-ft)	Water Supply Storage (ac-ft)	Normal Surface Area (acres)	Owner & Completion Date
Atoka [1]	North Boggy Creek	ws, r	125,000	123,500	700	5,700	City of Oklahoma City; 1964
Bluestem [2]	Middle Bird Creek	ws,r	17,000	—	—	762	City of Pawhuska; 1958
Carl Blackwell	Stillwater Creek	ws, r	61,500	61,500	7,000	3,370	Oklahoma State University; 1937
Chickasha	Spring Creek	ws, r	41,080	41,080	7,500	820	City of Chickasha; 1958
Dripping Springs	Salt Creek	ws, r, fc	16,200	16,200	7,412	1,150	City of Okmulgee; 1976
Ellsworth	East Cache Creek	ws, r	72,500	65,500	23,500	5,600	City of Lawton; 1962
Eucha	Spavinaw Creek	ws, r	79,567	79,567	84,000	2,860	City of Tulsa; 1952
Fuqua [3]	Black Bear Creek	ws, r, fc	21,100	17,600	2,654	1,500	City of Duncan; 1962
Hefner [4]	Bluff Creek	ws, r	75,000	75,000	—	2,500	City of Oklahoma City; 1943
Konawa	Jumper Creek	cw	23,000	23,000	—	1,350	Oklahoma Gas & Electric; 1968
Lawtonka	Medicine Creek	ws, r	56,574	56,574	23,500	2,398	City of Lawton; 1905
McMurtry	North Stillwater Creek	ws, r, fc	19,733	13,500	3,002	1,155	City of Stillwater; 1971
Murray	Anadarche Creek	r	153,250	153,250	—	5,728	State of Oklahoma; 1937
Overholser [5]	North Canadian River	ws, r	15,000	15,000	5,000	1,500	City of Oklahoma City; 1919
Shawnee	South Deer Creek	ws, r	34,000	34,000	4,400	2,436	City of Shawnee; 1935 & 60
Sooner [6]	Greasy Creek	ws, r, fc, cw	149,000	149,000	3,600	5,400	Oklahoma Gas & Electric; 1972
Spavinaw [7]	Spavinaw Creek	ws, r, fw	38,000	30,600	—	1,584	City of Tulsa; 1924
Stanley Draper [8]	East Elm Creek	ws, r	100,000	100,000	—	2,900	City Oklahoma City.; 1962
			1,097,504	**1,054,871**	**172,268**	**48,713**	

[1] Yield does not include supply pumped from McGee Creek Reservoir for transfer to Lake Stanley Draper.
[2] Water supply information not available.
[3] Yield includes that of Clear Creek and Duncan Lakes which provide supply for City of Duncan.
[4] Dependable yield negligible.
[5] Yield does not include releases from Canton Lake.
includes potential yield from drainage basin.
[7] Yield negligible; serves as terminal storage for releases from Eucha Lake.
[8] Yield negligible; serves as terminal storage for water pumped from Atoka Lake and McGee Creek Reservoirs.

n/a = not applicable; ws = water supply; r = recreation; fc = flood control; cw = cooling water; fw = fish & wildlife; p = power.

miles. More than 2,000 square miles of land area make up the Salt Fork drainage, 708 square miles of it in Oklahoma.

The North Fork of the Red River originates in Carson County, Texas and flows eastward for a river distance of 72 miles where it enters the state several miles north of Interstate 40 near Texola, Oklahoma. After passing near Sayre, it turns southeasterly and southerly passing through Lugert-Altus Reservoir to its confluence with the mainstem of the Red River west of Davidson, a total distance of 220 river miles, with 148 miles in Oklahoma. The North Fork has a 4,828-square mile drainage area, 3,605 square miles of which is in Oklahoma. Otter Creek, a major tributary of the North Fork, impounds Tom Steed Reservoir.

The Elm Fork of the North Fork of the Red River begins in the southwestern part of Wheeler County, Texas, and flows east-southeasterly where it enters Oklahoma near the Harmon/Beckham County line. It continues in the same general direction until it enters the North Fork at river mile 70. The Elm Fork has total drainage area of 915 square miles, 540 square miles in Oklahoma. The tributary has a total length of 97 miles, 68 miles in the state.

Cache Creek, which consists of a relatively short mainstem less than eight miles long, forms near the Oklahoma/Texas border at the confluence of its two relatively large tributaries, East Cache (101 miles long) and West Cache (61 miles) Creeks. These two important tributaries traverse Caddo, Comanche, Tillman and Cotton Counties and drain approximately 773 square miles. The total area of the Cache Creek Basin is 1,895 square miles, of which 617 square miles is in Deep Red Creek, a 62-mile long tributary of West Cache Creek. Following the confluence, Cache Creek flows southerly and southwesterly prior to joining the mainstem of the Red River at mile 912. East Cache Creek impounds Lake Ellsworth, one of Lawton's two major water supplies. Medicine Creek, a contributor to East Cache, impounds Lake Lawtonka near the slopes of Mount Scott in the granitic Wichita Mountains.

Beaver Creek, 76 miles long, originates in northwestern Comanche County and southwestern Grady County. It flows in a southerly direction through Waurika Lake prior to its confluence with the mainstem of the Red River at mile 882. Beaver Creek has a drainage area of 865 square miles.

Mud Creek originates in the southwest part of Stephens County and runs 75 miles in a southeasterly direction through Jefferson County prior to joining the Red River in southwest Love County. It has a drainage area of 688 square miles.

Walnut Bayou Creek heads in Carter County and extends 32 miles south through Love County to its confluence with the Red River at mile 808. Walnut Bayou has a drainage area of 334 square miles.

The flow of the Washita River begins in southeastern Roberts County, Texas, and runs in an easterly direction to the Texas/Oklahoma state line. The turbid river then enters Oklahoma in Roger Mills County, extending southeasterly through Beckham, Dewey, Custer (where it impounds Foss Reservoir), Washita, Kiowa, Caddo, Canadian, Comanche, Grady, Stephens, McClain, Garvin, Murray, Carter, Pontotoc, Johnston, Marshall and Bryan Counties to its confluence with the Red River in Lake Texoma at mile 732. It extends a total of 626 miles (580 miles in Oklahoma) and covers 7,945 square miles of drainage area. Lake Chickasha and Arbuckle Reservoir lie on two of the Washita River's major tributaries -- Spring and Rock Creeks. Another tributary, Cobb Creek, impounds Fort Cobb Reservoir northwest of Carnegie.

The spring-fed Blue River heads in Pontotoc County, near Roff, and flows 147 miles in a southeasterly direction to its confluence with the Red River near Wade, in Bryan County. The Blue River basin is long and narrow with a maximum width of about 14 miles and a total drainage area of 676 square miles.

Boggy Creek starts in eastern Pontotoc and southwestern Hughes Counties, then flows more than 24 miles in a southerly and southeasterly direction to its confluence with the Red River at about mile 644, near Hugo. The Boggy and its two large tributaries, Muddy Boggy Creek (131 miles long) and Clear Boggy Creek (88 miles), make up 2,429 square miles of drainage area. Two of Oklahoma City's water supply lakes in the southeast, Atoka Lake and McGee Creek Reservoir, lie on other smaller tributaries of the Muddy Boggy.

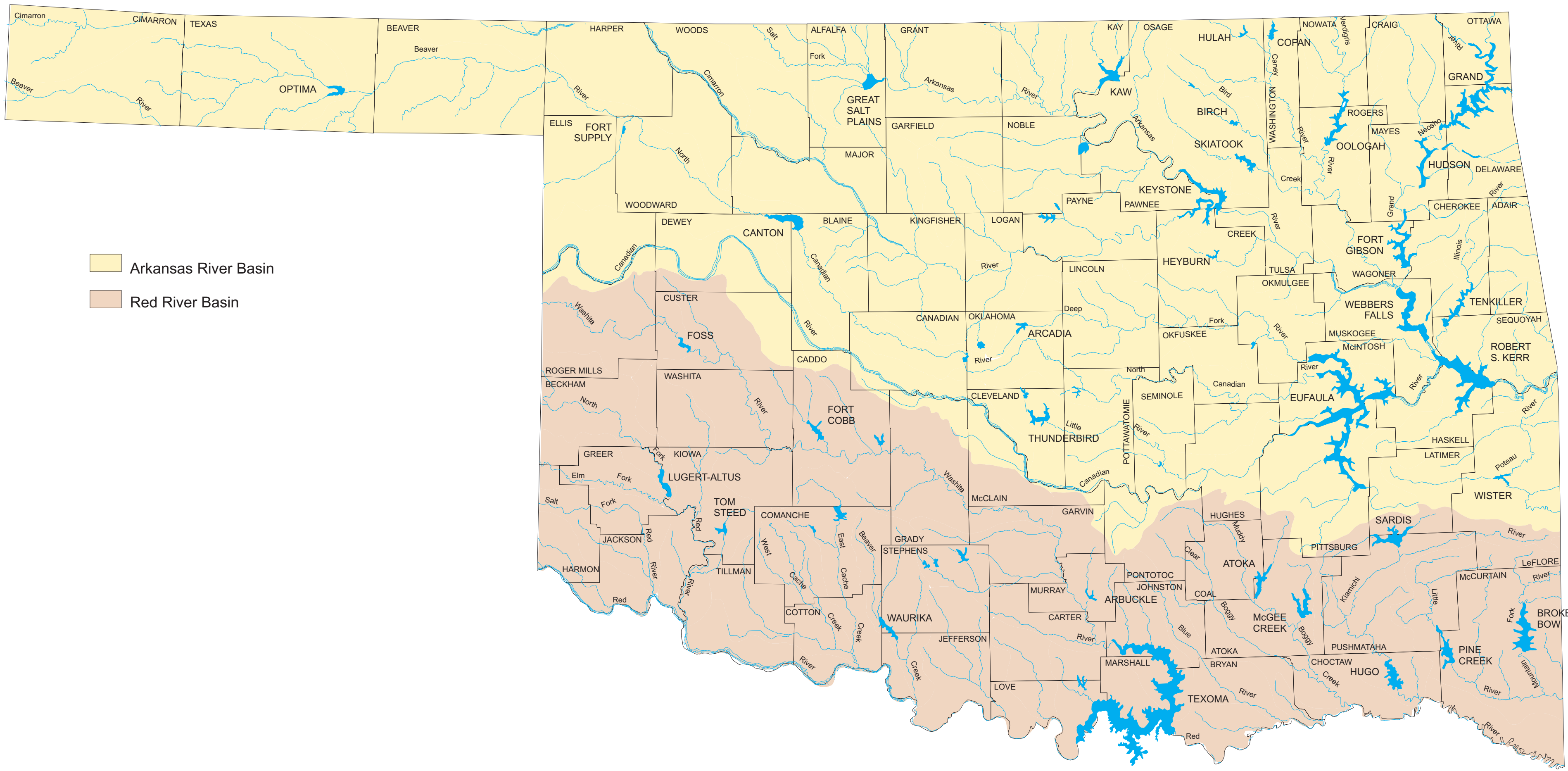
The Kiamichi River has its source in the Kiamichi and Ouachita Mountain ranges in southeastern LeFlore County, Oklahoma. It flows 169 miles in a westerly path through Latimer and Pittsburg Counties, then south through Atoka, Pushmataha and Choctaw Counties, where it impounds Hugo Lake prior to entering the Red River at mile 607. It has a drainage area of 1,830 square miles and is a major tributary of the Red River. Jackfork Creek, a tributary of the Kiamichi, impounds Sardis Lake.

The Little River, which has a total length of 217 miles (130 in Oklahoma), heads in the southern portion of LeFlore County, extends for a few miles into Arkansas and then back into Oklahoma before crossing over the Pushmataha County line. Following this horseshoe route, the Little River traverses southerly and southeasterly into McCurtain County (where it impounds Pine Creek Lake), turns easterly near Idabel and continues in the same general direction until it leaves the state at river mile 78. With its two crystal clear tributaries, Mountain Fork River and Glover Creek, it has a total combined drainage area of 2,269 square miles at the state line and 2,029 miles in Oklahoma, excluding a portion of its headwaters in Arkansas. A section of the upper Mountain Fork River, which flows into Broken Bow Lake, is noted for its high quality and has been designated as one of Oklahoma's six "scenic rivers," protected by the State Legislature due to their unique free-flowing beauty and recreational value to state citizens.

Arkansas River and Tributaries

The Arkansas River Basin, home of the state's five remaining scenic rivers, is the other major river basin in Oklahoma. From its source near the historic mining town of Leadville, in the heart of the Rocky Mountains in central Colorado, the Arkansas River flows southerly, then easterly, crossing the Kansas State line near Coolidge, Kansas. It proceeds generally easterly then northeasterly to Great Bend, Kansas, where it turns southeasterly and enters Kay County, Oklahoma, just south of Arkansas City, Kansas.

Extending southeasterly through Kaw Lake as the county line between Osage, Noble and Pawnee Counties, the Arkansas River reaches Keystone Lake. From Keystone, it continues its southeasterly direction through Tulsa County and the City of Tulsa, then becomes the county line between Wagoner and Muskogee Counties. Within Muskogee County, the Arkansas flows into Webbers Falls Reservoir,



OKLAHOMA COMPREHENSIVE
WATER PLAN

Figure 3
RED AND ARKANSAS RIVER BASINS
AND MAJOR TRIBUTARIES

then into Robert S. Kerr Reservoir, and after forming the county line between Sequoyah and LeFlore Counties, it leaves the state at mile 361 before it runs through Little Rock, Arkansas, and joins the Mississippi River. Much of the Arkansas River comprises the McClellan-Kerr Navigation System which links Oklahoma with foreign markets through New Orleans, the nation's second busiest port. The Arkansas River drains about two-thirds of the state's land area and 328 miles of its length lie in Oklahoma.

The Poteau River heads in Scott County, Arkansas, and enters Oklahoma in southeast LeFlore County, then begins a westerly to northwesterly trek to Wister Lake. At the confluence of Fourche Maline Creek it turns easterly and flows north, uncharacteristic of most state rivers, ending at its confluence with the Arkansas River at mile 362 at the Oklahoma/Arkansas border near Fort Smith. The 96-mile long Poteau River and its tributaries drain an area of 1,888 square miles, 1,328 square miles of which is in Oklahoma.

Originating in Colfax County, New Mexico, and flowing southeasterly through New Mexico and easterly through the Texas Panhandle, the Canadian River (often mistakenly referred to as the South Canadian) enters Oklahoma as the meandering boundary between Ellis and Roger Mills Counties. Moving easterly through Dewey County, then southeasterly through the northeast tip of Custer County and the southwest tip of Blaine County, it crosses the southwest portion of Canadian County and forms the line between Canadian, Grady, Cleveland, McClain, Pottawatomie, Seminole, Pontotoc, Hughes, Pittsburg and McIntosh Counties. The Canadian flows through Eufaula Lake and joins the Arkansas River prior to entering Robert S. Kerr Reservoir, completing its 411 miles trek across Oklahoma. The Canadian River has a total drainage area of 19,487 square miles in the state.

The North Canadian River has its source in northern Union County, New Mexico. It enters Oklahoma in southwest Cimarron County, loops south and flows through the State of Texas for about 12 miles until it again winds back into Oklahoma, impounding Optima Lake in Texas County. The North Canadian then takes a sharp northeasterly turn before assuming a primarily eastward path through Beaver County. After entering Harper County, a southeasterly direction is maintained through Woodward, Major, Dewey, Blaine, Canadian, Oklahoma, Lincoln and Pottawatomie Counties. Canton Lake lies on the North Canadian at river mile 394 while Wolf Creek, a tributary, impounds Fort Supply Lake 12 miles northwest of Woodward. After forming the county line between Pottawatomie, Seminole and Okfuskee Counties, the river enters Hughes County. It then reenters Okfuskee County before flowing into McIntosh County and Eufaula Lake. Following its hefty 747 mile trek through Oklahoma, making it the state's longest river, it joins the Canadian River near the town of Eufaula. The North Canadian impounds Lake Overholser which, in tandem with Lake Hefner, an off-channel reservoir, makes up Oklahoma City's venerable water supply system. Due to Hefner's small contributing drainage area, the lake depends almost entirely on water furnished through a five-mile long canal from Overholser. The North Canadian has approximately 9,100 square miles of drainage.

The Deep Fork of the North Canadian River (more commonly referred to as the Deep Fork River) heads in Oklahoma County, impounding Arcadia Lake, and then flows easterly through Lincoln, Creek, Okfuskee, Okmulgee and McIntosh Counties. After entering McIntosh County, it flows into Eufaula Lake and finally to its confluence with the North Canadian River at mile 14.4. The Deep Fork River has a drainage area of 2,548 square miles and a length of 230 miles.

The source of the Little River is in Oklahoma and Cleveland Counties. Flowing easterly through Lake Thunderbird, the Little River bisects Pottawatomie and Seminole Counties, then flows southeasterly into Hughes County to its confluence with the Canadian River near Holdenville. The Little River, not to be confused with the river of the same name in the Red River Basin, has a drainage area of 1,973 square miles and spans 120 miles across central Oklahoma.

The brackish Cimarron River originates in northeastern New Mexico near Raton. It begins near the Colorado State line as a small tributary called Cimarron Creek which becomes the Dry Cimarron River northeast of Capulin Mountain. Flowing easterly, the river enters Oklahoma near the town of Kenton in Cimarron County, then proceeds easterly and northeasterly where it enters Colorado near the northeast corner of the county. The river reenters Oklahoma at the northeast corner of Beaver County, exits the state again in northwest Harper County, then enters the state for a third time to form part of the eastern Harper County line. The river flows in a southeasterly direction to mark the county line between Woodward, Woods and Major Counties. Entering Kingfisher County, it flows eastward through Logan County to form a portion of the county line between Logan and Payne Counties. After entering Creek County, it continues eastward to its termination in Keystone Lake. Lake McMurtry and Lake Carl Blackwell, both near Stillwater, are located on tributaries of the Cimarron. The Cimarron River has 18,927 square miles of drainage area and a length of 698 miles, about 410 miles of which is in Oklahoma.

The Salt Fork of the Arkansas River enters Oklahoma from Kansas in the northeast section of Woods County and flows eastward through Alfalfa County to Great Salt Plains Lake. The Salt Fork continues its eastward route through Grant and Kay Counties and terminates at the confluence with the Arkansas River in Kay County at mile 637.8. The Salt Fork drains an area of 6,764 square miles and meanders 160 miles across northern Oklahoma.

The Chikaskia River heads in south central Pratt County, Kansas. Flowing southeasterly, it enters Oklahoma between Grant and Kay Counties, then continues southeasterly to its confluence with the Salt Fork of the Arkansas River in Kay County. The Chikaskia River has 3,340 square miles of drainage in Oklahoma and a total length of 145 miles, 49 of which is in Oklahoma.

From its source in Greenwood County, Kansas, the Verdigris River flows southerly where it enters Oklahoma in northern Nowata County. As a principal artery of the Arkansas River, it flows in a southerly direction through Oologah Lake into Rogers and Wagoner Counties, then enters Muskogee County and joins the Arkansas River at mile 460.2. The Verdigris drains 4,290 square miles within Oklahoma and has a total length of 162 miles within the state.

Bird Creek, located primarily in Osage and Tulsa Counties, is 111 miles long and has its 1,137-square mile drainage area entirely within Oklahoma. Bird Creek enters the Verdigris River at mile 78.3.

The Caney River originates in southwestern Elk County, Kansas, then flows southerly and southeasterly where it enters Oklahoma and Hulah Lake in the northeast portion of Osage County. It continues easterly into Washington and Rogers Counties to its confluence with the Verdigris River near Claremore in central Rogers County. The Little Caney River impounds Copan Lake in Washington County. The Caney River has a total length of 118 miles and a drainage area of 1,616 square miles within Oklahoma.

The Illinois River, which has its source in the Boston Mountains of northwest Arkansas, enters Oklahoma in Adair County near the town of Watts and travels southwesterly through Cherokee and Sequoyah Counties before its confluence with the Arkansas River at mile 427. Another scenic river which is an exceedingly popular spot for weekend canoeists and other recreationists, the Illinois stretches through 110 miles of eastern Oklahoma cliffs and countryside. Tenkiller Ferry Lake, a haven for scuba divers, is formed on the Illinois River and utilizes a large part of the river's 1,660 square miles of total drainage area. Two of its tributaries, Flint and Baron Fork Creeks, have also been designated as scenic rivers.

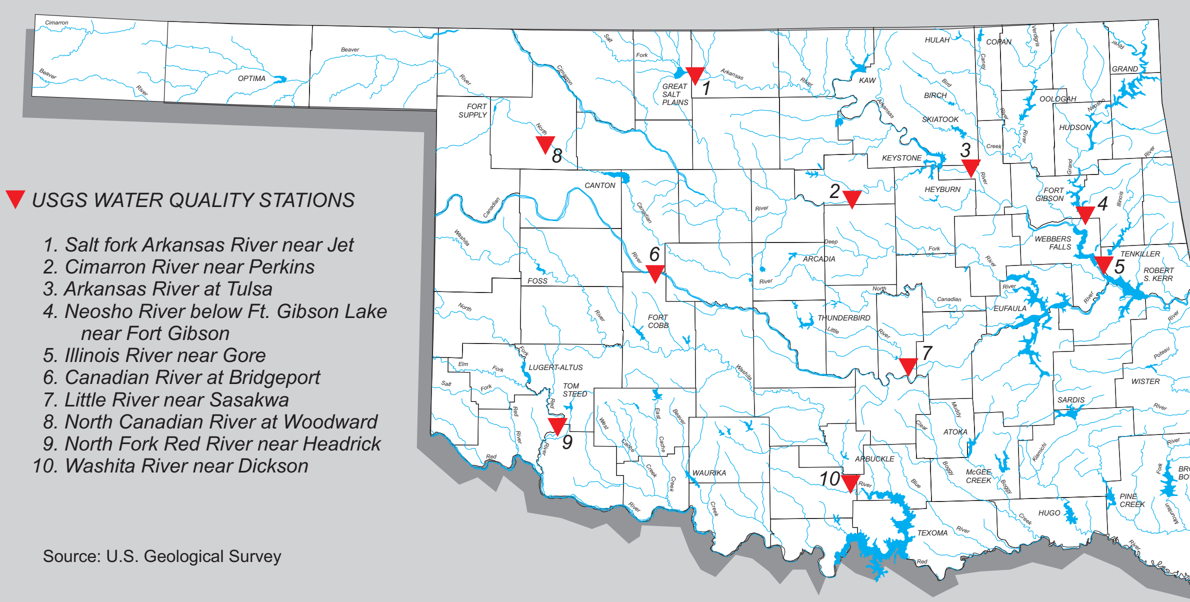
The Grand (Neosho) River, another major contributor to the Arkansas River, has its source in Mavis County, Kansas, then flows southerly and southeasterly where it enters the Ozark Region of northeast Oklahoma forming a portion of the Craig/Ottawa County line. Impounding the serpentine Grand Lake O' the Cherokees, Lake Hudson and Fort Gibson Lake, the Grand River winds through lush valleys in Delaware, Mayes, Wagoner and Cherokee Counties before joining the Arkansas River in Muskogee County at mile 459.5. Grand Lake is one of Oklahoma's most popular tourist and recreation spots. Spavinaw and Eucha Lakes -- on Spavinaw Creek, a major tributary of the Grand River -- are two high quality water supply reservoirs operated by the City of Tulsa. The Grand River has approximately 12,520 square miles of total drainage, with 6,727 square miles in Oklahoma. It has a total length of 450 miles, 164 miles in Oklahoma.

STREAM WATER QUALITY

With few exceptions, surface water in western Oklahoma is unsuitable for public supply due to undependable flows and large concentrations of dissolved minerals. In the east, however, surface supplies are normally of sufficient quantity and quality for public use and consumption. Point source discharges from municipalities and various industries, though now effectively regulated in the state and nationwide, still pose a potential threat to Oklahoma's streams and rivers. However, nonpoint source pollution -- determined to a great extent by land use in a particular drainage basin as well as by local physiography, climate, geological and related characteristics -- has become a major determinant of surface water quality in the state. Common pollutants of state stream waters from various sources include oil-well drilling wastes, sewage, poultry wastes, oil, saltwater from oil and gas extraction, pesticides, fertilizers, gasoline, diesel fuel, lawn chemicals, cattle and horse manure, nitrates, sulfuric acid, hydrogen sulfide and dissolved metals.

Water quality standards specific to designated beneficial uses of state waters have been promulgated by the OWRB. All Oklahoma streams and rivers have state-designated beneficial uses of recreation and fish and wildlife propagation. Although 19,791 miles of streams and rivers were directly assigned beneficial uses in the 1988 Oklahoma Water Quality Standards, only 4,393 miles have been assessed first-hand to determine whether they meet state standards for each designated use. Of the assessed rivers and streams, 269 miles (6 percent) fully support designated uses, 2,299 miles (52 percent) fully support designated uses but are threatened, and 1,825 miles (42 percent) partially support designated uses. A stream is classified as partially supporting designated

Figure 4
WATER QUALITY MONITORING SITES



Source: U.S. Geological Survey

beneficial uses if one or more of its beneficial uses is partially supported.

A general summary of water quality in the state's major river basins and subbasins -- garnered from data collected, analyzed and maintained by the U.S. Geological Survey and U.S. Environmental Protection Agency, with assistance from the Oklahoma Conservation Commission, Oklahoma Department of Wildlife Conservation and OWRB (from the USGS National Water Summary, 1990-91) -- is presented here. Much of the information was obtained from water samples collected at 10 selected monitoring stations located throughout Oklahoma for water years (for hydrologic data purposes, the period October 1 through September 30) 1987-89 (Figure 4). In addition, upward and downward trends in certain water quality parameters from 1980-89 are noted. Local water quality problems that affect aquatic life or public health are not fully addressed.

The Salt Fork of the Arkansas River and Cimarron River basins, underlain by massive gypsum deposits, are the location of numerous natural brine seeps and springs. Agriculture is the principal land use in the region which includes grassland and grazing land. The Salt Fork just downstream of Great Salt Plains Lake suffers somewhat from excessive concentrations of chloride, dissolved solids, nutrients, pesticides, toxic chemicals and suspended sediment. Great Salt Plains Lake itself has been partially filled with sediment and, in most areas, water is only about four feet deep. Fertilizers and pesticides from agricultural operations in the basin contribute nutrients (nitrogen and phosphorus) and organic compounds to the reservoir. While the shallow depth of the lake enables wind mixing to keep the reservoir aerobic, it also allows nutrient- and pesticide-bearing sediment particles to remain in suspension.

Median concentrations of sulfate (500 mg/L), chloride (920 mg/L) and dissolved solids (2,400 mg/L) in water samples from the Great Salt Plains site were among the largest for the 10 monitoring stations. All sulfate, chloride and dissolved-solids concentrations at the site exceeded concentrations recommended by the state for recreation (250 mg/L) and fish and wildlife propagation (500 mg/L).

Agricultural cropland is the principal land use upstream of the Perkins area (Payne County) on the Cimarron River. Oil production, however, has had a significant effect on water quality. Also, large concentrations of chlordane from an unknown source have been detected in the river. Fecal coliform bacteria concentrations are greater than the state standard for water supply (a monthly geometric mean of 5,000 colonies per 100 ml), perhaps owing to runoff from livestock grazing and feedlot areas. Upstream and downstream from the site, river water quality is affected by oil and grease, fecal coliform bacteria, chlorides, dissolved solids, pesticides and suspended solids. Natural brine seeps and springs (and, to a lesser extent, oilfield activities) contribute large quantities of chloride to streams in the area, making the water unsuitable for irrigation and industrial and commercial uses. Although downward trends have been reported in dissolved chlorides and dissolved solids, an upward trend is noted in dissolved sulfate.

Samples collected at the Perkins site had among the largest median concentrations of fecal coliform bacteria (180 col/100 ml), chloride (1,400 mg/L), dissolved solids (3,240 mg/L), nitrite plus nitrate (0.69 mg/L), phosphate (0.08 mg/L) and suspended sediment (126 mg/L). Extensive agricultural activities in the basin may be a contributor to these large concentrations.

Much of the Arkansas River basin in Oklahoma is underlain by shale, limestone and fine-to-course-grained sandstone. Water flowing through these rocks may dissolve large quantities of minerals, primarily sodium and sulfate. The Salt Fork of the Arkansas and Cimarron Rivers, two primary tributaries of the Arkansas, add highly mineralized water to the river. Water quality also is affected by oilfield activities, agriculture and municipal wastewater discharges. Large chlordane and polychlorinated biphenyl concentrations have been detected in the river at Tulsa, downstream of Keystone Lake. Both upstream and downstream from the site, the river contains elevated concentrations of pesticides, organic compounds and pathogenic indicators, although downward trends are reported in fecal coliform bacteria.

Samples collected at the site had a median suspended sediment concentration of 21 mg/L, among the lowest for the 10 monitoring stations. This level of concentration might have been the result of sediment entrapment in Keystone Lake.

The Neosho and Illinois Rivers, which flow through the Ozark Plateaus, are located in one of the state's most popular tourist and recreation areas. The rivers are impounded by a series of reservoirs located in low mountains and underlain by chert, limestone, shale and sandstone.

Human activities in the two river basins have had a detrimental impact upon water quality. Extensive lead and zinc mining in the Neosho River basin has increased concentrations of these trace metals in the river. Just upstream of the monitoring station, located below Fort Gibson Lake but above the Neosho's confluence with the Arkansas and Verdigris Rivers, the river contains excessive levels of organic compounds, toxic metals, pH and suspended solids.

Median concentrations of sulfate (34 mg/L), chloride (8.7 mg/L) and dissolved solids (155 mg/L) in water samples from the Neosho River site were among the smallest for the 10 stream sites. The Neosho River also had the smallest median suspended sediment concentration (12 mg/L), due in part to the site's location downstream from a series of large, sediment-trapping reservoirs. Trends in water quality indicate reductions in dissolved sulfate, chloride and solids.

The Illinois River has been designated by the Oklahoma State Legislature as a state scenic river. However, widespread development in the Illinois River basin has led to increased nitrate and phosphorus concentrations contributed by nonpoint source discharges. The Illinois River contains excessive levels of nutrients, suspended solids and organic compounds. Although recent USGS data do not indicate a problem, the Oklahoma Conservation Commission reports violations of the state's dissolved oxygen standard more than 20 percent of the time at the monitoring station near Gore, just upstream of the Illinois' confluence with the Arkansas River. These conditions affect fishery resources and recreation in the area. As in the Neosho River, median concentrations of sulfate (9.9 mg/L), chloride (11 mg/L) and dissolved solids (114 mg/L) in the Illinois River site were relatively small in comparison to most other stream sites.

Upstream from the Blaine/Canadian/Caddo County Line, the Canadian River lies entirely within the Central Lowland which, along with land use in the basin (cropland), contributes significantly to the water quality characteristics of the river.

The basin is underlain by fine-grained sandstone, dolomite, shale and gypsum. The median concentration of sulfate (560 mg/L) at the Bridgeport site, in Caddo County, was among the largest measured at the 10 monitoring stations. It is likely that this sulfate is contributed by one or more agricultural compounds, such as ammonium sulfate, poultry-dusting powders, sulfur-containing fungicides and, especially, gypsum.

The headwaters of the Little River are located in central Oklahoma. Land in the basin, which is underlain primarily by shale and fine-grained sandstone, is commonly used for pasture and growing hay, although the Cities of Moore and Norman are near the headwaters. Human activity affects the river in those urban areas where large concentrations of cadmium, chromium and lead have been identified. The exact sources of these toxic metals are unknown, but could be contributed by industry in the Moore/Norman area. Cadmium and chromium have not been detected in excessive concentrations at the site near Sasakwa, in southern Seminole County. Some upstream tributaries of the river contain high levels of pesticides and toxic metals.

The western reach of the North Canadian River drains cropland in the Great Plains. Downstream from the Woodward monitoring site, excessive sedimentation and high turbidity levels adversely affect the fishery resource of Canton Lake. There are also concerns that the fishery is being impacted by agricultural runoff containing pesticides and excess nutrients. The area has had several fishkills, some likely caused by aerial pesticide application. Gypsum beds in the underlying geologic formations might have been the source of excessive sulfate (median, 230 mg/L) and dissolved solids (median, 1,080 mg/L) in the river beginning around 1987. The large concentration of fecal coliform bacteria at the site could be a result of runoff from area feedlots. Trends show a reduction in dissolved phosphate.

The North Fork of the Red River lies within the Central Lowland in southwestern Oklahoma and land use in the basin is primarily cropland. The river downstream of Headrick, east of Altus in Jackson County, has been assessed as fully supporting designated uses but threatened by pesticides, metals and suspended solids. The reach upstream from the site was assessed as fully supporting designated uses.

Dissolution of gypsum beds contributes large quantities of sulfate to the river. Water samples from the Headrick site had the largest median concentrations of sulfate (830 mg/L) and dissolved solids (3,420 mg/L) for the 10 monitoring stations; the median concentration of chloride (1,100 mg/L) was the second largest. Natural brine discharges increase the chloride concentration and make several streams in southwest Oklahoma unsuitable for municipal use or irrigation. The median concentration of nitrite plus nitrate (1.3 mg/L), probably contributed by agricultural runoff, was relatively large and trends indicate a recent increase in that contaminant.

The Washita River basin, dominated by grazed, open woodland, is underlain by shale, siltstone, sandstone and interbedded gypsum deposits. The river suffers from excessive concentrations of chloride, nutrients, pesticides and suspended sediment. Solution of gypsum is the primary source of dissolved sulfate in the Washita and limits the river's use as a public water supply. The median concentration of sulfate in water samples collected near Dickson, east of Ardmore in Carter County, was 460 mg/L during water years 1987-89, indicating a recent increase in dissolved sulfate, along with dissolved solids. Past cultivation practices in the primarily agricultural region have resulted in large suspended sediment concentrations in the river upstream from the Dickson site. The median concentration of suspended sediment (376 mg/L) was the largest for the monitoring stations that had sufficient data for statistical analysis.

While southeast Oklahoma water quality is not represented by any of the 10 sites summarized above, quality in the Kiamichi River Basin is generally considered excellent and there are no concerns that should preclude any of the river's designated beneficial uses. The water is suitable for irrigation and, with treatment, is an excellent source for municipal and industrial purposes. However, heavy metals (including cadmium, mercury, lead and arsenic), usually associated with increases in sediment loading during periods of high runoff, may create occasional problems for those diverting water directly from the river for various uses. Dissolved solids generally increase in the lower reaches of the river due to calcium carbonate hardness.

Lakes, unlike most watercourses, have relatively limited ability to cleanse themselves. As a result, they are particularly susceptible to contamination. Major water quality problems that impair Oklahoma lakes include nonpoint pollution from various sources and activities in the watershed; excessive concentrations of inorganic suspended solids and/or turbidity levels which often result from nonpoint sources; toxicity concerns due to a myriad of pollutants; and excessive productivity and oxygen depletion which often results in lake eutrophy.

The OWRB continually monitors the quality of selected Oklahoma lakes as part of the Statewide Lakes Water Quality Assessment. Researchers have determined that, of the total lake surface acres in the state (excluding farm ponds), approximately three-quarters have nonpoint pollution concerns; one-third have recreational concerns; and almost one-half have toxicity concerns. In addition, 60 percent of the total surface acreage is considered to be eutrophic or hypereutrophic.

GROUNDWATER RESOURCES

Groundwater is water that has percolated downward from the surface, filling voids or open spaces in the rock formations. Lying almost motionless beneath the earth's surface, groundwater is truly Oklahoma's buried treasure to recover as the need arises and to preserve when surface sources yield adequate supplies. Oklahoma is underlain by 23 major groundwater basins containing an estimated 320 million acre-feet of water in storage, perhaps half of which is recoverable for beneficial use. Many of the minor basins may also yield significant amounts of fresh water. Wells and springs supply more than 60 percent of the total water use, including almost 90 percent of the state's irrigation needs, and provide municipal water for more than 300 Oklahoma cities and towns.

The underground zone of water saturation begins at the point where subsurface voids are full or completely saturated. A rock formation, or group of formations, that contains sufficient saturated material to yield significant quantities of water to wells and springs is called a groundwater basin, or aquifer. The amount of water available to wells depends on the saturated thickness (the thickness of the zone below the water table in which all the interstices are filled with groundwater), area of the basin and specific yield (the ratio of the volume of water a given mass of saturated material will yield by gravity to the volume of that mass). The amount of water that can be pumped from a well perennially, without depletion of the groundwater in storage, depends upon the amount of recharge from precipitation or runoff.

Western Oklahoma, though lacking in surface supplies, has tapped tremendous groundwater sources for use in irrigation and cattle feedlot operations. Texas County, in the Panhandle, is the largest water user among Oklahoma's 77 counties. The Ogallala Aquifer, an extensive bedrock formation in the Panhandle and northwestern Oklahoma, provides nearly all of the Panhandle's irrigation needs.

Oklahoma's major water-bearing formations may be divided into four general groups: semi-consolidated sand and gravel underlying the High Plains; unconsolidated alluvial deposits of sand and gravel along streams and adjacent to valleys; sandstone aquifers; and limestone (including dolomite and gypsum) aquifers. They range in age from Cambrian and Ordovician (represented by the Arbuckle Group) to Quaternary stream-laid deposits.

Due to an absence of available stream water, groundwater development is greatest in the west where it is used for irrigation and municipal, industrial and domestic purposes. In eastern areas, where surface water supplies are more abundant, groundwater resources are utilized primarily by small towns and rural homeowners.

Alluvial and terrace deposits are found along rivers, the terrace deposits lying higher than the alluvial basins. Geologically, they constitute a single water-bearing unit. Terraces represent older, higher stages of the rivers that have since cut their channels deeper. Water in the terrace accumulates from rainfall on the deposits and influent seepage of streams crossing it. Alluvial deposits of gravels, silts, sands and clays are still being laid down by streams in Oklahoma valleys. Throughout its history, a river has alternate periods of cutting and deposition as it meanders from side to side, widening its valley and irregularly depositing both coarse and fine sediments. Water enters the alluvium through direct rainfall, runoff and influent seepage from the river and its tributaries as they cross the alluvium.

Alluvial and terrace deposits along the major rivers -- the Arkansas, Salt Fork of the Arkansas, Red, North Canadian, Canadian, Washita, North Fork of the Red River and Cimarron -- extend from one to 15 miles from the river banks. The thickness of these deposits ranges from a few feet to about 200 feet. Yields of wells in these basins range from 100 to 1200 gpm. The deposits are unconfined and consist of sand, clay, silt and gravel.

In estimating the yield of a groundwater basin, these factors must be considered: well spacing, number of wells, rate and schedule of pumping, methods of well construction and development, and hydrogeologic characteristics. Unless the overlying property owner(s) chooses to drill a well, the water remains in the basin. In other cases, as the basin is de-watered, wells must be drilled deeper and water lifted greater distances to the surface. Although a groundwater basin is never completely depleted, higher pumping costs may eventually make use of a well infeasible.

Nearly one-half of Oklahoma's groundwater is found in the prolific bedrock basins of the west, including the massive Ogallala Formation and western alluvial and terrace deposits. Wells in those formations commonly yield as much as 2,000 gpm, but average about 300 gpm. Central Oklahoma contains about one-third of the state's groundwater resources where major aquifers generally yield 200 gpm, a generous supply for rural homes and some communities and industries. The average yield of aquifers underlying eastern Oklahoma is approximately 100 gpm. Specific information on the state's major groundwater basins is provided in the following section. Oklahoma's major bedrock and alluvial and terrace aquifers are delineated in Figures 5 and 6.

Whether referred to as stream or groundwater, springs remain an important source of supply for domestic, municipal, industrial, agriculture and other uses of water in the state. In addition, many springs supplement the flow -- or, in some cases, provide the headwaters and base flow -- for numerous rivers and streams in Oklahoma. Most springs of notable size in the state issue from aquifers in limestone and/or sandstone formations such as those in the Arbuckle Mountains, the Ozark region of the northeast, and the Black Mesa region of the Panhandle. Johnston County, much of which is underlain by the prolific Arbuckle-Simpson Aquifer, is likely home to the greatest density of measurable springs in Oklahoma that contribute substantially to the flows of Blue, Honey, Pennington and Mill Creeks as well as other streams draining mountains in the region.

Western Groundwater Basins

Withdrawals from the prolific aquifers in western Oklahoma account for approximately 80 percent of the state's total groundwater use. Major basins in the west are the Arbuckle-Timbered Hills Group, Blaine Formation, Rush Springs Sandstone, Elk City Sandstone, Cedar Hills Sandstone, Ogallala Formation and alluvial and terrace deposits.

The most prolific aquifer of the west -- and indeed, of the state -- is the Ogallala Formation underlying the Panhandle and parts of extreme western and northwestern counties. The Ogallala's areal extent, thickness and high permeability contribute to its capacity to store some 86.6 million acre-feet of water. Estimates in 1988 showed that 205,873 acres were irrigated from the Ogallala -- more than 90 percent of that total lying in the three Panhandle counties. In addition, it was estimated that some 3,200 high-capacity wells tapped the Ogallala region.

The greatest concentrations of high-capacity wells lie in south central (near Guymon) and northwestern Texas County. In Cimarron County, heavily developed well fields are found near Boise City and in the southwestern corner, near Felt. Overdevelopment and high pumpage could threaten the well-being of the aquifer and the agricultural economy it sustains. Overpumping of closely spaced wells can create a cone of depression, causing interference between wells and reducing the amount of water available to them. Such drawdown is common in more heavily irrigated areas. The long-term consequences of this situation include a decrease in the rate at which the pumps will deliver water, higher pumping costs, lower well yields, saline water encroachment and depletion of the aquifer. However, during the past several years, depressed markets for agricultural products and high fuel costs have encouraged some growers to return to dryland farming, allowing water levels in the Ogallala to stabilize somewhat.

In the southwest, reliance on groundwater is great and some areas are threatened by overdevelopment. The number of high-capacity wells has increased markedly over the past 30 years with groundwater supplying domestic, municipal and irrigation needs in the region. Pressure on groundwater supplies for irrigation is relieved somewhat in the Altus area where the W.C. Austin Project supplies stream water from Lugert-Altus Reservoir for irrigation of about 48,000 acres.

The climate in the southwest is semiarid; the 27 inches of annual rainfall is poorly distributed and droughts are frequent. Recharge from precipitation is much less than the amount of water withdrawn each year. Overdevelopment of groundwater resources is a problem in several basins of the southwest. The number of irrigation wells supplied by the Tillman Terrace deposits has increased from 80 in 1952 to 1,100 in 1988, resulting in water level declines around Tipton and Frederick. Dramatic changes in water levels have also been noted in the Rush Springs Sandstone of Caddo County, where declines have been reported in the Sickles area. The Blaine Formation also appears to be overdeveloped.

The Arbuckle-Timbered Hills Group (Cambrian-Ordovician in age) consists predominantly of carbonate rocks (limestone and dolomite) that outcrop in Comanche, Caddo and Kiowa Counties. The aquifer, approximately 6,000 feet in thickness, locally has high porosity and wells generally yield between 25 and 500 gpm. The aquifer is largely undeveloped and is used primarily for drinking water.

The Blaine Formation (Permian) occurs in Harmon and parts of Jackson, Greer and Beckham Counties. The groundwater basin, used almost exclusively for irrigation, consists of interbedded shale, gypsum, anhydride, dolomite and limestone that are characterized by solution channels and zones of secondary porosity. The yield from wells tapping the Blaine can reach as much as 2,500 gpm. However, due to the erratic nature of solution channels and cavities, it is difficult to predict yield or estimate amounts in storage. For a well to yield enough water for irrigation, it must tap a water-filled solution cavity in the aquifer. Water levels in the groundwater basin respond rapidly to infiltration of precipitation and to the effects of pumping.

The Rush Springs Sandstone (Permian) is an extensive groundwater basin outcropping throughout an area of 1,900 square miles from Stephens County in the south to Harper County in the north. 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 northern areas of the basin. Well yields average about 400 gpm. The primary use of the aquifer is for irrigation.

The Cedar Hills Sandstone (Permian) is found in Woods, Alfalfa and Major Counties. It is a fine- to medium-grained, reddish-brown sandstone, siltstone and silty shale. Thickness ranges from 150 to 180 feet. Well yields range from 150 to 300 gpm.

The Elk City Sandstone (Permian) occurs in western Washita and eastern Beckham Counties. It is similar to the Rush Springs basin in being a fine-grained sandstone with little or no shale; however, it differs from the Rush Springs in its smaller areal extent and relative thinness. Well yields range from 60 to 200 gpm.

The Ogallala Formation (Tertiary) consists of interbedded sand, siltstone, clay, lenses of gravel, thin limestone and caliche. The Ogallala, also referred to as the High Plains Aquifer, underlies almost the entire Panhandle region and extends into portions of Harper, Ellis, Woodward and Dewey Counties. Total thickness ranges from a few feet to more than 500 feet due to the irregular surface on which the Ogallala was deposited. Average thickness in the Panhandle is 300 feet.

The Ogallala is the major source of water in the Oklahoma Panhandle. While public suppliers throughout the region rely upon the aquifer, irrigation is by far the primary use of the Ogallala. More than 2,500 irrigation wells have been drilled in this area, many yielding as much as 1,000 gpm. In western Roger Mills and northern Beckham Counties, the Ogallala is partly eroded and thins to the east. Yields may be as great as 800 gpm, but because of thinning and erosion of the formation, typical yields are about 200 gpm.

In the northwest, the most prolific alluvial and terrace deposits lie along the North Canadian, Canadian and Cimarron Rivers where deposits are thick and yield as much as 700 gpm. Average yields for the alluvium and terrace are between 100 and 300 gpm. In the southwest, the deposits provide water in areas adjacent to the Washita, North Fork of the Red and Red Rivers in Roger Mills, Custer, Beckham, Greer, Kiowa, Jackson, Tillman and Cotton Counties. Total thickness of the alluvial and terrace deposits averages 70 feet, but saturated thickness is zero to 50 feet. Wells generally yield from 200 to 300 gpm, but locally may yield more than 500 gpm.

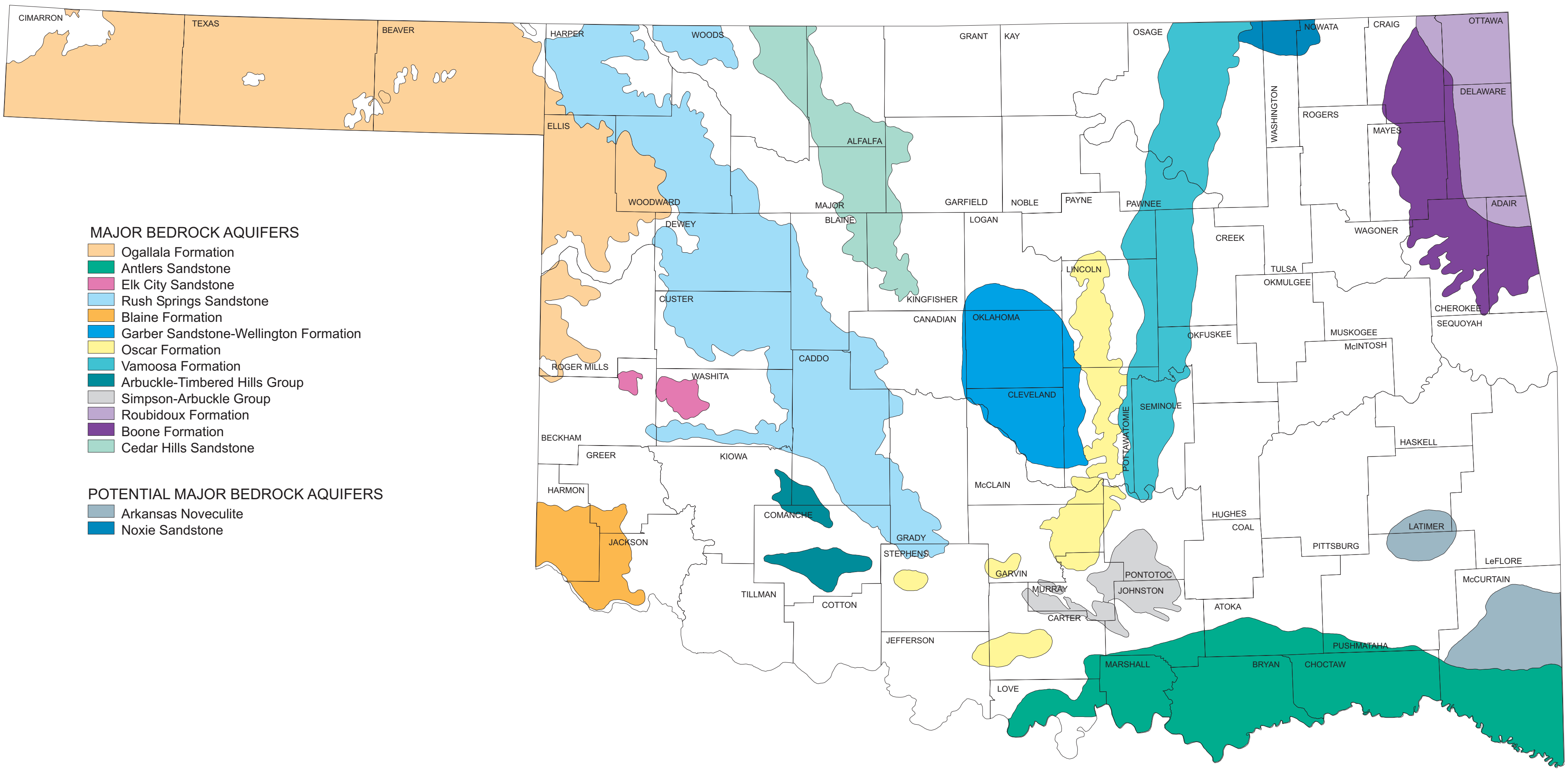
Central Groundwater Basins

Major groundwater basins in central Oklahoma are the Arbuckle-Simpson Group, Ada-Vamoosa Formation, Oscar Formation, Garber-Wellington Formation and alluvial and terrace deposits.

Development of the groundwater resources has increased rapidly due to growth in the cities, towns and rural areas that rely upon wells for domestic, municipal and industrial water. Growth in the suburbs and rural areas surrounding Oklahoma City has put heavy demands on the Garber-Wellington. The alluvial and terrace deposits of the North Canadian River are sources of water supply for many growing cities and for some central Oklahoma industries and irrigators. The Ada-Vamoosa Formation extends in a band from north to south in east central Oklahoma. It remains relatively undeveloped and most of the withdrawals are for municipal and industrial use. Oilfield brines and wastes have caused some local quality problems and overpumping could cause intrusion of saline water. The Arbuckle-Simpson Aquifer is largely undeveloped, although the basin is estimated to contain approximately nine million acre-feet of water in storage. Development in the Oscar Formation is sparse and the basin is of small areal extent.

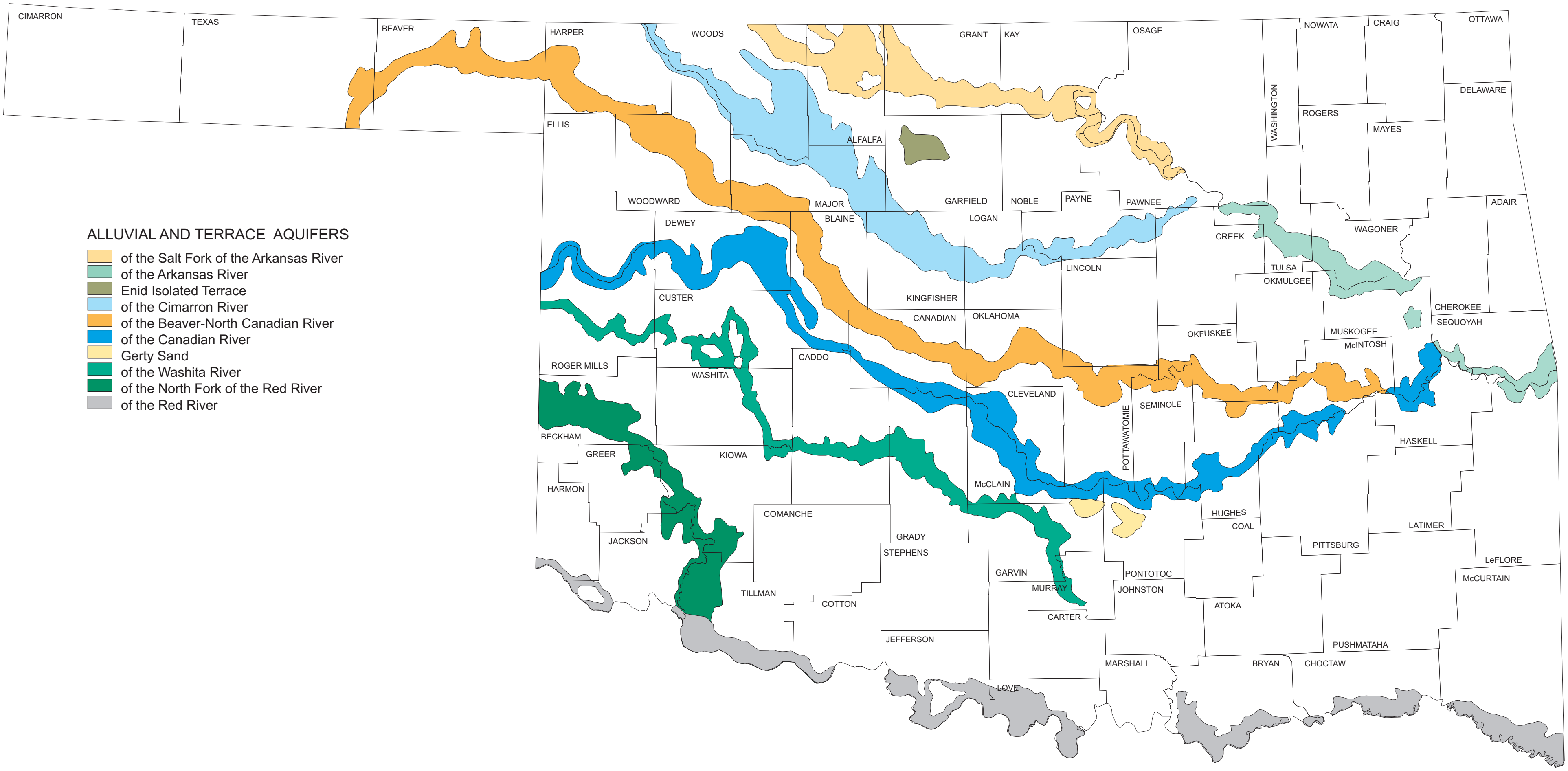
The Arbuckle-Simpson Group, consisting of the Arbuckle and Simpson Formations, is used primarily for drinking water but is largely undeveloped. The Arbuckle Formation (Cambrian-Ordovician) is limestone and dolomite, 5,000 to 6,000 feet thick. Relatively high permeability results from fractures, joints and solution channels in the limestone. In eastern Murray County, the formation is known to produce large quantities of water. Yields of 200 to 500 gpm are common and deeper tests have produced quantities in excess of 2,500 gpm. Well development is currently sparse.

The Simpson Formation (Ordovician) consists of fine-grained, loosely cemented and friable sandstones. The ground-



OKLAHOMA COMPREHENSIVE
WATER PLAN

Figure 5
MAJOR GROUNDWATER BASINS
BEDROCK



OKLAHOMA COMPREHENSIVE
WATER PLAN

Figure 6
MAJOR GROUNDWATER BASINS
ALLUVIAL AND TERRACE

water basin outcrops in an area of about 40 square miles in southwestern Murray and northeastern Carter Counties. Wells usually yield 100 to 200 gpm.

The Ada-Vamoosa Formation (Upper Pennsylvanian) is composed of 125 to 1,000 feet of interbedded sandstone, shale and conglomerate, with the proportion of shale increasing northward. The Ada-Vamoosa outcrops in Seminole, Okfuskee, Pottawatomie, Osage, Creek, Pawnee, Payne and Lincoln Counties. The formation supplies water for drinking and other municipal purposes as well as oil and gas operations. The most prolific wells are in the Seminole area where they produce up to 500 gpm. Yields change northward, decreasing from 250 gpm to around 10 gpm.

The Oscar Formation (Pennsylvanian) consists of interbedded shale, sandstone and limestone conglomerate with lithology varying from place to place. The formation is 300 to 400 feet thick and occurs in western Stephens, southwestern Garvin, southwestern Carter, western Lincoln and eastern Jefferson Counties. Depth to water is generally 100 feet below the surface. Well yields range from 60 to as much as 400 gpm but average 150 to 180 gpm. The groundwater basin is of major importance locally, but its long-term potential is unknown due to a lack of information and sparse well development.

The Garber-Wellington Formation (Permian), consisting of the Garber Sandstone and Wellington Formations, is primarily used for public supply and self-supplied domestic use. The two geologic units are considered a single water-bearing aquifer and were deposited under similar conditions, both containing alternating beds of sandstone and shale. The total thickness of the combined formations is 80 to 900 feet. Depth to water varies from 100 to 350 feet or less in areas of outcrop and ranges to 350 feet in structural depressions (such as Midwest City). Well yields range from 50 to more than 500 gpm and average 200 gpm. In Logan County, the aquifer is shaly and yields are 10 gpm or less near Guthrie.

In the north, alluvial and terrace deposits occur 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 through Kingfisher County into Logan County. The alluvial and terrace deposits along the Salt Fork of the Arkansas reach a maximum thickness of about 150 feet, while similar deposits along the Cimarron attain a thickness of up to 120 feet. Maximum saturated thicknesses of the Salt Fork and Cimarron are 35 and 50 feet, respectively. Well yields from the alluvium of the Salt Fork average between 100 and 200 gpm, and yields from the terrace are about 100 to 500 gpm. Well yields along the Cimarron range from 1,000 gpm to less than 50 gpm and average between 100 and 500 gpm.

In the Oklahoma City area, the alluvial and terrace deposits occur along the Canadian and North Canadian Rivers and Deep Fork of the North Canadian. Well yields range from less than 100 gpm to as much as 600 gpm, averaging 200 gpm. In the south, alluvial and terrace deposits provide generous 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. However, most wells yield smaller supplies of 20 to 100 gpm due to fine-grain sediments in the alluvial fill.

Eastern Groundwater Basins

Eastern Oklahoma's major groundwater basins are the Roubidoux Formation, Boone Formation, Antlers Sandstone and alluvial and terrace deposits. These major basins offer abundant water to municipalities and industries in the region. Overdevelopment is a problem in the Roubidoux Formation near the City of Miami where clustered wells have resulted in interference between wells and reduction in artesian head. Water that previously flowed at the surface now must be lifted 500 feet or more.

In the northeast, development in the alluvium occurs primarily along the Arkansas River where wells generally yield more than 100 gpm. There is also development potential in the springs of the Boone Formation which consists of fractured chert and cherty limestone. Where it outcrops, the basin produces bountiful springs that flow at the rate of about 100 million gallons per day.

Southeastern groundwater resources remain largely undeveloped because stream water is available in generous supply. Development occurs predominantly in the Antlers Sandstone and alluvial and terrace deposits. The area of greatest potential development lies along the Red River where wells yielding several hundred gallons per minute (gpm) are commonplace. The most favorable well sites are in formations with the greatest saturated thickness and coarsest material, such as the Antlers Sandstone, which supplies water to parts of Atoka, Bryan, Choctaw, Johnston, McCurtain and Pushmataha Counties. Yields range from a few gpm to more than 500 gpm.

The Roubidoux Formation (Upper Cambrian-Lower Ordovician) consists primarily of sandstone and cherty dolomite. The aquifer includes the Cotter, Jefferson City, 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 800 to 1,200 feet. The artesian or confined water is under sufficient pressure to rise above the surface. Due to years of pumpage, the artesian head has declined and, in some wells, water is lifted more than 500 feet to the surface. Yields can exceed 600 gpm, but the average is approximately 150 gpm.

The Antlers Sandstone (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 10-mile-wide belt in parts of Atoka, Bryan, Choctaw, Johnston, McCurtain and Pushmataha Counties. The aquifer ranges in thickness from 180 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 five to 50 gpm for water table wells to 50 to 650 gpm in artesian wells. An average yield for wells completed in the groundwater basin is 100 to 150 gpm.

The Boone Formation (early to late Mississippian) consists of limestone and cherty limestone averaging about 300 feet in thickness. Containing numerous fractures and solution channels, the Boone is the source of many springs that play an important part in maintaining the year-round flow of area streams.

Alluvial and terrace deposits along the Arkansas River, which occur in a band from one to six miles wide, are extremely generous in their water supply. Near Tulsa, the alluvium is about 30 feet thick while, downstream at Webbers Falls, the thickness is about 55 feet. Yields generally range from 100 to 500 gpm with the greatest yields issuing from sand layers.

Along the Arkansas and Canadian Rivers, total thickness of the deposits averages 42 feet and the saturated thickness is between 25 and 75 feet. Well yields range from 100 to 500 gpm. Along the Canadian River, the alluvium is 35 feet thick locally, yielding up to 200 gpm in most areas. In the southeast, 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 about 200 gpm.

GROUNDWATER QUALITY

The natural quality of groundwater reflects the chemical composition of the rocks with which it comes in contact. As water seeps through soil and rock, it takes varying types and concentrations of minerals into solution, depending upon the geologic constituents of individual formations, solubility of minerals in those formations and duration of contact. Groundwater quality is also determined, to a great extent, by human activities which contribute nitrates, chlorides and varying concentrations of numerous other substances to underground supplies.

Due to the potential for harm to human health, state and federal agencies keep a close eye on groundwater quality. Stringent federal standards have been developed for groundwater that is used for drinking while Oklahoma has promulgated separate guidelines to protect underground supplies used by industry, agriculture and other users. In 1982, as a preliminary step toward development of comprehensive groundwater standards for Oklahoma, the OWRB initiated an extensive groundwater quality/well sampling program in cooperation with the U.S. Geological Survey. Although the statewide program was discontinued several years ago, the USGS, OWRB and various other agencies and municipalities continue localized and program- specific groundwater quality monitoring efforts throughout Oklahoma.

The 1982 Oklahoma Water Quality Standards were the first to designate standards and beneficial uses for the state's major groundwater basins while the 1985 document was the first to include specific organic parameters for groundwater. Unlike stream water quality standards, EPA does not approve or disapprove state groundwater quality standards. The standards apply to all fresh groundwater (defined under state law as groundwater with a maximum total dissolved solids concentration of less than 5,000 parts per million) in the state. In general, they require that groundwater be maintained to prevent alteration of its chemical properties by harmful substances not naturally found in groundwater. This is accomplished by utilizing narrative criteria, 36 numeric standards for organic compounds, and a three-tired classification system based on the resource characteristics of each individual groundwater basin. The state continues efforts to develop comprehensive quality standards for Oklahoma groundwaters.

Except for the Dog Creek-Blaine and Arbuckle-Timbered Hills aquifers, where large sulfate and fluoride concentrations, respectively, preclude their general use for public water supply, the majority of the state's principal groundwater formations provide water supplies that generally meet federal and state standards for drinking water. However, not all areas or depths within these aquifers produce water suitable for public supply. In addition, water is hard to very hard in all principal aquifers but the Arbuckle-Timbered Hills and all contain water of acceptable quality for irrigation of at least some crops. Water from Oklahoma's alluvial and terrace aquifers, though typically very hard, is withdrawn primarily for irrigation and domestic supply. However, high nitrate, chloride and sulfate concentrations found in some areas and at various depths decrease the suitability of that water for public supply.

Primarily utilizing representative data provided by the USGS from water samples collected from 1946 to 1986, the following section presents a generalized overview of water quality in the state's major groundwater basins and alluvial and terrace formations.

Western Groundwater Basins

Where permeability is high, water in the Arbuckle-Timbered Hills Group may be suitable for industrial use. The water is soft and of a sodium-potassium mixed type. Throughout much of the formation, chloride concentrations are high and fluoride concentrations are very high. This generally precludes use of the aquifer for public supply.

Water quality in the Blaine Formation is poor due to its hardness and very high calcium sulfate concentrations, primarily resulting from the solution of gypsum and dolomite in the aquifer. Locally, in southeastern and northwestern Harmon County, the water has a high sodium chloride content. Water in the Blaine is used exclusively for irrigation and is unsuitable for public supply.

Most of the water derived from the Rush Springs Sandstone is suitable for domestic, municipal, irrigation and industrial use, although chloride and sulfate concentrations exceed drinking water standards in some areas. However, in most areas, concentrations of dissolved solids are within the recommended level for public supply.

Although limited data is available on water quality in the Cedar Hills Sandstone, it is generally considered suitable for most purposes, as is water from the Elk City Sandstone.

Water yielded from the Panhandle portion of the Ogallala Formation is of a calcium-magnesium chloride-sulfate type. Although hard, the water is suitable for use as public supply. However, excessive concentrations of chloride, sulfate and fluoride make the water unsuitable in some areas.

Water quality in alluvial and terrace deposits in northwest Oklahoma is affected by adjacent streams and the water is generally poor where the deposits directly overlie the Ogallala and are not in contact with Permian red beds in the region. In the southwest, water quality is good and, except for hardness and localized nitrate problems, the water is appropriate for domestic, irrigation, industrial and municipal use.

Central Groundwater Basins

Water in the Arbuckle-Simpson Group is generally very hard and of a calcium magnesium bicarbonate type. In the Simpson Formation at Sulphur, water from the sandstones is of poor quality. Overall, total dissolved solids are relatively low and the quality is good, however, large concentrations of chloride and fluoride in certain areas may make the water unsuitable for public supply.

Although water quality is generally good in the Ada-Vamoosa Formation, iron infiltration and hardness are problems in some areas. The water is of a sodium bicarbonate or sodium calcium bicarbonate type. Chloride and sulfate concentrations are generally low and, except for areas of local contamination resulting from past oil and gas activities, water is suitable for use as public supply. Similarly, water from the Oscar Formation is considered suitable for municipal use and most other purposes.

Water from the Garber-Wellington Formation is of a calcium magnesium bicarbonate type and ranges from hard to very hard. In general, concentrations of dissolved solids, chloride and sulfate are low. Water from the aquifer is normally suitable for public water supply, but concentrations of sulfate, chloride, fluoride or other mineral constituents in some areas may exceed drinking water standards.

The quality of water varies in alluvial and terrace deposits in the central region. Water from the Cimarron and Salt Fork of the Arkansas River terrace deposits is generally suitable for most purposes, except in some areas where saltwater encroachment has precluded its use for domestic purposes. The water is generally hard and of a calcium magnesium bicarbonate type. In most areas, dissolved solids concentrations in the Cimarron and Salt Fork formations are below drinking water standards. Water from the alluvium deposits is generally poor due to high sulfate and chloride concentrations.

Hardness, nitrates and total dissolved solids are the principal water quality problems in alluvial and terrace deposits of the Canadian, North Canadian and Deep Fork of the North Canadian Rivers where water is of a calcium magnesium bicarbonate type. In the south, overall quality is good although water is better in the terrace than alluvium because the terrace deposits generally receive less water from the adjacent bedrock basin and are not affected by influent seepage of sometimes mineralized river water. Overall, dissolved solids concentrations are high in the Red and Washita River alluvial and terrace formations.

Eastern Groundwater Basins

Although water in the Roubidoux Formation is hard, it has a generally low total mineral content. In Ottawa County, the water is a calcium bicarbonate type of good quality and is widely used for public supply. However, in some areas, especially farther west, concentrations of chloride, sulfate and fluoride exceed drinking water standards. Except for moderate hardness, water from the adjacent Boone Formation is of good quality but, due to its lithology, the aquifer is susceptible to contamination from surface sources.

The quality of water is good in the outcrop areas of the Antlers Sandstone and is suitable for industrial, municipal and irrigation use. Downdip from the outcrop, the quality of the water deteriorates somewhat.

Alluvial and terrace deposits in the east yield water which is generally hard. Water in the Arkansas River alluvium, typically of a sodium or calcium bicarbonate type, exceeds drinking water standards in some areas. Water in the Canadian River alluvium is predominantly of a calcium magnesium bicarbonate type and variable in dissolved solids content. It is generally suitable for most purposes.

Overview of Water and Related Resources

Part 2

Natural Resource & Socioeconomic Characteristics

An almost endless array of environmental and socioeconomic characteristics -- including climate, geography, geology, minerals, soils, agriculture, wildlife, recreation, archeology, commerce population and employment -- which affect the current and future availability and use of Oklahoma's surface and groundwater supplies.

CLIMATE

Climate, along with geography, has a profound influence on water resources and hydrologic characteristics in Oklahoma, which lies across two divergent climatic regions. The state's relatively long distance from the moderating effect of the oceans and an absence of mountains to the north often allows cold arctic winds to reach Oklahoma during the winter, which is normally short and mild. In the spring, large thunderstorms develop when warm, moist air from the Gulf of Mexico converges with colder northern, humid eastern and dry western air masses, often producing tornadoes and large hail. Summers in Oklahoma are usually long and hot, punctuated by droughts of varying degree and duration. Fall, though often wet, normally features mild days and cool nights. May ranks as the wettest month while January is the driest.

Annual rainfall (Figure 7) varies from more than 50 inches in the relatively warm and humid pine forests of the Ouachita Mountains in southeast Oklahoma to approximately 16 inches in the high plains of the western Panhandle where warm days and cool nights predominate. The state-averaged precipitation is 33.5 inches. The temperatures in Oklahoma (Figure 8) vary from approximately 54 to 62 degrees Fahrenheit from west to east with a state average of 60.5 degrees. Average snowfall accumulations range from less than five inches in the southeast to 25 inches in the northwest and Panhandle. The growing season, defined as the period between the average date of the latest freeze in the spring and the first freeze in the fall, ranges from 170 days in the Panhandle to 240 days in south central Oklahoma.

Official records show an all-time low annual rainfall total of 6.53 inches at Regnier in Cimarron County (1956) while, one year later, the record high of 84.47 inches was recorded at Kiamichi Tower in LeFlore County. High temperature readings of 120 degrees mark the official record at several reporting stations (Altus, Alva and Poteau, 1936; Tishomingo, 1943; and Tipton, 1994) while minus 27 degrees occupies the record low at Watts (1930) and Vinita (1905).

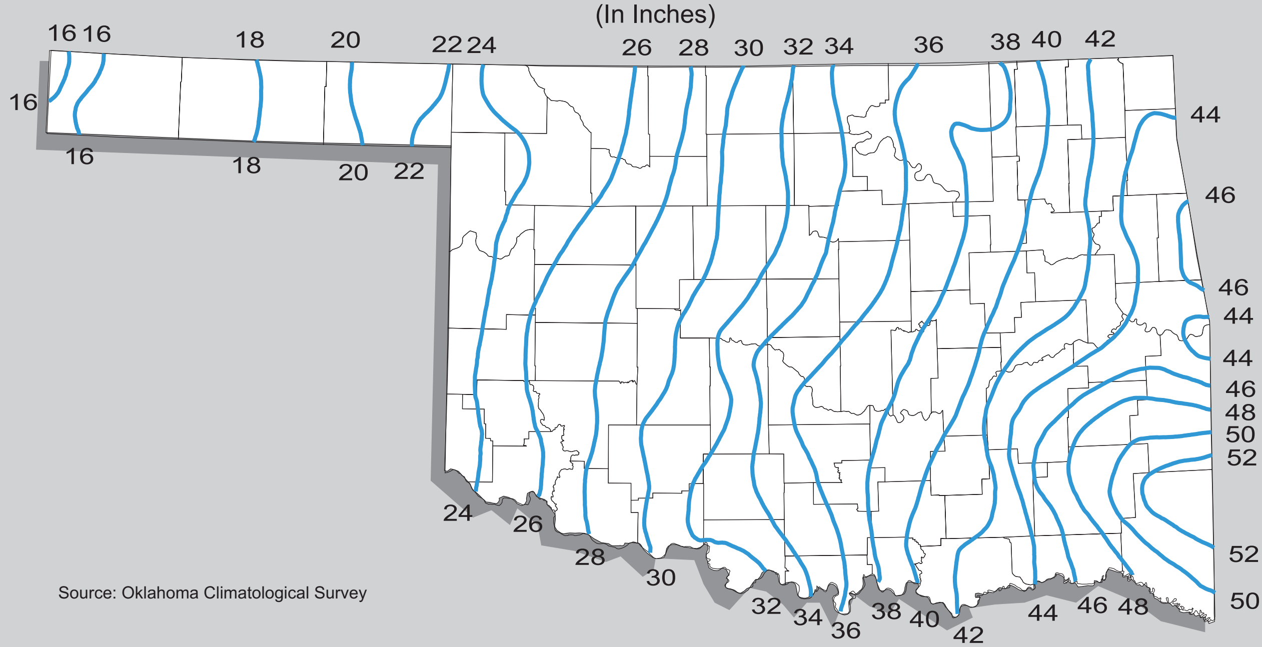
Only Texas, Kansas and Iowa report more tornado sightings than does Oklahoma. Although they can occur at any time, tornados most often appear during the spring months of April and May moving along cold fronts from the southwest to northeast. From 1950 to 1992, Oklahoma County has had the most tornado occurrences (72), followed by Kay (70) and Caddo (69).

Flooding has plagued Oklahomans throughout history, with the most frequent and damaging events occurring in the east. Some of the early catastrophic flooding events which affected Oklahoma, such as those in 1912 and 1913, occurred when the Mississippi River overran its banks. During the 1923 flood, the North Canadian River breached Lake Overholser Dam, inundating much of Oklahoma City. Perhaps the most widespread flood in modern Oklahoma history occurred in 1957. Virtually all railroad and highway bridges in the Cimarron River Basin were damaged or destroyed and hundreds of thousands of acres of agricultural land was inundated throughout the state.

As Oklahoma developed, flood losses grew. The years between 1955 and 1975, during which the state suffered some $167 billion in flood losses, were punctuated by the Enid flood of 1973 that caused $78 million in damages and took nine lives. The City of Tulsa, a community ravaged by regular flooding, experienced one of the worst natural disasters in state history when 14 lives were lost and damages in excess of $180 million were incurred as a result of the 1984 Memorial Day flood.

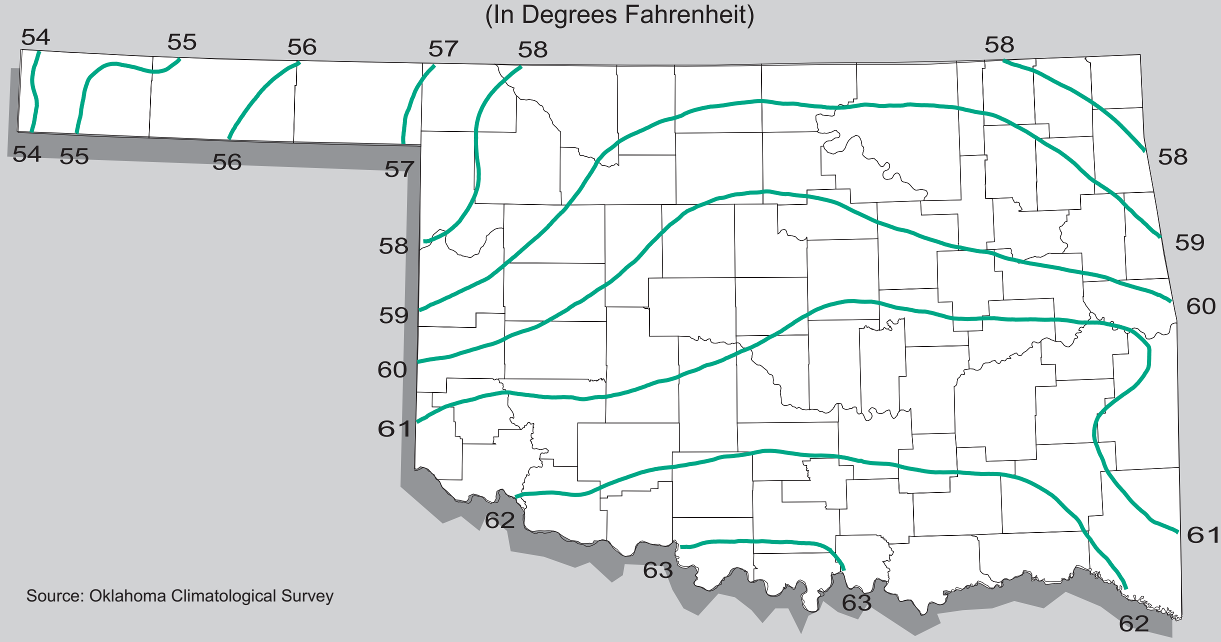
Like other southern Great Plains states, Oklahoma has scorched under extended periods of drought. While determination of the onset and conclusion of drought is a rather subjective undertaking, the most serious episodes seem to impact the state in approximate 20-year cycles. Notable among them were the dry years that occurred at the end of the century and again in 1910 and 1919. However, utilizing data gathered from long-term streamflow measurement stations established in the 1920's and 30's, the U.S. Geological Survey has identified four major droughts in Oklahoma history. The initial episode, which lasted from 1929 to 1941, is probably the most notable due to the major soil damage and wind erosion which resulted during the

Figure 7
AVERAGE ANNUAL PRECIPITATION 1961-1990
(In Inches)



Source: Oklahoma Climatological Survey

Figure 8
MEAN ANNUAL TEMPERATURE 1951-1980
(In Degrees Fahrenheit)



Source: Oklahoma Climatological Survey

Figure 9
AVERAGE ANNUAL RUNOFF 1951-1980
(In Inches)

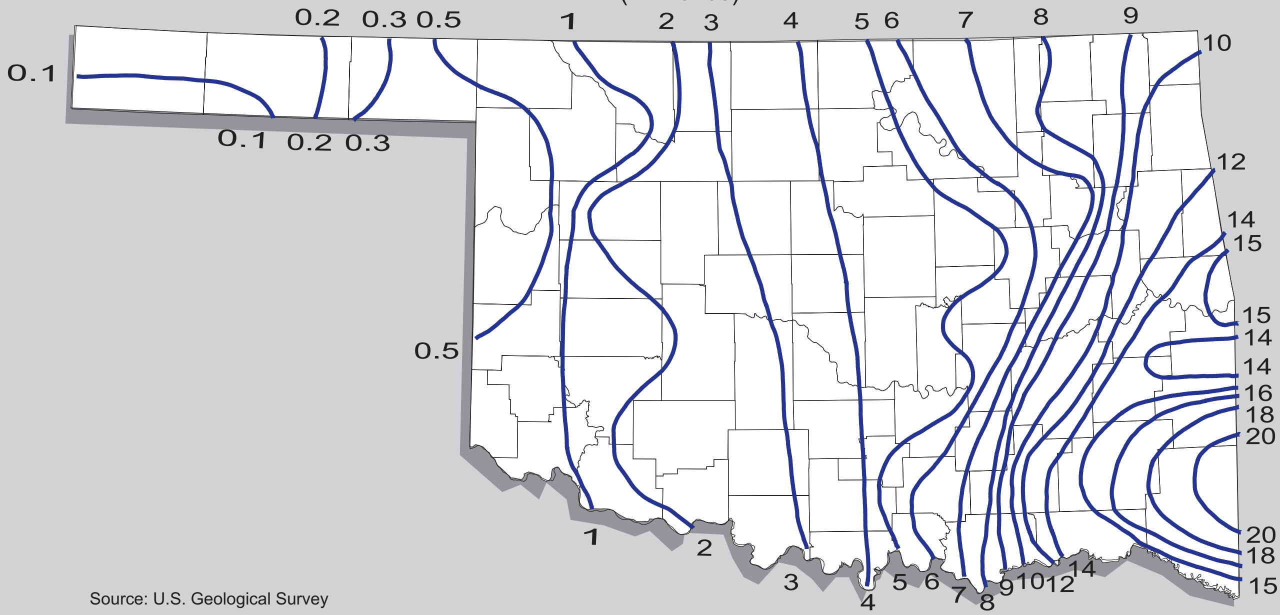
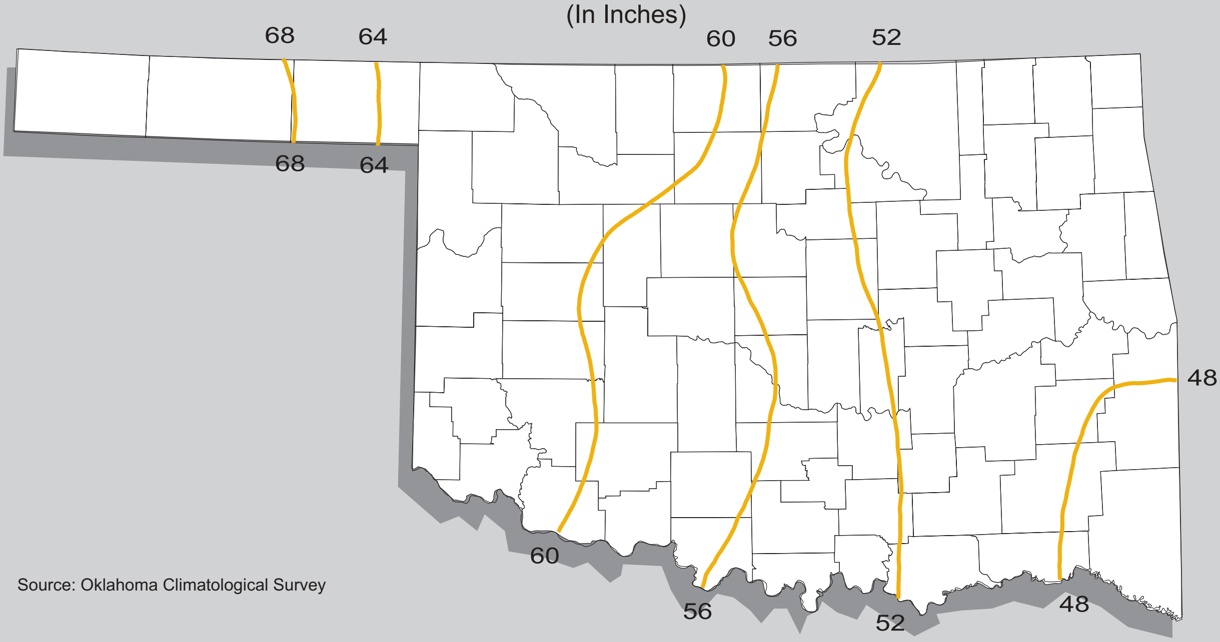


Figure 10
AVERAGE ANNUAL LAKE EVAPORATION 1961-1990
(In Inches)

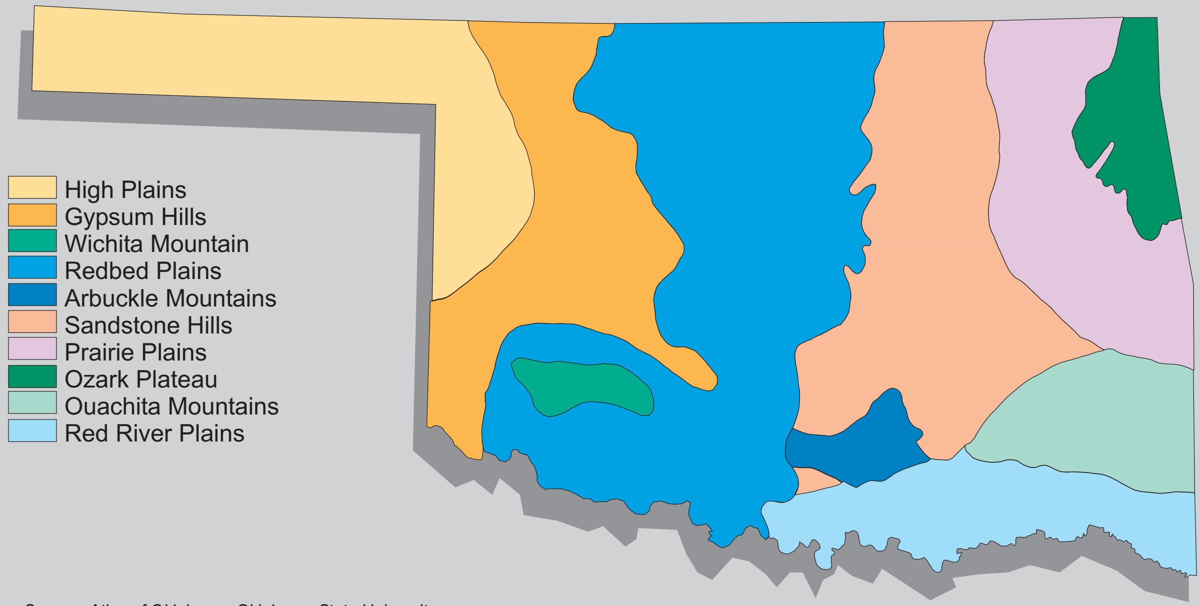


"Dust Bowl" period. The 1951-57 drought was less severe but more widespread, prompting many Oklahoma communities to improve and enlarge their water supplies. The entire state was again affected by the 1961-72 drought, although it was temporarily interrupted by a brief period of above average streamflow. The latest, and relatively least severe, drought occurred from about 1975 to 1982.

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

The state's abnormal rainfall pattern, coupled with evaporation enhanced by strong winds and percolation of water into the ground, results in an average annual runoff of .20 to 20 inches from west to east, respectively (Figure 9). Runoff, a measure of the amount of precipitation that flows over the surface, is the

Figure 11
PHYSIOGRAPHIC REGIONS



Source: *Atlas of Oklahoma,* Oklahoma State University

most telling factor regarding water availability. Evaporation (Figure 10) and percolation preclude immediate use of approximately 80 percent of Oklahoma's water. Average annual lake evaporation ranges from 48 inches in the extreme east to 65 inches in the southwest, numbers that far exceed the average yearly rainfall in those areas. Despite an often crucial need for water in the semi-arid west and significant development of surface sources in the humid east, an estimated 34 million acre-feet of unused water flows out of the state each year through Oklahoma's two major river basins.

GEOGRAPHY

From northwest to southeast, the Oklahoma topography slopes gently (about five feet per mile) while vegetation thickens as the country-side changes from semi-arid plains to woodlands and mountains. Elevations range from 4,973 feet on Black Mesa, the three-mile-long remnant of a basaltic lava flow in the northwest corner of the Panhandle, to 287 feet above sea level where the Little River enters Arkansas in the southeast. The state's varied physiography is presented in Figure 11.

The High Plains of western Oklahoma is actually a plateau region with a relatively dramatic, though gentle, eastward/southeastward slope of 12 feet per mile in some areas. The altitude drops almost 3,000 feet from the summit of Black Mesa to western Woodward County, where it begins to level off somewhat to the southeast corner of McCurtain County. Resistant rock masses have been folded, faulted and thrust upward to form the state's three principal mountain systems -- the Wichita Mountains in the southwest, the Arbuckle Mountains in south central Oklahoma, and the Ouachita Mountains in the southeast. Sugar Loaf Mountain, eight miles west of Poteau, represents the highest relief in Oklahoma as it rises some 2,000 feet above the surrounding plains.

Southeast Oklahoma is marked by pine and mixed forests, but other large portions of the east are covered with hardwoods. A broad area of primarily oak forest, known as the "Cross Timbers," dominates a substantial section of central Oklahoma. Between these wooded areas and west of the Cross Timbers lie regions of tall-grass prairie, most of which have been converted to fertile farmland. As the land continues its upward slope west of the Cross Timbers, trees are less common and plains become the dominant feature.

The natural vegetation of Oklahoma can be divided into three major categories. In order of abundance, they are grasslands; savannahs and woodlands; and forests. A mixed-grass prairie covers most of western Oklahoma, which has been cultivated into one of the most productive wheat-producing regions in the world. While most of the Panhandle is shortgrass prairie, areas in the extreme west feature vegetation more commonly found in rugged plateau areas characteristic of the American west. Tall grasses are common in the north and east. Savannahs and woodlands, which include the Cross Timbers, are found throughout Oklahoma, except in the Ouachita Mountains and Ozark Plateau.

Approximately one-fifth of Oklahoma's total land area is forested, especially in the east where rainfall is abundant and the rugged topography is not conducive to most agricultural uses. State forests contain 144 species of native trees with varied species reflecting the state's considerable geographic range. Varieties include short leafed and loblolly pine, sweet gum, pecan, cypress, mesquite, pinyon-juniper, several types of oak, cottonwood and walnut. The Ouachita Mountains are home to the largest forested area in the state.

In the early 1900's, Oklahoma's forests covered some 19 million acres, or 40 percent of the state's total land area. Since that time, many forested areas have been cleared for crop production and pastureland or have been inundated by large reservoirs. Although the amount of the state's land area covered by forests has dwindled considerably today, forests continue to provide substantial erosion control and protect the quality of Oklahoma's water resources. They also supply vital habitat for wildlife and enhance opportunities for tourism and recreation. In addition, the forest industry contributes enormously to the state's economy.

According to data compiled for the National Resources Inventory (1982-87), Oklahoma has a total area of 44,771,700 acres, with 43,964,600 land acres. This land area includes 14,546,100 acres classified as rangeland; 11,557,300 acres of cropland; 7,590,100 acres of pastureland; 6,504,900 acres of forest land; and 926,300 acres of urban and built-up land.

Osage is the state's largest county, covering 2,251 square miles; Marshall County, 371 square miles, is the smallest. Cimarron County, in the Panhandle, is the only county in the nation whose border is adjacent to four other states (Kansas, Colorado, New Mexico and Texas).

GEOLOGY

Most of the rocks that outcrop in Oklahoma are of sedimentary origin, consolidated from sediments deposited during the Paleozoic, Mesozoic and Cenozoic Eras. The Paleozoic strata, consisting principally of sandstone and shale, cover about 75 percent of the state and they are as much as 40,000 feet thick in some areas. Most of the Panhandle region and some of western Oklahoma is covered by rocks of Tertiary age, represented in the Ogallala Formation. The oldest rocks in Oklahoma are the Precambrian granites and rhyolites formed more than one billion years ago. Precambrian and Cambrian igneous and metamorphic rocks underlie all of the state and provide the "floor" upon which all younger rocks rest.

The three principal mountain belts -- southern Oklahoma's Ouachita, Arbuckle and Wichita Mountains -- were formed by folding, faulting, and uplift during the Pennsylvanian Period. North of these mountain uplifts lie the deep Anadarko and Arkoma basins, and still farther north, the relatively undisturbed shelf areas of Oklahoma.

Mesozoic sedimentary rocks of Oklahoma were deposited in a mixture of marine and non-marine environments. Shallow seas covered southern and western Oklahoma during some of the era's Cretaceous Period, resulting in the deposition of limestone and shale.

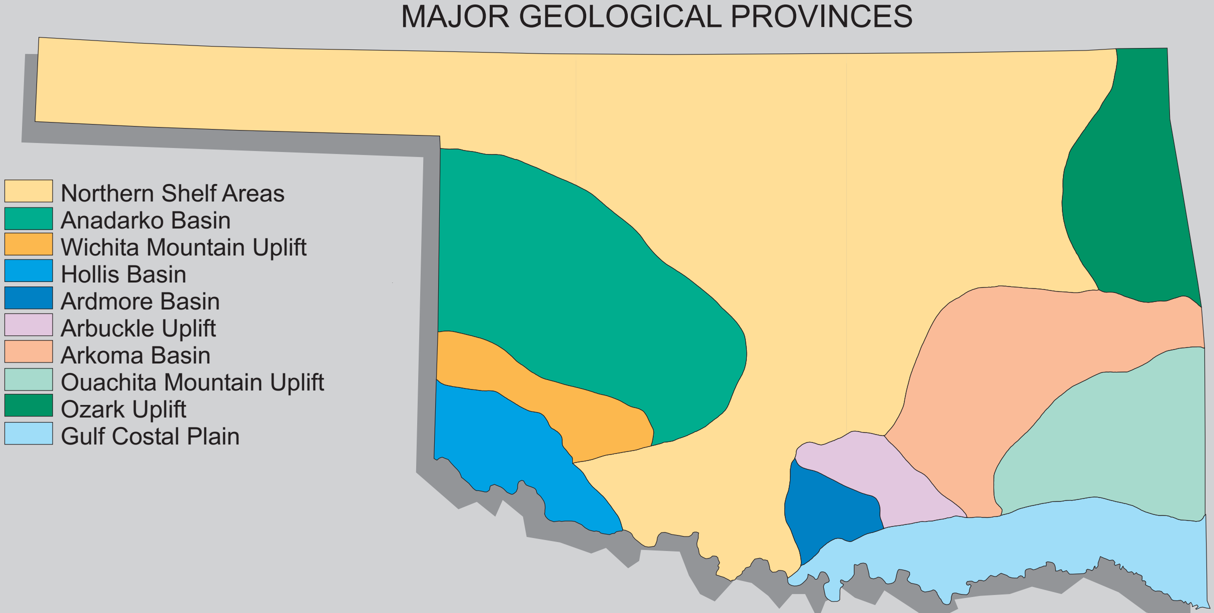
Since the beginning of the Tertiary Period, none of the state has been covered by sea water. Because Oklahoma's land surface sloped down to the east and southeast, extensive deposits of Tertiary sand and gravel were washed in by large rivers flowing eastward from the newly formed Rocky Mountains.

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

Oklahoma's subsurface contains 10 major geological provinces (Figure 12). The Northern Shelf Area, the state's largest province extending over most of north Oklahoma and the entire Panhandle, is comprised of outcrops of sand, sandstone and shale, with a scattering of gypsum. The Anadarko Basin, in the west central region, contains large deposits of gypsum, shale and sandstone.

The Wichita Mountain Uplift is characterized by peaks of Cambrian granite and related igneous rocks that tower up to 1,100 feet above the surrounding terrain. This province also contains extensive outcrops of limestone, sand and shale. The adjoining Hollis Basin, in extreme southwest Okla-

Figure 12
MAJOR GEOLOGICAL PROVINCES



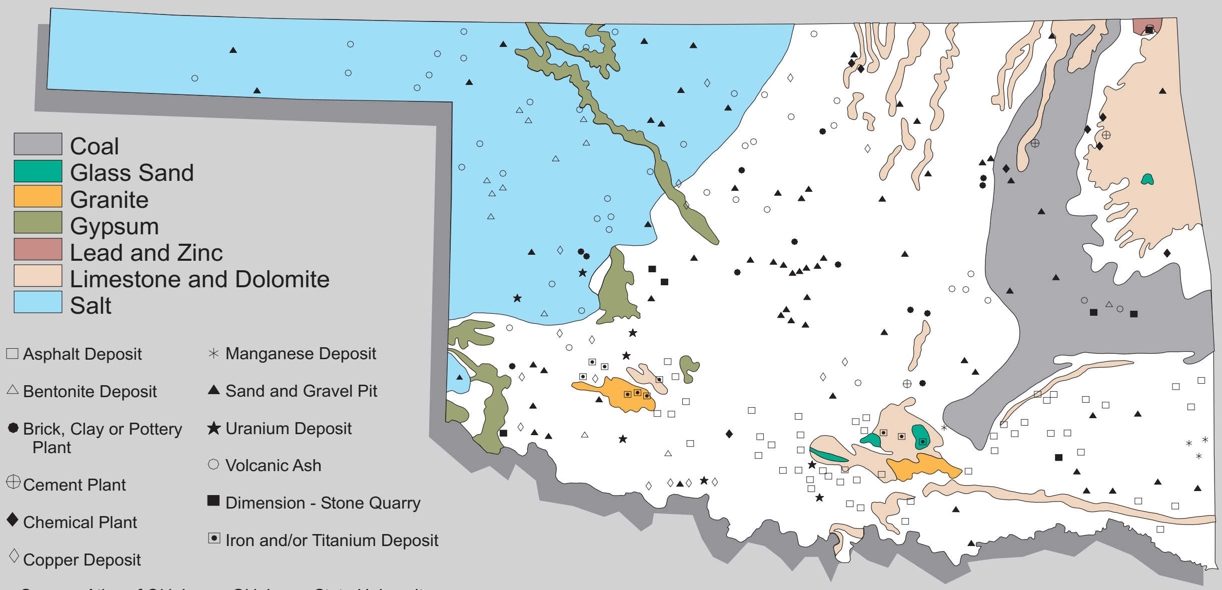
Source: *Atlas of Oklahoma,* Oklahoma State University

homa, contains outcrops of gypsum, shale and sandstone.

The Ozark Uplift, which occupies much of northeast Oklahoma, consists of deeply dissected Mississippian limestone and cherts. The Arkoma Basin, in the east central region, is comprised primarily of limestone, sandstone and shale while tightly folded sedimentary rock types, Ordovician to Pennsylvanian in age, make up the adjacent Ouachita Mountain Uplift.

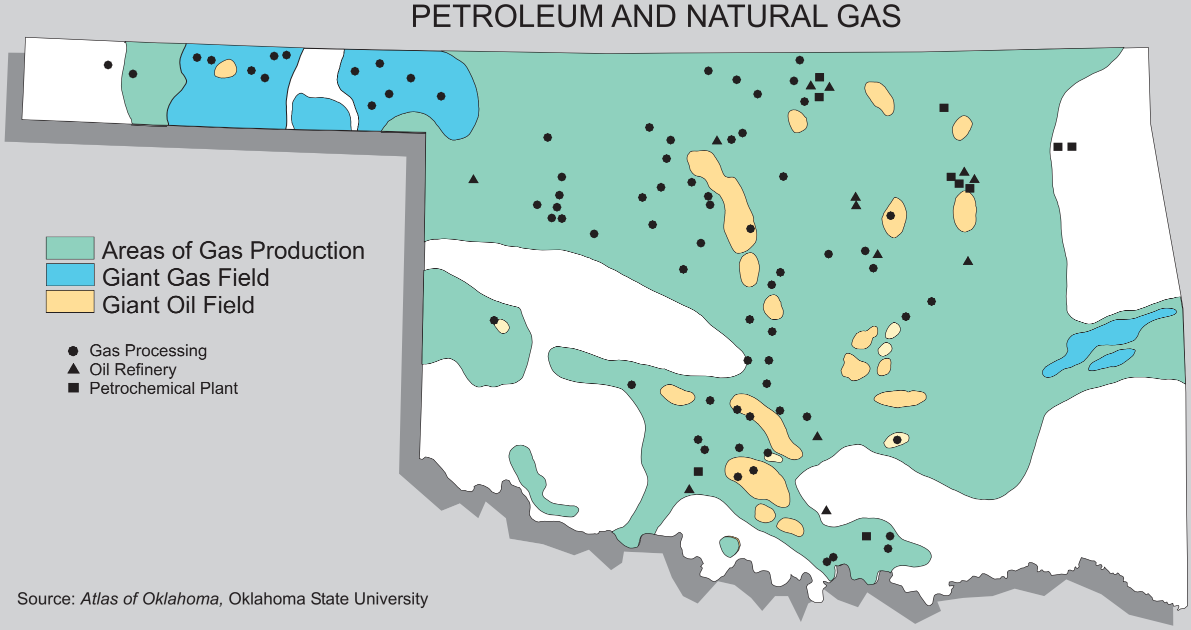
Along the Red River in southeastern Oklahoma, the Gulf Coastal Plain is comprised of shale, limestone, sandstone and large deposits of sand. The state's final two geological provinces are located entirely within state boundaries in southern Oklahoma. The Arbuckle Uplift contains primarily limestone and dolomite, Cambrian to Mississippian in age, along

Figure 13
MINERAL RESOURCES



Source: *Atlas of Oklahoma,* Oklahoma State University

Figure 14
PETROLEUM AND NATURAL GAS



Source: *Atlas of Oklahoma,* Oklahoma State University

with sandstone, granite and gneiss. The nearby Ardmore Basin consists of outcrops of Mississippian, Pennsylvanian and Permian shales with sandstones and thin limestones.

MINERALS

Oklahoma's primary mineral resources are oil and gas, with a number of other minerals produced on a smaller scale. Reflecting the worldwide escalation of oil prices, the total value of mineral production in Oklahoma reached a record $11 billion in 1983, compared to approximately $5.5 billion in 1993. About 95 percent of the 1993 value was derived from the production of fossil fuels while a wide variety of nonmetallic minerals (such as granite, gypsum, iodine, stone, sand and gravel) accounted for the remaining five percent. Figure 13 shows the general locations of mineral resources in Oklahoma.

Crude oil and natural gas (Figure 14) are the leading mineral commodities in the state. In the 17-year period from 1977-94, Oklahoma produced approximately 2.3 billion barrels of oil valued at $51 billion and 33.5 trillion cubic feet of gas valued at $59 billion. Oil and/or natural gas have been produced in every county in the state except Adair, Choctaw, and Delaware Counties.

Coal is one of the primary resources in an 8,000 square-mile area of eastern Oklahoma. Coal beds in this region range in thickness from one to eight feet while overall coal resources total approximately 7.2 billion tons. Thick sequences of salt underlie most of western Oklahoma at depths of 30 feet to more than 30,000 feet. An estimated 20 trillion tons of salt reserves remain virtually untapped in the region. Current salt production occurs at a single solar evaporation plant in Woods County.

Other resources produced in the state are dolomite, limestone, granite, sand and gravel, glass sand, gypsum, clays and iodine. Dolomite and limestone deposits are located primarily in northeastern Oklahoma and in the Arbuckle and Wichita Mountains. Granite is quarried near Snyder and Granite in southwestern Oklahoma and near Mill Creek and Davis in the Arbuckles. Sand and gravel pits are located throughout the state. Glass sand, used in the manufacture of high-purity glass, is produced in the south central region. Gypsum outcrops in the west yield about 2.7 million tons of the mineral each year. Oklahoma is the only domestic producer of iodine; in 1993, the state's three iodine companies (located in northwest Oklahoma) produced about 2 million kilograms, approximately one-third of the nation's iodine needs.

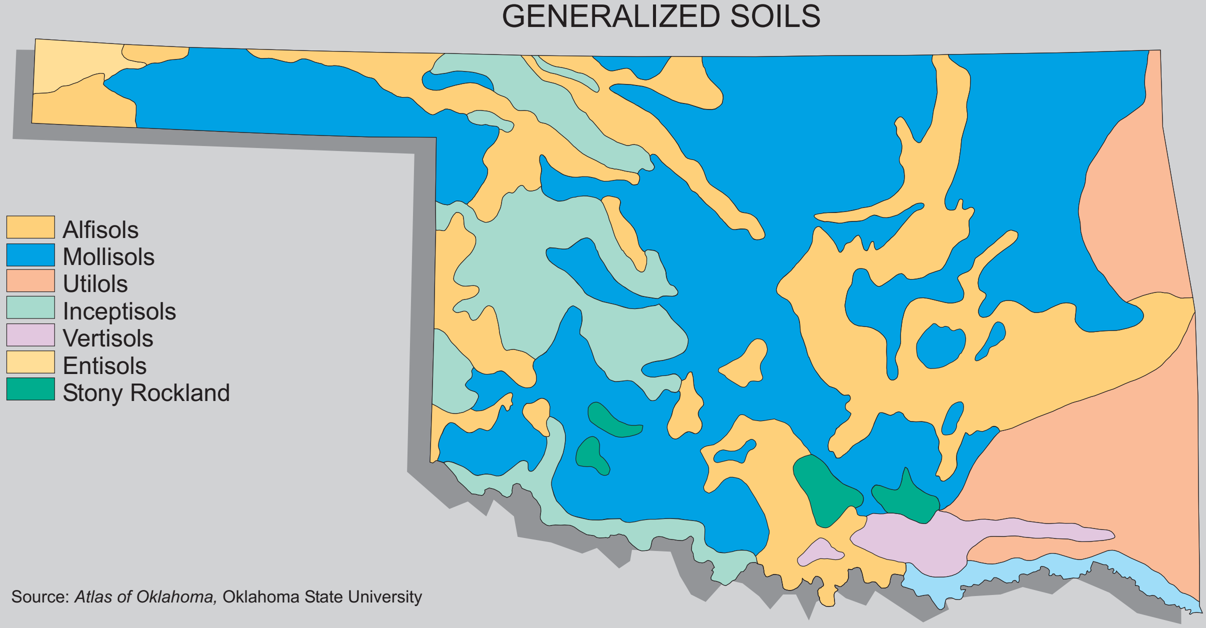
SOILS

Oklahoma soils are diverse, ranging from the rich limestone soils of the prairie to alluvial soils of river valleys to thin sandy and red clay soils. Seven of the eleven soil orders recognized in soil taxonomy -- Alfisols, Aridisols, Entisols, Inceptisols, Mollisols, Ultisols and Vertisols -- are found inside the state's borders (Figure 15). Within orders, soils are subdivided into groups, subgroups, families and, finally, into a soil series. In turn, soil series are grouped into associations which occur in a defined proportional pattern or on a unique landscape whose characteristics, such as climate, parent material and natural vegetation, are similar. Oklahoma soil surveys are made according to this type of soil classification system.

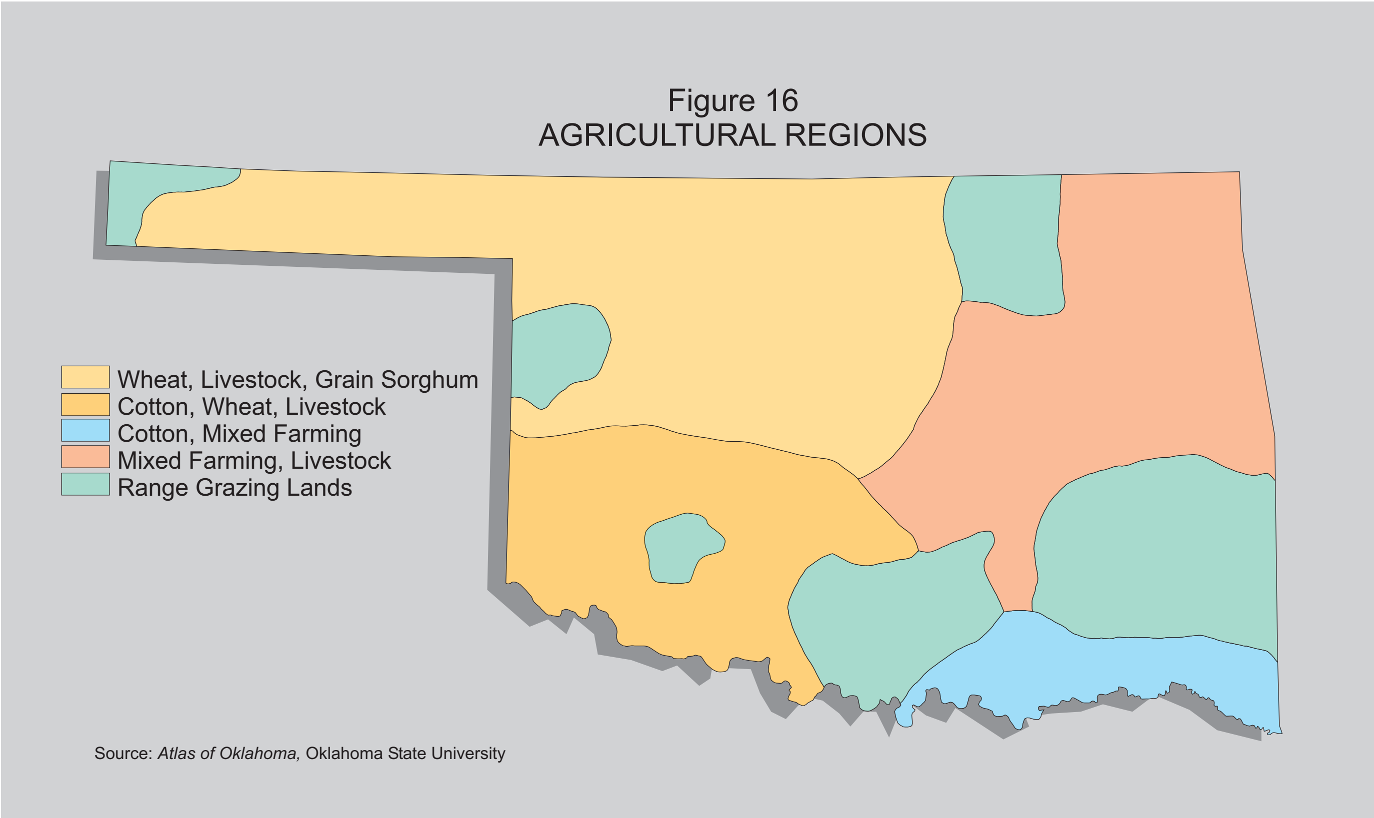
Alfisols are found throughout much of the state but are most prevalent in areas where surface organic matter is low and precipitation is high enough to develop subsoils with translocated clays. Aridisols are found only in the western parts of the Panhandle region. These soils are usually shallow or very sandy and hold only small amounts of available plant water.

Entisols are found throughout the state and are normally considered as

Figure 15
GENERALIZED SOILS



Source: *Atlas of Oklahoma,* Oklahoma State University



"young" soils due to their position or stage of development. They occur either as recent depositional soils along floodplains or as shallow, slightly weathered soils on slide slopes and summits of landscapes. Inceptisols are soils where profiles have shown only weak horizon development. While found statewide, the largest concentrations occur in western Oklahoma.

Mollisols, Oklahoma's most abundant soil order, normally have thick, dark surface horizons rich in organic matter. They are generally considered as grassland prairie soils found in northern, central and western Oklahoma. Ultisols, which occur only in the warm, humid climate of eastern Oklahoma, are highly leached and generally have low natural fertility with relatively high acid content. Vertisols contain high shrink/swell clays that form deep cracks upon drying. They are found primarily in prairie soil formed from limestones or in playa lakebeds in the Panhandle region.

AGRICULTURE

Oklahoma agriculture is both rich and diverse, contributing significantly to the state's economy. Agricultural products and activities range from cattle feedlots, ranches and large farms in the High Plains and Panhandle to heavily irrigated cotton and wheat in the southwest region, to the dairy and diversified farming of central Oklahoma and the timber and small farm operations in the southeast. The state's generalized agricultural regions are delineated in Figure 16.

A recent study by Oklahoma State University measured the total economic impact of agriculture -- the state's second leading industry, next to petroleum and natural gas -- to be $6.1 billion annually. Chief agricultural products include beef cattle, sheep, hogs, poultry, milk, wheat, hay, sorghum and other grains, peanuts and cotton. Oklahoma is second in the nation in total wheat production, fourth in cattle/calf, fourth in pecans, seventh in peanuts and tenth in peaches. In 1994, the state boasted more than 70,000 farms and ranches (only a very minor decrease from 1981) averaging 486 acres in size and covering some 34 million acres. Associated earnings for these operations were approximately $1.2 billion while the average realized net income per farm was $18,540 in 1993. The average age of farm workers is 55, according to the 1992 Agricultural Census, and many supplement their primary incomes with off-farm work.

The state's wheat crop, which vies with Kansas and North Dakota in total yearly production, is centered primarily in the grassland area of northwest. The climate and long growing season of the southwest (in excess of 210 days) promotes dominance of cotton and grain in that region. Mixed farming -- especially corn, peanuts and assorted vegetables, in addition to primary cotton crops -- and livestock raising is a common source of supplemental income in the east. Rich soils and sufficient water supplies support grasses in range-grazing lands located throughout the state.

WILDLIFE

Oklahoma's diverse climate and geography is again reflected in the state's wide variety of fish and wildlife species, as well as in their habitats. The abundance of lakes, rivers, ponds, plains and forestland provide excellent fishing and hunting opportunities, as well as considerable aesthetic benefits, which contribute significantly to the state's reputation as an outdoor haven for both residents and visitors. In addition, outdoor activities enabled through the comprehensive management and preservation of the state's fish and wildlife resources by the Oklahoma Department of Wildlife Conservation and U.S. Fish and

Wildlife Service, in partnership with other agencies and the public, add millions of dollars each year to local and state economies in the form of licensing fees, purchases of fishing and hunting equipment, lodging expenses and retail sales.

Sportfish native to Oklahoma include largemouth, smallmouth, white and spotted bass; crappie; channel, flathead and blue catfish; sunfish; sauger; and paddlefish. Introduced species are also popular with fishing enthusiasts. The striped bass, a salt water native, has been stocked in Texoma (where it comprises the major sportfish species), Kaw, Keystone, Foss and Canton Reservoirs. Walleye were established in the 1960's while, more recently, the saugeye -- a cross between the walleye and sauger -- and a striped/white bass hybrid have flourished upon introduction to Oklahoma waters. The state also maintains seven put-and-take rainbow trout fishing areas: in the Illinois River below Tenkiller dam, in the lower Mountain Fork River below Broken Bow dam (where brown trout have also been introduced), in Lake Etling at Black Mesa State Park, below Carlton Lake at Robber's Cave State Park, at the Quartz Mountain Trout Area, the Blue River Public Fishing and Hunting Area, and in Lake Watonga.

Oklahoma is home to five big game species, including white-tail deer and wild turkey in all 77 counties. Mule deer and pronghorn antelope occupy much of the dry, open northwest and Panhandle regions while elk, recently introduced in the east, are found in the Wichita Mountains National Wildlife Refuge of southwest Oklahoma. Smaller upland game, especially bobwhite quail, are also prevalent and abundant pheasant populations thrive in the Panhandle. Prairie chickens, scaled quail, squirrels, rabbits, doves, ducks and geese are also favorites of hunters in Oklahoma who spend some 3.5 million hunter-days each year tracking and harvesting game species. The state's location on the Central Flyway, a migratory path extending from Canada to Mexico, is a boon to hunters and waterfowl enthusiasts alike. In addition, there are numerous public hunting areas and wildlife refuges where unique species of animals are preserved and enjoyed by campers and naturalists.

Habitat destruction is the single most serious threat to wildlife and plants although over-exploitation, disease, pollution and introduction of non-native species can also contribute to population declines. Through the federal Endangered Species Act, passed in 1973, troubled species in Oklahoma receive special protection until they can be restored to a secure status in the wild. The U.S. Fish and Wildlife Service maintains a list of both endangered and threatened species in the nation while the State Department of Wildlife Conservation oversees a separate list of those species who reproduce, migrate or overwinter in Oklahoma.

Ten wildlife species in the state are officially listed by the federal government as endangered while nine are considered threatened. Currently listed endangered species -- those who face the immediate threat of extinction -- include the Ouachita rock-pocketbook mussel, American burying beetle, American peregrine falcon, whooping crane, interior least tern, red-cockaded woodpecker, black-capped vireo, Ozark big-eared bat, Indiana bat and gray bat. In addition, the Arkansas River shiner has been proposed for addition to the list as endangered. The bald eagle was recently reclassified from endangered to threatened status while the American peregrine falcon is being considered for complete removal from the federally-threatened and endangered species list.

RECREATION

Oklahoma has 58 state-owned parks, including 24 recreation areas and five resort lodges, that offer excellent opportunities for camping, fishing, hunting, hiking, bicycling, water skiing, site-seeing and countless other outdoor activities. These facilities and the abundant activities they support make tourism one of Oklahoma's top industries.

The state's five lodges are located at Lake Murray State Park, Quartz Mountain State Park and Resort on Lugert-Altus Reservoir, Lake Texoma State Park, Sequoyah State Park on Fort Gibson, and Roman Nose State Park and Resort on Lakes Watonga and Boecher. In addition, cabins are available at many state parks. Other popular recreation spots include Alabaster Caverns, one of the largest natural gypsum caves in the world; Little Sahara State Park, the state's only naturally occurring sand dunes; Black Mesa State Park, which contains numerous dinosaur fossils; Robber's Cave State Park, a former refuge for outlaws; and Spiro Mound Archaeological State Park, where earthen Indian mounds date to the year 1200.

South central Oklahoma's Chickasaw National Recreation Area at Sulphur, one of the nation's first national parks (formerly Platt National Park), is still a popular attraction while Grand Lake, in the northeast, has been extensively developed by private interests. Grand Lake's wooded hills, scenic lake waters and luxurious vacation and retirement homes are unique in the southwest U.S.

The state boasts a panorama of scenery such as the Talimena Skyline Drive in the southeast. Southwestern Oklahoma's Wichita Mountain Wildlife Refuge, established in 1905, is one of only a handful of national refuges supporting wild buffalo herds. Mount Scott, in the Wichitas, is the state's best known peak. The recently established National Tallgrass Prairie Preserve, in Osage County, supports numerous plant and animal species unique to the rapidly diminishing prairie plains environment of the western U.S. Oklahoma is also home to much of the original U.S. Route 66, the nation's first continuous stretch of paved highway.

ARCHEOLOGICAL AND HISTORIC RESOURCES

Oklahoma has 844 archeological and historic properties currently listed in the National Register of Historic Places. These resources -- i.e., the buildings, sites, structures and objects which represent human activity throughout what is now the State of Oklahoma -- illustrate the rich and diverse heritage inherent to the state's past.

There are approximately 14,000 recorded archaeological resources located throughout Oklahoma's, but it is estimated that this figure represents only about 10 percent of the number of such resources that exist. The locations of these sites indicate that prehistoric and early historic civilizations and groups occupied many areas of the state. Woods County is home to possibly one of the oldest dated sites known in North America, the Burnham site. Also in northwest Oklahoma are the Cooper and Waugh sites in Harper County, the only bison kills directly associated with the 10,000-year-old Folsom culture. At Caddo County's Domebo site exists one of the best documented Southern Plains mammoth kills associated with the 11,000-year-old Clovis culture. Spiro Mounds, located south of Sallisaw, is a nationally renowned ceremonial center which was used by one of the most advanced known societies in the eastern U.S.

between A.D. 800 and 1400. It is Oklahoma's only prehistoric archaeological site open for public visitation.

Approximately 20,000 historic resources have been recorded in both rural and urban Oklahoma, including early nineteenth century log buildings, territorial commercial buildings, bridges, oil well sites, parks designed by the Civilian Conservation Corps and World War II landmarks. Well-known properties listed on the state's National Register are the Creek Council House in Okmulgee, Maple Ridge Historic District in Tulsa, the Nancy Taylor #1 Oil Well near Haskell, the Pioneer Woman in Ponca City, the Skirvin Hotel in Oklahoma City, the Fort Sill Historic District at Fort Sill, and the Washita Battlefield near Cheyenne.

Coordination of historic and archeological resource identification, evaluation and preservation is accomplished at the state level through efforts of the Oklahoma Historical Society, Oklahoma Archeological Society and Oklahoma Anthropological Society. However, these organizations receive valuable assistance from numerous state and federal agencies, local governments, nonprofit organizations and individuals.

COMMERCE

Lower establishment costs, plentiful natural resources (including available land and water), an abundance of labor and lower living costs have attracted business and industry to Oklahoma in recent years, spurring rapid and highly diversified social and economic growth. As part of the nation's "Sunbelt" region, Oklahoma can expect further development and growth if it can continue to offer the water, land, energy and capital needed by new residents and industries without compromising its social and environmental standing.

The Oklahoma economy, once largely dependent upon agriculture and the oil and gas industry, has recently expanded its base to include manufacturing and business services. Making up the gross state product are manufacturing; wholesale and retail trade and services; finance, insurance and real estate; state, local and federal government and education; transportation and communications; mining (including oil and gas); research, printing and publishing; agriculture; and tourism. Major commodities include non-electrical machinery; petroleum and coal products; food products; fabricated metal products; glass, rubber and plastic products; and transportation equipment.

From 1987 to 1993, manufacturing employment in Oklahoma grew by 7.1 percent while the national rate decreased by 5.2 percent. Oklahoma's two industrial centers, Oklahoma City and Tulsa, account for more than one-half of the state's manufacturing employment of 167,900, according to 1993 figures. In 1994, the state boasted 3,858 industrial firms.

Oklahoma's top manufacturing sectors, in order of production, are: transportation equipment; petroleum and coal products; non-electrical machinery; food processing; and electronic and electrical equipment. In the service sector, telecommunications represents the area of fastest growth.

POPULATION, EMPLOYMENT, LABOR AND INCOME

Throughout Oklahoma history, the state's population has experienced sudden upward and downward fluctuations, primarily due to variations in the social and economic climate. Following slight growth in the 1960's that continued through the early 1980's, the state experienced a small decrease in population, primarily due to a decline in the oil industry. In recent years, that trend has leveled off with most urban areas experiencing population growth at the expense of rural Oklahoma, which has shown a slight decrease. While only 19.2 percent of the population lived in urban areas in 1910, 67.7 percent lived in urban areas during the 1990 census.

The Oklahoma population has increased from 258,657 in 1890 to 3,258,100 in 1994, ranking it below Connecticut but above Oregon in total population by state. Currently, the Tulsa and Oklahoma City metropolitan areas account for more than one-half of the state's population while Norman recently surpassed Lawton as the state's third largest city. According to 1994 estimates, the state's five largest counties, by population, are Oklahoma, Tulsa, Cleveland, Comanche and Canadian; the five smallest are Cimarron, Harmon, Harper, Roger Mills and Ellis. Based on projections from the Oklahoma Department of Commerce, the state's population is expected to reach 3,426,000 in 2000 and 3,717,500 by 2020.

Oklahoma has traditionally experienced a higher percentage of employed persons -- or conversely, a lower unemployment rate -- than the national average. This is an indication of the generally healthy condition of the state's economy and its relative immunity to short-term fluctuations in the national economy. Except for the late 1980's, when the average state unemployment rate was slightly higher than the national average, Oklahoma has enjoyed a very stable employment base. In 1993, Oklahoma's average unemployment rate was six percent (1,432,000) of the total labor force (1,524,000) employed. This is below the national unemployment rate of 6.8 percent for the same year.

Although Oklahoma boasts a favorable overall employment ratio (averaging about 4.5 in mid-1995, compared to a national average of about 6.0), certain regions and counties sustain much higher unemployment rates than others. Southeastern Oklahoma historically suffers high unemployment rates while rates in the northwest are nominal -- a variation explained, in part, by the nature of industry in each region. While the southeast's manufacturing and mining industries are sensitive to drop-offs in demand and register subsequent layoffs, farmers in the northwest are forced to remain in agricultural pursuits due to their large personal capital investments, even despite downward trends in the market. Population densities also influence the unemployment rate because they determine the size of the labor force. For example, southeast Oklahoma's higher concentration of people causes available labor to exceed demand, resulting in a higher unemployment rate than in the sparsely populated northwest, where there is more of a balance between labor and demand.

In 1993, the highest employment (covered) was recorded in wholesale and retail trade, which employed 289,145; service industries, which employed 278,679; and public administration, which employed 217,273. These three industries accounted for two-thirds of the average monthly employment for 1993.

In terms of income, Oklahoma ranks somewhat below the national average of $20,131, with a 1993 per capita personal income of $17,035. Coinciding with the pattern of employment across the state, personal income is lower in the southeast and higher in metropolitan areas and the west. Due to its small population base and high farm incomes, Cimarron County had the highest 1992 per capita income ($22,801) while Washington County, with extensive employment in the oil and gas industry, had the second highest income ($21,107).

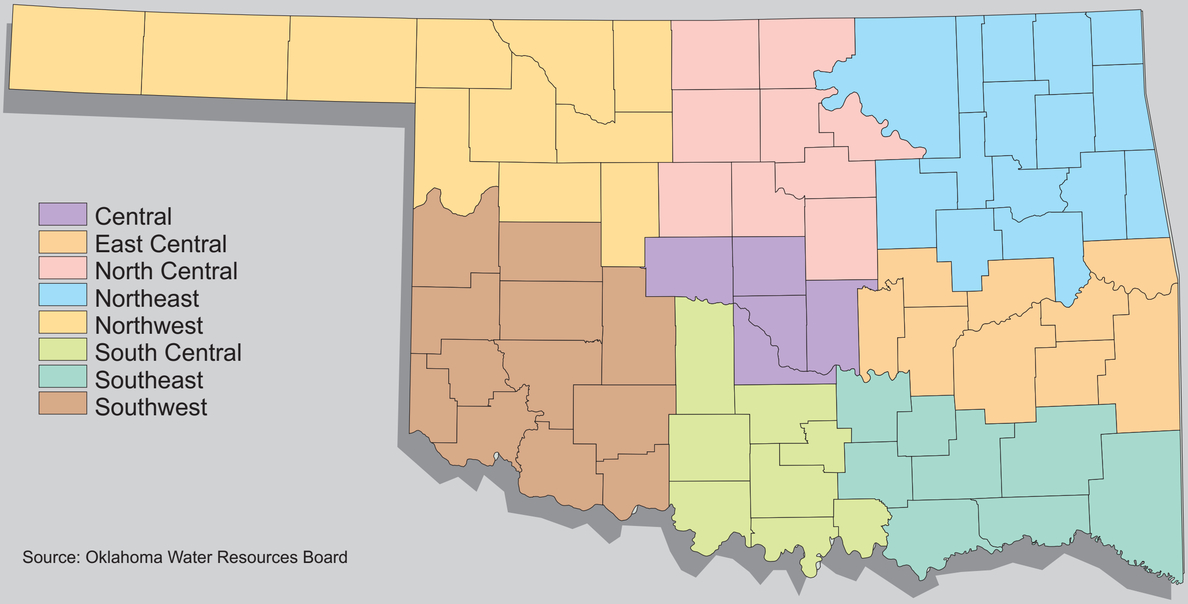
Statewide Water Use Projections

Introduction

Estimating projections of future water requirements is a difficult but necessary task in planning for future water needs. The approach taken in updating water use projections for Oklahoma was a three-part process. Municipal and industrial water demand projections were made in cooperation with the U.S. Army Corps of Engineers, Tulsa District, using the Institute for Water Resources Municipal and Industrial Needs (IWR-MAIN) forecasting model. Agricultural water projections were estimated in cooperation with the Bureau of Reclamation and based upon recent irrigation and livestock watering trends and assumptions of future scenarios in agricultural water demands. Water needed for power generation has been forecasted according to the best available information on the future plans of Oklahoma's power generating companies.

It is obvious that a great deal of uncertainty is inherent in undertaking any type of projection as far as 50 years into the future. The tendency of planners is to take into account the ultimate water needs within reason when attempting to foresee whether future water use and supply can be balanced. Thus, the following water demand projections for the state's eight planning regions are based upon methodologies designed to meet relatively high, yet reasonable, scenarios of projected water use. The planning regions are delineated in Figure 17.

Figure 17
OKLAHOMA COMPREHENSIVE WATER PLAN
PLANNING REGIONS



Municipal and Industrial Water Use Projections

The U.S. Army Corps of Engineers, under authority of their Planning Assistance to States Program, cooperated with the Oklahoma Water Resources Board in identifying future municipal and industrial water needs in the state using the Corps' Institute for Water Resources Municipal and Industrial Needs (IWR-MAIN) model. The model is a computerized forecasting system that contains a range of forecasting models, parameter-generating procedures and data management techniques. The IWR-MAIN model forecasts water use based upon actual and projected socioeconomic characteristics of a study area. Future water use is projected as a function of the most likely determinants of water demand, including (1) number, market value and type of housing units in the residential sector; (2) employment in commercial and manufacturing industries; (3) water pricing; (4) median income; and (5) weather/climate conditions. The analysis includes water use models for each of the 77 counties in Oklahoma. These models can be updated as more current information becomes available.

The IWR-MAIN model was used to estimate water use for 1990 and project water needs, by decade, from 2000 through 2040. The trend developed in IWR-MAIN projections for 2000 to 2040 is used to derive figures for the year 2050. County-level data required by the IWR-MAIN model were aggregated for each of the eight planning regions as delineated in the 1980 Oklahoma Comprehensive Water Plan. The IWR-MAIN model requires four basic parameters to estimate and project water use: population, income, housing and employment. The model uses these basic parameters in conjunction with water use data imbedded within the model. Values for each parameter, along with average water pricing information, are required to determine estimated water use for the base year. Water pricing information (marginal price and bill difference) for each county in Oklahoma was based upon a 1985 study conducted by Planning Associates for the U.S. Army Corps of Engineers Institute for Water Resources. An estimate of actual water use is required not as an input parameter, but as an external check for how well the model simulates base-year usage. Since the projection frame for this analysis is the decades between 1990 and 2050, external projection data for three parameters -- population, income and employment -- were required for each decade between 1990 and 2050. Housing projections were determined internally by the model.

POPULATION

Population data for this update for the years 2000 to 2020 were derived from Oklahoma Department of Commerce (ODOC) projections published in April 1993. For projected figures beyond the year 2020, the rates of change for 2020 to 2040 were developed by applying the U.S. Bureau of Economic Analysis county-level projections to ODOC's 2020 figures while a straight-line extrapolation was used to project figures for the year 2050.

EMPLOYMENT

To account for water demand by industry, the model requires information on employment in commercial and manufacturing industries by place of employment. Consequently, U.S. Bureau of Census County Business Patterns non-farm employment data were used for the base-year estimates. Employment projections were based primarily upon the projected labor force participation rates in the U.S. Bureau of Economic Analysis county-level projections (adjusted for non-farm labor participation) and the projected population figures identified above. During the verification process, IWR-MAIN appeared to "under-predict" consumption in several counties where a large amount of self-supplied industrial water use existed. More specific information was obtained on these industries and the appropriate water use coefficients were adjusted accordingly.

INCOME

The IWR-MAIN model requires median household income data for both the base year and projected years. The 1990 census data provided base-year household income data. The rate of change from the U.S. Bureau of Economic Analysis was applied to the base year to derive projected household income figures. The rate of change between 2030 and 2040 was held constant to derive the 2050 figure.

HOUSING

The 1990 Census of Population and Housing provides the number of housing units by type of unit and value categories. These categories were used for the base-year data. The census data provides the percentage of homes attached to a public sanitary sewer. This percentage was used to estimate the number of unsewered homes, an optional input for the model. No external housing projections were used. The IWR-MAIN model applied the 1990 housing/population ratio to the projected population figures.

FORECAST ASSUMPTIONS

The estimates of future water derived by the IWR-MAIN model were based upon the following assumptions:

- The water use forecast values will follow the trend in explanatory variables, including population, number and type of housing units, employment and median household income.
- Future estimates of water demand reflect normal weather conditions based upon the latitude and longitude of each study area and climatic variables obtained from the IWR-MAIN Library of Climatic Conditions.
- The forecasts of residential water use assume that future prices of water will be maintained at current price levels in real terms; therefore, no increases in the real price of water are assumed.
- The estimates of water use do not account for current or planned water conservation activities.
- All estimates of water use are calculated from the IWR-MAIN actual and revised computational equations and water use coefficients adjusted to water use patterns in Oklahoma.

RESULTS

Table 3 presents municipal and industrial water projections by decade for each of the eight delineated planning regions. This table displays the 1990 demands estimated by IWR-MAIN. These 1990 estimates are used as a gauge for the model's ability to project demands. As shown in Figure 18, comparisons to actual 1990 water use figures, derived from several sources (in-

Table 3
COUNTY/REGIONAL MUNICIPAL & INDUSTRIAL
WATER USE PROJECTIONS 1990-2050
(IN 1,000AC-FT PER YEAR)

PLANNING REGION & COUNTY	*YEAR*						
	1990	***2000***	***2010***	***2020***	***2030***	***2040***	***2050***
CENTRAL							
Canadian	15.2	18.8	18.9	19.7	20.2	20.6	21.1
Cleveland	31.6	38.9	41.7	43.2	44.0	44.5	44.9
McClain	5.2	6.2	6.6	6.8	7.1	7.2	7.3
Oklahoma	140.6	164.4	180.3	188.6	195.4	197.5	199.5
Pottawatomie	12.4	14.9	16.0	17.0	17.6	18.4	19.2
Total	**205.0**	**243.2**	**263.5**	**275.3**	**284.3**	**288.2**	**292.0**
EAST CENTRAL							
Haskell	2.4	2.5	2.5	2.5	2.6	2.6	2.6
Hughes	2.8	3.1	3.5	3.7	3.9	4.0	4.1
Latimer	2.4	2.6	2.7	2.8	2.8	2.9	3.0
LeFlore	10.3	11.5	12.5	13.0	13.6	14.2	14.9
McIntosh	5.0	5.3	5.3	5.3	5.3	5.4	5.5
Okfuskee	2.6	2.7	2.8	2.9	2.9	3.0	3.1
Pittsburg	9.1	9.7	10.1	10.2	10.5	10.9	11.2
Seminole	5.7	6.2	6.5	6.7	6.8	7.1	7.3
Sequoyah	8.2	9.2	10.2	10.4	10.6	11.0	11.3
Total	**48.5**	**52.9**	**56.1**	**57.5**	**59.0**	**61.1**	**63.0**
NORTH CENTRAL							
Garfield	15.3	18.1	20.9	22.7	24.5	24.8	25.1
Grant	1.6	1.8	1.9	2.0	2.1	2.2	2.2
Kay	15.8	18.4	20.2	21.2	21.5	21.7	22.0
Kingfisher	3.0	3.2	3.5	3.6	3.6	3.7	3.8
Lincoln	5.2	6.3	6.9	7.3	7.7	8.2	8.6
Logan	7.1	7.6	8.2	9.0	9.4	9.6	9.7
Noble	1.5	1.6	1.7	1.8	1.9	2.0	2.1
Pawnee	3.5	3.9	4.3	4.5	4.7	4.9	5.2
Payne	16.5	19.3	19.9	20.0	20.5	21.1	21.4
Total	**69.5**	**80.2**	**87.5**	**92.1**	**95.9**	**98.2**	**100.1**

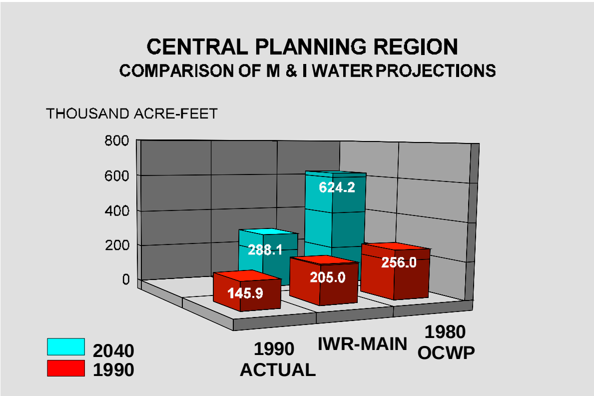
Continued

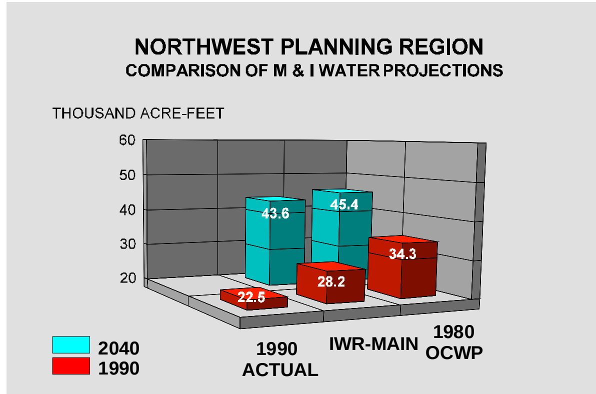
Table 3 (Continued)
COUNTY/REGIONAL MUNICIPAL & INDUSTRIAL WATER USE PROJECTIONS 1990-2050

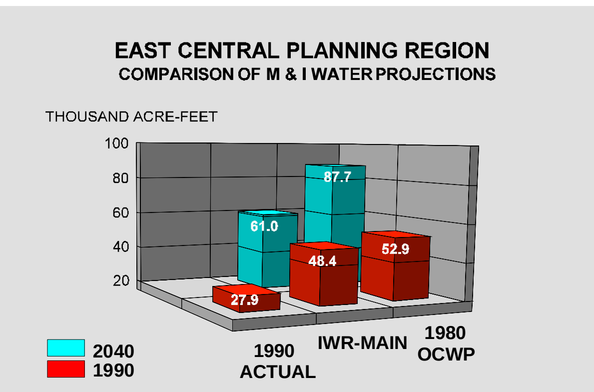
(IN 1,000 AC-FT PER YEAR)

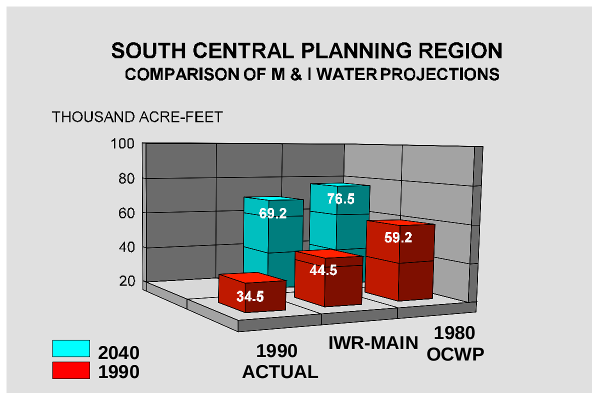
PLANNING REGION & COUNTY	YEAR						
	1990	2000	2010	2020	2030	2040	2050
NORTHEAST							
Adair	3.7	3.8	4.3	4.8	4.9	5.0	5.2
Cherokee	9.9	10.3	11.4	12.0	12.5	13.3	14.2
Craig	3.1	3.4	3.6	3.7	3.8	3.9	4.0
Creek	12.8	14.9	16.9	18.5	20.8	21.7	22.7
Delaware	6.6	6.8	6.9	6.9	7.2	7.3	7.4
Mayes	9.9	10.9	11.8	12.5	13.6	15.2	17.1
Muskogee	28.4	30.1	31.0	31.7	33.0	33.7	34.4
Nowata	2.0	2.2	2.4	2.4	2.5	2.6	2.7
Okmulgee	7.3	8.2	8.8	9.3	9.5	9.7	10.0
Osage	7.6	8.8	10.0	10.3	11.1	11.4	11.8
Ottawa	6.4	7.1	7.5	7.7	7.8	8.1	8.3
Rogers	9.2	10.9	12.0	12.5	12.9	13.1	13.3
Tulsa	139.0	149.4	159.0	164.2	168.3	174.6	181.1
Wagoner	8.8	10.2	10.5	10.8	11.1	11.3	11.6
Washington	12.5	14.1	15.0	16.2	17.1	17.8	18.0
Total	**267.2**	**291.1**	**311.1**	**323.5**	**336.1**	**348.7**	**361.8**
NORTHWEST							
Alfalfa	1.8	1.9	2.0	2.0	2.1	2.2	2.4
Beaver	1.8	2.0	2.2	2.4	2.4	2.5	2.6
Blaine	3.0	3.6	4.0	4.5	4.7	4.9	5.2
Cimarron	1.0	1.1	1.1	1.1	1.1	1.2	1.4
Dewey	1.2	1.3	1.3	1.5	1.6	1.6	1.6
Ellis	1.3	1.6	1.6	1.7	1.7	1.8	1.9
Harper	0.7	0.8	0.8	0.9	0.9	0.9	1.0
Major	1.9	2.0	2.0	2.1	2.1	2.2	2.4
Texas	5.4	7.3	8.3	8.8	9.2	9.3	9.4
Woods	2.9	3.0	3.1	3.4	3.5	3.6	3.8
Woodward	7.2	9.5	11.0	11.9	12.9	13.4	13.8
Total	**28.2**	**34.1**	**37.4**	**40.3**	**42.2**	**43.6**	**45.5**
SOUTH CENTRAL							
Carter	10.4	13.7	15.9	17.8	19.7	22.4	25.5
Garvin	8.6	9.7	10.3	11.0	11.1	11.4	11.8
Grady	8.7	9.9	10.5	11.0	11.2	12.1	13.1
Jefferson	1.3	1.6	1.7	1.8	1.9	2.0	2.1
Love	1.2	1.3	1.5	1.6	1.6	1.7	1.8
Marshall	2.0	2.4	2.7	2.7	2.9	3.1	3.4
Murray	3.1	3.8	4.3	4.6	5.0	5.4	5.7
Stephens	9.0	9.5	10.2	10.5	11.0	11.1	11.2
Total	**44.3**	**51.9**	**57.1**	**61.0**	**64.4**	**69.2**	**74.6**
SOUTHEAST							
Atoka	2.7	3.1	3.4	3.5	3.6	3.7	3.8
Bryan	7.7	8.7	9.1	9.5	9.5	9.9	10.2
Choctaw	3.2	3.6	4.0	4.6	4.7	4.8	4.9
Coal	1.5	1.9	2.0	2.2	2.5	2.6	2.7
Johnston	2.4	2.5	2.6	2.6	2.6	2.7	2.8
McCurtain	49.1	52.0	58.2	62.9	63.8	64.3	64.7
Pontotoc	10.2	12.2	12.3	12.5	12.7	12.9	13.1
Pushmataha	2.7	2.9	3.0	3.0	3.0	3.1	3.3
Total	**79.5**	**86.9**	**94.6**	**100.8**	**102.4**	**104.0**	**105.5**
SOUTHWEST							
Beckham	4.9	5.6	5.9	6.3	6.5	6.6	6.7
Caddo	6.3	7.2	8.0	8.6	8.7	9.1	9.4
Comanche	37.0	44.8	52.4	58.2	59.6	60.6	61.6
Cotton	1.5	1.8	2.1	2.2	2.5	2.9	3.4
Custer	8.0	8.4	8.6	8.6	8.7	8.7	8.7
Greer	1.3	1.7	1.9	2.1	2.2	2.5	2.7
Harmon	1.5	1.6	1.6	1.7	1.7	1.7	1.7
Jackson	5.9	10.5	14.8	18.6	20.0	20.3	20.5
Kiowa	2.1	2.4	2.5	2.5	2.5	2.5	2.5
RogerMills	1.1	1.2	1.3	1.5	1.6	1.7	1.8
Tillman	2.2	2.4	2.5	2.7	2.7	2.8	2.9
Washita	2.8	2.9	3.1	3.2	3.2	3.4	3.5
Total	**74.6**	**90.5**	**104.7**	**116.2**	**119.9**	**122.8**	**125.4**
GRAND TOTAL	**816.8**	**930.7**	**1012.0**	**1066.7**	**1104.2**	**1135.8**	**1167.9**

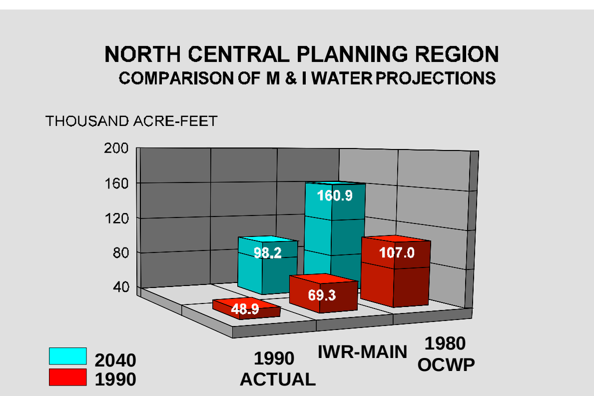
Figure 18
COMPARISON OF MUNICIPAL AND INDUSTRIAL
WATER USE PROJECTIONS

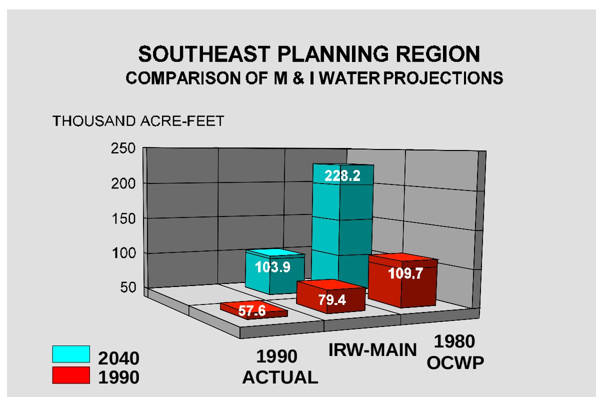


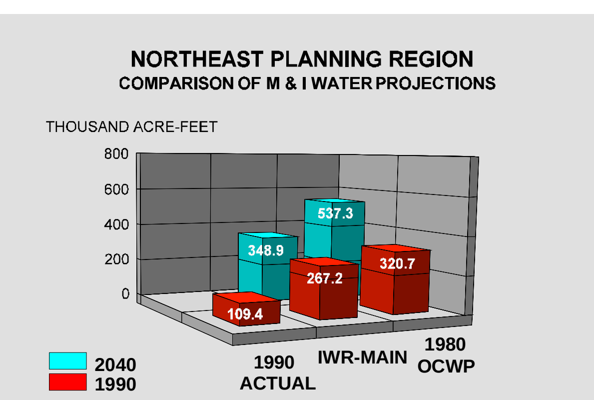


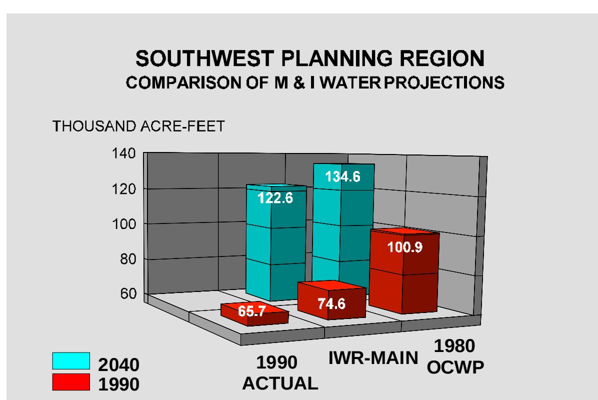












cluding OWRB water use reports), indicate that the IWR-MAIN 1990 estimates are reasonable.

Figure 18 also indicates that IWR-MAIN estimates for 1990 and projections for 2040 are lower than those projected in the 1980 Oklahoma Comprehensive Water Plan. This is largely attributed to shifts in actual and projected population and economic growth for Oklahoma.

Agricultural Water Use Projections

Agriculture is one of the most important segments of Oklahoma's economy. It is a rapidly expanding industry despite declining numbers of farms and farm operations. Its expansion is measured in terms of total value of production as well as product diversification. The paradoxical relationship between increased production and declining farm numbers may stem largely from an increase in farm efficiency, use of conservation programs, resource developments, improved technology, feed additives, fertilizers, insecticides and more efficient farm machinery.

Agricultural water demand forecasts were developed in cooperation with the Bureau of Reclamation's Oklahoma City Project Office under authority of their Technical Assistance to States Program. Agricultural projections include both irrigation and livestock water demands by decade for the forecast period 1990 through 2050.

LIVESTOCK

Livestock water demands were based upon the estimated and projected water use for cattle, hogs, sheep and poultry. Data from the Oklahoma Agricultural Statistics Service were used to estimate historical trends of livestock production (manufacturing and processing aspects are addressed under M&I projections). Estimates derived from conversations with the American Society of Agricultural Engineers, Corps of Engineers and Oklahoma Department of Commerce indicate that the livestock population is expected to remain relatively stable throughout the 50-year planning horizon, thus a relatively modest increase of 15 percent was used to project future livestock production over the planning period.

IRRIGATION

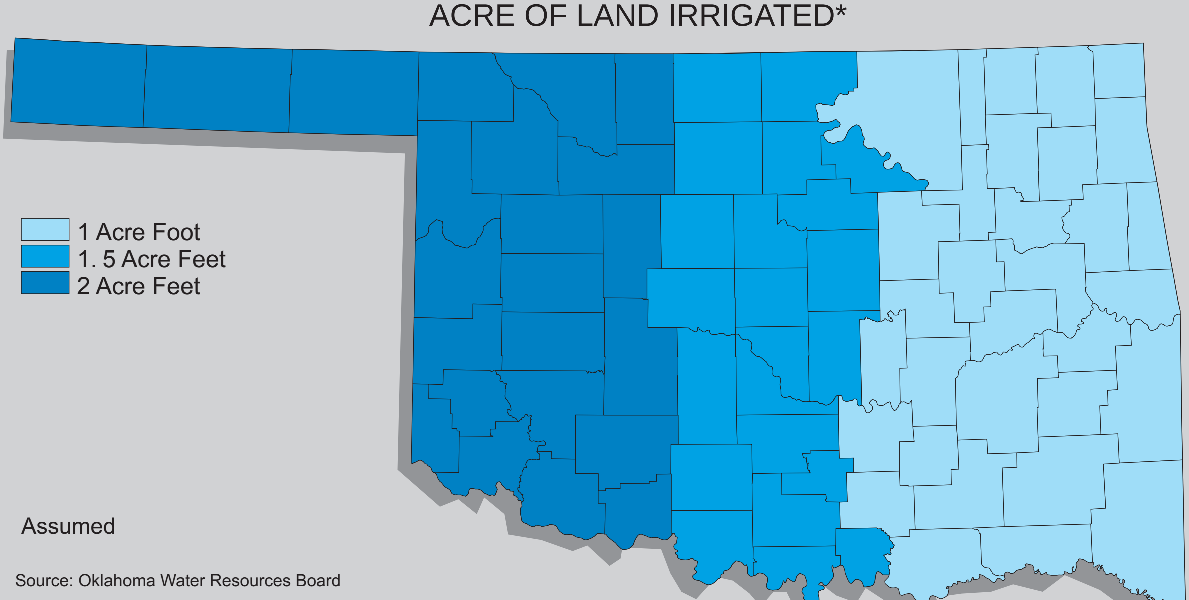
Contacts with various authorities indicate that it is virtually impossible to accurately forecast the need for irrigation water in the future for specific years. Variations in weather, politics and socioeconomic forces cause significant swings in demand. Nonetheless, it is necessary to adopt plausible guidelines to be used in planning for future demands for irrigation water.

The state's water needs and application rates for irrigation vary from county to county. For purposes of estimating present and future irrigation water demands, it was assumed that cultivated lands in the east require one acre-foot of irrigation water per acre of farmed land, increasing to a need of 1.5 acre-feet in the mid-region counties and two acre-feet in the western counties (see Figure 19). These general irrigation water rates, adopted by the Planning Committee in developing the 1980 Oklahoma Comprehensive Water Plan, take into account climate, geology, soil and surface and groundwater availability.

Oklahoma State University compiled biennial irrigation surveys, including information on the number of acres actually irrigated versus acres potentially available for irrigation, in 1983, 1985 and 1987. For the purpose of estimating current irrigation patterns, it was assumed that the report figures are valid and representative of recent irrigation patterns. These figures on actually irrigated acres were also compared to irrigation information from OWRB 1990 water use reports.

In order to provide a buffer against both over-reporting and under-reporting of irrigated lands, the number of acres actually irrigated in 1990 was estimated based upon a county-by-county average of the highest irrigated acreage for any one OSU report

Figure 19
AMOUNT OF WATER REQUIRED PER ACRE OF LAND IRRIGATED*



Source: Oklahoma Water Resources Board

survey year and irrigated acreage from 1990 water use reports. For example, the OSU reports indicated that the number of acres irrigated in Texas County was 172,500 acres in 1983; 177,315 acres in 1985; and 176,450 acres in 1987. The 1990 water use reports indicated that 133,725 acres were under irrigation in Texas County. Therefore, 1990 water use for Texas County irrigation was determined to be 155,520 acres -- calculated by taking the average of 177,315 and 133,725 acres. Irrigation water use for 1990 was estimated by applying the county water requirements, as shown in Figure 19, to the number of acres irrigated, as estimated above.

While water withdrawals for irrigation have historically comprised the largest portion of statewide water use, irrigation water use peaked in the early 1980's. Due primarily to improved conservation, more efficient irrigation practices and better technology, irrigated farmlands are not expected to expand beyond that acreage which is potentially available for irrigation; water use per irrigated acre is expected to decrease 20 percent by the year 2050. The number of acres (by county) potentially available for irrigation was based upon the highest reported potential irrigated acres for any one survey year from OSU's 1981 through 1987 biennial irrigation surveys. It should be noted that potential irrigated acres include not only acres currently being irrigated, but also those lands that have been irrigated or are accessible by developed irrigation systems. By basing projections upon potential irrigated acres, future irrigation of lands that may come out of the Conservation Reserve Program (CRP) will likely be encompassed in the water use projections. (The CRP, authorized by the conservation title of the Food Security Act of 1985, encourages farmers, through 10-15 year contracts with USDA, to stop growing crops on land subject to excessive erosion or land that contributes to a significant water quality problem and, instead, plant it to a protective cover of grass or trees.) Therefore, projections of acres irrigated by 2050 were based upon a straight-line extrapolation of the 1990 actual acres irrigated increased to the number of potential irrigated acres identified in the OSU reports. Projections of irrigation water demands were made by applying the water rates (Figure 19) with the 20 percent conservation efficiency decrease over time.

RESULTS

Based upon the methodologies and assumptions described above, Table 4 presents agricultural water demand projections by decade for each planning region. As shown in Figure 20, comparisons to actual 1990 water use figures derived from OWRB water use reports show that the above methodology results in water use estimates which are higher than the total reported for each region. Figure 20 also indicates that the updated agricultural water demand projections are substantially lower that those projected in the 1980 Oklahoma Comprehensive Water Plan. This is largely attributed to the highly optimistic perspective in 1980 of Oklahoma's role in national food production as well as on the future economy of the farming sector in general.

Table 4
COUNTY/REGIONAL AGRICULTURAL
WATER USE PROJECTIONS
1990-2050

(IN 1,000 AC-FT PER YEAR)

PLANNING REGION & COUNTY	***1990***	***2000***	***2010***	***2020***	***2030***	***2040***	***2050***
CENTRAL							
Canadian	10.1	11.5	12.9	14.4	15.8	17.3	18.7
Cleveland	2.7	2.9	3.1	3.3	3.5	3.7	3.8
McClain	3.0	3.0	3.1	3.1	3.1	3.2	3.2
Oklahoma	3.7	3.7	3.8	3.8	3.9	3.9	4.0
Pottawatomie	6.9	7.0	7.1	7.3	7.4	7.6	7.7
Total	**26.4**	**28.1**	**30.0**	**31.9**	**33.7**	**35.7**	**37.4**
EAST CENTRAL							
Haskell	1.6	1.6	1.7	1.8	1.8	1.9	1.9
Hughes	12.5	12.8	13.2	13.6	13.9	14.3	14.6
Latimer	0.8	0.8	0.8	0.9	0.9	0.9	0.9
LeFlore	6.0	6.1	6.2	6.3	6.4	6.5	6.6
McIntosh	1.1	1.2	1.4	1.5	1.6	1.7	1.9
Okfuskee	1.9	2.0	2.0	2.1	2.2	2.2	2.3
Pittsburg	2.5	2.6	2.6	2.7	2.8	2.9	3.0
Seminole	1.8	2.2	2.6	3.0	3.3	3.7	4.1
Sequoyah	3.3	3.5	3.7	4.0	4.2	4.5	4.7
Total	**31.5**	**32.8**	**34.2**	**35.9**	**37.1**	**38.6**	**40.0**
NORTH CENTRAL							
Garfield	2.9	3.0	3.1	3.2	3.3	3.4	3.5
Grant	2.1	2.3	2.5	2.7	2.9	3.1	3.3
Kay	2.0	2.1	2.1	2.2	2.2	2.3	2.3
Kingfisher	19.8	20.2	20.6	21.0	21.5	21.9	22.3
Lincoln	1.2	1.2	1.3	1.3	1.3	1.4	1.4
Logan	3.8	4.0	4.2	4.3	4.5	4.7	4.9
Noble	1.4	1.5	1.6	1.7	1.7	1.8	1.9
Pawnee	1.7	1.9	2.2	2.5	2.7	3.0	3.3
Payne	1.7	1.8	1.8	1.8	1.9	1.9	1.9
Total	**36.6**	**38.0**	**39.4**	**40.7**	**42.0**	**43.5**	**44.8**

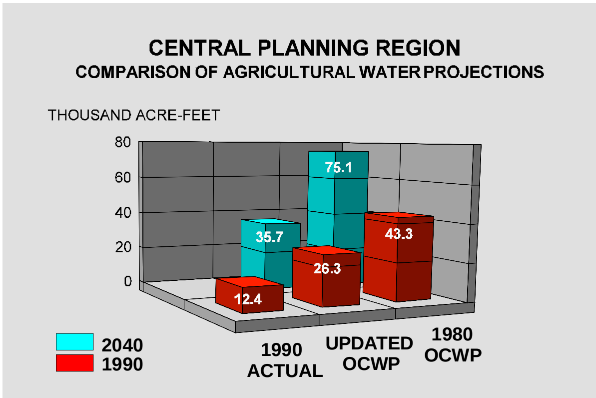
(Continued)

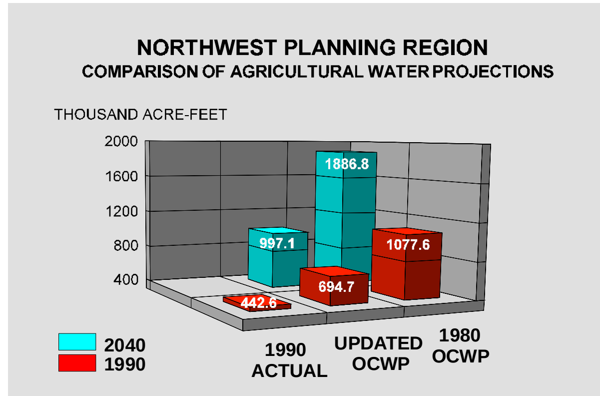
Table 4 (Continued)
COUNTY/REGIONAL AGRICULTURAL WATER USE PROJECTIONS 1990-2050

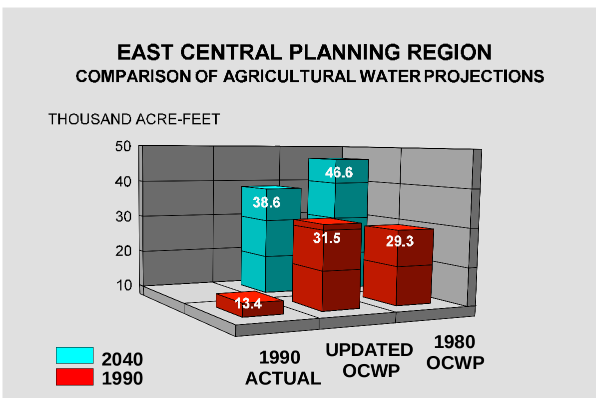
(IN 1,000 AC-FT PER YEAR)

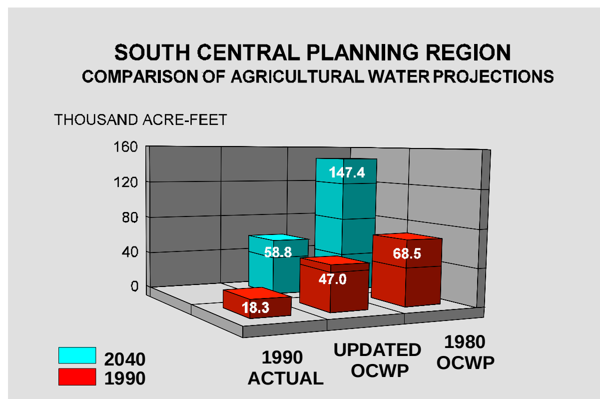
PLANNING REGION & COUNTY	YEAR 1990	2000	2010	2020	2030	2040	2050
NORTHEAST							
Adair	3.0	3.0	3.1	3.2	3.3	3.3	3.4
Cherokee	2.3	2.4	2.5	2.6	2.7	2.7	2.8
Craig	2.4	2.5	2.7	2.8	2.9	3.0	3.2
Creek	1.1	1.1	1.2	1.2	1.3	1.3	1.4
Delaware	1.4	1.4	1.4	1.5	1.6	1.6	1.7
Mayes	2.1	2.2	2.3	2.4	2.5	2.7	2.8
Muskogee	6.2	6.6	7.0	7.4	7.8	8.2	8.7
Nowata	1.0	1.1	1.3	1.4	1.5	1.7	1.8
Okmulgee	1.4	1.4	1.4	1.5	1.5	1.5	1.6
Osage	2.8	2.8	2.9	3.0	3.1	3.2	3.3
Ottawa	1.4	1.5	1.5	1.6	1.6	1.7	1.7
Rogers	1.9	2.0	2.1	2.1	2.2	2.3	2.3
Tulsa	4.5	4.7	5.0	5.2	5.4	5.7	5.9
Wagoner	2.8	2.9	3.0	3.1	3.3	3.4	3.5
Washington	2.1	2.2	2.3	2.3	2.4	2.5	2.5
Total	**36.4**	**37.8**	**39.7**	**41.3**	**43.1**	**44.8**	**46.6**
NORTHWEST							
Alfalfa	7.3	7.7	8.2	8.7	9.2	9.7	10.1
Beaver	60.7	70.1	79.5	88.9	98.3	107.7	117.1
Blaine	4.3	4.8	5.3	5.8	6.3	6.8	7.2
Cimarron	173.2	195.5	217.9	240.2	262.6	284.9	307.3
Dewey	5.6	5.7	5.8	5.9	6.0	6.1	6.2
Ellis	44.7	45.4	46.1	46.8	47.4	48.1	48.8
Harper	32.2	32.5	32.8	33.1	33.4	33.7	34.0
Major	18.1	20.0	21.9	23.8	25.7	27.6	29.5
Texas	317.9	340.9	363.9	386.9	409.9	432.9	455.9
Woods	8.5	8.8	9.0	9.3	9.5	9.8	10.1
Woodward	22.2	23.7	25.3	26.8	28.4	29.9	31.5
Total	**694.7**	**755.1**	**815.7**	**876.2**	**936.7**	**997.2**	**1057.7**
SOUTH CENTRAL							
Carter	5.0	5.1	5.2	5.3	5.5	5.6	5.7
Garvin	6.4	7.6	8.8	10.1	11.3	12.5	13.7
Grady	17.5	17.8	18.1	18.3	18.6	18.9	19.2
Jefferson	3.3	3.5	3.7	4.0	4.2	4.4	4.7
Love	4.0	4.2	4.3	4.5	4.6	4.8	4.9
Marshall	5.7	5.8	6.0	6.2	6.4	6.6	6.8
Murray	1.8	1.9	2.1	2.2	2.3	2.4	2.6
Stephens	3.2	3.3	3.4	3.5	3.5	3.6	3.7
Total	**46.9**	**49.2**	**51.6**	**54.1**	**56.4**	**58.8**	**61.3**
SOUTHEAST							
Atoka	2.5	3.3	4.1	5.0	5.8	6.7	7.5
Bryan	11.9	12.4	12.9	13.5	14.0	14.6	15.1
Choctaw	2.5	2.6	2.6	2.6	2.7	2.7	2.7
Coal	2.5	2.7	2.9	3.0	3.2	3.4	3.5
Johnston	3.1	3.3	3.6	3.9	4.1	4.4	4.7
McCurtain	4.3	4.5	4.8	5.0	5.3	5.5	5.7
Pontotoc	3.6	3.7	3.7	3.8	3.9	4.0	4.1
Pushmataha	1.2	1.3	1.4	1.5	1.6	1.7	1.8
Total	**31.6**	**33.8**	**36.0**	**38.3**	**40.6**	**43.0**	**45.1**
SOUTHWEST							
Beckham	6.7	7.4	8.0	8.7	9.3	10.0	10.7
Caddo	140.4	141.6	142.8	144.0	145.2	146.4	147.6
Comanche	5.9	5.9	5.9	6.0	6.0	6.0	6.1
Cotton	2.5	3.0	3.6	4.1	4.6	5.2	5.7
Custer	9.6	13.7	17.8	21.9	26.0	30.1	34.1
Greer	15.4	17.2	19.1	20.9	22.8	24.6	26.5
Harmon	40.6	40.7	40.7	40.7	40.8	40.8	40.9
Jackson	113.7	117.4	121.2	125.0	128.8	132.5	136.3
Kiowa	9.6	9.9	10.2	10.5	10.9	11.2	11.5
RogerMills	13.6	14.3	15.0	15.7	16.4	17.1	17.8
Tillman	44.7	48.6	52.6	56.5	60.5	64.4	68.4
Washita	14.8	16.8	18.5	20.3	22.2	24.1	25.9
Total	**417.5**	**436.5**	**455.4**	**474.3**	**493.5**	**512.4**	**531.5**
GRAND TOTAL	**1321.6**	**1411.3**	**1502.0**	**1592.7**	**1683.1**	**1774.0**	**1864.4**

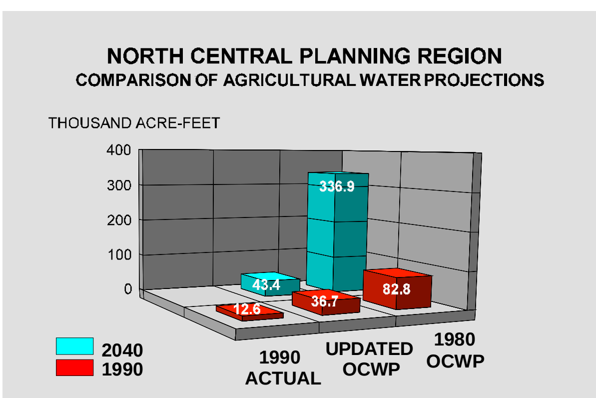
Figure 20
COMPARISON OF AGRICULTURAL
WATER USE PROJECTIONS

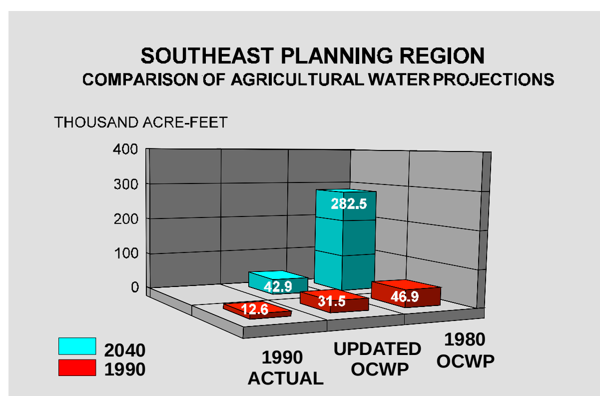


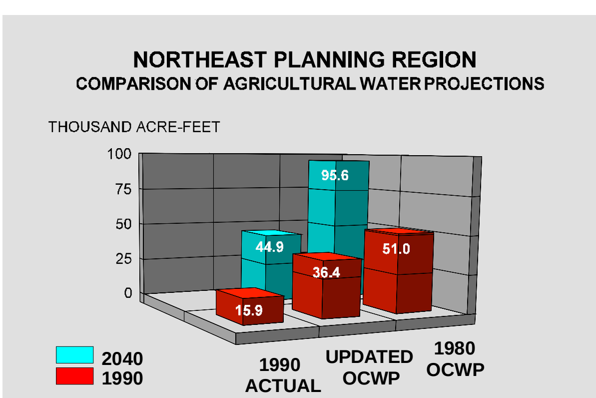


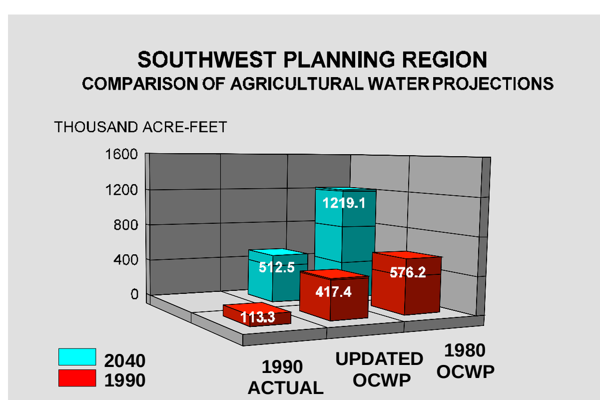












Electric Power Generation Water Use Projections

Water used for electric (thermoelectric) power generation is defined as the amount of water withdrawn in the production of electric power generated with fossil fuels, such as coal, oil and natural gas.

The 1990 estimates of water withdrawals for power generation were derived from three sources: 1990 OWRB water use reports; background data compiled for U.S. Geological Survey Circular 1080, Estimated Use of Water in the United States, 1990; and U.S. Department of Energy Form EIA-767, "1989 Cooling System Design Parameters" and "1989 Cooling System Annual Operations."

Projections of future water use for power generation were based upon projections of power generation from the October 1991 Fourth Biennial Electric System Planning Report prepared by Decision Focus Incorporated for the Oklahoma Corporation Commission. Statewide forecasts through the year 2000 were generated by summing the values for the individual utilities. Statewide energy demand is forecasted to grow at 2.3 percent annually through the year 2000; values for individual utilities ranged from 1.3 percent to 3.3 percent. The 2.3 percent annual growth rate was applied to 1990 county water use estimates for electric power generation and a straight-line extrapolation was used to project figures through the year 2050.

RESULTS

Table 5 displays the power water demand projections by decade for each county and planning region. A regional comparison between the updated power demand figures and those contained in the 1980 Oklahoma Comprehensive Water Plan for years 1990 and 2040 is shown in Figure 21.

Table 5
COUNTY/REGIONAL ELECTRIC POWER GENERATION (COOLING WATER)
WATER USE PROJECTIONS 1990-2050

(IN 1,000 AC-FT PER YEAR)

PLANNING REGION & COUNTY	YEAR						
	1990	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
CENTRAL							
Canadian	2.0	2.5	3.0	3.7	4.6	5.6	6.8
Cleveland	---	---	---	---	---	---	---
McClain	---	---	---	---	---	---	---
Oklahoma	6.4	7.9	9.7	12.0	14.7	18.1	22.2
Pottawatomie	---	---	---	---	---	---	---
Total	**8.4**	**10.3**	**12.7**	**15.6**	**19.2**	**23.6**	**29.0**
EAST CENTRAL							
Haskell	---	---	---	---	---	---	---
Hughes	---	---	---	---	---	---	---
Latimer	---	---	---	---	---	---	---
LeFlore	---	---	---	---	---	---	---
McIntosh	---	---	---	---	---	---	---
Okfuskee	---	---	---	---	---	---	---
Pittsburg	---	---	---	---	---	---	---
Seminole	21.8	26.8	33.0	40.6	50.0	61.5	75.6
Sequoyah	---	---	---	---	---	---	---
Total	**21.8**	**26.8**	**33.0**	**40.6**	**50.0**	**61.5**	**75.6**
NORTH CENTRAL							
Garfield	---	---	---	---	---	---	---
Grant	---	---	---	---	---	---	---
Kay	---	---	---	---	---	---	---
Kingfisher	---	---	---	---	---	---	---
Lincoln	---	---	---	---	---	---	---
Logan	---	---	---	---	---	---	---
Noble	---	---	---	---	---	---	---
Pawnee	21.5	26.4	32.5	40.0	49.2	60.5	74.4
Payne	---	---	---	---	---	---	---
Total	**21.5**	**26.4**	**32.5**	**40.0**	**49.2**	**60.5**	**74.4**
NORTHEAST							
Adair	---	---	---	---	---	---	---
Cherokee	---	---	---	---	---	---	---
Craig	---	---	---	---	---	---	---
Creek	---	---	---	---	---	---	---
Delaware	---	---	---	---	---	---	---
Mayes	9.3	11.4	14.1	17.3	21.3	26.2	32.2
Muskogee	42.0	51.7	63.5	78.2	96.1	118.2	145.4
Nowata	---	---	---	---	---	---	---
Okmulgee	---	---	---	---	---	---	---
Osage	---	---	---	---	---	---	---

(Continued)

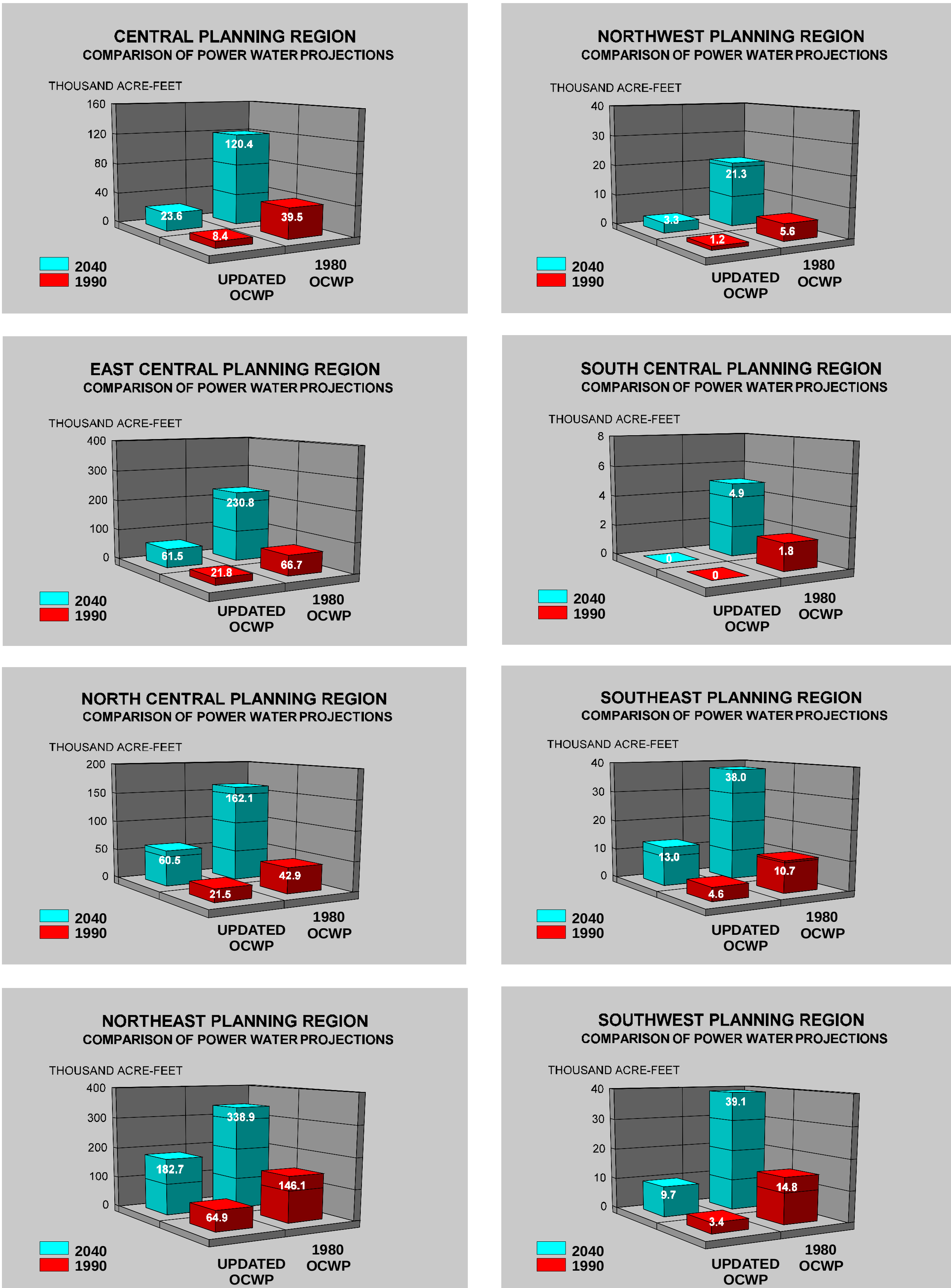
Table 5 (Continued)

COUNTY/REGIONAL ELECTRIC POWER GENERATION (COOLING WATER) WATER USE PROJECTIONS 1990-2050

(IN 1,000 AC-FT PER YEAR)

PLANNING REGION & COUNTY	**1990**	**2000**	**YEAR 2010**	**2020**	**2030**	**2040**	**2050**
Ottawa	---	---	---	---	---	---	---
Rogers	10.0	12.3	15.1	18.6	22.9	28.2	34.6
Tulsa	3.6	4.4	5.4	6.7	8.2	10.1	12.5
Wagoner	---	---	---	---	---	---	---
Washington	---	---	---	---	---	---	---
Total	**64.9**	**79.8**	**98.2**	**120.8**	**148.5**	**182.7**	**224.7**
NORTHWEST							
Alfalfa	---	---	---	---	---	---	---
Beaver	---	---	---	---	---	---	---
Blaine	---	---	---	---	---	---	---
Cimarron	---	---	---	---	---	---	---
Dewey	---	---	---	---	---	---	---
Ellis	---	---	---	---	---	---	---
Harper	---	---	---	---	---	---	---
Major	---	---	---	---	---	---	---
Texas	---	---	---	---	---	---	---
Woods	---	---	---	---	---	---	---
Woodward	1.2	1.5	1.8	2.2	2.7	3.3	4.1
Total	**1.2**	**1.5**	**1.8**	**2.2**	**2.7**	**3.3**	**4.1**
SOUTH CENTRAL							
Carter	---	---	---	---	---	---	---
Garvin	---	---	---	---	---	---	---
Grady	---	---	---	---	---	---	---
Jefferson	---	---	---	---	---	---	---
Love	---	---	---	---	---	---	---
Marshall	---	---	---	---	---	---	---
Murray	---	---	---	---	---	---	---
Stephens	---	---	---	---	---	---	---
Total	**---**	**---**	**---**	**---**	**---**	**---**	**---**
SOUTHEAST							
Atoka	0.1	0.1	0.2	0.2	0.2	0.3	0.3
Bryan	---	---	---	---	---	---	---
Choctaw	4.4	5.4	6.7	8.2	10.1	12.4	15.2
Coal	---	---	---	---	---	---	---
Johnston	---	---	---	---	---	---	---
McCurtain	---	---	---	---	---	---	---
Pontotoc	0.1	0.1	0.2	0.2	0.2	0.3	0.3
Pushmataha	---	---	---	---	---	---	---
Total	**4.6**	**5.7**	**7.0**	**8.6**	**10.5**	**13.0**	**15.9**
SOUTHWEST							
Beckham	---	---	---	---	---	---	---
Caddo	1.7	2.1	2.6	3.2	3.9	4.8	5.9
Comanche	1.7	2.1	2.6	3.2	3.9	4.8	5.9
Cotton	---	---	---	---	---	---	---
Custer	---	---	---	---	---	---	---
Greer	---	---	---	---	---	---	---
Harmon	---	---	---	---	---	---	---
Jackson	---	---	---	---	---	---	---
Kiowa	---	---	---	---	---	---	---
Roger Mills	---	---	---	---	---	---	---
Tillman	---	---	---	---	---	---	---
Washita	---	---	---	---	---	---	---
Total	**3.4**	**4.2**	**5.2**	**6.4**	**7.9**	**9.7**	**11.9**
GRAND TOTAL	**125.8**	**154.7**	**190.4**	**234.2**	**288.0**	**354.3**	**435.6**

Figure 21
COMPARISON OF ELECTRIC POWER GENERATION
WATER USE PROJECTIONS



Total Water Use Projections

The ultimate goal in developing water use projections is to determine the amount of water needed to meet future consumptive water demands of municipal, industrial, agricultural and power sectors in Oklahoma. In turn, these projections provide the basis for estimating the adequacy of existing water sources in meeting water demands through the year 2050 and determining whether alternatives for additional supplies should be pursued.

Table 6 summarizes 1990-2050 water use projections by category (municipal and industrial, agricultural and power) for each of the eight planning regions and the state. Figure 22 shows total state water demands for centennial years 1990-2050. The estimated 1990 water use of almost 2.26 million acre-feet annually is projected to increase to almost 3.47 million acre-feet per year by 2050, more than a 52 percent increase in projected water demand over the 50-year planning horizon.

Figure 22
STATEWIDE WATER USE PROJECTIONS

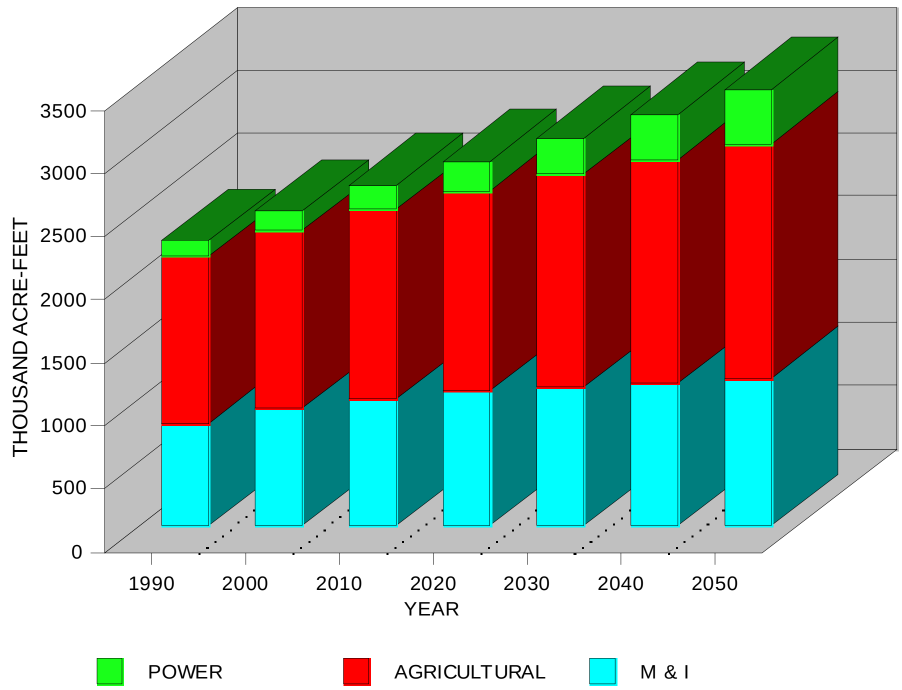


Table 6
REGIONAL/STATEWIDE WATER USE PROJECTIONS
BY CONSUMPTIVE WATER USE CATAGORY

(IN 1,000 AC-FT PER YEAR)

PLANNING REGION & USE	***1990***	***2000***	***2010***	***2020***	***2030***	***2040***	***2050***
CENTRAL							
M & I	205.0	243.2	263.5	275.3	284.3	288.2	292.0
Agricultural	26.4	28.1	30.0	31.9	33.7	35.7	37.4
Power	8.4	10.3	12.7	15.6	19.2	23.6	29.0
Total	**239.8**	**281.6**	**306.2**	**322.8**	**337.2**	**347.5**	**358.4**
EAST CENTRAL							
M & I	48.5	52.8	56.1	57.5	59.0	61.1	63.0
Agricultural	31.5	32.8	34.2	35.9	37.1	38.6	40.0
Power	21.8	26.8	33.0	40.6	50.0	61.5	75.6
Total	**101.8**	**112.4**	**123.3**	**134.0**	**146.1**	**161.2**	**178.6**
NORTH CENTRAL							
M & I	69.5	80.2	87.5	92.1	95.9	98.2	100.1
Agricultural	36.6	38.0	39.4	40.7	42.0	43.5	44.8
Power	21.5	26.4	32.5	40.0	49.2	60.5	74.4
Total	**127.6**	**144.6**	**159.4**	**172.8**	**187.1**	**202.2**	**219.3**
NORTHEAST							
M & I	267.2	291.1	311.1	323.5	336.1	348.7	361.8
Agricultural	36.4	37.8	39.7	41.3	43.1	44.8	46.6
Power	64.9	79.8	98.2	120.8	148.5	182.7	224.7
Total	**368.5**	**408.7**	**449.0**	**485.6**	**527.7**	**576.2**	**633.1**
NORTHWEST							
M & I	28.2	34.1	37.4	40.3	42.0	43.6	45.5
Agricultural	694.7	755.1	815.7	876.2	936.7	997.2	1057.7
Power	1.2	1.5	1.8	2.2	2.7	3.3	4.1
Total	**724.1**	**790.7**	**854.9**	**918.7**	**981.4**	**1044.1**	**1107.3**

Continued

Table 6 (Continued)
REGIONAL/STATEWIDE WATER USE PROJECTIONS
BY CONSUMPTIVE WATER USE CATAGORY

(IN 1,000 AC-FT PER YEAR)

PLANNING REGION & USE	***YEAR***						
	1990	***2000***	***2010***	***2020***	***2030***	***2040***	***2050***
SOUTH CENTRAL							
M & I	44.3	51.9	57.1	61.0	64.4	69.2	74.6
Agricultural	46.9	49.2	51.6	54.1	56.4	58.8	61.3
Power	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**91.2**	**101.1**	**108.7**	**115.1**	**120.8**	**128.0**	**135.9**
SOUTHEAST							
M & I	79.5	86.9	94.6	100.8	102.4	104.0	105.5
Agricultural	31.6	33.8	36.0	38.3	40.6	43.0	45.1
Power	4.6	5.7	7.0	8.6	10.5	13.0	15.8
Total	**115.7**	**126.4**	**137.6**	**147.7**	**153.5**	**160.0**	**166.4**
SOUTHWEST							
M & I	74.6	90.5	104.7	116.2	119.9	122.8	125.4
Agricultural	417.5	436.5	455.4	474.3	493.5	512.4	531.5
Power	3.4	4.2	5.2	6.4	7.9	9.7	11.8
Total	**495.5**	**531.2**	**565.3**	**596.9**	**621.3**	**644.9**	**668.7**
STATEWIDE							
M & I	816.8	930.7	1012.0	1066.7	1104.2	1135.8	1167.9
Agricultural	1321.6	1411.3	1502.0	1592.7	1683.1	1774.0	1864.4
Power	125.8	154.7	190.4	234.2	288.0	354.3	435.4
TOTAL	**2264.2**	**2496.7**	**2704.4**	**2893.6**	**3075.3**	**3264.1**	**3467.7**

Table 8 includes a composite regional summary of existing supplies and projected demands. Despite the apparent surplus of available supplies, water quality is marginal in some areas of the Northwest, Southwest, and South Central Planning Regions and additional supplies of higher quality municipal and industrial water may be required there. Reallocations of hydropower storage may also be required in the Northeast and Southeast Planning Regions. It should also be noted that the net surplus shown in Table 8 and subsequent regional "supply and demand analysis" tables include yields from groundwater, SCS/NRCS and municipal lakes as well as from major federal lakes. Water from sources other than major federal lakes are more localized in nature and may not be realistically available to meet regional demands. In addition, estimates of water supply were not limited by water quality considerations or sedimentation.

Table 7
COMPOSITE WATER RIGHTS
STATE OF OKLAHOMA

STREAM WATER ALLOCATIONS
(acre-feet)

REGION	**Municipal**	**Industrial**	**Agricultural**	**Commercial**	**Rec, F&W**	**Power**	**Other**	**TOTAL**
Central	145,816	326	18,056	228	3,185	12,304	---	179,915
East Central	143,635	40,221	33,705	505	4,224	35,000	---	257,290
North Central	143,794	17,230	17,959	125	11,723	77,765	---	268,596
Northeast	657,190	76,007	98,057	1,266	6,013	228,262	20	1,066,815
Northwest	6,971	107	27,741	20	6,776	---	---	41,615
South Central	99,580	7,634	47,900	901	22,670	---	111	178,796
Southeast	232,840	50,597	57,900	53	10,021	32,285	---	383,696
Southwest	152,170	7,191	147,462	26	9,113	1,636	2,000	319,598
TOTAL	**1,581,996**	**199,313**	**448,780**	**3,124**	**73,725**	**387,252**	**2,131**	**2,696,321**

GROUNDWATER ALLOCATIONS
(acre-feet)

REGION	**Municipal**	**Industrial**	**Agricultural**	**Commercial**	**Rec, F&W**	**Power**	**Other**	**TOTAL**
Central	180,586	8,294	87,904	17,935	3,090	15,266	467	313,542
East Central	8,083	7,845	31,400	1,010	1,619	90	5	50,051
North Central	63,070	12,107	89,280	963	294	171	29	165,914
Northeast	30,327	23,908	29,759	326	64	427	768	85,578
Northwest	105,655	10,652	1,312,012	2,444	3,876	4,864	242	1,439,745
South Central	44,512	19,236	97,160	508	804	4,200	20	166,440
Southeast	66,890	11,459	26,570	799	368	2,602	---	108,688
Southwest	48,666	36,114	674,016	2,514	1,076	3,697	191	766,273
TOTAL	**547,789**	**129,615**	**2,348,101**	**26,499**	**11,191**	**31,317**	**1,722**	**3,096,232**
GRAND TOTAL	**2,129,785**	**328,928**	**2,796,881**	**29,623**	**84,916**	**418,569**	**3,853**	**5,792,553**

Note: Agricultural allocations include Irrigation. Mining included in Industrial.
Source of data: Oklahoma Water Resource Board printout dated June 23, 1994.

Table 8
COMPOSITE SUPPLY AND DEMAND ANALYSIS
STATE OF OKLAHOMA

(1,000 ACRE-FEET)

	REGION								
	Central	**East Central**	**North Central**	**Northeast**	**Northwest**	**South Central**	**Southeast**	**Southwest**	**TOTALS**
M& I Supply	366.1	186.6	246.5	532.3	133.1	144.6	218.6	240.8	2,068.6
2050 M&I Demand	292.0	63.0	100.1	361.8	45.5	74.6	105.5	125.4	1,167.9
Local M&I Surplus/(Deficit)	74.1	123.6	146.4	170.5	87.6	70.0	113.1	115.4	900.7
Agricultural Supply	115.0	107.1	138.4	110.7	1,319.5	186.2	85.9	813.8	2,876.6
2050 Agricultural Demand	37.4	40.0	44.8	46.6	1,057.7	61.3	45.1	531.5	1,864.4
Local Agricultural Surplus/(Deficit)	77.6	67.1	93.6	64.1	261.8	124.9	40.8	282.3	1,012.2
Power Supply	27.6	76.5	76.8	293.9	4.9	4.2	34.6	10.6	529.1
2050 Power Demand	29.0	75.6	74.4	224.7	4.1	---	15.8	11.8	435.4
Local Power Surplus/(Deficit)	(1.4)	0.9	2.4	69.2	0.8	4.2	18.8	(1.2)	93.7
Regional Surplus Availability [1]	---	15.9	33.6	57.3	---	163.5	530.3	---	800.6
TOTAL SUPPLY	**508.7**	**386.1**	**495.3**	**994.2**	**1,457.5**	**498.5**	**869.4**	**1,065.2**	**6,274.9**
TOTAL 2050 DEMAND	**358.4**	**178.6**	**219.3**	**633.1**	**1,107.3**	**135.9**	**166.4**	**668.7**	**3,467.7**
NET SURPLUS/(DEFICIT)	**150.3**	**207.5**	**276.0**	**361.1**	**350.2**	**362.6**	**703.0**	**396.5**	**2,807.2**

[1] Unallocated from major federal lakes.

Central Planning Region

REGIONAL DESCRIPTION

The Central Planning Region consists of five counties -- Canadian, Cleveland, McClain, Oklahoma, and Pottawatomie -- primarily in the North Canadian and Canadian River Basins (Figure 23). The region displays many of the physical diversities of the state, from metropolitan Oklahoma City to the open farmlands of Canadian County. This region benefits from the convergence of coast-to-coast and border-to-border interstate highways, including I-40 and I-35.

The Central Region is the smallest of the eight planning regions, comprising only 3,544 square miles. However, Oklahoma County is projected to account for more than 17 percent of the total projected municipal and industrial (M&I) water demand for the entire state, and more than 68 percent of the total M&I water demand for the region in the year 2050. The region's agricultural water demand is projected to be relatively low.

The climate is generally pleasant with annual mean temperatures ranging between 60 and 62 degrees. Summer high temperatures generally approach 100°F while winter lows dip into the mid-teens. Annual evaporation within the region ranges from 63 inches per year in western areas to 57 inches per year in the east. Rainfall averages vary from 28 inches per year in western Canadian County to more than 34 inches in southeastern Pottawatomie County. As with most of the state, thunderstorms are a frequent occurrence during much of the spring and summer and are often accompanied by heavy rain, lightning, hail and tornados. In addition, these storms may generate flash floods, making flood control storage a critical element in most reservoirs in the region.

WATER RESOURCES

Stream Water

Table 9 summarizes the stream water sources of the Central Planning Region. Although the region is generally bounded by the North Canadian and Canadian Rivers, much of the stream water within the region is of poor quality and not suitable for most M&I uses.

The Canadian River typically experiences high levels of chloride and total dissolved solids (TDS). Downstream of Oklahoma City, return flows from wastewater treatment plants enter the river and constitute a significant portion of the flow. Water quality has improved in recent years with the addition of secondary treatment of wastewater flows; however, the water remains unsuitable for many uses.

The North Canadian River has similar water quality problems. TDS and chloride levels are relatively high and Oklahoma City wastewater return flows constitute a large percentage of the North Canadian River's total flow. While some stream water quality parameters have improved, others -- such as dissolved nitrate plus nitrate -- have worsened.

The Upper Little River is located in the eastern portion of the region in Cleveland and Pottawatomie Counties. The water is of good quality with low mineral content. Lake Thunderbird exists at the headwaters of the Little River.

The Deep Fork River, located in Oklahoma County, is of fair quality with moderate mineral content. However, at certain times of the year, the chloride content approaches the maximum allowed under Safe Drinking Water Act standards.

MAJOR RESERVOIRS

There are two major impoundments within the Central Planning Region. The largest is Lake Thunderbird in Cleveland County. This Bureau of Reclamation project was constructed in 1965 for flood control (storage for which is operated by the Corps of Engineers), water supply, recreation, and fish and wildlife purposes. Located on the Little River, its water is of excellent quality with a firm dependable water supply yield of 21,700 af/yr (approximately 19.4 mgd). All available yield is allocated to the Central Oklahoma Master Conservancy District which provides municipal and industrial supplies to the cities of Norman, Midwest City and Del City.

Arcadia Lake is the other major impoundment in the region. Completed by the Corps of Engineers in 1986, the lake provides water supply, flood control, and recreation opportunities along the Deep Fork River in Oklahoma County. The reservoir provides 12,100 af/yr (11 mgd) of water supply. The entire available yield is allocated to the Edmond Public Works Authority.

MUNICIPAL LAKES

There are five major municipal lakes within the Central Planning Region; three are owned and operated by Oklahoma City while the City of Shawnee and Pottawatomie County Development Authority own the others. The largest municipal lake is Lake Stanley Draper, on East Elm Creek in Cleveland County. Built in 1962 by the City of Oklahoma City, the impoundment is utilized primarily as terminal storage for water pumped, via a 90 mgd pipeline, from Atoka and McGee Creek Reservoirs in the Southeast Planning Region. The lake has little dependable yield of its own; the 86,000 af/yr (76.8 mgd) of dependable yield is comprised of deliveries from Atoka (63,776 af/yr) and McGee Creek (40,000 af/yr), minus evaporative losses. Water in Lake Draper is of excellent quality and the lake provides many recreational benefits.

Lake Hefner, also owned and operated by Oklahoma City, was built on Bluff Creek in 1943 for water supply and recreation in northwest Oklahoma County. As with Lake Draper, the lake has virtually no yield of its own, serving as terminal storage for diversions from the North Canadian River and releases from Canton Lake. Though containing some chlorides, the water is of fair quality and suitable for most uses.

Lake Overholser, the third Oklahoma City reservoir in the area, is located on the North Canadian River in eastern Canadian County. The lake was built in 1919 for water supply and recreational purposes; its dependable yield of 5,000 af/yr (4.5 mgd) is supplemented by releases from Canton Reservoir. Water in the lake is of fair quality and, during periods of low flow, the river is diverted around Overholser to avoid worsening the lake's quality.

Shawnee Lake, on South Deer Creek in Pottawatomie County, is owned and operated by the City of Shawnee. The lake is actually two impoundments connected by a 10-foot-deep canal. Lake Number One was built in 1935 and covers a surface area of 1,336 acres; Lake Number Two was built in 1960 and has a surface area of 1,100 acres. The combined reservoirs have a dependable yield of 4,400 af/yr (3.9 mgd).

Wes Watkins Reservoir (Site 1M) is an NRCS project currently under construction on North Deer Creek in far northwest Pottawatomie County. When completed, the lake is estimated to have a dependable yield of 2,050 af/yr (1.8 mgd).

OTHER IMPOUNDMENTS

There are numerous other NRCS projects, small municipal lakes and private reservoirs within the Central Planning Region. These small lakes provide municipal supply, irrigation water and recreational opportunities. Cedar Lake (1,125 ac-ft of approximate conservation storage), Lake Dahlgren (222 ac-ft), Tecumseh Lake (1,118 ac-ft), Purcell Lake (2,600 ac-ft), El Reno Lake (709 ac-ft), Lake Hiwassee (2,400 ac-ft), Wiley Post Memorial Lake (2,082 ac-ft) and Uncle John Creek (S-10; 1,080 ac-ft) are some of the larger impoundments in this category.

AUTHORIZED DEVELOPMENT

There are no major authorized water supply projects within the Central Planning Region.

POTENTIAL DEVELOPMENT

There are very few potential sites within the Central Planning Region for the development of new water supply projects. This is due in part to the poor water quality of many of the major streams and rivers in the region. Two sites which have been studied are Purcell Reservoir and West Elm Lake.

Purcell Reservoir is a potential site on Walnut Creek in McClain County, northwest of Purcell. The potential yield of the reservoir is 19,000 af/yr (17 mgd), with an additional 40,000 ac-ft of flood control storage. The proposed lake would inundate 5,400 acres at normal conservation pool. No potential water quality data is available at this time.

West Elm Lake -- located on West Elm Creek in Cleveland County southwest of Lake Stanley Draper -- is a potential terminal storage site for Oklahoma City. Due to its limited watershed of 16 square miles, the lake is not anticipated to have any dependable yield. If fully developed, the lake would impound 3,300 acres at normal conservation pool and have conservation storage of 103,600 ac-ft.

STREAM WATER RIGHTS

As of June 1994, the OWRB had issued stream water allocation permits totaling 179,915 ac-ft per year from lakes, rivers and streams within the Central Planning Region. Table 10 provides a breakdown of these stream water allocations.

Groundwater

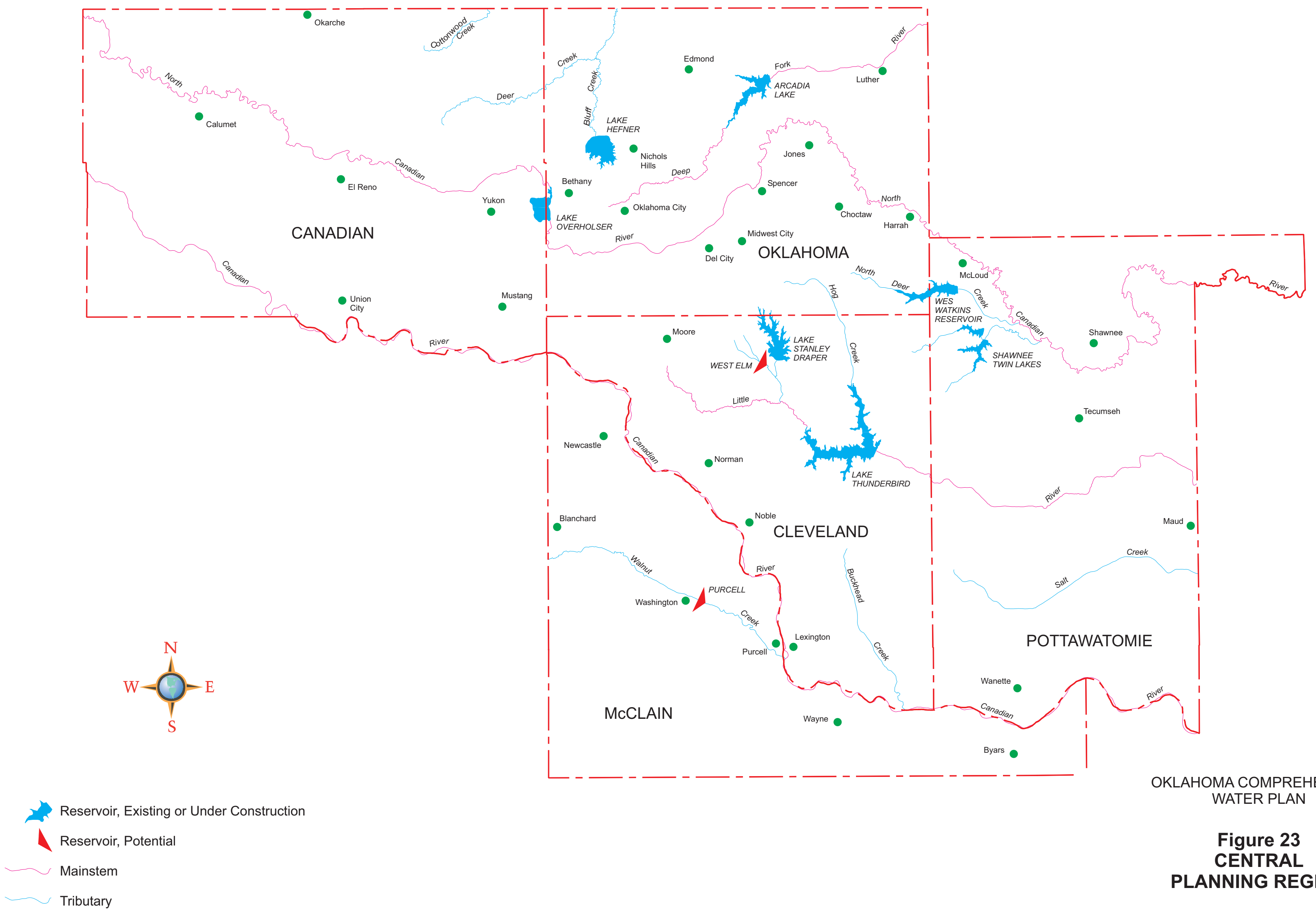
Central Oklahoma overlies the Garber-Wellington Formation and alluvium and terrace deposits of three major rivers. The Garber-Wellington Aquifer is a fine-grained sandstone with shale and siltstone. It has a maximum thickness of approximately 900 feet with a saturated thickness of 150 to 650 feet. Well depths are generally 100 to 200 feet deep where the formation is unconfined and 200 to 900

Table 9
STREAM WATER DEVELOPMENT
Central Planning Region

PROJECT	STREAM	PURPOSE*	FLOOD CONTROL STORAGE (acre-feet)	WATER SUPPLY STORAGE (acre-feet)	WATER SUPPLY YIELD (ac-ft/year)
		EXISTING OR UNDER CONSTRUCTION			
Arcadia	Deep Fork Creek	ws, fc, r	64,430	27,380	12,320
Stanley Draper	East Elm Creek	ws, r	---	100,000	86,000 [1]
Hefner	Bluff Creek	ws, r	---	75,000	17,000 [2]
Overholser	North Canadian River	ws, r	---	15,000	5,000 [2]
Thunderbird	Little River	ws, fc, r, fw	76,600	105,900	21,700
Shawnee	South Deer Creek	ws, r	---	34,000	4,400
Wes Watkins	North Deer Creek	ws	---	---	2,050
TOTAL			**141,030**	**357,280**	**148,470**
		POTENTIAL			
Purcell	Walnut Creek	ws, fc, r	40,000	98,000	19,000 [3]
West Elm	West Elm Creek	ws, r	---	103,600	---- [4]
TOTAL			**40,000**	**201,600**	**19,000**
TOTAL YIELD					**167,470**

*ws-municipal water supply, fc-flood control, r-recreation, fw-fish and wildlife.

[1] Draper Lake is terminal storage for water pumped from Lake Atoka in Southeast Region via Atoka pipeline. Draper Lake will also store water pumped from McGee Creek Reservoir in Southeast Region. Available yield from pipeline (90 mgd = 100,800 af/yr), minus evaporation losses, is 86,000 af/yr.
[2] Yields do not include releases from Canton Reservoir.
[3] Proposed impoundment located northwest of Purcell, Oklahoma. This potential project should not be confused with Purcell Lake (2,600 ac-ft storage), south of the Town of Purcell.
[4] Proposed terminal storage with no dependable yield.



OKLAHOMA COMPREHENSIVE WATER PLAN

Figure 23
CENTRAL
PLANNING REGION

Mapping and Graphics - Oklahoma Water Resources Board

feet deep in confined areas. Wells commonly yield 100 to 300 gpm from the formation but may exceed 500 gpm in some locations.

Water from the Garber-Wellington is generally of a calcium magnesium bicarbonate type. Dissolved solids concentrations are usually less than 500 mg/L. The aquifer becomes more saline with depth and in the western areas of the region. Heavy pumpage in some areas has led to drawdowns of 100 to 200 feet and saltwater intrusion from below, as well as contamination from oilfield brines in shallow areas.

The alluvial and terrace deposit aquifers are usually found around major rivers in the region, extending outward from one to 15 miles. These deposits are present in all five counties of the region along the Canadian River, North Canadian River and Deep Fork of the North Canadian River. Well yields range from less than 100 gpm to as much as 600 gpm. Formation deposits are as much as 60 to 80 feet thick and consist of clays, sand, silt and gravels. Hardness and total dissolved solids are the major water quality problems, with reported values frequently exceeding 500 mg/L for each.

GROUNDWATER DEVELOPMENT

Extensive development of groundwater supplies has occurred in the Central Planning Region. Many communities, including numerous Oklahoma City suburbs, rely on groundwater for all or part of their water supply needs. With the limited availability of suitable quality surface water, groundwater is expected to remain an important part of the region's water supplies.

GROUNDWATER RIGHTS

As of June 1994, the OWRB had issued groundwater allocation permits totaling 313,542 ac-ft per year from aquifers within the Central Planning Region. Table 10 provides a breakdown of these groundwater allocations.

SUPPLY AND DEMAND ANALYSIS

Despite its relatively small size, the Central Planning Region is the most populated planning region. The long-range projection for municipal and industrial water demand in the year 2050 is 292,000 af/yr (259.9 mgd), or approximately 81 percent of the region's total projected water demand. As shown in Table 11, current supplies indicate that anticipated demands could be met with relatively few local deficits. Continued use of out-of-basin sources is essential to ultimately meeting the long-range water supply needs of the region, since existing sources include groundwater or marginal quality surface impoundments.

Table 10
WATER RIGHTS
Central Planning Region

STREAM WATER ALLOCATIONS (acre-feet)

COUNTY	Municipal	Industrial	Agricultural	Commercial	Rec, F&W	Power	Other	TOTAL
Canadian	---	99	4,744	120	1,176	---	---	6,139
Cleveland	21,600	---	836	---	401	---	---	22,837
McClain	160	20	4,013	---	205	---	---	4,398
Oklahoma	92,500	207	2,835	108	1,401	12,304	---	109,355
Pottawatomie	31,556	---	5,628	---	2	---	---	37,186
TOTAL	**145,816**	**326**	**18,056**	**228**	**3,185**	**12,304**	**---**	**179,915**

GROUNDWATER ALLOCATIONS (acre-feet)

COUNTY	Municipal	Industrial	Agricultural	Commercial	Rec, F&W	Power	Other	TOTAL
Canadian	4,770	2,094	46,237	362	991	11,602	---	66,056
Cleveland	48,161	716	12,358	8,335	280	60	15	69,925
McClain	6,070	54	8,890	9	10	---	---	15,033
Oklahoma	114,175	4,921	11,564	9,140	1,678	3,604	452	145,533
Pottawatomie	7,412	508	8,855	90	131	---	---	16,995
TOTAL	**180,586**	**8,294**	**87,904**	**17,935**	**3,090**	**15,266**	**467**	**313,542**

Note: Agricultural allocations include Irrigation. Mining included in Industrial.
Source of Data: Oklahoma Water Resource Board printout, June 23, 1994.

Table 11
SUPPLY AND DEMAND ANALYSIS
Central Planning Region

(1,000 ACRE-FEET/YEAR)

SOURCE	COUNTY Canadian	Cleveland	McClain	Oklahoma	Pottawatomie	TOTAL
			MUNICIPAL AND INDUSTRIAL COMPONENT			
Arcadia	---	---	---	12.3	---	12.3
Stanley Draper	---	---	---	86.0	---	86.0
Hefner	---	---	---	17.0	---	17.0
Overholser	---	---	---	5.0	---	5.0
Shawnee	---	---	---	---	4.4	4.4
Thunderbird	---	21.7	---	---	---	21.7
Wes Watkins	---	---	---	---	2.1	2.1
SCS & Municipal Lakes	2.4	0.6	1.8	1.9	0.6	7.3
Groundwater	8.2	57.5	6.1	130.4	8.1	210.4
M & I Supply	**10.6**	**79.8**	**8.0**	**252.6**	**15.1**	**366.1**
2050 M & I Demand	**21.1**	**44.9**	**7.3**	**199.5**	**19.2**	**292.0**
M & I Surplus/(Deficit)	**(10.5)**	**34.9**	**0.7**	**53.1**	**(4.1)**	**74.1**
			AGRICULTURAL COMPONENT			
SCS & Municipal Lakes	5.1	1.7	12.6	3.4	4.4	27.1
Groundwater	46.2	12.4	8.9	11.6	8.9	87.9
Agricultural Supply	**51.3**	**14.0**	**21.5**	**15.0**	**13.2**	**115.0**
2050 Agricultural Demand	**18.7**	**3.8**	**3.2**	**4.0**	**7.7**	**37.4**
Agricultural Surplus/(Deficit)	**32.6**	**10.2**	**18.3**	**11.0**	**5.5**	**77.6**
			POWER COMPONENT			
Horsehoe Lake	---	---	---	12.3	---	12.3
Groundwater	11.6	0.1	---	3.6	---	15.3
Power Supply	**11.6**	**0.1**	**---**	**15.9**	**---**	**27.6**
2050 Power Demand	**6.8**	**---**	**---**	**22.2**	**---**	**29.0**
Power Surplus/(Deficit)	**4.8**	**0.1**	**---**	**(6.3)**	**---**	**(1.4)**
			TOTALS			
Total Local Supply	**73.5**	**93.9**	**29.5**	**283.5**	**28.4**	**508.7**
Total 2050 Demand	**46.6**	**48.7**	**10.5**	**225.7**	**26.9**	**358.4**
Net Surplus/(Deficit)	**26.9**	**45.2**	**19.0**	**57.8**	**1.5**	**150.3**

East Central Planning Region

REGIONAL DESCRIPTION

Covering approximately 11.2 percent of the state (7,829 square miles), Haskell, Hughes, Latimer, LeFlore, McIntosh, Okfuskee, Pittsburg, Seminole and Sequoyah Counties comprise the East Central Planning Region (Figure 24). The region's terrain varies from the forested Kiamichi Mountains to the rolling river basin plains of the Arkansas River, to the foothills of the Ozark Mountains. Stream and surface water sources are abundant within the region.

The East Central Region has one of the lowest projected M&I water demands for the year 2050. The region is lightly populated with McAlester as the largest city. Projected 2050 agricultural demands are the lowest of any planning region.

The region's climate is mild, with annual mean temperatures varying from 51 to 62 degrees. Annual evaporation ranges from 56 inches per year in the western portion of the region to 48 inches per year in the east. Rainfall averages closely approximate evaporation rates, making the region well-suited for reservoirs.

WATER RESOURCES

Stream Water

Table 12 summarizes the stream water sources of the East Central Planning Region. Major streams include the North Canadian and Canadian Rivers, Little River, Deep Fork River, Poteau River and the headwaters of the Kiamichi River. Some of the streams in the middle and lower eastern portions of the region contain good quality water. However, some streams in the west contain water of poor quality and restrict M&I uses.

The Canadian River upstream of Lake Eufaula experiences unacceptable chloride and TDS levels. Upstream wastewater return flows contribute to high nutrient loadings in the river which joins the Arkansas River at Robert S. Kerr Reservoir. The overall water quality improves at this point due to dilution with higher quality waters of the Arkansas River.

The Arkansas River, the principal waterway of the region, collects flows of the Illinois, Poteau and the Canadian Rivers. The river water has a generally low mineral content in this region. Overall, the water tends to be hard but is acceptable for most M&I uses.

The North Canadian River within the region experiences many of the same water quality problems noted in the Central Region. Levels of TDS and chlorides remain high and quality is the poorest of the region's available stream water sources.

The Poteau River is located in the southeastern portion of the East Central Planning Region in LeFlore County. The water is of good quality with low mineral content.

MAJOR RESERVOIRS

There are four major impoundments within the East Central Planning Region. The largest of these is Eufaula Lake in McIntosh, Pittsburg and Haskell Counties. This Corps of Engineers project was constructed in 1964 for flood control, water supply, navigation and hydropower purposes. The flood control storage of 1,510,800 ac-ft is credited with preventing more than $107 million dollars of flood-related damages since becoming operational. The lake, located on the Canadian River about 12 miles east of Eufaula, is the fifteenth largest manmade impoundment in the United States, with a surface area of 105,500 acres at normal pool. The lake has a dependable water supply yield of 56,000 af/yr (50 mgd). Power pool storage of 1,407,000 ac-ft is available for reallocation to water supply, should it be needed. The water is of fair quality and suitable for most municipal and industrial uses.

Robert S. Kerr Reservoir, on the Arkansas River in LeFlore County, is a key component in the McClellan-Kerr Arkansas River Navigation System. The reservoir was constructed in 1970 for navigation, hydroelectric power and recreational purposes. The powerhouse is equipped with four 27,500 kW turbines having a total capacity of 110,000 kW and an average annual potential energy output of 459 MkWh. The navigational lock is 110 feet wide by 600 feet long and can provide 48 feet of lift to vessels. The reservoir has a power pool capacity of 525,700 ac-ft which extends to Webbers Falls Lock & Dam. The power pondage is 84,700 ac-ft. The reservoir has no dedicated water supply storage; however, 33,734 af/yr has been allocated from the power pool to the Sequoyah Water Distribution Authority for municipal water supply.

Tenkiller Ferry Lake is located on the Illinois River in Cherokee and Sequoyah Counties. The reservoir straddles the East Central and Northeast Planning Regions. Completed in 1953 by the Corps of Engineers, the lake's authorized purposes are flood control and hydroelectric power. Water supply is not an authorized purpose of the reservoir even though the conservation pool is comprised of 25,400 ac-ft (29,792 af/yr yield) of water supply storage, 345,600 ac-ft (392,050 af/yr yield) of power drawdown storage and 283,100 ac-ft of dead storage. The lake also provides 576,700 ac-ft of flood control storage.

Wister Lake is the fourth major impoundment in the East Central Region. The lake was built by the Corps of Engineers in 1948 to provide flood control, water supply and low flow augmentation on the Poteau River in LeFlore County. The lake contains 388,399 ac-ft of flood control and conservation pool storage, varying between 39,082 and 61,423 ac-ft, depending upon the time of year. Of the varying conservation pool, 14,000 ac-ft is set aside for water supply which yields 31,400 af/yr (27.9 mgd). The water is of good quality and suitable for all uses.

MUNICIPAL LAKES

There are four large municipal lakes and one large private lake within the East Central Planning Region. The largest is Konawa Reservoir on Jumper Creek in Seminole County. Built in 1968 by Oklahoma Gas and Electric Company, the impoundment is utilized as cooling water for its Seminole Power Plant. The lake has 23,000 ac-ft of storage and provides recreational opportunities for the region.

McAlester Lake, in Pittsburg County, is an impoundment owned and operated by the City of McAlester. The lake, built on Bull Creek in 1930 for water supply and recreation, has a yield of 9,200 af/yr (8.2 mgd). Water is of good quality and suitable for all uses.

Okemah Lake is a City of Okemah impoundment in Okfuskee County. Located on Buckeye Creek, it was built for water supply and recreational purposes. The lake has conservation storage of 13,100 ac-ft and an estimated yield of 6,550 af/yr (5.8 mgd), based on recharge factors for the county. Water in the lake is of fair quality.

Holdenville Lake, on a tributary to Little River in Hughes County, is owned and operated by the City of Holdenville for water supply and recreational purposes. The lake was built in 1931 with a surface area of 550 acres and conservation storage of 11,000 ac-ft. Based on the recharge factor for the county, the lake has an estimated yield of 5,500 af/yr (4.9 mgd).

Lloyd Church Lake (SCS #7) is an NRCS project on Bandy Creek in Latimer County. Owned by the City of Wilburton, the lake has conservation storage of 3,060 ac-ft and a dependable yield of 1,523 af/yr (1.36 mgd). The lake's purposes include water supply, flood control and recreation.

OTHER IMPOUNDMENTS

There are numerous other NRCS projects, small municipal lakes and private reservoirs within the East Central Planning Region. These lakes provide municipal supply, irrigation water and recreational opportunities. Cohee Lake (1,500 ac-ft of conservation storage), Wetumka Lake (1,839 ac-ft), Sportsman Lake (5,349 ac-ft), Wewoka Lake (3,301 ac-ft), Brown Lake (4,525 ac-ft), Wayne Wallace Lake (1,746 ac-ft), New Spiro Lake (2,160 ac-ft) and Brushy Creek Reservoir (3,258 ac-ft) are some of the larger impoundments in this category.

AUTHORIZED DEVELOPMENT

There are no major authorized water supply projects within the East Central Planning Region.

POTENTIAL DEVELOPMENT

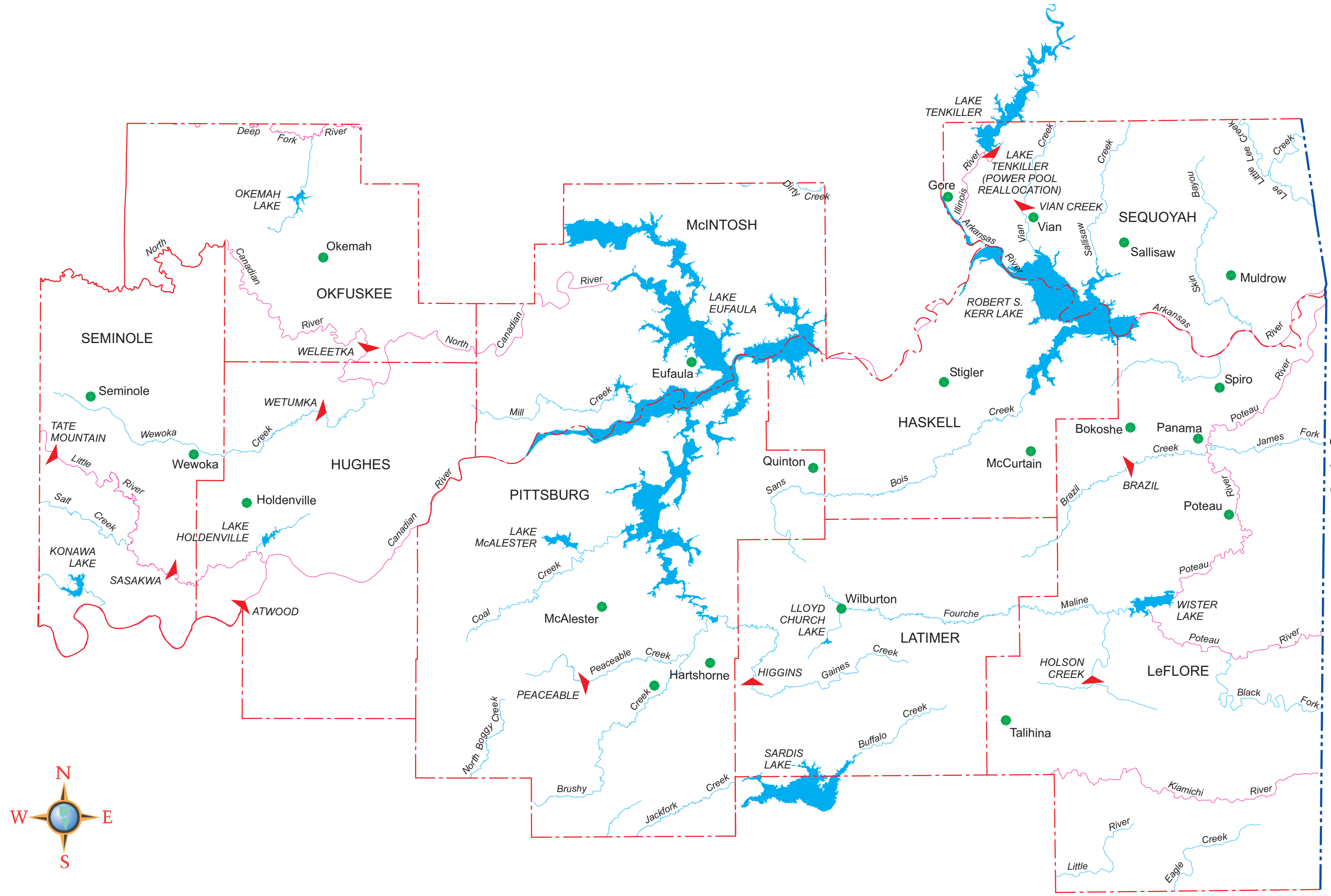
There are numerous sites within the East Central Planning Region with potential for development of new water supply projects. The abundance of rainfall within the region could also aid in

Table 12
STREAM WATER DEVELOPMENT
East Central Planning Region

PROJECT	STREAM	PURPOSE*	FLOOD CONTROL STORAGE (acre-feet)	WATER SUPPLY STORAGE (acre-feet)	WATER SUPPLY YIELD (ac-ft/year)
		EXISTING OR UNDER CONSTRUCTION			
Eufaula	Canadian River	ws, fc, p, n	1,510,800	56,000	56,000
Holdenville	Tributary to Little River	ws, r	0	11,000	5,500
Konawa	Jumper Creek	p, r	---	23,000	---
Lloyd Church (SCS #7)	Bandy Creek	w s	---	3,060	1,523
McAlester	Bull Creek	ws, fc, r	---	13,398 [1]	9,200 [1]
Okemah	Buckeye Creek	ws, r	---	13,100	6,550
Robert S. Kerr	Mainstem Arkansas	p, r, n	---	---	33,606 [2]
Sardis	Jackfork Creek	ws, fc, r, fw	---	---	1,000 [3]
Tenkiller (Water Supply Pool Allocations)	Illinois River	fc, p	576,700	25,400 [4]	10,992 [4]
Wister	Poteau River	ws, fc, flow	388,399	39,082	31,400
TOTAL			**2,475,899**	**184,040**	**155,771**
		POTENTIAL			
Atwood	Canadian	ws, r	---	---	44,800
Brazil	Brazil Creek	ws, fc, r	108,000	190,000	87,400
Higgins	Gaines Creek	ws, r	---	195,000	68,400
Holson Creek	Holson Creek	ws, r	---	30,000	22,400
Peaceable	Peaceable Creek	ws, r	---	---	33,600
Sasakwa	Little River	ws, fc, r	209,000	325,000	79,900
Tate Mountain	Little River	ws, r	---	134,600	49,800
Tenkiller (Power Pool Allocations)	Illinois River	fc, p	---	345,600 [5]	392,050 [5]
Vian Creek [6]	Vian Creek	ws, fc, r	10,400	17,500	10,100
Weleetka [7]	North Canadian River	ws, r	---	---	35,800
Wetumka	Wewoka Creek	ws, fc, r	110,000	210,000	67,200
TOTAL			**437,400**	**1,447,700**	**891,450**
TOTAL YIELD					**1,047,221**

*ws-municipal water supply, fc-flood control, p-power, r-recreation, fw-fish and wildlife, n-navigation, flow-low flow augmentation.

[1] City of McAlester no longer uses Lake Talawanda No. 1 & 2 for water supply. Values reflect only McAlester Lake.
[2] Robert S. Kerr has no water supply storage or yield. However, 33,606 af/yr of hydropower pool is allocated to water supply.
[3] Located in Southeast Planning Region. Total water supply yield is 156,800 af/yr, of which 1,000 af/yr is allocated to East Central Planning Region.
[4] Total water supply yield is 29,792 af/yr, of which 18,800 af/yr is allocated to Northeast Planning Region.
[5] Reallocation of 345,600 ac-ft of hydropower storage yielding 392,050 af/yr for water supply. Also listed as potential source for Northeast Planning Region.
[6] Regulating storage reservoir to regulate excess flows from Arkansas River.
[7] Storage requirements have not been developed. Yields are based on 60% of average annual streamflow in drainage area.



Reservoir, Existing or Under Construction

Reservoir, Potential Modification

Reservoir, Potential

Mainstem

Tributary

OKLAHOMA COMPREHENSIVE WATER PLAN

Figure 24
EAST CENTRAL PLANNING REGION

Mapping and Graphics - Oklahoma Water Resources Board

this development. Of the 11 sites identified in Table 12, several have been extensively studied.

Holson Reservoir is a proposed multipurpose impoundment on Holson Creek in the Poteau River Basin of LeFlore County. The potential yield of the reservoir is 22,400 af/yr (20 mgd) from the 30,000 ac-ft of conservation storage.

Sasakwa Lake, proposed for development on the Little River in Seminole County, is another potential multipurpose site under consideration. The recommended configuration calls for 209,000 ac-ft of flood control storage and 325,000 ac-ft of conservation storage yielding 79,900 af/yr (71.3 mgd) of marginal quality water supply. Chloride and high iron concentrations could cause objectionable taste.

Tate Mountain Reservoir is proposed on the Little River, approximately 6.5 miles northwest of Sasakwa, in Seminole County. The potential reservoir, recommended in an April 1989 Bureau of Reclamation study, includes 134,600 ac-ft of conservation storage yielding 49,800 af/yr (44.5 mgd) of water supply. No flood control storage is proposed. The dam site is situated to avoid inflows from Salt Creek, thus making the water of acceptable quality for most uses.

Wetumka Creek is another potential multipurpose project in the East Central Region. Located on Wewoka Creek in Hughes County, the reservoir is planned to have 110,000 ac-ft of flood control storage and 103,600 ac-ft of conservation storage yielding 67,200 af/yr (60 mgd) of water supply. Stream water in the area contains large quantities of oilfield brines. Without prior clean-up and containment of these inflows, the water would be questionable for M&I use.

Modifications to Wister Lake were proposed in the 1980 Oklahoma Comprehensive Water Plan. However, potential dam safety issues and downstream channelization problems identified with the project resulted in its removal from consideration by the Corps of Engineers.

STREAM WATER RIGHTS

As of June 1994, the OWRB had issued stream water allocation permits totaling 257,290 ac-ft per year from lakes, rivers and streams in the East Central Planning Region (Table 13).

Table 13
WATER RIGHTS
East Central Planning Region

STREAM WATER ALLOCATIONS
(acre-feet)

COUNTY	Municipal	Industrial	Agricultural	Commercial	Rec, F&W	Power	Other	TOTAL
Haskell	2,540	5	404	55	---	---	---	3,004
Hughes	5,400	20	10,270	3	816	---	---	16,509
Latimer	4,405	60	911	30	483	---	---	5,889
LeFlore	6,788	15,357	8,510	169	615	---	---	31,439
McIntosh	7,311	5	297	176	473	---	---	8,262
Okfuskee	1,582	15	3,733	---	428	---	---	5,758
Pittsburg	35,406	21,309	5,652	30	1	---	---	62,398
Seminole	3,957	142	1,289	---	367	35,000	---	40,755
Sequoyah	76,246	3,308	2,639	42	1,041	---	---	83,276
TOTAL	**143,635**	**40,221**	**33,705**	**505**	**4,224**	**35,000**	**---**	**257,290**

GROUNDWATER ALLOCATIONS
(acre-feet)

COUNTY	Municipal	Industrial	Agricultural	Commercial	Rec, F&W	Power	Other	TOTAL
Haskell	242	---	90	---	1,542	---	---	1,874
Hughes	1,556	10	11,117	---	20	---	---	12,703
Latimer	34	---	134	34	---	---	---	202
LeFlore	31	---	7,321	170	---	---	---	7,522
McIntosh	556	---	240	---	---	---	5	801
Okfuskee	300	7,043	1,730	783	---	---	---	9,856
Pittsburg	380	8	1,407	---	---	---	---	1,795
Seminole	4,815	784	1,522	18	57	90	---	7,285
Sequoyah	169	---	7,839	5	---	---	---	8,013
TOTAL	**8,083**	**7,845**	**31,400**	**1,010**	**1,619**	**90**	**5**	**50,051**

Note: Agricultural allocations include Irrigation. Mining included in Industrial.
Source of Data: Oklahoma Water Resource Board printout, June 23, 1994.

Groundwater

East Central Oklahoma overlies the Ada-Vamoosa Formation and alluvium and terrace deposits of the Canadian and Arkansas Rivers. The Ada-Vamoosa Aquifer is a fine- to very fine-grained sandstone with siltstone and interbedded limestone. It has a maximum thickness of approximately 550 feet and saturated thickness of 100 to 200 feet. Wells are generally 100 to 500 feet deep and commonly yield 100 to 300 gpm from the formation but may exceed 500 gpm in some locations. Water from the Vamoosa Formation is generally of a sodium bicarbonate or sodium calcium bicarbonate type while dissolved solids are usually less than 500 mg/L.

Wells in the two major alluvial and terrace deposit aquifers of the region yield from 200 to 800 gpm. Formation deposits average 42 feet in thickness, with saturated thickness averaging 25 feet, and consist of clays, sand, silt and gravels. Hardness is the major water quality problem; TDS values are usually less than 500 mg/L in the Arkansas River Basin and less than 1,000 mg/L in the Canadian River Basin. However, these waters are generally suitable for most M&I uses.

GROUNDWATER DEVELOPMENT

Extensive development of groundwater supplies has not occurred in the East Central Planning Region due to the abundance of stream water. Some communities in Seminole and Okfuskee Counties utilize the Vamoosa Formation while smaller communities along the Canadian and Arkansas Rivers utilize the alluvial and terrace deposits.

GROUNDWATER RIGHTS

As of June 1994, the OWRB had issued groundwater allocation permits totaling 50,051 ac-ft per year from aquifers in the East Central Planning Region (Table 13).

SUPPLY AND DEMAND ANALYSIS

The East Central Planning Region is well-prepared for anticipated future growth. Existing reservoirs within the region currently have surplus and/or unallocated water available. Table 14 displays the availability of water from existing sources. The long-range projection for M&I water demand in the year 2050 is 63,000 af/yr (56.2 mgd). The power demand of 75,600 af/yr (67.5 mgd) is projected to be the largest component of future water demands within the region. As shown in Table 15, current supplies indicate that anticipated demands should be satisfied without deficits.

Table 14
SURPLUS WATER AVAILABILITY
East Central Planning Region
(1,000 ACRE-FEET/YEAR)

SOURCE	TOTAL YIELD	LOCAL ALLOCATION	OUT OF REGION ALLOCATION	POTENTIAL SURPLUS
Eufaula	56.0	48.5	---	7.5
Holdenville	5.5	5.5	---	---
Lloyd Church	1.5	1.5	---	---
McAlester	9.2	9.2	---	---
Okemah	6.6	6.6	---	---
Robert S. Kerr (Power Pool Allocations)	33.6	33.6	---	---
Tenkiller (Water Supply Pool Allocations)	29.8	11.0	18.8	---
Wister	31.4	23.0	---	8.4
SCS & Municipal Lakes	103.7	103.7	---	---
Groundwater	50.1	50.1	---	---
TOTAL	**327.3**	**292.7**	**18.8**	**15.9**
Other Potential Sources				
Atwood	44.8	---	---	44.8
Brazil	87.4	---	---	87.4
Higgins	68.4	---	---	68.4
Holson Creek	22.4	---	---	22.4
Peaceable	33.6	---	---	33.6
Sasakwa	79.9	---	---	79.9
Tate Mountain	49.8	---	---	49.8
Tenkiller (Power Pool Allocations) [1]	392.1	---	---	392.1
Vian	10.1	---	---	10.1
Weleetka	35.8	---	---	35.8
Wetumka	67.2	---	---	67.2
TOTAL	**891.5**	**---**	**---**	**891.5**
TOTAL SURPLUS WATER AVAILABILITY	**1,218.8**	**292.7**	**18.8**	**907.4**

[1] Also considered as potential source for Northeast Planning Region.

Table 15
SUPPLY AND DEMAND ANALYSIS
East Central Planning Region

(1,000 ACRE-FEET/YEAR)

SOURCE	COUNTY Haskell	Hughes	Latimer	LeFlore	McIntosh	Okfuskee	Pittsburg	Seminole	Sequoyah	TOTAL
MUNICIPAL AND INDUSTRIAL COMPONENT										
Eufaula	2.9	---	---	---	5.8	---	38.3	---	---	47.1
Holdenville	---	5.5	---	---	---	---	---	---	---	5.5
Lloyd Church	---	---	1.5	---	---	---	---	---	---	1.5
McAlester	---	---	---	---	---	---	9.2	---	---	9.2
Okemah	---	---	---	---	---	6.6	---	---	---	6.6
Robert S. Kerr	---	---	---	---	---	---	---	---	33.6	33.6
Sardis [1]	---	---	1.0	---	---	---	---	---	---	1.0
Tenkiller (Water Supply Pool Allocations)	---	---	---	---	---	---	---	---	11.0	11.0
Wister	---	---	---	23.0	---	---	---	---	---	23.0
SCS & Municipal Lakes	---	1.3	1.8	2.3	1.7	5.5	7.7	4.3	4.9	29.7
Groundwater	1.8	1.6	0.1	0.2	0.6	8.1	0.4	5.7	0.2	18.6
M & I Supply	**4.7**	**8.4**	**4.4**	**25.5**	**8.1**	**20.2**	**55.7**	**10.0**	**49.7**	**186.6**
2050 M&I Demand	**2.6**	**4.1**	**3.0**	**14.9**	**5.5**	**3.1**	**11.2**	**7.3**	**11.3**	**63.0**
M&I Surplus/(Deficit)	**2.1**	**4.3**	**1.4**	**10.6**	**2.6**	**17.1**	**44.5**	**2.7**	**38.4**	**123.6**
AGRICULTURAL COMPONENT										
Eufaula	---	---	---	---	1.4	---	---	---	---	1.4
Robert S. Kerr	---	---	---	---	---	---	---	---	0.1	0.1
SCS & Municipal Lakes	5.1	21.2	7.5	6.8	0.3	10.2	8.1	11.5	3.7	74.2
Groundwater	0.1	11.1	0.1	7.3	0.2	1.7	1.4	1.5	7.8	31.4
Agricultural Supply	**5.2**	**32.3**	**7.6**	**14.1**	**1.9**	**11.9**	**9.5**	**13.1**	**11.6**	**107.1**
2050 Agricultural Demand	**1.9**	**14.6**	**0.9**	**6.6**	**1.9**	**2.3**	**3.0**	**4.1**	**4.7**	**40.0**
Agricultural Surplus/(Deficit)	**3.3**	**17.7**	**6.7**	**7.5**	**---**	**9.6**	**6.5**	**9.0**	**6.9**	**67.1**
POWER COMPONENT										
Konawa	---	---	---	---	---	---	---	41.4	---	41.4
Canadian River	---	---	---	---	---	---	---	35.0	---	35.0
Groundwater	---	---	---	---	---	---	---	0.1	---	0.1
Power Supply	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**76.5**	**---**	**76.5**
2050 Power Demand	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**75.6**	**---**	**75.6**
Power Surplus/(Deficit)	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**0.9**	**---**	**0.9**
TOTALS										
Total Local Supply	**9.8**	**40.7**	**12.0**	**39.6**	**10.0**	**32.1**	**65.2**	**99.6**	**61.3**	**370.3**
2050 Demand	**4.5**	**18.7**	**3.9**	**21.5**	**7.4**	**5.4**	**14.2**	**87.0**	**16.0**	**178.6**
Net Surplus/(Deficit)	**5.3**	**22.0**	**8.1**	**18.1**	**2.6**	**26.7**	**51.0**	**12.6**	**45.3**	**191.7**

[1] From Southeast Planning Region.

North Central Planning Region

REGIONAL DESCRIPTION

Garfield, Grant, Kay, Kingfisher, Lincoln, Logan, Noble, Pawnee and Payne County comprise the North Central Planning Region (Figure 25). Covering 7,689 square miles, the region is drained by the Cimarron, Chikaskia, Salt Fork of the Arkansas and the Arkansas Rivers. The topography of this region ranges from the densely forested east to the sand hills of the western portion of the region. Elevations range from 850 to 1,100 feet above mean sea level.

This region encompasses 10.8 percent of the total land area of the state, with approximately one-half of the region consisting of pastureland or cropland. The region's climate is moist and subhumid with a mean annual temperature ranging from 60 to 61 degrees. Annual lake evaporation, which exceeds precipitation, ranges from 62 inches in the west to 55 inches in the east. Rainfall peaks in the spring and fall with May being the wettest month of the year. Annual precipitation ranges from 28 inches in the west to 36 inches in the east portion of the region, including an average annual snowfall of 14 inches. Frequent droughts cause severe crop damage while severe flooding occurs as a result of concentrated, heavy precipitation. Thunderstorms -- accompanied by high winds, hail and heavy rain -- increase the likelihood of flash flooding and emphasize the need for watershed protection and flood prevention projects.

WATER RESOURCES

Stream Water

Table 16 summarizes the stream water sources of the North Central Planning Region. The three major stream systems in this region are the Cimarron, Salt Fork of the Arkansas and Arkansas Rivers. Water quality in these streams is generally of poor quality and unsuitable for most uses, a factor which has limited surface water development in the region.

The Salt Fork of the Arkansas River and Cimarron River Basins include areas containing large gypsum deposits. Natural brine seeps and springs, which are found throughout the region, contribute large quantities of chlorides to streams and make the water unsuitable for irrigation, industrial and commercial purposes. Water in both rivers is very hard with high pH levels, dissolved oxygen levels near saturation, and moderate turbidity. In the Salt Fork of the Arkansas River, levels of heavy metals (i.e., chromium, lead and mercury) exceed allowable standards. The Cimarron River contains elevated levels of iron, manganese, lead, silver, cadmium and arsenic.

The quality of the Arkansas River, which forms part of the eastern boundary of the region, is affected by highly mineralized water from major tributaries and by oilfield activities, agriculture and municipal wastewater discharges. Downstream of Keystone Lake, chemical pollutants -- such as pesticides, organic compounds and pathogenic indicators -- have been detected.

MAJOR RESERVOIRS

There are two major impoundments in the North Central Planning Region. The largest is Keystone Lake, located on the mainstem of the Arkansas River, approximately 15 miles west of Tulsa. Completed by the Corps in 1964, Keystone Lake has a drainage area of 74,506 square miles and is authorized for flood control, water supply, hydroelectric power, navigation, and fish and wildlife purposes. The lake contains 1,167,232 ac-ft of flood control storage, 267,122 ac-ft of power storage, and 20,000 ac-ft of water supply storage. The water supply yield is 22,400 af/yr (19.94 mgd). The two 35,000-kW power generating units became operational in May 1968 and produce an energy output of 228,000,000 kWh annually. Water is released for power generation and at other intervals to aid navigation on the McClellan-Kerr Arkansas River Navigation System. Poor water quality in Keystone limits beneficial uses, although the lake is an important recreational facility for residents and tourists in the North Central Region.

Kaw Lake is also located on the mainstem of the Arkansas River, approximately eight miles east of Ponca City, in Kay County. This Corps project, completed in 1976, has a drainage area of 46,530 square miles and is authorized for flood control, water supply, water quality, recreation, and fish and wildlife purposes. A powerhouse substructure, intake monolith and penstock were incorporated into the spillway even though power is not an authorized purpose. The generating facilities were completed and power generation began in August 1989. The lake contains 867,310 ac-ft of flood control storage and 203,000 ac-ft of water supply and water quality storage. The water supply yield, including water quality storage, is 230,720 af/yr (205.34 mgd). Water quality in the reservoir is fair and suitable for most uses.

MAJOR MUNICIPAL LAKES

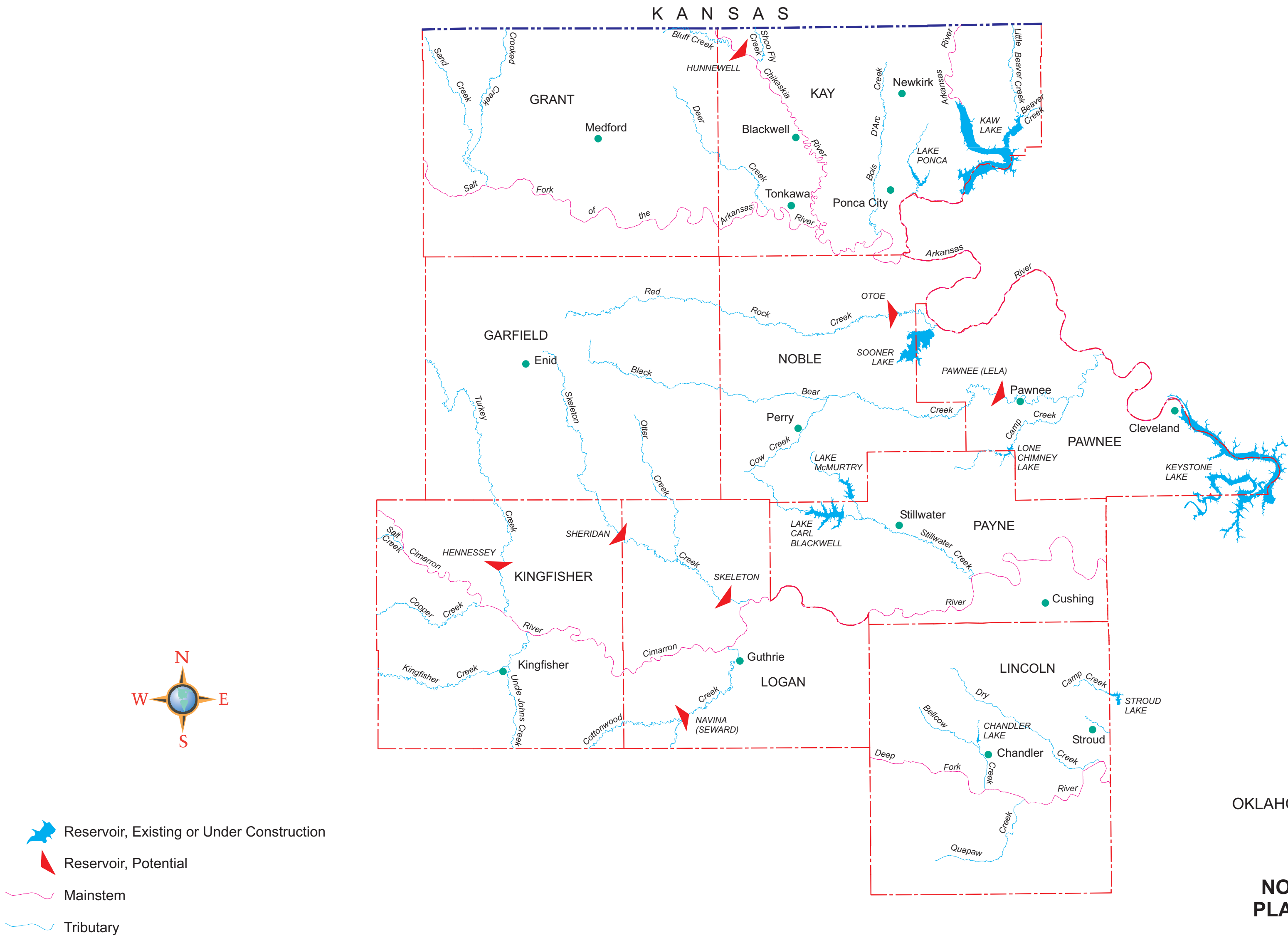
Lake Carl Blackwell, a water supply and recreation lake completed in 1937, is located on Stillwater Creek in Payne and Noble Counties. It is owned and operated by Oklahoma State University and contains 61,500 ac-ft of water supply storage with an annual yield of 7,000 ac-ft (6.23 mgd). OSU uses water supply from the lake and sells water to the City of Stillwater for municipal and industrial uses.

Chandler Lake (SCS Site 1M) is a water supply and recreation lake completed in 1954. It is owned and operated by the City of Chandler in Lincoln County. The lake is located on Bellcalf Creek and contains 2,778 ac-ft of water supply storage with a yield of 4,558 af/yr (4.06 mgd).

Lone Chimney Lake (Lower Black Bear Creek Site 19M) is owned and operated by Tri-County Development Authority. Constructed for water supply, flood control and recreation, the lake was completed in 1984. Lone Chimney Lake is located on Camp Creek in Pawnee and Payne Counties and contains 6,200 ac-ft of water supply storage with a yield of 2,509 af/yr (2.23 mgd).

Lake McMurtry (Stillwater Creek Site 40), a water supply, flood control and recreation lake completed in 1971, is owned and operated by the City of Stillwater. The lake is located on North Stillwater Creek in Noble County and contains 5,000 ac-ft of flood control storage and 13,500 ac-ft of water supply storage. The water supply yield is 3,002 af/yr (2.67 mgd).

Lake Ponca is a water supply and recreation lake owned and operated by the City of Ponca City. The lake was constructed in 1935 on Big and Little Turkey Creeks in Kay County. Lake Ponca contains 14,400 ac-ft of water supply storage with a yield of 9,000 af/yr (8.01 mgd). The City of Ponca City combines lake water with groundwater to meet the city's water supply needs.



OKLAHOMA COMPREHENSIVE WATER PLAN

Figure 25
NORTH CENTRAL PLANNING REGION

Mapping and Graphics - Oklahoma Water Resources Board

Sooner Reservoir, a cooling water lake completed in 1972, is owned and operated by Oklahoma Gas and Electric Company. The lake is located on Greasy Creek in Pawnee County and contains 47,500 ac-ft of flood control storage and 149,000 ac-ft of water supply storage. The water supply yield of 3,600 af/yr (3.20 mgd) could be developed from the drainage basin. Releases from Kaw Reservoir are diverted into Sooner Lake for additional cooling water.

Stroud Lake (Salt-Camp Creek Site 12) is owned and operated by the City of Stroud. Completed in 1968, authorized uses include water supply, flood control and recreation. The lake is located on Camp Creek in Creek and Lincoln Counties and has a water supply yield of 1,299 af/yr (1.16 mgd).

OTHER IMPOUNDMENTS

Other significant municipal lakes include Liberty Lake (2,740 ac-ft of approximate conservation storage), Guthrie Lake (3,875 ac-ft), Boomer Lake (3,200 ac-ft), Cushing Municipal Lake (3,304 ac-ft), Meeker Lake (1,818 ac-ft), Perry Lake (6,892 ac-ft), Pawnee Lake (3,855 ac-ft) and Cleveland City Lake (2,200 ac-ft). Other small municipal and private lakes also exist in the North Central Planning Region. The NRCS has 28 impoundments in this region for watershed protection and flood prevention.

AUTHORIZED DEVELOPMENT

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

POTENTIAL DEVELOPMENT

The potential for stream water development within this region is generally limited to tributary streams due to the poor water quality of the region's major streams. Seven potential sites have been previously identified.

Hennessey Lake is a potential impoundment on Turkey Creek, in Kingfisher County, and is anticipated to supply a combination of agricultural and M&I uses. The project would encompass a drainage area of 291 square miles with a conservation pool of 7,700 acres. It would contain 82,000 ac-ft of flood storage, 130,000 ac-ft of conservation storage, and have a water supply yield of 18,800 af/yr (16.8 mgd). The water quality in this impoundment should be suitable for all uses.

Navina Lake (sometimes called Seward) is proposed on Cottonwood Creek in Logan County. Much of the interest in this impoundment comes from other planning regions. Potential users of this project include Oklahoma City, Kingfisher and Okarche. Navina would encompass a drainage area of 229 square miles with a conservation pool of 7,000 acres. It would contain 111,846 ac-ft of conservation storage with a yield of 34,600 af/yr (30.9 mgd). The quality of water in this impound-

Table 16
STREAM WATER DEVELOPMENT
North Central Planning Region

PROJECT	STREAM	PURPOSE*	FLOOD CONTROL STORAGE (acre-feet)	WATER SUPPLY STORAGE (acre-feet)	WATER SUPPLY YIELD (ac-ft/year)
		EXISTING OR UNDER CONSTRUCTION			
Carl Blackwell	Stillwater Creek	ws, r	---	61,500	7,000
Chandler (SCS-1M)	Bellcalf Creek	ws, r	---	2,778	4,558
Kaw	Arkansas River	ws, fc, wq, r, fw	867,310	203,000 [1]	230,720 [1]
Keystone	Arkansas River	ws, fc, p, fw, n	1,167,232	20,000 [2]	---- [3]
Lone Chimney (SCS-19M)	Camp Creek	ws, r	---	6,200	2,509
McMurtry (SCS-40)	North Stillwater Creek	ws, fc, r	5,000	13,500	3,002
Ponca	Big and Little Turkey Creeks	ws, r	---	14,440	9,000
Sooner	Greasy Creek	fc, p, r	47,500	149,000	3,600 [4]
Stroud	Camp Creek	ws, r	---	---	1,299
TOTAL			**2,087,042**	**470,418**	**261,688**
		POTENTIAL			
Hennessey	Turkey Creek	ws, r, fw, i	82,000	130,000	18,800
Hunnewell	Chikaskia River	ws, fc, r, i	112,000	473,400	54,700
Navina (Seward)	Cottonwood Creek	ws, fc, r	---	111,846	34,600
Otoe	Red Rock Creek	ws, fc, r, i	142,000	403,300	46,000
Pawnee (Lela)	Black Bear Creek	ws, fc, r	190,000	210,350	48,200
Sheridan	Skeleton Creek	ws, fc, r, i	92,500	127,600	23,500
Skeleton	Skeleton Creek	ws, fc	72,100	250,000	41,500
TOTAL			**618,500**	**1,456,496**	**267,300**
TOTAL YIELD					**528,988**

*ws-municipal water supply, fc-flood control, wq-water quality, p-power, r-recreation, fw-fish and wildlife, i-irrigation, n-navigation.

[1] Includes 31,800 ac-ft for water quality control storage which yields 43,680 af/yr and 171,000 ac-ft for water supply.
[2] Does not include 267,122 ac-ft of power storage.
[3] Water supply yield of 22,400 af/yr allocated to Northeast Planning Region.
[4] Includes 128,000 ac-ft of inactive storage which is utilized as a heat sink for cooling by Oklahoma Gas & Electric's generating station. Listed yield is developed locally from Greasy Creek Basin and does not include releases from Kaw Lake.

ment should be suitable for all uses.

Pawnee Reservoir (or Lela) is a potential lake on Black Bear Creek in Pawnee County. The project is anticipated to encompass a drainage area of 545 square miles with a conservation pool of 10,000 acres. It would contain 190,000 ac-ft of flood control storage and 210,350 ac-ft of conservation storage with a water supply yield of 48,200 af/yr (43 mgd). Although chloride concentrations in Black Bear Creek have typically exceeded EPA criteria by about 20 percent, water quality in this impoundment should be suitable for all uses.

Sheridan Lake is a proposed reservoir in Kingfisher County that has been studied as a municipal and industrial supply. The project encompasses a drainage area of 299 acres with a conservation pool of 9,100 acres. It would contain flood control storage of 92,500 ac-ft, conservation storage of 127,600 ac-ft, and a water supply yield of 23,520 af/yr (21 mgd). Water quality in this impoundment would probably meet most raw water criteria. However, petroleum-related quality problems have occurred in the area and agricultural runoff (fertilizers) may cause algal blooms, affecting taste and odor.

Skeleton Lake, proposed on Skeleton Creek in Logan County, has been studied as a municipal and industrial water supply. The project encompasses a drainage area of 547 square miles with a conservation pool of 14,000 acres. It would contain 72,100 ac-ft of flood control storage, 250,000 ac-ft of conservation storage, and a water supply yield of 41,500 af/yr (37 mgd).

Hunnewell, in northwest Kay County, and Otoe, in Noble County, are the other potential lake sites identified within the North Central Region. While these sites remain as potential reservoir candidates, recent evaluations have discounted their likelihood due to an anticipated lack of water demand in the immediate vicinity and problems related to dependable yield, available storage, relocation costs and water quality.

STREAM WATER RIGHTS

As of June 1994, the OWRB had issued stream water allocation permits totaling 268,596 ac-ft per year from lakes, rivers and streams within the North Central Planning Region (Table 17).

Groundwater

Groundwater is the major water supply source for much of the region. The North Central Planning Region overlies two major groundwater basins, the Ada-Vamoosa and Garber-Wellington Formations, along with alluvial and terrace deposits of the Cimarron River and Salt Fork of the Arkansas River. The Ada-Vamoosa Aquifer is a fine- to very fine-grained sandstone with siltstone, shale and conglomerate. It has a maximum thickness of 550 feet with a saturated thickness of 100 to 200 feet. Well depths are generally 100 to 500 feet and wells commonly yield 100 to 300 gpm from the formation, but may exceed 500 gpm in some locations. Water from the aquifer is generally of a sodium bicarbonate or sodium calcium bicarbonate type. Dissolved solids are usually less than 500 mg/L. Water quality in the upper part of the aquifer is generally suitable for all uses but becomes increasingly saline near the interface between potable and saline water in the deeper confined part of the aquifer.

The Garber-Wellington Aquifer is

Table 17
WATER RIGHTS
North Central Planning Region

STREAM WATER ALLOCATIONS
(acre-feet)

COUNTY	Municipal	Industrial	Agricultural	Commercial	Rec, F&W	Power	Other	TOTAL
Garfield	179	70	1,148	---	448	---	---	1,845
Grant	---	941	302	5	15	---	---	1,263
Kay	61,368	14,280	1,583	---	---	---	---	77,231
Kingfisher	---	107	2,411	---	189	---	---	2,707
Lincoln	5,747	40	5,112	---	744	---	---	11,643
Logan	4,660	1,783	4,035	---	323	---	---	10,801
Noble	5,471	5	1,258	---	179	---	---	6,913
Pawnee	3,734	4	315	120	---	76,600	---	80,773
Payne	62,635	---	1,795	---	9,825	1,165	---	75,420
TOTAL	**143,794**	**17,230**	**17,959**	**125**	**11,723**	**77,765**	**---**	**268,596**

GROUNDWATER ALLOCATIONS
(acre-feet)

COUNTY	Municipal	Industrial	Agricultural	Commercial	Rec, F&W	Power	Other	TOTAL
Garfield	8,865	1,151	3,747	191	232	---	---	14,186
Grant	27,101	90	9,231	---	---	---	---	36,422
Kay	6,341	4,523	11,510	4	40	171	25	22,614
Kingfisher	4,948	2,023	46,532	---	---	---	3	53,506
Lincoln	1,799	820	924	1	20	---	---	3,564
Logan	4,426	1,365	6,884	321	2	---	---	12,998
Noble	352	20	4,506	---	---	---	---	4,878
Pawnee	3,094	211	980	298	---	---	1	4,584
Payne	6,145	1,904	4,966	148	---	---	---	13,163
TOTAL	**63,070**	**12,107**	**89,280**	**963**	**294**	**171**	**29**	**165,914**

Note: Agricultural allocations include Irrigation. Mining included in Industrial.
Source of data: Oklahoma Water Resource Board printout, June 23, 1994.

composed of finely-grained sandstone with shale and siltstone. The maximum thickness of the formation is about 900 feet with a saturated thickness ranging from 150 to 650 feet. The aquifer is generally unconfined to partly confined with well depths of 100 to 200 feet and yields of 100 to 300 gpm in the unconfined portions, although yields generally decrease in the Logan County area. Water quality is generally suitable for all uses, although excessive pumping may cause upswelling of the underlying saltwater in some areas.

Alluvial and terrace deposits are found along the major rivers in all counties of the region. Along the Cimarron River, the formation consists of silt and clay in the upper portion grading downward to sandy clay, sand and fine gravel with a maximum thickness of about 80 feet. Terrace deposits are typically overlain by dune sand as much as 100 feet thick. The aquifer is generally unconfined with well depths of 50 to 100 feet and yields of 200 to 500 gpm in the alluvium and 100 to 200 gpm in the terrace. The water is typically of a calcium magnesium bicarbonate type and very hard.

Along the Salt Fork of the Arkansas River, alluvium deposits have a maximum thickness of 60 feet while terrace deposits have a maximum thickness of 150 feet. The formations are typically clay and silt in the upper portion, changing into fine to coarse sand with local lenses of fine gravel. The aquifer is generally unconfined with well depths of 50 to 150 feet and yields of 100 to 200 gpm in the alluvium portion and 100 to 500 gpm in the terrace. The water is very hard and generally of a calcium magnesium bicarbonate type; dissolved solids are typically less than 500 mg/L.

GROUNDWATER DEVELOPMENT

The lack of widespread high quality surface water in the region dictates a heavy reliance upon groundwater sources. Many small and medium-sized communities receive their water supply from wells, primarily from the Vamoosa Formation which is regarded as having the greatest development potential in the region.

GROUNDWATER RIGHTS

As of June 1994, the OWRB had issued groundwater allocation permits totaling 165,914 ac-ft per year from aquifers in the North Central Planning Region (Table 17).

SUPPLY AND DEMAND ANALYSIS

The long-range projection of M&I water demand in the North Central Region in the year 2050 is 100,100 ac-ft (approximately 46 percent of the total 2050 demand for the entire region). Table 18 indicates that the region currently has a surplus of unallocated water, primarily from Kaw Reservoir. As shown in Table 19, 2050 demands could be met with current supplies without causing a deficit condition.

Table 18
SURPLUS WATER AVAILABILITY
North Central Planning Region
(1,000 ACRE-FEET/YEAR)

SOURCE	TOTAL YIELD	LOCAL ALLOCATION	OUT OF REGION ALLOCATION	POTENTIAL SURPLUS
Kaw	230.7	197.1	---	33.6
SCS & Municipal Lakes	18.6	18.6	---	---
Groundwater	76.5	76.5	---	---
TOTAL	**325.8**	**292.2**	**---**	**33.6**
Other Potential Sources				
Hennessey	18.8	---	---	18.8
Hunnewell	54.7	---	---	54.7
Navia (Seward)	34.6	---	---	34.6
Otoe	46.0	---	---	46.0
Pawnee (Lela)	48.2	---	---	48.2
Sheridan	23.5	---	---	23.5
Skeleton	41.5	---	---	41.5
TOTAL	**267.3**	**---**	**---**	**267.3**
TOTAL SURPLUS WATER AVAILABILITY	**593.1**	**292.2**	**---**	**300.9**

Table 19
SUPPLY AND DEMAND ANALYSIS
North Central Planning Region

(1,000 ACRE-FEET/YEAR)

	COUNTY									
SOURCE	**Garfield**	**Grant**	**Kay**	**Kingfisher**	**Lincoln**	**Logan**	**Noble**	**Pawnee**	**Payne**	**TOTAL**
				MUNICIPAL AND INDUSTRIAL COMPONENT						
Carl Blackwell	---	---	---	---	---	---	---	---	7.0	7.0
Chandler	---	---	---	---	4.6	---	---	---	---	4.6
Kaw	25.0	---	42.9	---	---	---	---	---	56.2	124.1
Lone Chimney	---	---	---	---	---	---	---	2.5	---	2.5
McMurtry	---	---	---	---	---	---	---	---	3.0	3.0
Ponca	---	---	9.0	---	---	---	---	---	---	9.0
Sooner	---	---	---	---	---	---	---	---	---	---
Stroud	---	---	---	---	1.3	---	---	---	---	1.3
SCS & Municipal Lakes	---	---	0.2	---	1.1	6.7	3.4	3.9	3.1	18.6
Groundwater	10.4	27.2	10.9	7.0	2.6	6.1	0.4	3.6	8.2	76.5
M & I Supply	**35.4**	**27.2**	**63.0**	**7.0**	**9.6**	**12.9**	**3.8**	**10.0**	**77.5**	**246.5**
2050 M & I Demand	**25.1**	**2.2**	**22.0**	**3.8**	**8.6**	**9.7**	**2.1**	**5.2**	**21.4**	**100.1**
M & I Surplus/(Deficit)	**10.3**	**25.0**	**41.0**	**3.2**	**1.0**	**3.2**	**1.7**	**4.8**	**56.1**	**146.4**
				AGRICULTURAL COMPONENT						
SCS & Municipal Lakes	8.7	0.2	2.4	3.1	9.4	7.5	10.9	3.1	4.0	49.1
Groundwater	3.7	9.2	11.5	46.5	0.9	6.9	4.5	1.0	5.0	89.2
Agricultural Supply	**12.4**	**9.4**	**13.9**	**49.6**	**10.3**	**14.4**	**15.4**	**4.1**	**9.0**	**138.4**
2050 Agricultural Demand	**3.5**	**3.3**	**2.3**	**22.3**	**1.4**	**4.9**	**1.9**	**3.3**	**1.9**	**44.8**
Agricultural Surplus/(Deficit)	**8.9**	**6.1**	**11.6**	**27.3**	**8.9**	**9.5**	**13.5**	**0.8**	**7.1**	**93.6**
				POWER COMPONENT						
Kaw	---	---	---	---	---	---	---	73.0	---	73.0
Sooner	---	---	---	---	---	---	---	3.6	---	3.6
Groundwater	---	---	---	0.2	---	---	---	---	---	0.2
Power Supply	**---**	**---**	**---**	**0.2**	**---**	**---**	**---**	**76.6**	**---**	**76.8**
2050 Power Demand	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**74.4**	**---**	**74.4**
Power Surplus/(Deficit)	**---**	**---**	**---**	**0.2**	**---**	**---**	**---**	**2.2**	**---**	**2.4**
				TOTALS						
Total Local Supply	**47.8**	**36.6**	**76.9**	**56.8**	**19.9**	**27.2**	**19.2**	**90.7**	**86.5**	**461.7**
Total 2050 Demand	**28.6**	**5.5**	**24.3**	**26.1**	**10.0**	**14.6**	**4.0**	**82.9**	**23.3**	**219.3**
Total Surplus/(Deficit)	**19.2**	**31.1**	**52.6**	**30.7**	**9.9**	**12.6**	**15.2**	**7.8**	**63.2**	**242.4**

Northeast Planning Region

REGIONAL DESCRIPTION

Fifteen counties form the Northeast Planning Region – Adair, Cherokee, Craig, Creek, Delaware, Mayes, Muskogee, Nowata, Okmulgee, Osage, Ottawa, Rogers, Tulsa, Wagoner and Washington (Figure 26). Stream and surface water sources are abundant in the region.

Encompassing some of the most scenic areas of the state, the region's terrain includes forested mountains, rolling plains and rich river basins. The Northeast Region has abundant oil and gas supplies and strong industrial development aided, in part, by barge traffic of the McClellan-Kerr Navigation System. The region is predicted to have the highest overall M&I and power demands for water by 2050. Major cities within the region include Tulsa, Bartlesville and Muskogee.

The region's climate is mild with annual mean temperatures varying from 59 to 61 degrees. Annual evaporation within the region ranges from 56 inches in the west to 46 along the Arkansas and Missouri borders. Rainfall averages 34 to 44 inches per year; May is the wettest month.

WATER RESOURCES

Stream Water

Table 20 summarizes the stream water resources of the Northeast Planning Region. The region's major streams include the Arkansas, Deep Fork, Illinois and Grand (Neosho) Rivers. Stream water quality in the region is generally good, with the exception of the Arkansas River and some streams in the western part of the region that contain water of poor quality which is unsuitable for most M&I uses due to high mineral content and man-made pollutants.

The Arkansas River is the major drainage basin in the region. Because the basin is underlain by shale, limestone and sandstone, the river water tends to experience unacceptable levels of sulfates and TDS. Elevated levels of chlordane and PCB's have also been detected upstream of Tulsa. Downstream, the water quality improves as flows from the Grand River join the Arkansas River at Webbers Falls.

The Deep Fork River within the region has poor quality water. The water is very hard with high turbidity and contains high levels of TDS, dissolved oxygen, sulfate, chloride and suspended sediment. The water is unsuitable for most M&I uses; however, impoundment tends to improve the quality.

The Grand (Neosho) and Illinois Rivers are located in the Ozark Mountain Plateaus. They flow through a series of impoundments, creating some of the state's most popular tourist attractions. The water is of excellent quality and suitable for all M&I uses. Development within the two river basins has led to increased water pollutants, including traces of heavy metals.

MAJOR RESERVOIRS

There are 10 major impoundments within the Northeast Planning Region. Birch Lake, completed in 1977, is the smallest Corps impoundment in the region. It is located on Birch Creek, a tributary of Bird Creek in Osage County. Authorized uses include flood control, water supply, water quality, recreation, and fish and wildlife conservation. The lake has conservation storage of 15,165 ac-ft, flood control storage of 39,805 ac-ft, and a dependable water supply yield of 6,700 af/yr (6 mgd). The water quality is considered good.

Copan Lake is a multipurpose Corp of Engineers reservoir on the Little Caney River in northern Washington County. The lake contains 184,300 ac-ft of flood control storage and 33,600 ac-ft of conservation storage (net of sediment storage) which yields 21,300 af/yr (19 mgd), including 17,900 af/yr of water quality control storage. Authorized uses of the reservoir include flood control, water supply, water quality control, recreation, and fish and wildlife conservation.

Fort Gibson Lake is located on the Grand (Neosho) River in northern Wagoner County. The lake was constructed by the Corps in 1953 for flood control and hydropower generation. The lake is operated by the Grand River Dam Authority and has 919,200 ac-ft of flood control storage along with 53,900 ac-ft of power pool storage. The dam has four 11,250 kW capacity hydroturbines installed with a dependable power output of 45,000 kW. The water is of excellent quality and, although water supply is not an authorized use, several entities (including Muskogee) receive their water supply from Fort Gibson Lake.

Grand Lake O' The Cherokees, upstream of Fort Gibson, is another impoundment on the Grand (Neosho) River. The lake, located primarily in Delaware County in northeast Oklahoma, was completed in 1941 by GRDA. While flood control in the reservoir is operated by the Corps of Engineers, GRDA controls all other operations. The authorized purposes are hydroelectric power production and flood control. The reservoir has 525,000 ac-ft of flood control storage and 1,192,000 ac-ft of power storage. The powerhouse has six units capable of a total power output of 86,400 kW (14,400 kW each). Several entities contract with GRDA for water supply from Grand Lake.

Heyburn Lake is a flood control, water supply, recreation, and fish and wildlife conservation reservoir on Polecat Creek in Creek County. The lake was completed by the Corps of Engineers in 1950 and contains 48,290 ac-ft of flood control storage. Of the 4,140 ac-ft of conservation storage, 2,340 ac-ft is available for water supply which yields 1,900 af/yr (1.7 mgd).

Lake Hudson is the middle impoundment of the three lakes on the Grand (Neosho) River. Located in Mayes County, the lake was completed in 1964 by the GRDA who controls most reservoir operations. The Corps of Engineers operates the flood control storage. As with the other GRDA impoundments, authorized purposes are hydroelectric power and flood control. The lake contains 244,200 ac-ft of flood control storage and 200,300 ac-ft of power pool storage. The powerhouse contains a total capacity of 100,000 kW (four 25,000 kW units).

Hulah Lake is a Corps project on the Caney River in Osage County. Authorized purposes include flood control, water supply and low-flow regulation. The project was completed in 1951 and provides 257,900 ac-ft of flood control storage and 26,960 ac-ft of conservation storage yielding 18,900 af/yr (16.9 mgd) of water supply. The water quality is excellent.

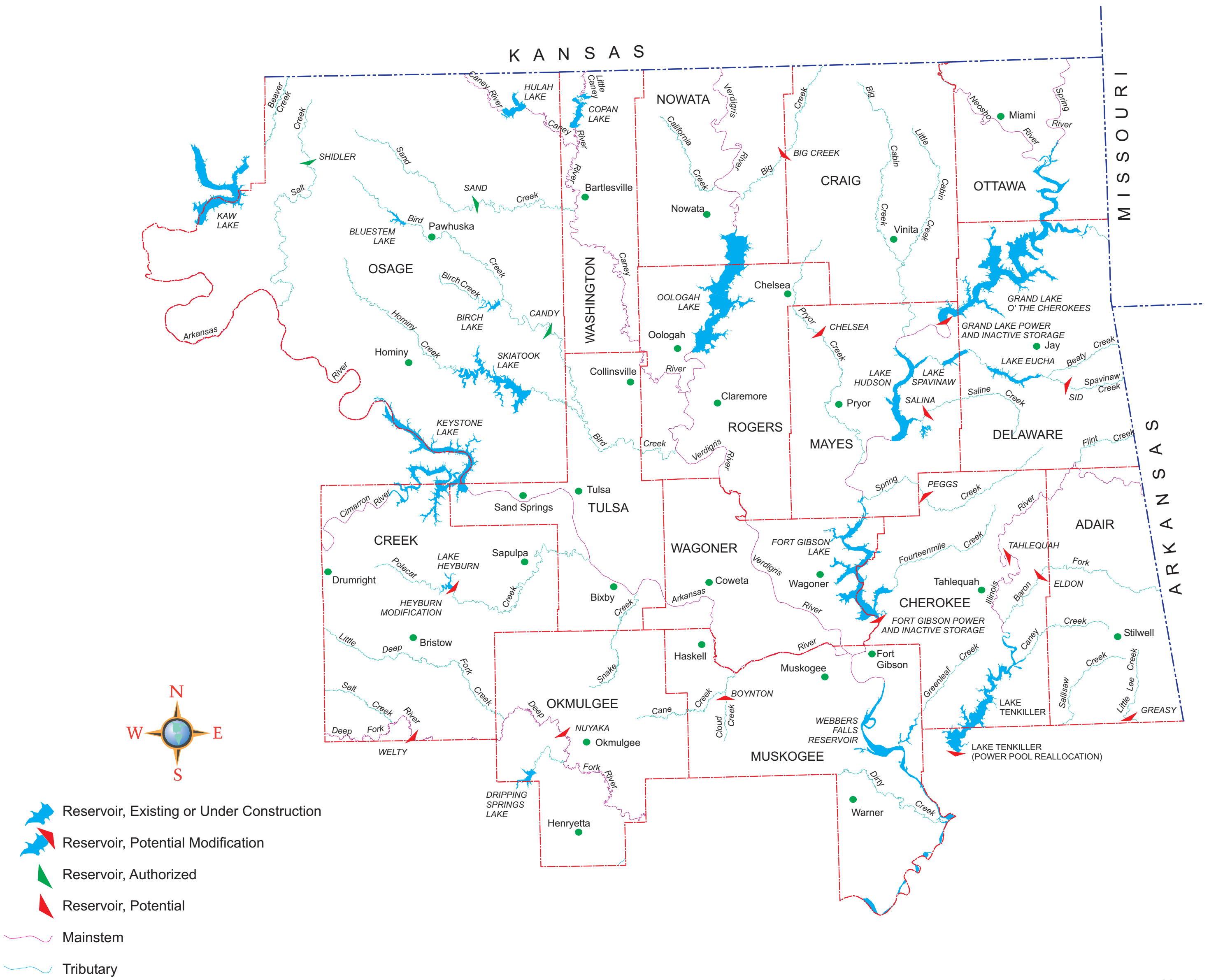
Oologah Lake is located on the Verdigris River in northern Rogers County and southern Nowata County. The reservoir was built by the Corps of Engineers for

Table 20
STREAM WATER DEVELOPMENT
Northeast Planning Region

PROJECT	STREAM	PURPOSE*	FLOOD CONTROL STORAGE (acre-feet)	WATER SUPPLY STORAGE (acre-feet)	WATER SUPPLY YIELD (ac-ft/year)
		EXISTING OR UNDER CONSTRUCTION			
Birch	Birch Creek	ws, fc, wq, r, fw	39,805	15,165	6,700 [1]
Copan	Little Caney River	ws, fc, wq, r, fw	184,300	33,600 [2]	21,300
Dripping Springs	Salt Creek	ws, fc, r	---	16,200	7,412
Eucha & Spavinaw	Spavinaw Creek	ws, r	---	110,167	84,000 [3]
Fort Gibson	Grand (Neosho) River	fc, p	919,200	---	66,600 [4]
Grand	Grand (Neosho) River	fc, p	525,000	---	21,400 [4]
Heyburn	Polecat Creek	ws, fc, r, fw	48,290	2,340	1,900
Hudson (Markham Ferry)	Grand (Neosho) River	fc, p	244,200	---	3,000 [4]
Hulah	Caney River	ws, fc, flow	257,900	26,960 [5]	18,900
Keystone	Arkansas River	ws, fc, p, fw	---- [6]	---- [6]	22,400 [6]
Oologah	Verdigris River	ws, fc, r, fw, n	1,007,060	342,600	172,500
Skiatook	Hominy Creek	ws, fc, wq, r, fw	176,100 [7]	280,200	85,100 [7]
Tenkiller (Water Supply Allocations)	Illinois River	fc, p	---- [8]	345,600 [8]	18,800 [8]
Webbers Falls	Arkansas River	p, n	---	---	---
TOTAL			**3,401,855**	**1,172,832**	**530,012**
		AUTHORIZED			
Candy [9]	Candy Creek	ws, fc, r	31,260	43,110	8,620
Sand [10]	Sand Creek	ws, fc, wq, r, fw	51,700	35,000	15,450
Shidler [11]	Salt Creek	ws, fc, r, fw	49,050	57,880	16,800
TOTAL			**132,010**	**135,990**	**40,870**
		POTENTIAL			
Big Creek	Big Creek	ws, r	---	---	32,500
Boynton	Cloud Creek	ws, r	65,000	116,000	44,800
Chelsea	Pryor Creek	ws, r	47,000	65,000	21,300
Eldon	Baron Fork Creek	ws, r	---	280,000	157,900
Fort Gibson Power & Inactive Storage	Grand (Neosho) River	ws, fc, p, r	---	---	223,80
Grand Lake Power & Inactive Storage	Grand (Neosho) River	ws, fc, p	---	---	203,300
Greasy	Greasy Creek	ws, fc, p	9,900	16,350	6,700
Heyburn Modification	Polecat Creek	ws, fc, r	70,500	101,500	18,800
Nuyaka	Deep Fork River	ws, fc, r	700,000	1,400,000	224,000
Peggs	Spring Creek	ws, r	---	88,000	20,000
Salina	Saline Creek	ws, r	---	73,000	16,000
Sid	Spavinaw Creek	ws, r	---	95,000	20,000
Tahlequah	Illinois River	ws, fc, r	200,000	1,500,000	350,000
Tenkiller (Power Pool Allocations)	Illinois River	ws, fc, p, r	---	---	392,050 [12]
Welty	Deep Fork River	ws, r, fw	---	816,000	207,200
TOTAL			**1,092,400**	**4,550,850**	**1,938,350**
TOTAL YIELD					**2,509,232**

*ws-municipal water supply, fc-flood control, wq-water quality, p-power, r-recreation, fw-fish and wildlife, n-navigation, flow-low flow augmentation.

[1] Water supply yield includes 7,600 ac-ft for water quality control (3,350 af/yr yield).
[2] Water supply storage includes 26,100 ac-ft for water quality control (17,920 af/yr yield).
[3] Combined yield of both lakes. All yield goes to City of Tulsa.
[4] Reallocation from hydropower pool.
[5] Water supply storage includes 7,100 ac-ft (4.5 mgd yield) for water quality control.
[6] Located in and allocated from North Central Planning Region.
[7] Flood control storage after 100-year sediment. Yield includes water quality control storage of 240,000 ac-ft which yields 69,440 af/yr.
[8] Located on boundary with East Central Planning Region. Total water supply yield is 29,792 af/yr, of which 10,992 isallocated to East Central Planning Region.
[9] Construction halted at 15% completion, with deferred status since 1984. COE has recommended project for deauthorization.
[10] Project status is Inactive.
[11] Project status is Deferred.
[12] Also considered as potential source for East Central Planning Region.



OKLAHOMA COMPREHENSIVE WATER PLAN

Figure 26
NORTHEAST PLANNING REGION

Mapping and Graphics - Oklahoma Water Resources Board

flood control, water supply, navigation, recreation, and fish and wildlife conservation. Construction was performed in several phases with completion of the initial phase in 1963. The lake contains 1,007,060 ac-ft of flood control storage and 342,600 ac-ft of water supply storage; it reserves 168,000 ac-ft for navigation. The dependable water supply yield is 172,500 af/yr (154 mgd). The City of Tulsa is the major water user.

Skiatook Lake, a Corps impoundment completed in 1984, is located on Hominy Creek in Osage County. The project provides flood control, water supply, water quality control, recreation, and fish and wildlife conservation benefits. The lake contains 176,100 ac-ft of flood control storage, 62,900 ac-ft of water supply storage, 233,000 ac-ft for water quality control, and 15,700 ac-ft for sedimentation. The water supply and water quality storage combine to provide 85,100 af/yr (76 mgd) of fair quality water.

Webbers Falls Lock & Dam is on the Arkansas River approximately five miles northwest of the Town of Webbers Falls in Muskogee County. The primary purposes of the project are navigation and hydroelectric power. The lock and dam, important components of the McClellan-Kerr Navigation System, became operational in 1970; power generation began in 1973. The powerhouse contains three 20 megawatt units.

MUNICIPAL LAKES

There are three large municipal lakes within the Northeast Planning Region:

Table 21
WATER RIGHTS
Northeast Planning Region

STREAM WATER ALLOCATIONS
(acre-feet)

COUNTY	Municipal	Industrial	Agricultural	Commercial	Rec, F&W	Power	Other	TOTAL
Adair	13,265	53	22,597	1,166	4	---	---	37,085
Cherokee	29,258	56,110	8,833	90	450	---	20	94,761
Craig	3,620	---	---	---	---	---	---	3,620
Creek	9,341	32	4,167	---	515	---	---	14,055
Delaware	868	---	2,806	---	---	---	---	3,674
Mayes	183,382	---	160	---	---	---	---	183,542
Muskogee	61,823	16,019	8,664	---	---	149,084	---	235,590
Nowata	1,730	509	886	---	240	---	---	3,365
Okmulgee	19,694	1	2,694	---	2,246	---	---	24,635
Osage	88,089	632	12,112	---	122	25,000	---	125,955
Ottawa	---	---	280	---	---	---	---	280
Rogers	179,552	405	12,213	---	1,531	35,565	---	229,266
Tulsa	1,120	33	1,459	10	13	18,613	---	21,248
Wagoner	39,635	2,213	10,374	---	677	---	---	52,899
Washington	25,813	---	10,812	---	215	---	---	36,840
TOTAL	**657,190**	**76,007**	**98,057**	**1,266**	**6,013**	**228,262**	**20**	**1,066,815**

GROUNDWATER ALLOCATIONS
(acre-feet)

COUNTY	Municipal	Industrial	Agricultural	Commercial	Rec, F&W	Power	Other	TOTAL
Adair	581	---	1,214	25	---	---	5	1,825
Cherokee	337	---	166	34	10	---	20	567
Craig	908	---	40	---	---	---	---	948
Creek	3,748	685	881	30	---	---	---	5,344
Delaware	2,928	---	3,176	151	6	---	23	6,283
Mayes	112	---	4	23	---	---	---	139
Muskogee	740	---	8,281	50	---	382	---	9,453
Nowata	---	---	---	---	---	---	---	---
Okmulgee	---	---	---	---	---	---	---	---
Osage	2,668	12,369	7,078	13	---	---	---	22,128
Ottawa	16,935	1,825	536	---	---	---	---	19,296
Rogers	---	---	160	---	30	45	---	235
Tulsa	1,371	8,942	5,885	---	8	---	---	16,206
Wagoner	---	87	2,338	---	10	---	720	3,155
Washington	---	---	---	---	---	---	---	---
TOTAL	**30,327**	**23,908**	**29,759**	**326**	**64**	**427**	**768**	**85,578**

Note: Agricultural allocations include Irrigation. Mining included in Industrial.
Source of data: Oklahoma Water Resource Board printout, June 23, 1994.

Dripping Springs, Eucha and Spavinaw. Dripping Springs Lake is a NRCS-constructed project on Salt Creek in southern Okmulgee County. Owned by the City of Okmulgee, the lake provides flood control, water supply and recreational opportunities. Constructed in 1976 as Okfuskee Tributaries Site 1, the impoundment has conservation storage of 16,200 ac-ft and provides a dependable yield of 7,412 af/yr (6.6 mgd).

Eucha Lake is a large impoundment located on Spavinaw Creek in Delaware County. It was constructed in 1952 by the City of Tulsa for the primary purposes of water supply and recreation. With conservation storage of 79,567 ac-ft, the lake has a dependable yield of 84,000 af/yr (75 mgd) of excellent quality water. The impoundment is located approximately three miles upstream of the third major municipal lake in the region, Spavinaw Lake.

Spavinaw Lake, located on Spavinaw Creek in Delaware and Mayes Counties, is also owned by the City of Tulsa. The lake has conservation storage of 38,000 ac-ft, although it has little dependable yield of its own, acting primarily as terminal storage for releases from Eucha Lake. Spavinaw was built in 1924 and was Oklahoma's first major transbasin water supply project.

Table 22
SURPLUS WATER AVAILABILITY
Northeast Planning Region
(1,000 ACRE-FEET/YEAR)

SOURCE	TOTAL YIELD	LOCAL ALLOCATION	OUT OF REGION ALLOCATION	POTENTIAL SURPLUS
Birch	6.7	6.7	---	---
Copan	21.3	7.5	---	13.8
Eucha & Spavinaw [1]	84.0	84.0	---	---
Fort Gibson [2]	66.6	66.6	---	---
Grand [2]	21.4	21.4	---	---
Hudson	3.0	3.0	---	---
Hulah	18.9	13.9	---	5.0
Oologah [3]	172.5	172.5	---	---
Skiatook	85.1	46.6	---	38.5
SCS & Municipal Lakes	372.5	372.5	---	---
Groundwater	85.2	85.2	---	---
TOTAL	**937.2**	**879.9**	**---**	**57.3**
Authorized Sources				
Candy	8.6	---	---	8.6
Sand	15.5	---	---	15.5
Shidler	16.8	---	---	16.8
TOTAL	**40.9**	**---**	**---**	**40.9**
Other Potential Sources				
Big Creek	32.5	---	---	32.5
Boynton	44.8	---	---	44.8
Chelsea	21.3	---	---	21.3
Eldon	157.9	---	---	157.9
Fort Gibson Power & Inactive Storage	223.8	---	---	223.8
Grand Power & Inactive Storage	203.3	---	---	203.3
Greasy	6.7	---	---	6.7
Heyburn (Modification)	18.8	---	---	18.8
Nuyaka	224.0	---	---	224.0
Peggs	20.0	---	---	20.0
Salina	16.0	---	---	16.0
Sid	20.0	---	---	20.0
Tahlequah	350.0	---	---	350.0
Tenkiller (Power Pool Allocations) [4]	392.1	---	---	392.1
Welty	207.2	---	---	207.2
TOTAL	**1,861.1**	**---**	**---**	**1,861.1**
TOTAL SURPLUS WATER AVAILABILITY	**2,839.1**	**879.9**	**---**	**1,959.2**

[1] All water allocated to City of Tulsa.
[2] Additional yield may be available from reallocation of power storage.
[3] Term permits not included in analysis.
[4] Also considered as potential source for East Central Planning Region.

OTHER IMPOUNDMENTS

There are numerous other NRCS projects, small municipal lakes and private reservoirs within the Northeast Planning Region. These small lakes provide municipal supply, irrigation water and recreational opportunities. Bluestem Lake (17,000 ac-ft of approximate conservation storage), Claremore Lake (7,900 ac-ft), Hominy Lake (5,000 ac-ft), Hudson Lake (4,000 ac-ft), Sahoma Lake (4,850 ac-ft), Waxoma Lake (2,000 ac-ft), Shell Lake (9,500 ac-ft), Yahola Lake (6,645 ac-ft) and Fairfax Lake (1,795 ac-ft) are some of the larger impoundments in this category.

AUTHORIZED DEVELOPMENT

There are three authorized water supply projects within the Northeast Planning Region, all in Osage County.

Candy Lake is an authorized impoundment for water supply, flood control and recreation on Candy Creek in Osage County. The project is authorized for 31,260 ac-ft of flood control storage and 44,160 ac-ft of conservation storage yielding 8,625 af/yr (7.7 mgd) of municipal water supply. Construction began in 1976 but the project was halted at 15 percent completion when the U.S. Justice Department withdrew condemnation proceedings to acquire mineral rights from the Osage Indian Nation. The project has been in deferred status since 1984 and has been recommended for deauthorization.

Sand Lake, on Sand Creek, is another proposed project in Osage County. Authorized uses include water supply, flood control, water quality control, recreation, and fish and wildlife conservation. The project is anticipated to have 51,700 ac-ft of flood control storage and 35,000 ac-ft of conservation storage. The anticipated water supply yield is 8,740 af/yr (7.8 mgd). The project is currently classified as inactive.

Shidler Lake is the third authorized project in the Northeast Planning Region. The proposed project would contain 49,900 ac-ft of flood control storage and 58,200 ac-ft of conservation storage yielding 16,000 af/yr (15 mgd) for water supply (13.7 mgd) and fish and wildlife mitigation (1.3 mgd). The project status is currently deferred.

POTENTIAL DEVELOPMENT

Numerous sites within the Northeast Planning Region have potential for the development of new water supply projects, primarily due to the abundance of rainfall and suitable sites within the region. Of the 10 most likely sites identified in Table 20, several have been extensively studied.

Boynton Lake is a potential impoundment on Cloud Creek in Muskogee County. The lake, at full conservation pool, is anticipated to cover 7,300 acres and provide 116,000 ac-ft of conservation storage and 65,000 ac-ft of flood control storage. The dependable yield is estimated to be 44,800 af/yr (40 mgd) and the water should be suitable for all uses.

Chelsea Lake is a potential project on Pryor Creek in Mayes County. With an estimated drainage area of 104 square miles, the lake would cover 4,500 acres at full conservation pool and provide 65,000 ac-ft of conservation storage, along with 47,000 ac-ft of flood control storage. The dependable yield is estimated to be 21,300 af/yr (19 mgd). The water is anticipated to be suitable for all uses.

Welty Lake is proposed on the Deep Fork River in Creek County. At full conservation pool, the lake would cover an estimated 35,100 acres and provide 816,000 ac-ft of conservation storage. The dependable yield from the 1,299-square-mile drainage area is estimated to be 350,000 af/yr (185 mgd). The water should be suitable for all uses.

STREAM WATER RIGHTS

As of June 1994, the OWRB had issued stream water allocation permits totaling 1,066,815 ac-ft per year from lakes, rivers and streams in the Northeast Planning Region (Table 21).

Groundwater

Four major groundwater basins exist in the Northeast Planning region -- the Ada-Vamoosa Formation, alluvium and terrace deposits of the Arkansas River, the Roubidoux Aquifer and the Keokuk-Reed Springs Aquifer. The Ada-Vamoosa Formation consists of a fine- to very fine-grained sandstone with siltstone and interbedded limestone which occurs in portions of Creek and Osage Counties. It has a maximum thickness of 550 feet with a saturated thickness of 100 to 200 feet. Wells are generally 100 to 500 feet deep and commonly yield 100 to 300 gpm, although they may exceed 500 gpm in some locations. Water from the Vamoosa is generally of a sodium bicarbonate or sodium calcium bicarbonate type. Dissolved solids are usually less than 500 mg/L.

Wells in the Arkansas River alluvium deposits range from 200 to 500 gpm while wells in the terrace deposits range from 100 to 200 gpm. Formation deposits are commonly 50 to 100 feet in depth with saturated thickness averaging 25 to 75 feet. The formation consists of clays, sand, silt and gravels. Hardness is the major water quality problem and TDS values are usually less than 500 mg/L. The water is generally suitable for most M&I uses, although heavy pumping can cause chloride intrusion into the formation.

The Roubidoux is a fractured dolomite aquifer found in Ottawa and Delaware Counties. The formation usually contains two or three confined sandy zones with depths ranging between 800 and 1,200 feet. Yields from the aquifer average 150 gpm with some wells exceeding 600 gpm. The water is moderately hard but suitable for most M&I uses.

The Keokuk-Reed Springs is a minor aquifer found in portions of Ottawa, Delaware, Mayes, Cherokee and Adair Counties. The formation consists of weathered residual chert and clay in the upper portions and very cherty limestone in the lower portions. The maximum thickness of the formation is 500 feet with average well depths of 50 to 300 feet. Wells from this formation yield from 1 to 10 gpm with some occasionally approaching 80 gpm. Surface springs from the formation can yield from 600 to 3,500 gpm. Water from this aquifer is very hard with high concentrations of calcium bicarbonate. This formation is susceptible to surface contamination.

GROUNDWATER DEVELOPMENT

Despite the presence of abundant surface water, groundwater development is an essential resource to many communities in the Northeast Region. The Roubidoux Aquifer is the major supply source for the cities of Miami, Afton, Quapaw and Picher. Alluvium and terrace deposits in Muskogee, Wagoner, Tulsa and Osage

Counties are also heavily utilized. Within Osage County, the Vamoosa Formation is used extensively where surface water is not readily available.

GROUNDWATER RIGHTS

As of June 1994, the OWRB had issued groundwater allocation permits totaling 85,578 ac-ft per year from aquifers within the Northeast Planning Region (Table 21).

SUPPLY AND DEMAND ANALYSIS

Table 22 indicates the availability of water from existing sources. When the potential reallocation of water quality and some hydroelectric power storage is included, most, if not all, demands can be satisfied. The long-range projection for M&I water demand in the year 2050 is 361,800 af/yr (323 mgd). As shown in Table 23, current supplies should satisfy anticipated demands. Local areas may experience deficits, although ample supply from proposed projects in the region would likely meet these needs.

Table 23
SUPPLY AND DEMAND ANALYSIS
Northeast Planning Region
(1,000 ACRE-FEET/YEAR)

	COUNTY															
SOURCE	Adair	Cherokee	Craig	Creek	Delaware	Mayes	Muskogee	Nowata	Okmulgee	Osage	Ottawa	Rogers	Tulsa	Wagoner	Washington	TOTAL
MUNICIPAL AND INDUSTRIAL COMPONENT																
Birch	---	---	---	---	---	---	---	---	---	1.9	---	4.8	---	---	---	6.7
Copan	---	---	---	---	---	---	---	---	---	---	---	---	---	---	7.5	7.5
Dripping Springs	---	---	---	---	---	---	---	---	7.4	---	---	---	---	---	---	7.4
Eucha & Spavinaw	---	---	---	---	---	---	---	---	---	---	---	---	84.0	---	---	84.0
Fort Gibson	---	---	---	---	---	---	34.4	---	---	---	---	---	---	---	---	34.4
Grand	---	---	3.1	---	4.3	14.0	---	---	---	---	---	---	---	---		21.4
Heyburn	---	---	---	1.9	---	---	---	---	---	---	---	---	---	---	---	1.9
Hudson	---	---	---	---	---	3.0	---	---	---	---	---	---	---	---	---	3.0
Hulah	---	---	---	---	---	---	---	---	---	---	---	---	---	---	13.9	13.9
Oologah	---	---	---	---	---	---	---	2.7	---	---	---	16.2	140.9	---	2.1	161.9
Skiatook	---	---	---	17.6	---	---	---	---	---	8.8	---	2.5	16.8	---	1.0	46.6
Tenkiller	2.2	13.8	---	---	---	---	---	---	---	---	---	---	---	---	---	16.0
SCS & Municipal Lakes	2.7	---	---	12.2	---	---	7.4	---	13.2	24.0	---	6.9	4.4	1.6	---	72.2
Groundwater	0.6	0.4	0.9	4.5	3.1	0.1	0.8	---	---	15.1	18.8	---	10.3	0.8	---	55.3
M&I Supply	**5.5**	**14.2**	**4.0**	**36.1**	**7.4**	**17.1**	**42.6**	**2.7**	**20.6**	**49.7**	**18.8**	**30.4**	**256.4**	**2.4**	**24.5**	**532.2**
2050 M&I Demand	**5.2**	**14.2**	**4.0**	**22.7**	**7.4**	**17.1**	**34.4**	**2.7**	**10.0**	**11.8**	**8.3**	**13.3**	**181.1**	**11.6**	**18.0**	**361.8**
M&I Surplus/(Deficit)	**0.3**	**—**	**—**	**13.4**	**—**	**—**	**8.2**	**—**	**10.6**	**37.9**	**10.5**	**17.1**	**75.3**	**(9.2)**	**6.5**	**170.5**
AGRICULTURAL COMPONENT																
Tenkiller	---	2.8	---	---	---	---	---	---	---	---	---	---	---	---	---	2.8
SCS & Municipal Lakes	3.9	0.3	0.3	9.8	0.7	24.6	4.8	0.7	7.4	15.8	0.2	2.8	1.6	0.9	4.4	78.1
Groundwater	1.2	0.2	---	0.9	3.2	---	8.3	---	---	7.1	0.5	0.2	5.9	2.3	---	29.8
Agricultural Supply	**5.1**	**3.2**	**0.3**	**10.7**	**3.8**	**24.6**	**13.1**	**0.7**	**7.4**	**22.9**	**0.8**	**2.9**	**7.5**	**3.2**	**4.4**	**110.7**
2050 Agricultural Demand	**3.4**	**2.8**	**3.2**	**1.4**	**1.7**	**2.8**	**8.7**	**1.8**	**1.6**	**3.3**	**1.7**	**2.3**	**5.9**	**3.5**	**2.5**	**46.6**
Agricultural Surplus/(Deficit)	**1.7**	**0.4**	**(2.9)**	**9.3**	**2.1**	**21.8**	**4.4**	**(1.1)**	**5.8**	**19.6**	**(0.9)**	**0.6**	**1.6**	**(0.3)**	**1.9**	**64.1**
POWER COMPONENT																
Fort Gibson	---	---	---	---	---	32.2	---	---	---	---	---	---	---	---	---	32.2
Keystone	---	---	---	---	---	---	22.4	---	---	---	---	---	---	---	---	22.4
Oologah	---	---	---	---	---	---	---	---	---	---	---	10.6	---	---	---	10.6
Stream Water Allocations	---	---	---	---	---	---	149.1	---	---	25.0	---	35.6	18.6	---	---	228.3
Groundwater	---	---	---	---	---	---	0.4	---	---	---	---	---	---	---	---	0.4
Power Supply	**—**	**—**	**—**	**—**	**—**	**32.2**	**171.9**	**—**	**—**	**25.0**	**—**	**46.2**	**18.6**	**—**	**—**	**293.9**
2050 Power Demand	**—**	**—**	**—**	**—**	**—**	**32.2**	**145.4**	**—**	**—**	**—**	**—**	**34.6**	**12.5**	**—**	**—**	**224.7**
Power Surplus/(Deficit)	**—**	**—**	**—**	**—**	**—**	**—**	**26.5**	**—**	**—**	**25.0**	**—**	**11.6**	**6.1**	**—**	**—**	**69.2**
TOTALS																
Total Local Supply	**10.6**	**17.4**	**4.3**	**46.8**	**11.2**	**73.9**	**227.5**	**3.4**	**28.0**	**97.6**	**19.5**	**79.5**	**282.5**	**5.6**	**28.9**	**936.8**
Total 2050 Demand	**8.6**	**17.0**	**7.2**	**24.1**	**9.1**	**52.1**	**188.3**	**4.5**	**11.6**	**15.1**	**10.0**	**50.2**	**199.5**	**15.1**	**20.5**	**633.1**
Net Surplus/(Deficit)	**2.0**	**0.4**	**(2.9)**	**22.7**	**2.1**	**21.8**	**39.2**	**(1.1)**	**16.4**	**82.5**	**9.5**	**29.3**	**83.0**	**(9.5)**	**8.4**	**303.7**

Northwest Planning Region

REGIONAL DESCRIPTION

The Northwest Planning Region covers 11 counties totaling 14,339 square miles (Figure 27). The counties include Alfalfa, Beaver, Blaine, Cimarron, Dewey, Ellis, Harper, Major, Texas, Woods and Woodward. The Panhandle counties of Cimarron, Texas and Beaver are generally flat while the remainder of the region is characterized by rough terrain marked with high sand hills and deep erosion. This region contains 20.2 percent of the state's total land area and supports the most extensive agricultural activities in Oklahoma. The Northwest Planning Region accounts for approximately 59 percent of the total statewide projected agricultural water demand. Crops and feed cattle flourish on lands irrigated from the Ogallala Aquifer and terrace and alluvium deposits.

The climate is semi-arid in the Panhandle and sub-humid in the remainder of the region. Annual precipitation ranges from 16 to 28 inches, including an average of 18 inches of snowfall. The majority of the precipitation occurs in the spring with May being the wettest month of the year. Thunderstorms producing high winds and damaging hail are a common occurrence throughout the region. Annual evaporative losses from lakes in the region range from 56 to 64 inches and greatly exceed precipitation. These losses create critical and persistent water problems and greatly affect the design of reservoirs in the region. Droughts are fairly common and mean annual temperatures range from 54 degrees in the Panhandle to 60 degrees in the southeast corner of the region. While flooding is relatively uncommon in the Northwest Region, four large flood control reservoirs and a few smaller watershed protection structures protect the area from widespread agricultural and property losses.

WATER RESOURCES

Stream Water

Table 24 summarizes stream water development of the Northwest Planning Region. The four major streams in the region are the Cimarron River, Salt Fork of the Arkansas River, North Canadian (Beaver) River and Canadian River. Available stream water quality is inadequate and quantity is insufficient to provide significant amounts of water to the region. Water quality in all major streams is poor, containing excessive amounts of salt and other dissolved minerals. This results in most local surface water being unacceptable under public health standards for municipal or industrial use.

The Cimarron River, encompassing 18,927 square miles of drainage area, originates in New Mexico and terminates in Keystone Lake. Of its 698 total miles of length, approximately 410 are in Oklahoma. Water quality in the river is degraded by salt sources near the Harper/Woods County line, often raising the salt content of the river to levels that exceed that of sea water. The water is very hard with moderate to high turbidity and some toxic metals problems. Dissolved oxygen levels are typically at or near saturation throughout the year.

The Salt Fork of the Arkansas River enters the state from Kansas in northeast Woods County. While water quality in many of its tributaries is of good or fair quality, the river is highly mineralized and chemically unsuitable for most beneficial uses.

The North Canadian River, also known as the Beaver River, enters Oklahoma in southwestern Cimarron County from New Mexico and has a drainage area of approximately 9,100 square miles. Water quality of the river in this region is generally poor due to elevated levels of nitrogen and phosphorus in the upper portion and increased mineralization by sulfates and chlorides downstream. Downstream from where Palo Duro Creek joins the North Canadian River east of Hardesty, high levels of sodium and other dissolved minerals cause fair to poor quality for irrigation purposes. Upstream from the junction with Palo Duro Creek, water is of good quality and suitable for most uses.

The Canadian River enters into Oklahoma from Texas. Within this planning region, water in the river is hard and highly mineralized. Nutrient levels are high where the river enters the state, but diminish as it flows through the state. Turbidity and pH occasionally exceed standards but dissolved oxygen is typically at or near saturation throughout most of the year.

MAJOR RESERVOIRS

There are four major reservoirs in the Northwest Planning Region. Canton and Fort Supply provide water for municipal and industrial use, while Great Salt Plains Lake and Optima Reservoir serve primarily as flood control structures.

Canton Lake is located in Blaine County on the North Canadian River in the Arkansas River Basin approximately two miles north of Canton and 75 miles northwest of Oklahoma City. The project, completed by the Corps of Engineers in April 1948, has a drainage area of 12,483 square miles. Its authorized purposes are flood control, water supply and irrigation. In addition, eight recreation areas have been developed around the lake which is the primary source of walleye eggs used by state fish hatcheries for stocking in other lakes. The lake contains 265,790 ac-ft of flood control storage, 97,170 ac-ft of water supply storage, and has a water supply yield of 13,440 af/yr (12 mgd). All yield, including irrigation storage, is allocated to Oklahoma City in the Central Planning Region.

Fort Supply Lake, located on Wolf Creek, a tributary of the North Canadian River in Woodward County, is about one mile south of the town of Fort Supply and about 12 miles northwest of Woodward. This Corps project, completed in May 1942, encompasses a drainage area of 1,735 square miles. Flood control and water supply are the authorized uses of the lake. The Corps maintains four public use areas covering 542 acres at the project. The lake contains 86,800 ac-ft of flood control storage, 13,900 ac-ft of conservation storage (which includes 400 ac-ft of water supply storage), and has a water supply yield of 224 af/yr (0.2 mgd).

Great Salt Plains Lake is located on the Salt Fork of the Arkansas River in Alfalfa County, approximately 5.5 miles northeast of Jet and about 12 miles east of Cherokee. This project, built by the Corps in 1941, is authorized for flood control, recreation, and fish and wildlife and has a drainage area of 3,200 square miles. Except for 761 acres in the vicinity of the dam, which is under Corps jurisdiction, the Great Salt Plains National Wildlife Refuge is administered by the U.S. Fish and

Wildlife Service. The lake contains 239,980 ac-ft of flood control storage and conservation storage of 31,420 ac-ft. Due to high mineral content, the lake is not utilized for water supply.

Optima Lake is located on the North Canadian River in Texas County, about 4.5 miles northeast of Hardesty and 20 miles east of Guymon. The project was completed by the Corps of Engineers in 1978. However, to date, the conservation pool has yet to fill; the maximum water surface elevation attained was 3.1 feet below the top of the inactive pool (May 1980). The lake is authorized for flood control, water supply, recreation, and fish and wildlife purposes with a drainage area of 5,029 square miles. The lake contains 71,800 ac-ft of flood control storage and 76,200 ac-ft of water supply storage. There is no dependable water supply yield in Optima at this time.

MAJOR MUNICIPAL LAKES

There are six major municipal lakes in the Northwest Planning Region, all owned by the State of Oklahoma with recreation as their authorized purpose. They are Lake Carl Etling (1,717 ac-ft of approximate conservation storage), Lake Schultz (528 ac-ft), Lake Chambers (708 ac-ft), Lake Lloyd Vincent (2,579 ac-ft), American Horse Lake (2,200 ac-ft) and Lake Watonga (656 ac-ft). None of the lakes are used for water supply.

AUTHORIZED DEVELOPMENT

There are no major authorized water supply projects in the Northwest Planning Region.

POTENTIAL DEVELOPMENT

The northwest Oklahoma/southwest Kansas area has been extensively studied for potential water supply projects. But, due to water quality considerations and the insufficient availability of stream water, there is limited potential for additional stream water development in this region (Table 24).

Modifications to Fort Supply have been proposed to increase the annual yield to 11,500 af/yr (10.3 mgd). To accomplish this, the conservation storage would be raised to 30,000 ac-ft while the existing spillway crest would be raised five feet to maintain the 86,800 ac-ft of flood control storage.

Forgan Reservoir is a potential project on the Cimarron River in southwest Kansas, near the Kansas/Oklahoma border. As proposed, the project would include 77,500 ac-ft of conservation storage, 26,500 ac-ft of flood control storage, and a firm yield of 24,100 af/yr (21.5 mgd). However, water from the impoundment would require treatment (including implementation of a reverse osmosis process) to meet drinking water standards, reducing the yield for M&I purposes to 12,450 af/yr (11 mgd), one-half of which would be available to Oklahoma. Modification of the Arkansas River Basin Compact would be required prior to construction.

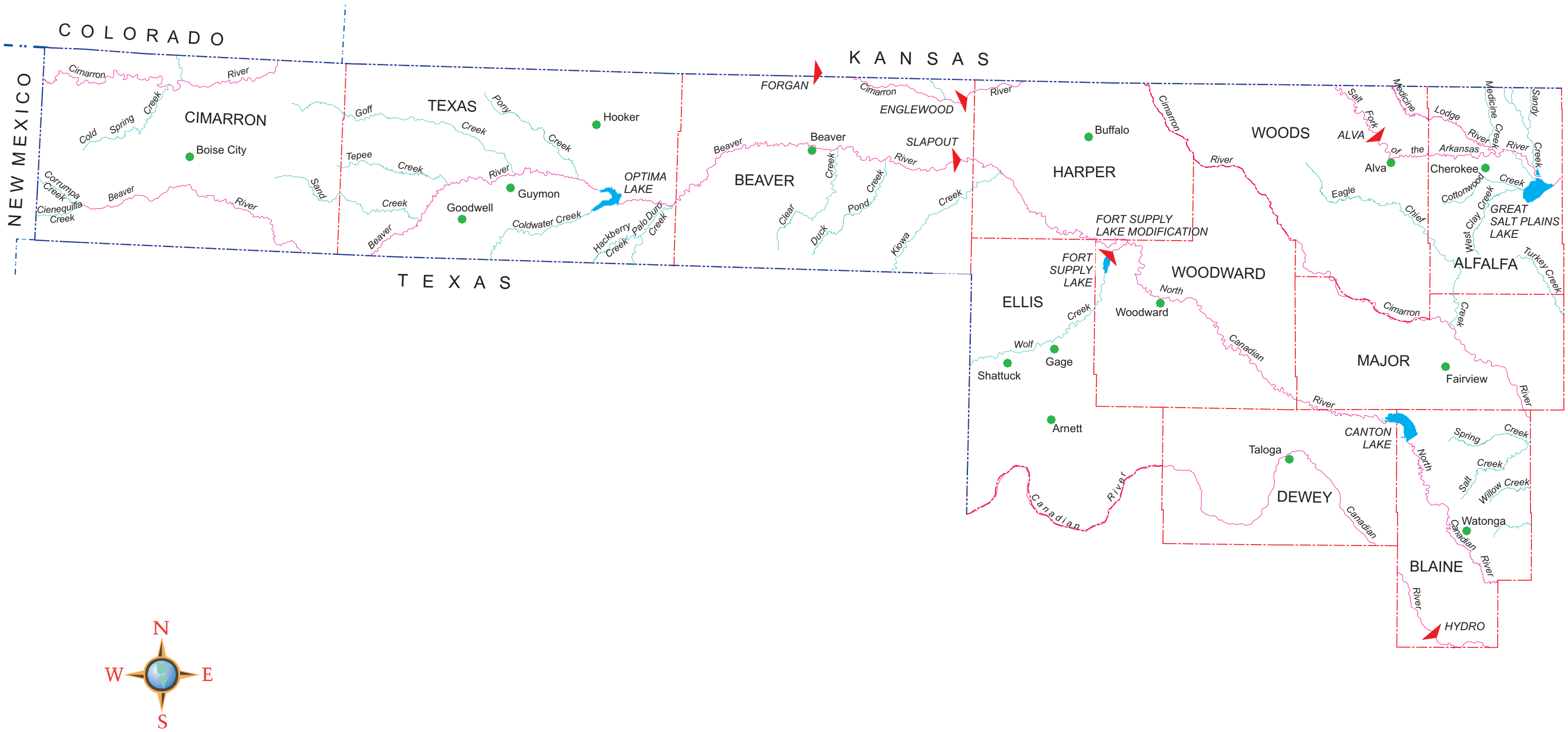
Englewood Reservoir is another potential impoundment on the Cimarron River in Beaver County. As proposed by the Corps of Engineers, the project would include 110,900 ac-ft of flood control storage and 63,500 ac-ft of conservation storage yielding 37,000 af/yr (33 mgd). As with

Table 24
STREAM WATER DEVELOPMENT
Northwest Planning Region

PROJECT	STREAM	PURPOSE*	FLOOD CONTROL STORAGE (acre-feet)	WATER SUPPLY STORAGE (acre-feet)	WATER SUPPLY YIELD (ac-ft/year)
		EXISTING OR UNDER CONSTRUCTION			
Canton	North Canadian River	ws, fc, i	265,790	97,170	---- [1]
Fort Supply	Wolf Creek	ws, fc	86,800	400	224
Great Salt Plains	Salt Fork of Arkansas River	fc, r, fw	239,980	---	---- [2]
Optima	North Canadian River	ws, fc, r, fw	71,800	76,200	---- [3]
TOTAL			**664,370**	**173,770**	**224**
		POTENTIAL			
Alva	Salt Fork of Arkansas River	ws, fc, r, fw, i	98,600	200,500	32,500
Englewood	Cimarron River	ws, fc, r, fw, i	110,900	63,500	37,000
Forgan	Cimarron River	ws, fc, r, fw	26,500	77,500	12,450 [4]
Fort Supply Modification	Wolf Creek	ws, fc, r, fw	---	29,600	11,276 [5]
Hydro	Canadian River	ws, fc, r, fw	---	173,000	114,900
Slapout	North Canadian River	ws, fc, r, fw	137,000	249,000	18,800
TOTAL			**373,000**	**793,100**	**226,926**
TOTAL YIELD					**227,150**

*ws-municipal water supply, fc-flood control, r-recreation, fw-fish and wildlife, i-irrigation.

[1] Entire 18,480 af/yr available yield allocated to Oklahoma City in the Central Region.
[2] Water unsuitable for use due to high mineral content.
[3] Lake has never filled; no dependable yield.
[4] Proposed reservoir in southwest Kansas. Of proposed 24,100 af/yr yield, approximately 17,000 af/yr would be available for M&I purposes, resulting in approximately 12,450 af/yr after treatment losses. One-half of the water would be available to Oklahoma.
[5] Additional yield with modification.



Reservoir, Existing or Under Construction
Reservoir, Potential Modification
Reservoir, Potential
Mainstem
Tributary

OKLAHOMA COMPREHENSIVE WATER PLAN

Figure 27
NORTHWEST PLANNING REGION

Mapping and Graphics - Oklahoma Water Resources Board

Forgan Reservoir, water quality would be poor and the Arkansas River Basin Compact would require modification to allow construction.

Hydro Reservoir is a project proposed for construction on the Canadian River in Blaine County. The reservoir would provide 173,000 ac-ft of conservation storage with a yield of 114,900 ac-ft (102.6 mgd). The water is anticipated to be of marginal quality, although chloride levels should be within acceptable limits. However, sulfates may require treatment.

Regarding other potential projects in the region, Alva is expected to have poor water quality and the proposed site is not in close proximity to areas with anticipated demands. Uncertainty regarding future storage flows at Slapout, which would be constructed downstream of Optima Lake, decreases the potential viability of that project.

STREAM WATER RIGHTS

As of June 1994, the OWRB had issued stream water allocation permits totaling 41,615 ac-ft per year from lakes, rivers and streams within the Northwest Planning Region (Table 25).

Groundwater

Groundwater is the major source of water supply in the Northwest Planning Region. The region overlies alluvium and terrace deposits of the Salt Fork of the Arkansas River, Cimarron River, Beaver/North Canadian River and Canadian River, as well as three bedrock aquifers -- the Ogallala Formation, Rush Springs Sandstone and Cedar Hills Sandstone.

The Ogallala Formation, which is the single largest source of groundwater in the state, underlies the Panhandle and portions of extreme western counties in Oklahoma. The water is of good quality, although hard, and some local portions of the formation have high fluoride and chloride concentrations. The semi-consolidated aquifer consists primarily of fine sands and silt with lesser quantities of gravel, clay and minor beds of limestone and caliche. The saturated thickness of the formation ranges from a few feet to more than 500 feet. Wells range from 100 to 500 feet in depth with yields commonly between 100 and 1,000 gpm. The Ogallala in Oklahoma has an estimated storage of 112 million acre-feet, based on USGS studies. Even with the aquifer's large storage volume, localized water levels have declined in recent years, with some wells reporting drops of up to 100 feet.

The Rush Springs Sandstone is a fine-grained sandstone aquifer with some shale, dolomite and gypsum. Within the region, the aquifer is found in portions of Blaine and Dewey Counties. Thickness of the formation ranges from 200 feet in the southern end to 300 feet in the north. Well depths are usually 200 to 400 feet and yield between 200 and 600 gpm. The water tends to be of a calcium bicarbonate type and very hard, though suitable for most uses. Levels of TDS are generally less than 500 mg/L.

The Cedar Hills Sandstone Aquifer is found in portions of Woods, Alfalfa and Major Counties. While not widely used, the aquifer is a fine- to medium-grained sandstone, siltstone and silty shale. Wells yield between 150 and 300 gpm from

Table 25
WATER RIGHTS
Northwest Planning Region

STREAM WATER ALLOCATIONS
(acre-feet)

COUNTY	Municipal	Industrial	Agricultural	Commercial	Rec, F&W	Power	Other	TOTAL
Alfalfa	---	---	1,093	---	3,494	---	---	4,587
Beaver	---	---	1,981	---	423	---	---	2,404
Blaine	---	5	2,015	---	553	---	---	2,573
Cimarron	---	---	4,087	10	665	---	---	4,762
Dewey	---	---	---	---	700	---	---	700
Ellis	---	---	429	---	380	---	---	809
Harper	---	42	10,822	10	270	---	---	11,144
Major	---	60	1,307	---	---	---	---	1,367
Texas	---	---	3,904	---	261	---	---	4,165
Woods	---	---	174	---	20	---	---	194
Woodward	6,971	---	1,929	---	10	---	---	8,910
TOTAL	**6,971**	**107**	**27,741**	**20**	**6,776**	**---**	**---**	**41,615**

GROUNDWATER ALLOCATIONS
(acre-feet)

COUNTY	Municipal	Industrial	Agricultural	Commercial	Rec, F&W	Power	Other	TOTAL
Alfalfa	10,184	1,590	14,428	324	110	---	240	26,876
Beaver	3,525	1,039	159,723	145	27	---	1	164,460
Blaine	4,904	957	22,042	7	124	---	---	28,034
Cimarron	3,200	275	304,600	72	---	---	---	308,147
Dewey	558	2,747	35,250	---	---	---	1	38,556
Ellis	3,683	102	57,403	---	10	---	---	61,199
Harper	2,997	8	45,889	80	---	---	---	48,974
Major	28,472	309	52,327	25	2,412	---	---	83,545
Texas	10,128	3,115	566,859	898	1,056	---	---	582,056
Woods	11,180	20	17,209	648	---	60	---	29,117
Woodward	26,824	489	36,283	245	137	4,804	---	68,782
TOTAL	**105,655**	**10,652**	**1,312,012**	**2,444**	**3,876**	**4,864**	**242**	**1,439,745**

Note: Agricultural allocations include Irrigation. Mining included in Industrial.
Source of data: Oklahoma Water Resource Board printout, June 23, 1994.

formation thicknesses of 150 to 180 feet. Little water quality data is available, although the water is generally suitable for most uses.

Alluvial and terrace deposits of the Cimarron River are normally found in silt and clay deposits degrading downward to sandy clay, sand and fine gravel. Maximum thicknesses reach 80 feet with well yields ranging between 100 and 200 gpm in the alluvium and 100 to 500 gpm in the terrace deposits which are overlain by sand dunes. The water, which is very hard, is classified as a calcium magnesium bicarbonate type. Extensive pumping makes this formation susceptible to saltwater intrusion.

In the alluvial and terrace deposits of the North Canadian River, the formation consists of fine- to coarse-grained sand with minor clay and silt and local lenses of basal gravel overlain by dune sand. Formation thicknesses average 30 feet in the alluvium with a maximum of 300 feet in the terrace deposits. Yields in the alluvium range between 300 and 600 gpm and between 100 and 300 gpm in the terrace. The water is a very hard calcium bicarbonate type with TDS concentrations of approximately 1,000 mg/L.

In the alluvial and terrace deposits of the Canadian River, the formation consists of clay and silt downgrading to fine- to coarse-grained sand with lenses of basal gravel. Formation thicknesses range from 20 to 40 feet in the alluvium with a maximum of 50 feet in the terrace deposits. Yields in the alluvium range between 100 and 400 gpm and between 50 and 100 gpm in the terrace. The water is a very hard calcium bicarbonate type with TDS concentrations of approximately 1,000 mg/L.

GROUNDWATER DEVELOPMENT

Groundwater allocations in the region exceed surface water allocations by a ratio of more than 34 to 1. The scarcity of surface water, along with high agricultural demands, contribute to the region's dependance upon groundwater. Careful groundwater utilization is essential to ensuring the continued viability of the resource.

GROUNDWATER RIGHTS

As of June 1994, the OWRB had issued groundwater allocation permits totaling 1,439,745 ac-ft per year from aquifers in the Northwest Planning Region (Table 25).

SUPPLY AND DEMAND ANALYSIS

Total 2050 demands for municipal and industrial, agricultural, and power uses in the Northwest are projected to reach 1,107,300 af/yr, substantially higher than any other planning region. Preliminary analysis indicates that these demands can be met with existing surface and groundwater sources (Table 26). Due to the uncertainty associated with long-term reliability of groundwater supplies, the development of new surface water sources, either inside or outside the region, may be necessary to satisfy future demands.

Table 26
SUPPLY AND DEMAND ANALYSIS
Northwest Planning Region
(1,000 ACRE-FEET/YEAR)

	COUNTY											
SOURCE	**Alfalfa**	**Beaver**	**Blaine**	**Cimarron**	**Dewey**	**Ellis**	**Harper**	**Major**	**Texas**	**Woods**	**Woodward**	**TOTAL**
MUNICIPAL AND INDUSTRIAL COMPONENT												
Canton	---	---	---	---	---	---	---	---	---	---	---	---
Fort Supply	---	---	---	---	---	---	---	---	---	---	7.0	7.0
Optima	---	---	---	---	---	---	---	---	---	---	---	---
SCS & Municipal Lakes	---	---	0.6	1.3	---	1.3	---	---	---	---	---	3.2
Groundwater	12.4	4.7	6.0	3.5	3.3	3.8	3.1	31.2	15.2	11.8	27.7	122.9
M & I Supply	**12.4**	**4.7**	**6.6**	**4.8**	**3.3**	**5.1**	**3.1**	**31.2**	**15.2**	**11.8**	**34.7**	**133.1**
2050 M & I Demand	**2.4**	**2.6**	**5.2**	**1.4**	**1.6**	**1.9**	**1.0**	**2.4**	**9.4**	**3.8**	**13.8**	**45.5**
M & I Surplus/(Deficit)	**10.0**	**2.1**	**1.4**	**3.4**	**1.7**	**3.2**	**2.1**	**28.8**	**5.8**	**8.0**	**20.9**	**87.6**
AGRICULTURAL COMPONENT												
Canton	---	---	---	---	---	---	---	---	---	---	---	---
Fort Supply	---	---	---	---	---	---	---	---	---	---	---	---
SCS & Municipal Lakes	0.1	0.5	1.3	---	3.3	0.2	1.1	0.2	0.4	0.4	0.1	7.5
Groundwater	14.4	159.7	22.0	304.6	35.3	57.4	45.9	52.3	566.9	17.2	36.3	1,312.0
Agricultural Supply	**14.5**	**160.2**	**23.3**	**304.6**	**38.5**	**57.6**	**47.0**	**52.5**	**567.3**	**17.6**	**36.4**	**1,319.5**
2050 Agricultural Demand	**10.1**	**117.1**	**7.2**	**307.3**	**6.2**	**48.8**	**34.0**	**29.5**	**455.9**	**10.1**	**31.5**	**1,057.7**
Agricultural Surplus/(Deficit)	**4.4**	**43.1**	**16.1**	**(2.7)**	**32.3**	**8.8**	**13.0**	**23.0**	**111.4**	**7.5**	**4.9**	**261.8**
POWER COMPONENT												
SCS & Municipal Lakes	---	---	---	---	---	---	---	---	---	---	---	---
Groundwater	---	---	---	---	---	---	---	---	---	0.1	4.8	4.9
Power Supply	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**0.1**	**4.8**	**4.9**
2050 Power Demand	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**4.1**	**4.1**
Power Surplus/(Deficit)	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**0.1**	**0.7**	**0.8**
TOTALS												
Total Local Supply	**27.0**	**165.0**	**29.9**	**309.4**	**41.8**	**62.7**	**50.1**	**83.7**	**582.5**	**29.5**	**75.9**	**1,457.5**
Total 2050 Demand	**12.5**	**119.7**	**12.4**	**308.7**	**7.8**	**50.7**	**35.0**	**31.9**	**465.3**	**13.9**	**49.4**	**1,107.3**
Net Surplus/(Deficit)	**14.5**	**45.3**	**17.5**	**0.7**	**34.0**	**12.0**	**15.1**	**51.8**	**117.2**	**15.6**	**26.5**	**350.2**

This section presents results of an evaluation of surface and groundwater supplies in Oklahoma. The study consisted of two phases. Phase I involved the evaluation of all existing and proposed water supply sources (both surface and groundwater) to determine availability. Phase II consisted of a comparison of available sources to projected demands in the year 2050.

For each region, existing major federal surface water supplies were evaluated for flood control storage, conservation storage and dependable yield. For the purpose of this analysis, water supply and water quality storage were classified as conservation storage available for use. Significant municipal lakes within each region were also investigated along with multipurpose Natural Resource Conservation Service (NRCS) lakes.

Small public and private lakes of 100 acre-feet or more of storage, along with all NRCS impoundments, were evaluated to determine approximate yields for each county. There are hundreds of small public, private and watershed protection lakes for which no dependable yield studies have been performed. Yield figures for these impoundments were estimated by applying OWRB-supplied county recharge rates to estimated storage.

Water permit allocation records were obtained from the OWRB for both surface and groundwater. Statewide/regional surface and groundwater permits are summarized in Table 7. OWRB allocations were also analyzed for each major reservoir to properly allocate supplies to the appropriate county. Existing groundwater allocations were used as the basis to estimate year 2050 groundwater supply.

Projected municipal and industrial (M&I), agricultural and power demands for water in the year 2050 were provided by the OWRB. These demands were compared with existing supplies on both a county and regional basis. All regions reflected a potential excess of water, although several counties indicated potential shortages.

South Central Planning Region

REGIONAL DESCRIPTION

Covering approximately 8.3 percent of the state (5,799 square miles), Carter, Garvin, Grady, Jefferson, Love, Marshall, Murray and Stephens Counties comprise the South Central Planning Region (Figure 28). Lying at the eastern edge of the Southern Great Plains, the region varies from lush pastures in the river bottoms to sparsely vegetated oilfields to the rugged foothills of the Arbuckle Mountains. Stream and surface water sources are abundant in the eastern portion of the region; however, they are relatively scarce in the west.

The South Central Region is projected to have the lowest overall water demand of any region for the year 2050. The region is sparsely populated, with the largest cities being Ardmore, Duncan and Chickasha. The projected 2050 agricultural demand is estimated to account for only 3.2 percent of the total statewide agricultural demand.

The region's climate is mild with annual mean temperatures varying from 61 to 64 degrees. Annual evaporation within the region ranges from 63 inches in the west to 55 inches in the east. Rainfall averages 30 inches per year in the west and approaches 39 inches per year in the east.

WATER RESOURCES

Stream Water

The region's major streams include the Red River and Washita River, along with Beaver Creek, Mud Creek and Walnut Bayou. Stream water is not a dependable supply source in this region due to intermittent flow in most streams and generally poor water quality.

Forming its southern border, the Red River is the major stream in the South Central Region. The river is highly mineralized above Lake Texoma, with chlorides and dissolved solids often exceeding EPA limits. The Red River Chloride Control Project has been proposed by the Corps of Engineers to reduce naturally occurring chloride levels in the River and its tributaries.

The Washita River flows through the northern portion of the region before joining the Red River in Lake Texoma. The Washita is also highly mineralized, although tributary streams improve overall quality in the lower reaches to make it suitable for most uses.

MAJOR RESERVOIRS

Table 27 lists existing and proposed reservoirs within the region. The largest of four existing major impoundments is Lake Texoma, on the Oklahoma/Texas border in Love and Marshall Counties.

Texoma, a Corps of Engineers project, was constructed in 1944 for flood control, water supply, recreation, navigation and hydropower purposes, as well as for regulation of Red River flows. Its flood control storage of 2,613,777 ac-ft is credited with preventing more than $101 million dollars in flood-related damages since becoming operational. The lake is located on the mainstem of the Red River and is subject to the Red River Compact which equally allocates water supplies to Texas and Oklahoma. Each state is allotted a dependable water supply yield of 168,000 af/yr (150 mgd). Lake Texoma has power pool storage of 1,010,170 ac-ft and installed hydroturbine capacity of 70,000 kW. The water is of generally poor quality and is not suitable for most municipal and industrial uses without treatment or blending. However, water in the Washita arm of the lake is generally suitable for most uses.

Lake of the Arbuckles was constructed by the Bureau of Reclamation in 1967. Located in Murray County on Rock Creek, a tributary of the Washita River, the impoundment provides water supply, flood control, recreation, and fish and wildlife mitigation. The reservoir has 36,400 ac-ft of flood control storage and 62,600 ac-ft of conservation storage which yields 24,000 af/yr (21.4 mgd). All of the available yield is allocated to the Arbuckle Master Conservancy District which provides water to the cities of Ardmore, Davis, Sulphur, Wynnewood and Dougherty. Quality of the water is good, making it suitable for all uses.

Lake Murray, a state-owned lake constructed in 1937 solely for recreational purposes, is one of southern Oklahoma's major tourist attractions, second only to Lake Texoma. Located on Hickory Creek in Love County, the lake has 153,250 ac-ft of conservation storage; however, none of that storage is for water supply. Several permits have been issued for recreation, fish and wildlife mitigation, and irrigation uses.

Waurika Lake is a Corps project on Beaver Creek in Jefferson County. The project was completed in 1982 for water supply, flood control, irrigation, water quality, recreation, and fish and wildlife mitigation purposes. The project contains 131,900 ac-ft of flood control storage (after sedimentation) and 170,200 ac-ft of conservation storage. The project yields 45,590 af/yr (40.7 mgd) of water supply (including water quality and irrigation uses). All yield is allocated to the Waurika Master Conservancy District which provides water service to the cities of Duncan, Lawton, Waurika, Temple and Comanche.

MUNICIPAL LAKES

There are 11 large municipal lakes within the South Central Planning Region. Ardmore City Lake, constructed in 1910, is one of the oldest impoundments in Oklahoma. The impoundment is on a tributary of Caddo Creek, approximately four miles north of the City of Ardmore in Carter County. Its primary use is now recreation; however, it is capable of providing 560 af/yr (0.5 mgd) of water supply from its 2,300 ac-ft of conservation storage.

Ardmore Mountain Lake is an impoundment on Hickory Creek in north central Carter County, approximately 21 miles northwest of Ardmore. The lake is owned by the City of Ardmore and is primarily used for recreation and water supply. The lake has 4,650 ac-ft of conservation storage and a dependable yield of 2,800 af/yr (2.5 mgd).

Clear Creek Lake (7,710 ac-ft), Duncan Lake (7,200 ac-ft), Lake Humphreys (SCS #22, 14,041 ac-ft) and Lake Fuqua (SCS #39, 21,100 ac-ft) are municipal lakes used by the City of Duncan for water supply and recreation. Clear Creek, Duncan and Humphreys are on tributaries of Wildhorse Creek in Stephens County; Fuqua is on Black Bear Creek in Stephens County. Humphreys and Fuqua are NRCS projects which also provide flood control storage. The combined yield of Clear Creek Lake, Duncan Lake and Lake Fuqua is 2,654 af/yr (2.4 mgd). The yield of Lake Humphreys is 2,442 af/yr (2.2 mgd).

Pauls Valley Lake is a 750-acre impoundment in Garvin County. Located on Washington Creek, the lake provides water supply and recreation for the City of Pauls Valley. The lake has 8,500 ac-ft of conservation storage which yields 4,000 af/yr (3.6 mgd) of water supply.

Lake R.C. Longmire (SCS-17M) is an NRCS project completed in 1990 for water supply, flood control and recreation in Garvin County on Keel Sandy Creek. The lake is owned by the City of Pauls Valley and has 4,142 ac-ft of flood control storage and 13,162 ac-ft of conservation storage which yields 3,360 af/yr (3 mgd).

Rock Creek Reservoir (SCS #18) is a multipurpose project on a tributary of Caddo Creek in Carter County, approximately seven miles northwest of Ardmore. The reservoir, with 248 surface acres, has 1,634 ac-ft of flood control storage. The 2,573 ac-ft of conservation storage yields 1,220 af/yr (1.1 mgd) of water supply for the City of Ardmore.

OTHER IMPOUNDMENTS

There are numerous other NRCS projects, small municipal lakes and private reservoirs within the South Central Planning Region. These small lakes provide municipal supply, irrigation water and recreational opportunities. Healdton (SCS #10; approximately 3,766 ac-ft of conservation storage), Taylor Lake (SCS #1; 1,8777 ac-ft), Madill Lake (3,000 ac-ft), Burtschi Lake (2,140 ac-ft), Comanche Lake (2,500 ac-ft), Carter Lake (990 ac-ft) and Veterans Lake (600 ac-ft) are some of the larger impoundments in this category.

AUTHORIZED DEVELOPMENT

There are no major authorized water supply projects within the South Central Planning Region.

POTENTIAL DEVELOPMENT

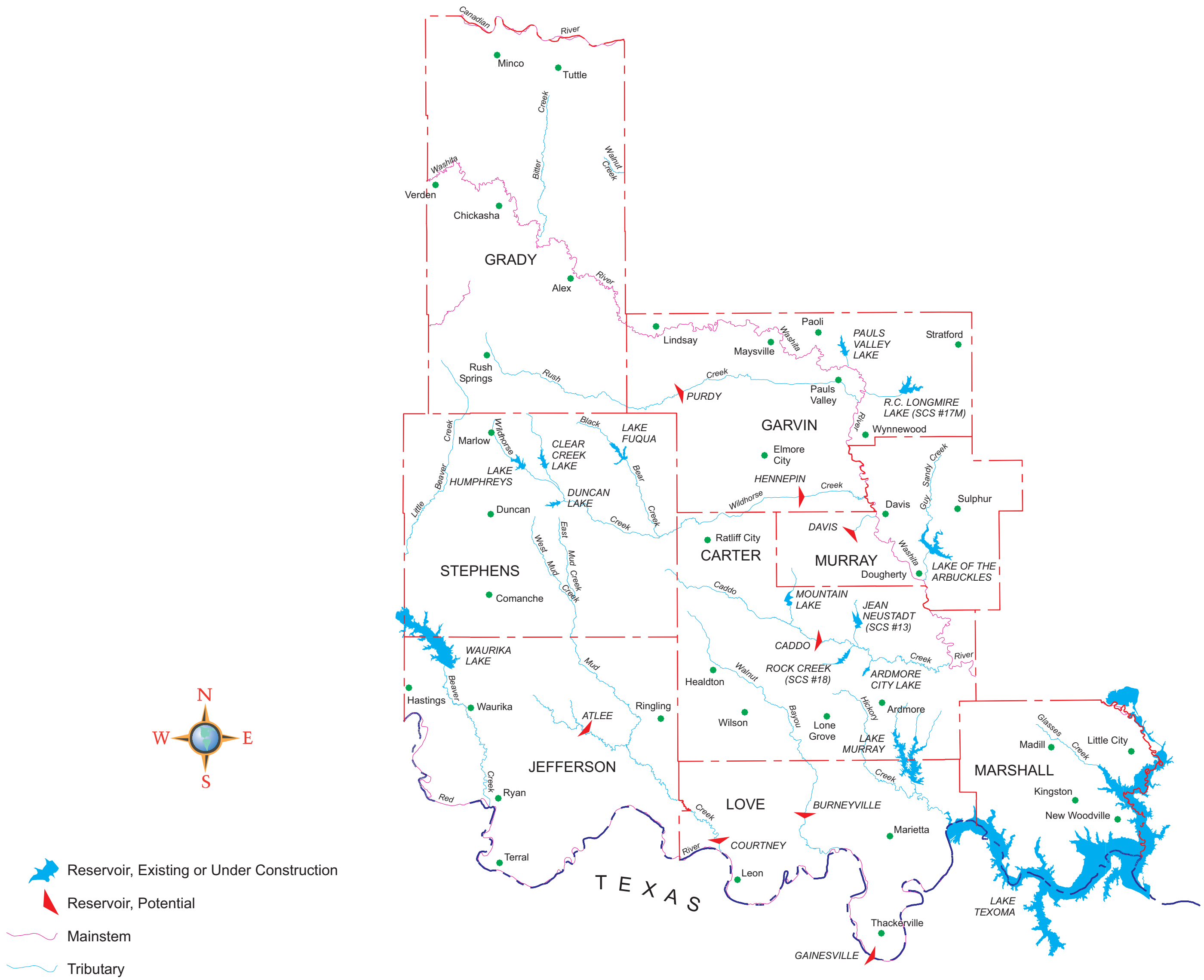
Several sites in the South Central Planning Region have potential for development of new water supply projects. Of the eight sites identified in Table 27, several have been extensively studied, although no local sponsors currently exist for any of these projects.

Table 27
STREAM WATER DEVELOPMENT
South Central Planning Region

PROJECT	STREAM	PURPOSE*	FLOOD CONTROL STORAGE (acre-feet)	WATER SUPPLY STORAGE (acre-feet)	WATER SUPPLY YIELD (ac-ft/year)
		EXISTING OR UNDER CONSTRUCTION			
Arbuckle	Rock Creek	ws, fc, r, fw	36,400	62,600	24,000
Ardmore	Tributary of Caddo Creek	ws, r	---	2,300	560
Clear Creek	Tributary of Wildhorse Creek	ws, r	---	7,710	----[1]
Duncan	Tributary of Wildhorse Creek	ws, r	---	7,200	----[1]
Fuqua	Black Bear Creek	ws, fc, r	3,500	17,600	2,654[1]
Fort Cobb	Cobb Creek	ws, fc, r, i	63,750	78,350	8,280[2]
Humphreys	Tributary of Wildhorse Creek	ws, fc, r	11,900	10,700	2,442
Longmire, R.C. (SCS 17M)	Keel Sandy Creek	ws, fc, r	4,142	13,162	3,360
Mountain	Tributary of Caddo Creek	ws, r	---	4,650	2,800
Murray	Tributary of Hickory Creek	r	---	153,250	---
Jean Neustadt (SCS 13)	Tributary of Caddo Creek	ws, fc, r	4,357	4,542	2,150
Pauls Valley	Washington Creek	ws, r	---	8,500	4,000
Rock Creek (SCS 18)	Tributary of Caddo Creek	ws, r	1,634	2,573	1,220
Texoma	Red River	ws, fc, p, r, n, flow	2,613,777	150,000	168,000[3]
Waurika	Beaver Creek	ws, fc, wq, r, fw, i	131,900	170,200	18,400[4]
TOTAL			**2,871,360**	**693,337**	**237,866**
		POTENTIAL			
Atlee	Mud Creek	w s	26,660	25,600	5,500
Burneyville	Walnut Bayou	ws, p, r	576,580	150,000	25,000
Caddo	Caddo Creek	ws, p, r	73,980	260,000	40,000
Courtney	Mud Creek	ws, p, r	79,000	224,100	45,100
Davis	Colbert Creek	w s	4,400	10,760	2,800
Gainesville	Red River	ws, p, r, fw, i	47,151	35,000	8,750[5]
Hennepin	Wildhorse Creek	ws, p	27,000	180,000	30,000
Purdy	Rush Creek	ws, fc, r	62,500	140,000	20,000
TOTAL			**897,271**	**1,025,460**	**177,150**
TOTAL YIELD					**415,016**

*ws-municipal water supply, fc-flood control, wq-water quality, p-power, r-recreation, fw-fish and wildlife, i-irrigation, n-navigation, flow-low flow augmentation.

[1] Combined yield of Clear Creek Lake, Lake Fuqua and Lake Duncan is 2,654 af/yr.
[2] Located in Southwest Planning Region; total yield is 18,000 af/yr, with 9,720 af/yr allocated to Southwest Planning Region.
[3] Lake Texoma is subject to Red River Compact Agreement between States of Oklahoma and Texas. Under terms of agreement, Oklahoma has rights to one-half of total water supply yield, or 168,000 af/yr (150 mgd).
[4] Total yield of Waurika Lake is 45,590 af/yr, including 5,040 af/yr of irrigation storage. All yield allocated to Waurika Master Conservancy District; approximately 18,400 af/yr allocated to South Central Region and 27,190 af/yr allocated to Southwest Region.
[5] Site located on interstate stream subject to Red River Compact Agreement. Total yield projected to be 17,500 af/yr, of which 8,750 af/yr would be available to Oklahoma.



OKLAHOMA COMPREHENSIVE
WATER PLAN

Figure 28
SOUTH CENTRAL
PLANNING REGION

Mapping and Graphics - Oklahoma Water Resources Board

Atlee Reservoir is a proposed water supply impoundment on West Mud Creek in Jefferson County. The potential yield of the reservoir is 5,500 af/yr (4.9 mgd) from the 26,500 ac-ft of conservation storage. Flood control storage of 26,660 ac-ft is anticipated in the reservoir. This project is an alternative site for Courtney Reservoir, discussed later.

Burneyville Lake is proposed for development on Walnut Bayou in Love County. The 8,500-acre project would provide water supply and hydropower. The potential yield is estimated at 25,000 af/yr (22.3 mgd) with 150,000 ac-ft of conservation storage. An additional 576,580 ac-ft of flood control storage is possible at this site.

Caddo Lake is a proposed multipurpose impoundment on Caddo Creek in Carter County. The lake would have 260,000 ac-ft of conservation storage yielding 40,000 af/yr (35.7 mgd). In addition, 73,980 ac-ft of flood control storage is planned.

Courtney Reservoir is a potential project on Mud Creek in western Love County. The potential yield of 45,100 af/yr (40.3 mgd) would be developed from 224,100 ac-ft of conservation storage. Flood control storage of 79,000 ac-ft is also possible.

Purdy Reservoir is a potential impoundment on Rush Creek in western Garvin County. Its conservation storage of 140,000 ac-ft is proposed to yield 20,000 af/yr (17.9 mgd), although quality of the water for M&I purposes is questionable. The site can also provide 62,550 ac-ft of flood control storage.

STREAM WATER RIGHTS

As of June 1994, the OWRB had issued stream water allocation permits totaling 178,796 ac-ft per year from lakes, rivers and streams in the South Central Planning Region (Table 28).

Groundwater

South Central Oklahoma overlies six principal groundwater aquifers -- the Arbuckle-Timbered Hills Group, Arbuckle-Simpson Group, Oscar Formation, Rush Springs Sandstone, Antlers Formation and alluvium and terrace deposits of the Red and Washita Rivers. Groundwater is the principal source of supply for most of the region's irrigation and serves as the major supply for many small communities in the region.

The Arbuckle-Timbered Hills Group is a confined limestone, dolomite, sandy dolomite, mudstone and conglomerate formation found in portions of Carter and Murray Counties. Well depths are commonly between 100 and 2,800 feet. Well yields range between 90 and 600 gpm. The water is generally soft; however, fluoride concentrations exceed EPA limits and chloride concentrations approach those limits at most locations. The water is generally not suited for public consumption.

The Arbuckle-Simpson Group is a limestone, dolomite and sandstone formation found in portions of Carter and Murray Counties. Formation thicknesses vary between 5,000 and 9,000 feet. Well depths are commonly between 100 and 2,500 feet with yields between 100 and 500 gpm. The water is of a calcium magnesium bicarbonate type and very hard. Dissolved solids are generally within acceptable limits and the water is suitable for most uses.

Table 28
WATER RIGHTS
South Central Planning Region

STREAM WATER ALLOCATIONS
(acre-feet)

COUNTY	Municipal	Industrial	Agricultural	Commercial	Rec, F&W	Power	Other	TOTAL
Carter	8,027	4,855	6,581	---	12,253	---	---	31,716
Garvin	4,993	182	9,026	10	1,452	---	---	15,663
Grady	1,951	180	18,458	100	1,301	---	---	21,990
Jefferson	44,582	112	3,597	112	180	---	---	48,583
Love	---	17	2,280	667	---	---	---	2,964
Marshall	6,175	---	4,244	2	100	---	111	10,632
Murray	27,135	1,953	1,444	10	2,116	---	---	32,658
Stephens	6,717	335	2,270	---	5,268	---	---	14,590
TOTAL	**99,580**	**7,634**	**47,900**	**901**	**22,670**	**---**	**111**	**178,796**

GROUNDWATER ALLOCATIONS
(acre-feet)

COUNTY	Municipal	Industrial	Agricultural	Commercial	Rec, F&W	Power	Other	TOTAL
Carter	1,978	1,812	16,297	40	---	---	---	20,127
Garvin	4,931	12,779	12,944	---	33	---	5	30,692
Grady	4,995	1,546	30,019	275	141	---	5	36,981
Jefferson	2,973	280	3,668	---	---	---	10	6,931
Love	3,338	555	21,082	100	510	---	---	25,584
Marshall	5,670	180	3,060	---	100	---	---	9,010
Murray	18,421	1,681	7,320	---	---	4,200	---	31,622
Stephens	2,207	403	2,771	93	20	---	---	5,494
TOTAL	**44,512**	**19,236**	**97,160**	**508**	**804**	**4,200**	**20**	**166,440**

Note: Agricultural allocations include Irrigation. Mining included in Industrial.
Source of data: Oklahoma Water Resource Board printout, June 23, 1994.

The Oscar Formation is an interbedded shale, sandstone and limestone conglomerate aquifer which is 300 to 400 feet thick. The formation is found in western Stephens, southwestern Garvin and Carter, and eastern Jefferson County. Wells range from 60 to 400 gpm. The water quality is suitable for most uses.

The Rush Springs Sandstone is a fine-grained sandstone aquifer with some shale, dolomite and gypsum. Within the region, the aquifer is found in portions of Grady and Stephens Counties. Thickness of the formation ranges from 200 feet in the southern end to 300 feet in the north. Wells are usually 200 to 400 feet deep and yield between 200 and 600 gpm. The water tends to be of a calcium bicarbonate type and very hard and TDS levels are generally less than 500 mg/L. The water is suitable for most uses

The Antlers Sandstone is a friable sandstone, silt, clay and shale formation with an average thickness of 450 feet. The formation is found in Love, Marshall and southern Carter Counties. Wells range between 200 and 800 feet deep with yields between 100 and 500 gpm. The water is of a sodium or calcium bicarbonate type with dissolved solids generally less than 1,000 mg/L, although they can exceed 3,000 mg/L in some areas. The aquifer is largely undeveloped with an estimated 32 million ac-ft in storage.

The major alluvial and terrace deposit aquifers are found around the two major rivers in the region, the Red and Washita. Wells in these formations yield from 200 to 500 gpm while formation deposits average 70 feet in thickness. The formations consist of silt and clays downgrading into fine to coarse sand. The water is hard to very hard and generally of a calcium magnesium bicarbonate type. TDS values are usually less than 1,000 mg/L in the Washita River Basin and less than 2,000 mg/L in the Red River Basin. Water levels have generally declined in recent years.

GROUNDWATER DEVELOPMENT

Development of groundwater supplies continues within the South Central Planning Region, despite generally low yields and poor water quality. Some communities have developed the Oscar Formation as their principal supply. Most irrigation in the region utilizes groundwater sources.

GROUNDWATER RIGHTS

As of June 1994, the OWRB had issued groundwater allocation permits totaling 166,440 ac-ft per year from aquifers in the South Central Planning Region (Table 28).

SUPPLY AND DEMAND ANALYSIS

The South Central Planning Region is the dividing line between the portion of Oklahoma containing ample water supply and the portion with insufficient supply. The western portion of the region may have local shortages without the development of future sources. Water quality is also a problem in the west. Table 29 reflects available surplus water within the region; Table 30 indicates the availability of water from existing sources. The long-range projection for M&I water demand in the year 2050 is 74,600 af/yr (66.6 mgd).

Table 29
SURPLUS WATER AVAILABILITY
South Central Planning Region
(1,000 ACRE-FEET/YEAR)

SOURCE	TOTAL YIELD	LOCAL ALLOCATION	OUT OF REGION ALLOCATION	POTENTIAL SURPLUS
Texoma	168.0	4.5	---	163.5
SCS & Municipal Lakes	94.2	94.2	---	---
Groundwater	166.4	166.4	---	---
TOTAL	**428.6**	**265.1**	**---**	**163.5**
Other Potential Sources				
Atlee	5.5	---	---	5.5
Burneyville	25.0	---	---	25.0
Caddo	40.0	---	---	40.0
Courtney	45.1	---	---	45.1
Davis	2.8	---	---	2.8
Gainsville	8.8	---	---	8.8
Hennepin	30.0	---	---	30.0
Purdy	20.0	---	---	20.0
TOTAL	**177.2**	**---**	**---**	**177.2**
TOTAL SURPLUS WATER AVAILABILITY	**605.8**	**265.1**	**---**	**340.7**

Table 30
SUPPLY AND DEMAND ANALYSIS
South Central Planning Region

(1,000 ACRE-FEET/YEAR)

SOURCE	Carter	Garvin	Grady	Jefferson	Love	Marshall	Murray	Stephens	TOTAL
				COUNTY					
			MUNICIPAL AND INDUSTRIAL COMPONENT						
Arbuckle	15.9	4.3	---	---	---	---	3.8	---	24.0
Ardmore	0.6	---	---	---	---	---	---	---	0.6
Clear Creek/Duncan/Fuqua	---	---	---	---	---	---	---	2.7	2.7
Fort Cobb [1]	---	---	8.3	---	---	---	---	---	8.3
Humphreys	---	---	---	---	---	---	---	2.4	2.4
Jean Neustadt (SCS-13)	2.2	---	---	---	---	---	---	---	2.2
Longmire, RC (SCS-17M)	---	3.4	---	---	---	---	---	---	3.4
Mountain	2.8	---	---	---	---	---	---	---	2.8
Pauls Valley	---	4.0	---	---	---	---	---	---	4.0
Rock Creek (SCS-18)	1.2	---	---	---	---	---	---	---	1.2
Waurika	---	---	---	9.2	---	---	---	9.2	18.4
SCS & Municipal Lakes	1.3	---	1.1	---	---	5.6	---	1.7	9.7
Groundwater	3.8	17.7	7.0	3.3	4.5	5.9	20.1	2.7	65.0
M & I Supply	**27.8**	**29.4**	**16.3**	**12.5**	**4.5**	**11.5**	**23.9**	**18.7**	**144.6**
2050 M & I Demand	**25.5**	**11.8**	**13.1**	**2.1**	**1.8**	**3.4**	**5.7**	**11.2**	**74.6**
M & I Surplus/(Deficit)	**2.3**	**17.6**	**3.2**	**10.4**	**2.7**	**8.1**	**18.2**	**7.5**	**70.0**
			AGRICULTURAL COMPONENT						
Texoma	1.0	---	---	---	---	3.5	---	---	4.5
SCS & Municipal Lakes	9.9	21.8	24.0	2.1	2.7	0.7	8.4	15.0	84.5
Groundwater	16.3	12.9	30.0	3.7	21.1	3.1	7.3	2.8	97.2
Agricultural Supply	**27.2**	**34.7**	**54.0**	**5.7**	**23.8**	**7.3**	**15.7**	**17.7**	**186.2**
2050 Agricultural Demand	**5.7**	**13.7**	**19.2**	**4.7**	**4.9**	**6.8**	**2.6**	**3.7**	**61.3**
Agricultural Surplus/(Deficit)	**21.5**	**21.0**	**34.8**	**1.0**	**18.9**	**0.5**	**13.1**	**14.0**	**124.9**
			POWER COMPONENT						
SCS & Municipal Lakes	---	---	---	---	---	---	---	---	---
Groundwater	---	---	---	---	---	---	4.2	---	4.2
Power Supply	**---**	**---**	**---**	**---**	**---**	**---**	**4.2**	**---**	**4.2**
2050 Power Demand	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**---**
Power Surplus/(Deficit)	**---**	**---**	**---**	**---**	**---**	**---**	**4.2**	**---**	**4.2**
			TOTALS						
Total Local Supply	**55.0**	**64.1**	**70.4**	**18.2**	**28.3**	**18.8**	**43.8**	**36.4**	**335.0**
Total 2050 Demand	**31.2**	**25.5**	**32.3**	**6.8**	**6.7**	**10.2**	**8.3**	**14.9**	**135.9**
Net Surplus/(Deficit)	**23.8**	**38.6**	**38.1**	**11.4**	**21.6**	**8.6**	**35.5**	**21.5**	**199.1**

[1] Allocated from Southwest Planning Region.

Southeast Planning Region

REGIONAL DESCRIPTION

Atoka, Bryan, Choctaw, Coal, Johnston, McCurtain, Pontotoc and Pushmataha are the eight counties that comprise the Southeast Planning Region (Figure 29). The region's terrain varies from the rugged Kiamichi Mountains to the rolling, alluvial plains of the Red River. Stream and surface water sources are abundant in the region which is noted for its vast timber resources.

The Southeast Region is projected to have the second lowest overall water demand of any planning region in the year 2050. McCurtain County, with its large timber and related industry, is a county-specific exception. Ada, Durant, Hugo and Idabel are the largest cities in the region.

The region's climate is mild with annual mean temperatures varying from 62 to 64 degrees. Rainfall is abundant, ranging from 40 inches per year in the west to more than 56 inches in northern McCurtain County. Annual evaporation ranges from 56 inches in western areas to 48 inches in the east.

WATER RESOURCES

Stream Water

The region's major streams include the Red River, Little River, Kiamichi River, Blue River, Clear Boggy Creek, Muddy Boggy Creek and the Washita River. With the exception of the Red River below Lake Texoma, the region's streams contain good quality water which is generally suitable for all uses.

The Red River is the largest and longest stream within the Southeast Planning Region. The water contains high levels of dissolved solids and chlorides through much of Bryan and Choctaw Counties. Downstream of its confluence with the Blue River, Boggy Creek(s) and Kiamichi River, the river is of acceptable quality for most uses.

The Blue River flows southeasterly through Pontotoc, Johnston and Bryan Counties to its confluence with the Red River. The river's drainage basin is approximately 80 miles long and contains 676 square miles. There are no impoundments on the Blue River and its water is classified as hard with moderate levels of inorganic turbidity.

The Boggy Creek Basin consists of Clear Boggy Creek and Muddy Boggy Creek. The drainage basin contains 2,400 square miles in Pontotoc, Coal, Atoka, Bryan and Choctaw Counties. Atoka Lake and McGee Creek Lake are the major impoundments in the river basin. The water in upper Muddy Boggy Creek is generally hard with high chloride and moderate sulfate concentrations. Downstream of Atoka, the water becomes moderately hard with lower sulfate and chloride levels. High turbidity and nutrient levels exist along the entire branch. Water in Clear Boggy Creek is relatively hard with moderate turbidity and moderate levels of chlorides and sulfates.

The Kiamichi River flows southeasterly through Pushmataha and Choctaw Counties. The drainage basin encompasses 1,830 square miles, including Sardis Reservoir and Hugo Lake. Water in the Kiamichi River is of high quality with little mineralization. The water is moderately turbid and classified as soft.

The Little River flows southeasterly through Pushmataha and McCurtain Counties before entering Arkansas. The Mountain Fork and Glover Rivers join the Little River in McCurtain County. Pine Creek Lake and Broken Bow Lake are located on the Little River and its tributaries. Turbidity levels and nutrient levels are moderate. The water quality is generally good and suited for all uses.

MAJOR RESERVOIRS

There are six major impoundments within the Southeast Planning Region (Table 31). Atoka Lake, located on North Boggy Creek in Atoka County, is a water supply lake owned by the City of Oklahoma City. Built in 1964, the reservoir provides 125,000 ac-ft of conservation storage yielding 65,000 af/yr (58 mgd) of good quality water. The water is transferred via pipeline to Lake Stanley Draper in the Central Region for use by Oklahoma City. The pipeline has a capacity of 90 mgd.

Broken Bow Lake is a Corps of Engineers impoundment on the Mountain Fork River in McCurtain County. The multipurpose reservoir, completed in 1970, provides water supply, flood control, recreation, hydropower, water quality, and fish and wildlife mitigation benefits. The reservoir has 450,160 ac-ft of flood control storage and 152,500 ac-ft yielding 196,000 af/yr (175 mgd) for water supply and water quality needs. Broken Bow Lake includes a re-regulation dam approximately nine miles downstream which satisfies low-flow requirements of the U.S. Fish and Wildlife Service and evens out fluctuations caused by power releases. Power facilities at Broken Bow Lake include two 50,000 kW generators which are fed from 317,320 ac-ft of power storage.

Hugo Lake, the largest lake in the Southeast Planning Region, is located on the Kiamichi River in Choctaw County. This Corps project provides flood control, water supply, water quality, recreation, and fish and wildlife mitigation. Hugo was completed in 1974 and contains 808,300 ac-ft of flood control storage that was completely filled during the floods of 1990. The lake also contains 121,500 ac-ft of conservation storage which yields 64,960 af/yr (58 mgd) of water supply and 100,800 af/yr (90 mgd) for water quality control purposes.

McGee Creek Reservoir is a Bureau of Reclamation project on McGee Creek, a tributary of Muddy Boggy Creek, in Atoka County. Completed in 1987, the project's purposes include water supply, water quality control, flood control, recreation, and fish and wildlife mitigation. The reservoir, which has a drainage area of 171 square miles, reserves 85,340 ac-ft of flood control storage and conservation storage of 107,980 ac-ft which yields 71,800 af/yr (64 mgd) of water supply. Oklahoma City, in the Central Planning Region, has the allocation rights to 40,000 af/yr (35.7 mgd) of the yield. The City of Atoka, Atoka County and the Southern Oklahoma Development Trust have allocations totaling 20,000 af/yr (17.9 mgd).

Pine Creek Lake, located on the Little River in McCurtain County, was completed by the Corps of Engineers in 1969 and provides flood control, water supply, water quality, recreation, and fish and wildlife mitigation. The lake currently has 412, 030 ac-ft of flood control storage and 46,610 ac-ft of conservation storage. When water supply demands require, the conservation pool is raised to 70,560 ac-ft (49,400 ac-ft of water supply; 21,160 ac-ft for water quality purposes), resulting in a yield of 94,080 af/yr (84 mgd) for water supply and 40,330 af/yr (36 mgd) for water quality control. Weyerhauser is the only significant user of the water, which is of excellent quality.

Sardis Lake is a relatively new lake in Oklahoma. Formerly known as Clayton Lake, the impoundment was completed by

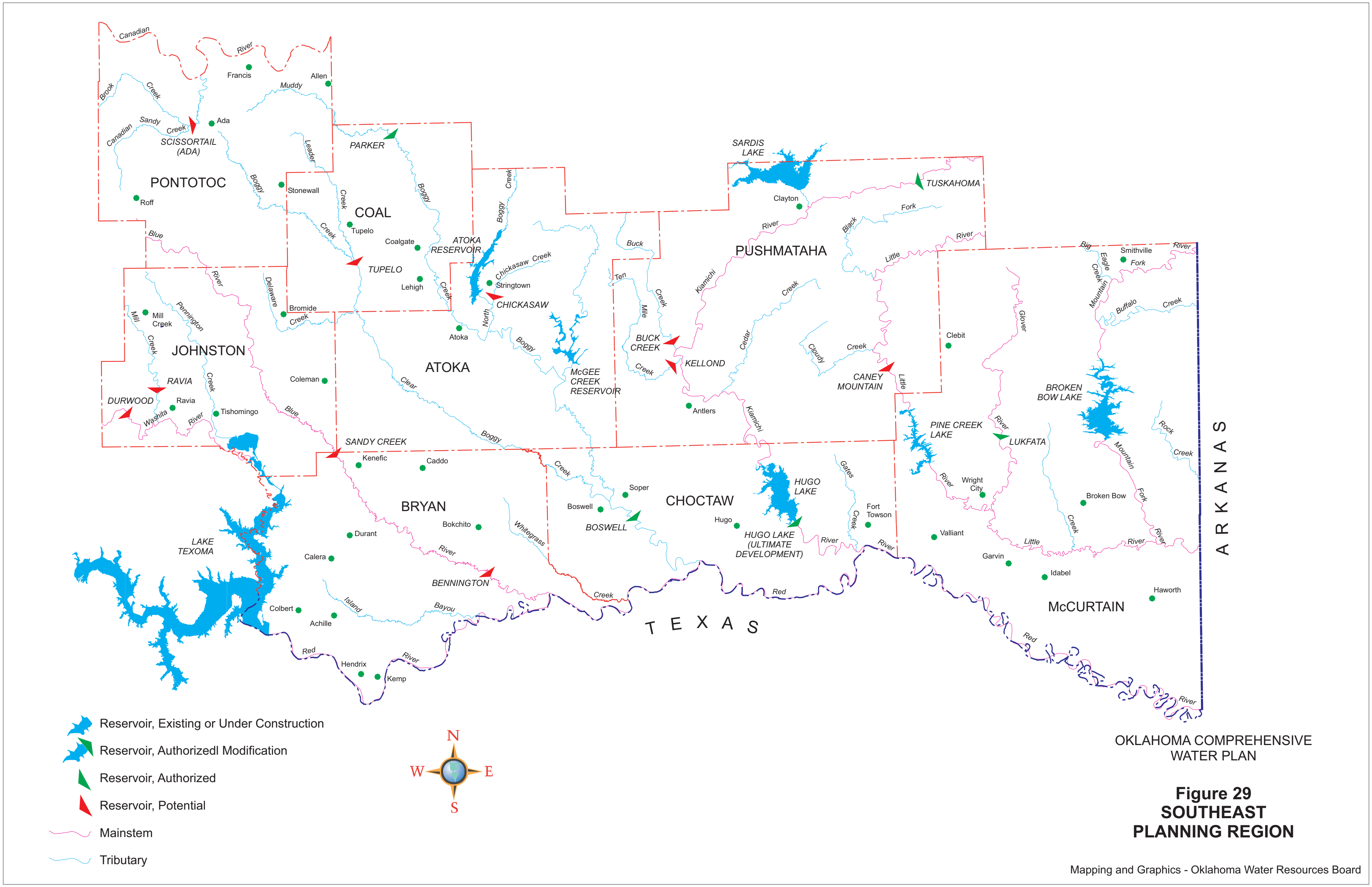


Figure 29
SOUTHEAST PLANNING REGION

the Corps in 1983 on Jackfork Creek, a tributary of the Kiamichi River, in Pushmataha County. Authorized uses include flood control, water supply, recreation, and fish and wildlife mitigation. The lake contains 121,670 ac-ft of flood control storage, 270,270 ac-ft of conservation storage, and yields 156,800 af/yr (140 mgd) of good quality water.

MUNICIPAL LAKES

There is only one municipal water supply lake in the Southeast Planning Region. Coalgate City Lake (SCS-#2), located on Coon Creek in Coal County, is used by the City of Coalgate for water supply, flood control and recreation. The lake was built in 1965 and contains 3,437 ac-ft of conservation storage.

OTHER IMPOUNDMENTS

There are numerous other NRCS projects and private reservoirs in the Southeast Planning Region. These small lakes, which provide irrigation water and various recreational opportunities, include Clayton Lake (953 ac-ft of approximate conservation storage), Bluestem (840 ac-ft), Lake Nanih Waiya (1,064 ac-ft), Lake Ozzie Cobb (833 ac-ft), Lake Raymond Gary (1,681 ac-ft) and Lake Schooler (306 ac-ft).

AUTHORIZED DEVELOPMENT

There are four authorized water supply projects in the Southeast Planning Region. Boswell Lake is an authorized project on Boggy Creek in Choctaw County. The reservoir, as initially authorized, would contain 1,096,000 ac-ft of flood

Table 31
STREAM WATER DEVELOPMENT
Southeast Planning Region

PROJECT	STREAM	PURPOSE*	FLOOD CONTROL STORAGE (acre-feet)	WATER SUPPLY STORAGE (acre-feet)	WATER SUPPLY YIELD (ac/ft/year)
		EXISTING OR UNDER CONSTRUCTION			
Atoka	North Boggy Creek	ws, r	---	123,500	700 [1]
Broken Bow	Mountain Fork River	ws, fc, wq, p, r, fw	450,160	152,500	96,000 [2]
Hugo	Kiamichi River	ws, fc, wq, r, fw	808,300	121,500 [3]	165,760 [3]
McGee Creek	McGee Creek	ws, fc, wq, r, fw	85,340	107,980	31,800 [4]
Pine Creek	Little River	ws, fc, wq, r, fw	388,080	70,560 [5]	134,400 [5]
Sardis [6]	Jackfork Creek	ws, fc, r, fw	121,670	270,270 [6]	156,800
TOTAL			**1,853,550**	**846,310**	**685,460**
		AUTHORIZED			
Boswell [7]	Boggy Creek	ws, fc, r, fw	294,100	60,870	56,000
Lukfata	Glover Creek	ws, fc, r, fw	172,000	31,000 [8]	69,450
Parker	Muddy Boggy Creek	ws, fc, r	100,300	109,940	45,900
Tuskahoma	Kiamichi River	ws, fc, r, fw	138,600	231,000	224,000 [9]
TOTAL			**705,000**	**432,810**	**395,350**
		POTENTIAL			
Bennington (Durant)	Blue River	ws, fc, r	359,590	287,420	179,000
Buck Creek	Buck Creek	ws, fc, p, r	36,300	48,300	56,000
Caney Mountain	Little River	p	---	77,067	104,000
Chickasaw	Chickasaw Creek	ws, fc, p, r	158,940	36,320	17,900
Durwood	Washita River	ws, p	245,230	119,730	232,000
Hugo (Ultimate Development)	Kiamichi River	ws, fc, wq, r, fw	651,800	284,300	137,000 [10]
Kellond	Ten Mile Creek	ws, fc, r	43,300	133,000	56,000
Ravia	Mill Creek	ws, r, fw	51,600	100,800	25,300
Sandy Creek	Blue River	ws, p	88,080	16,920	10,800
Scissortail (Ada)	Sandy Creek	ws, r	---	88,200	32,000
Tupelo	Clear Boggy Creek	ws, fc, r, fw, i	177,300	280,000	93,000
TOTAL			**1,812,140**	**1,472,057**	**943,000**
TOTAL YIELD					**2,023,810**

*ws-municipal water supply, fc-flood control, wq-water quality, p-power, r-recreation, fw-fish and wildlife, i-irrigation.

[1] Total yield is 65,000 af/yr, of which 64,300 af/yr is allocated to City of Oklahoma City (Central Region) and 700 af/yr to Southeast Region. Water from McGee Creek is pumped to Atoka for transfer to Stanley Draper Lake via Atoka Pipeline (90 mgd capacity).
[2] Includes 57,000 ac-ft of water supply storage (72,800 af/yr yield) and 95,500 af/yr for water quality control (123,200 af/yr yield).
[3] Includes 47,600 ac-ft of water supply storage (64,960 af/yr yield) and 73,900 ac-ft for water quality control (100,800 af/yr yield).
[4] Total yield is 71,800 af/yr, of which 40,000 af/yr is allocated to City of Oklahoma City (Central Region).
[5] Includes 49,400 ac-ft of water supply storage (94,100 af/yr yield) and 21,160 ac-ft for water quality control (40,300 af/yr yield).
[6] Formerly known as Clayton Reservoir (1980 *Oklahoma Comprehensive Water Plan*). Total initial conservation storage of 274,210 ac-ft includes 4,900 ac-ft for sediment. Value listed reflects net of 100-year sediment.
[7] Largest possible impoundment which can be constructed due to presence of McGee Creek Dam upstream.
[8] Does not include 4,000 ac-ft for other conservation storage and sediment reserve.
[9] 1989 Interagency Technical Report recommends inclusion of power as an authorized use, reducing size of impoundment to 49,100 ac-ft of conservation storage, no flood control, and water supply yield of 63,850 af/yr.
[10] Assumes reallocation of some flood control storage after construction of Sardis and Tuskahoma projects.

control storage and 1,243,800 ac-ft of water supply storage yielding 621,700 af/yr (555 mgd). However, subsequent re-evaluation has determined that the project would inundate the downstream toe of McGee Creek Dam. As such, the largest project that could now be constructed would provide 294,100 ac-ft of flood control storage and 60,870 ac-ft of conservation storage yielding 56,000 af/yr (50 mgd) of water supply. The project is not currently economically viable, based solely on flood control benefits. Should a local sponsor emerge for the water supply storage, the project could be reactivated.

Lukfata Lake is an authorized impoundment on Glover Creek in McCurtain County. Authorized uses include flood control and water supply. The project would have 172,000 ac-ft of flood control storage and 31,000 ac-ft of conservation storage yielding 69,450 af/yr (62 mgd) of excellent quality water supply. Lukfata Lake is the only impoundment in the seven-lake system authorized for the Little River Basin that has not yet been constructed. In 1977, Congressional funding for the project was halted due to the potential adverse effect on the area's Leopard Darter habitat. The Leopard Darter is a small fish on the threatened species list.

Parker Lake is a proposed impoundment, authorized by the Water Resources Development Act of 1986, on Muddy Boggy Creek in Coal County. The lake is authorized for flood control, water supply, recreation, and fish and wildlife mitigation uses. It is estimated to have a drainage area of 164 square miles and would provide 110,300 ac-ft of flood control storage and 109,940 ac-ft of conservation storage yielding 45,900 af/yr (41 mgd) of good quality water. Pre-construction engineering and design have been completed for the project, but construction is on hold until a local sponsor for the water supply storage is secured.

Tuskahoma Lake is the fourth authorized project in the Southeast Planning Region. The project, in deferred status since 1981, is proposed for construction on the Kiamichi River in Pushmataha and LeFlore Counties for the purposes of flood control, water supply, recreation, and fish and wildlife conservation. The reservoir would provide flood control storage of 138,600 ac-ft and conservation storage of 231,000 ac-ft. The estimated yield is 224,000 af/yr (200 mgd). The project was re-evaluated by the Corps of Engineers in 1989 with hydropower as a proposed use. The recommended configuration would have no flood control storage and only 49,100 ac-ft of conservation storage yielding 63,850 af/yr (57 mgd) of water supply. While hydropower benefits indicate that the project may be economically justified, hydropower is not an authorized use and the project does not meet federal criteria for participation.

POTENTIAL DEVELOPMENT

There are numerous potential sites in the Southeast Planning Region for the development of new water supply projects. The abundance of rainfall in the region aids in this potential development. Of the 10 sites identified in Table 31, local interest remains high for several projects.

Ravia Reservoir is a potential impoundment on Mill Creek in Johnston County. The reservoir would provide 51,600 ac-ft of flood control storage, 100,800 ac-ft of conservation storage, and a firm yield of 25,300 af/yr (22.6 mgd).

Scissortail Reservoir is a potential project on Canadian Sandy Creek, a Canadian River tributary, in Pontotoc County. Formally known as the Ada Reservoir project, the lake would provide municipal water supply, recreation, and fish and wildlife enhancement. The site is anticipated to provide 88,200 ac-ft of conser-

Table 32
WATER RIGHTS
Southeast Planning Region

STREAM WATER ALLOCATIONS
(acre-feet)

COUNTY	Municipal	Industrial	Agricultural	Commercial	Rec, F&W	Power	Other	TOTAL
Atoka	140,309	12,000	3,267	---	139	285	---	156,000
Bryan	13,435	644	11,964	5	6,626	---	---	32,674
Choctaw	30,500	---	6,349	---	290	32,000	---	69,139
Coal	3,266	---	5,474	---	64	---	---	8,804
Johnston	1,290	445	8,177	25	2,325	---	---	12,262
McCurtain	21,432	37,256	17,406	---	295	---	---	76,389
Pontotoc	8,700	252	3,073	23	24	---	---	12,072
Pushmataha	13,908	---	2,190	---	258	---	---	16,356
TOTAL	**232,840**	**50,597**	**57,900**	**53**	**10,021**	**32,285**	**---**	**383,696**

GROUNDWATER ALLOCATIONS
(acre-feet)

COUNTY	Municipal	Industrial	Agricultural	Commercial	Rec, F&W	Power	Other	TOTAL
Atoka	698	---	380	---	20	---	---	1,098
Bryan	4,395	248	6,826	---	10	---	---	11,479
Choctaw	3,566	2,754	1,765	---	60	---	---	8,145
Coal	837	---	30	---	---	---	---	867
Johnston	4,141	1,404	3,506	4	240	2	---	9,297
McCurtain	392	60	230	---	2	---	---	684
Pontotoc	52,781	6,991	13,581	794	30	2,600	---	76,777
Pushmataha	80	2	252	---	6	---	---	340
TOTAL	**66,890**	**11,459**	**26,570**	**799**	**368**	**2,602**	**---**	**108,688**

Note: Agricultural allocations include Irrigation. Mining included in Industrial.
Source of data: Oklahoma Water Resource Board printout, June 23, 1994.

vation storage and an average annual yield of 32,000 af/yr (28.6 mgd). The project has been extensively evaluated by the Bureau of Reclamation as a possible water supply source for the City of Ada.

Durwood Reservoir is a proposed multipurpose site on the Washita River in Johnston County. Potential uses include water supply, flood control, hydropower, irrigation and recreation. The reservoir is anticipated to provide 245,230 ac-ft of flood control storage and 119,730 ac-ft of conservation storage yielding 232,000 af/yr (207.1 mgd).

Of the remaining projects, Buck Creek, Caney Mountain, Chickasaw, Kellond and Tupelo did not pass Bureau of Reclamation screening criteria for potential hydropower, flood control, recreation and/or water supply projects during their last review. Bennington (Durant) Reservoir and Sandy Creek Reservoir were recommended as long-term potential projects since they did not meet the Bureau's selection criteria as viable projects for short-range development. Should certain economic conditions change in the future, their potential for development as long-range projects may prove feasible.

STREAM WATER RIGHTS

As of June 1994, the OWRB had issued stream water permits totaling 383,696 ac-ft per year from lakes, rivers and streams in the Southeast Planning Region (Table 32).

Groundwater

Southeast Oklahoma has two major groundwater aquifers, the Arbuckle-Simpson Group and Antlers Sandstone Formation.

The Arbuckle-Simpson Group is a limestone, dolomite and sandstone formation found in Pontotoc and Johnston Counties. Formation thicknesses vary between 5,000 and 9,000 feet. Well depths are commonly between 100 and 2,500 feet with yields between 100 and 500 gpm. The water is of a calcium magnesium bicarbonate type and very hard. Dissolved solids are generally within acceptable limits and the water is suitable for most uses. There is currently little development of this aquifer.

The Antlers Sandstone is a friable sandstone, silt, clay and shale formation with an average thickness of 450 feet. The formation is found in Bryan, Choctaw, McCurtain, Atoka and southern portions of Johnston and Pushmataha Counties. Well depths range between 200 and 800 feet with yields between 100 and 500 gpm. The water is generally of a sodium or calcium bicarbonate type with dis-

Table 33
SURPLUS WATER AVAILABILITY
Southeast Planning Region
(1,000 ACRE-FEET/YEAR)

SOURCE	TOTAL YIELD	LOCAL ALLOCATION	OUT OF REGION ALLOCATION	POTENTIAL SURPLUS
Atoka	65.0	0.7	64.3	---
Broken Bow	196.0	30.6	---	165.4
Hugo	165.8	63.3	---	102.5
McGee Creek	71.8	20.0	40.0	11.8
Pine Creek	134.4	33.6	---	100.8
Sardis	156.8	6.0	1.0	149.8
SCS & Municipal Lakes	75.4	75.4	---	---
Groundwater	109.4	109.4	---	---
TOTAL	**974.6**	**339.0**	**105.3**	**530.3**
Authorized Sources				
Boswell	56.0	0.1	---	55.9
Lukfata	69.5	---	---	69.5
Parker	45.9	---	---	45.9
Tuskahoma	224.0	5.0	---	219.0
TOTAL	**395.4**	**5.1**	**---**	**390.2**
Other Potential Sources				
Bennington (Durant)	179.0	---	---	179.0
Buck Creek	56.0	---	---	56.0
Caney Mountain	280.0	---	---	280.0
Chickasaw	17.9	---	---	17.9
Durwood	232.0	---	---	232.0
Kellond	56.0	---	---	56.0
Hugo (Ultimate Development)	137.0	---	---	137.0
Ravia	25.3	---	---	25.3
Sandy Creek	10.8	---	---	10.8
Scissortail (Ada)	32.0	---	---	32.0
Tupelo	100.8	---	---	100.8
TOTAL	**989.8**	**---**	**---**	**989.8**
TOTAL SURPLUS WATER AVAILABILITY	**2,222.8**	**344.2**	**105.3**	**2,047.3**

solved solids generally less than 1,000 mg/L, although they can exceed 3,000 mg/L in some areas. The aquifer is largely undeveloped with an estimated 32 million ac-ft in storage.

GROUNDWATER DEVELOPMENT

Extensive development of groundwater supplies has not occurred in the Southeast Planning Region due to the abundance of stream water.

GROUNDWATER RIGHTS

As of June 1994, the OWRB had issued groundwater allocation permits totaling 108,688 ac-ft per year from aquifers in the Southeast Planning Region (Table 32).

SUPPLY AND DEMAND ANALYSIS

The Southeast Planning Region is well-suited for anticipated future growth and existing reservoirs currently have surplus water available. Table 33 indicates the excess availability of water from existing sources. The long-range projection for M&I water demand in the year 2050 is 105,500 af/yr (94.2 mgd). An agricultural demand of 45,100 af/yr (40.3 mgd) is also projected along with a power demand of 15,800 af/yr (14.1 mgd). Table 34 summarizes the anticipated supply and demand for the region.

Table 34
SUPPLY AND DEMAND ANALYSIS
Southeast Planning Region
(1,000 ACRE-FEET/YEAR)

	COUNTY								
SOURCE	Atoka	Bryan	Choctaw	Coal	Johnston	McCurtain	Pontotoc	Pushmataha	TOTAL
MUNICIPAL AND INDUSTRIAL COMPONENT									
Atoka	0.7	0.0	---	---	---	---	---	---	0.7
Broken Bow	---	---	---	---	---	30.6	---	---	30.6
Hugo	---	---	30.5	---	---	---	---	0.8	31.3
McGee Creek	19.0	---	---	1.0	---	---	---	---	20.0
Pine Creek	---	---	---	---	---	33.6	---	---	33.6
Sardis	---	---	---	---	---	---	---	6.0	6.0
SCS & Municipal Lakes [1]	2.4	12.3	---	1.7	---	0.4	---	---	16.8
Groundwater	0.7	4.7	6.4	0.8	5.8	0.5	60.6	0.1	79.5
M & I Supply	**22.8**	**17.0**	**36.9**	**3.6**	**5.8**	**65.1**	**60.6**	**6.9**	**218.6**
2050 M & I Demand	**3.8**	**10.2**	**4.9**	**2.7**	**2.8**	**64.7**	**13.1**	**3.3**	**105.5**
M & I Surplus/(Deficit)	**19.0**	**6.8**	**32.0**	**0.9**	**3.0**	**0.4**	**47.5**	**3.6**	**113.1**
AGRICULTURAL COMPONENT									
SCS & Municipal Lakes	7.6	8.8	2.7	8.0	6.3	4.8	11.9	8.5	58.6
Groundwater	0.4	6.8	1.8	---	3.5	0.9	13.6	0.3	27.3
Agricultural Supply	**8.0**	**15.6**	**4.5**	**8.0**	**9.8**	**5.7**	**25.5**	**8.8**	**85.9**
2050 Agricultural Demand	**7.5**	**15.1**	**2.7**	**3.5**	**4.7**	**5.7**	**4.1**	**1.8**	**45.1**
Agricultural Surplus/(Deficit)	**0.5**	**0.5**	**1.8**	**4.5**	**5.1**	**---**	**21.4**	**7.0**	**40.8**
POWER COMPONENT									
Hugo	---	---	32.0	---	---	---	---	---	32.0
SCS & Municipal Lakes	---	---	---	---	---	---	---	---	---
Groundwater	---	---	---	---	---	---	2.6	---	2.6
Power Supply	**---**	**---**	**32.0**	**---**	**---**	**---**	**2.6**	**---**	**34.6**
2050 Power Demand	**0.3**	**---**	**15.2**	**---**	**---**	**---**	**0.3**	**---**	**15.8**
Power Surplus/(Deficit)	**(0.3)**	**---**	**16.8**	**---**	**---**	**---**	**2.3**	**---**	**18.8**
TOTALS									
Total Local Supply	**30.8**	**32.6**	**73.4**	**11.6**	**15.6**	**70.8**	**88.7**	**15.7**	**339.1**
Total 2050 Demand	**11.6**	**25.3**	**22.8**	**6.2**	**7.5**	**70.4**	**17.5**	**5.1**	**166.4**
Net Surplus/(Deficit)	**19.2**	**7.3**	**50.6**	**5.4**	**8.1**	**0.4**	**71.2**	**10.6**	**172.7**

[1] Bryan County values include surface water and storage off Blue River.

Southwest Planning Region

REGIONAL DESCRIPTION

Twelve counties, covering approximately 15.7 percent of the state, comprise the Southwest Planning Region (Figure 30). They are Beckham, Caddo, Comanche, Cotton, Custer, Greer, Harmon, Jackson, Kiowa, Roger Mills, Tillman and Washita Counties. The region lies at the center of the Southern Great Plains and normally experiences mild winters and long, hot summers. The region's terrain includes vast farming areas with rolling river bottoms and the rocky Wichita Mountains. Stream and surface water sources are relatively scarce in the region.

The Southwest Region is projected to have approximately 17 percent of the overall statewide water demand for the year 2050. The region is sparsely populated with the largest cities being Lawton, Altus, Anadarko and Hobart. The projected 2050 agricultural demand is estimated to be the second highest in the state, behind the Northwest Planning Region.

The region's climate is mild with annual mean temperatures varying from 59 to 64 degrees. Annual evaporation within the region ranges from 62 to 65 inches. Rainfall averages 22 inches per year in western areas to almost 32 inches per year in the east. These factors, along with the existence of numerous natural chloride deposits in southwest Oklahoma, lead to water quality problems in many of the region's stream systems.

WATER RESOURCES

Stream Water

The region's major streams include the Red and Washita Rivers and Cache Creek. Stream water is not a dependable supply source due to intermittent flow and generally poor water quality.

The Red River (including the Salt Fork and North Fork) is the major stream in the Southwest Region and forms its southern border. The water is highly mineralized with chlorides, sulfates and dissolved solids exceeding EPA limits most of the time.

The Washita River, which flows through the northern portion of the region, is also highly mineralized with dissolved solids usually exceeding 2,000 mg/L. Tributary streams of the Washita improve the overall stream quality in the lower reaches, making it suitable for irrigation.

Cache Creek, which flows through Caddo, Comanche and Cotton Counties, contains the best stream water quality in the region. However, intermittent flows limit the development of additional supplies. Flooding is also a significant problem in the Cache Creek area.

MAJOR RESERVOIRS

Table 35 summarizes the larger impoundments within the region, including five major reservoirs. Lugert-Altus Reservoir is a Bureau of Reclamation project on the North Fork of the Red River in Greer and Kiowa Counties. The reservoir was completed in 1946 for flood control, water supply and irrigation purposes. The impoundment provides 19,600 ac-ft of flood control storage and 132,830 ac-ft of conservation storage. The lake has a 20 percent dependable yield of 47,100 af/yr (42 mgd). The water, used primarily by the Lugert-Altus Irrigation District, is of fair quality and suitable for most uses.

Fort Cobb Lake is a Bureau of Reclamation project on Pond Creek, a tributary of the Washita River, in Caddo County. The lake was built in 1959 for flood control, water supply, fish and wildlife mitigation, and recreation. The lake contains 63,700 ac-ft of flood control storage and 78,340 ac-ft of water supply storage which yields 18,000 af/yr (16.1 mgd). All of the available yield is allocated to the Fort Cobb Master Conservancy District. The water is of fair quality with sulfates approaching acceptable limits.

Foss Reservoir is located on the Washita River, in Custer County. The lake was built by the Bureau in 1961 and provides 180,410 ac-ft of flood control storage and 165,480 ac-ft of water supply and irrigation storage. The dependable water supply yield of the lake is 18,000 af/yr (16.1 mgd), all of which is allocated to Foss Reservoir Master Conservancy District. The water in Foss Reservoir is highly mineralized and requires desalinization prior to municipal use, although it is suitable for irrigation uses without extensive treatment.

Tom Steed Reservoir is located on West Otter Creek, a tributary of the North Fork of the Red River, in Kiowa County. This Bureau of Reclamation project was completed in 1975 for water supply, flood control, recreation, and fish and wildlife mitigation. The reservoir has 20,310 ac-ft of flood control storage and 88,970 ac-ft of conservation storage. The dependable yield of 16,000 af/yr (14.3 mgd) is allocated to the Mountain Park Master Conservancy District. The water is of marginal quality with high levels of dissolved solids.

MUNICIPAL LAKES

There are three large municipal lakes in the Southwest Planning Region. Lake Ellsworth, on East Cache Creek in Comanche and Caddo Counties, is a water supply and recreation lake for the City of Lawton. The lake, which contains flood control storage of 116,710 ac-ft and conservation storage of 65,500 ac-ft, has a yield of 23,500 af/yr (21 mgd) due to the City of Lawton's ability to divert from other sources. The water is of excellent quality and suitable for all uses.

Lake Lawtonka is another City of Lawton impoundment on Medicine Creek in Comanche County. The lake, built in 1905 for water supply and recreation purposes, has flood control storage of 25,665 ac-ft and 56,574 ac-ft of conservation storage. Similar to Lake Ellsworth, Lawtonka has a yield of 23,500 af/yr (21 mgd) due to Lawton's ability to divert from other sources. Studies have shown that the reservoir needs only 32,000 ac-ft of conservation storage to develop its maximum yield, liberating an additional 24,574 ac-ft of flood control storage. The water is of excellent quality and suitable for all uses.

Lake Chickasha, built in 1958 for water supply and recreation, serves the City of Chickasha (South Central Planning Region). Located on Spring Creek in Caddo County, the lake has a surface area of 820 acres, conservation storage of 41,080 ac-ft, and a yield of 7,500 af/yr (6.7 mgd). Water quality problems severely restrict use of the lake for M&I purposes.

OTHER IMPOUNDMENTS

There are numerous NRCS projects, small municipal lakes and private reservoirs within the Southwest Planning Region that provide municipal supply, irrigation water and recreational opportunities. Clinton Lake (3,980 ac-ft of conservation storage), Hall Lake (560 ac-ft), Dead Indian Lake (SCS-#4; 977 ac-ft), Lake Elk City (SCS-#22 R; 2,583 ac-ft), Rocky Lake (2,500 ac-ft), Vanderwork Lake (990 ac-ft), Quanah Parker Lake (905 ac-ft) and Dave Boyer Lake (861 ac-ft) are some of the larger impoundments in this category.

AUTHORIZED DEVELOPMENT

The Red River Chloride Control Project's area in Harmon County is the only major authorized water project in the Southwest Planning Region.

POTENTIAL DEVELOPMENT

There are several potential sites in the Southwest Planning Region for the development of new water supply projects (Table 35). Several have been extensively studied.

Mangum Reservoir is proposed for the Salt Fork of the Red River in Greer County. The recommended alternative from a 1993 reservoir study by the Corps is for a small impoundment of 2,280 acres. The impoundment would have no flood control storage and provide 9,420 ac-ft of active conservation storage. The estimated yield for water supply is 3,056 af/yr (2.73 mgd). Water quality is anticipated to be fair to poor with elevated levels of sulfates and dissolved solids. However, local interest in the project remains high for recreation and irrigation benefits.

Cookietown Reservoir is a proposed impoundment on Deep Red Run Creek in Cotton and Tillman Counties. The reservoir would provide 37,500 ac-ft of flood control storage and 208,200 ac-ft of conservation storage. Its yield is estimated at 34,700 af/yr (31 mgd) and water quality would be fair.

STREAM WATER RIGHTS

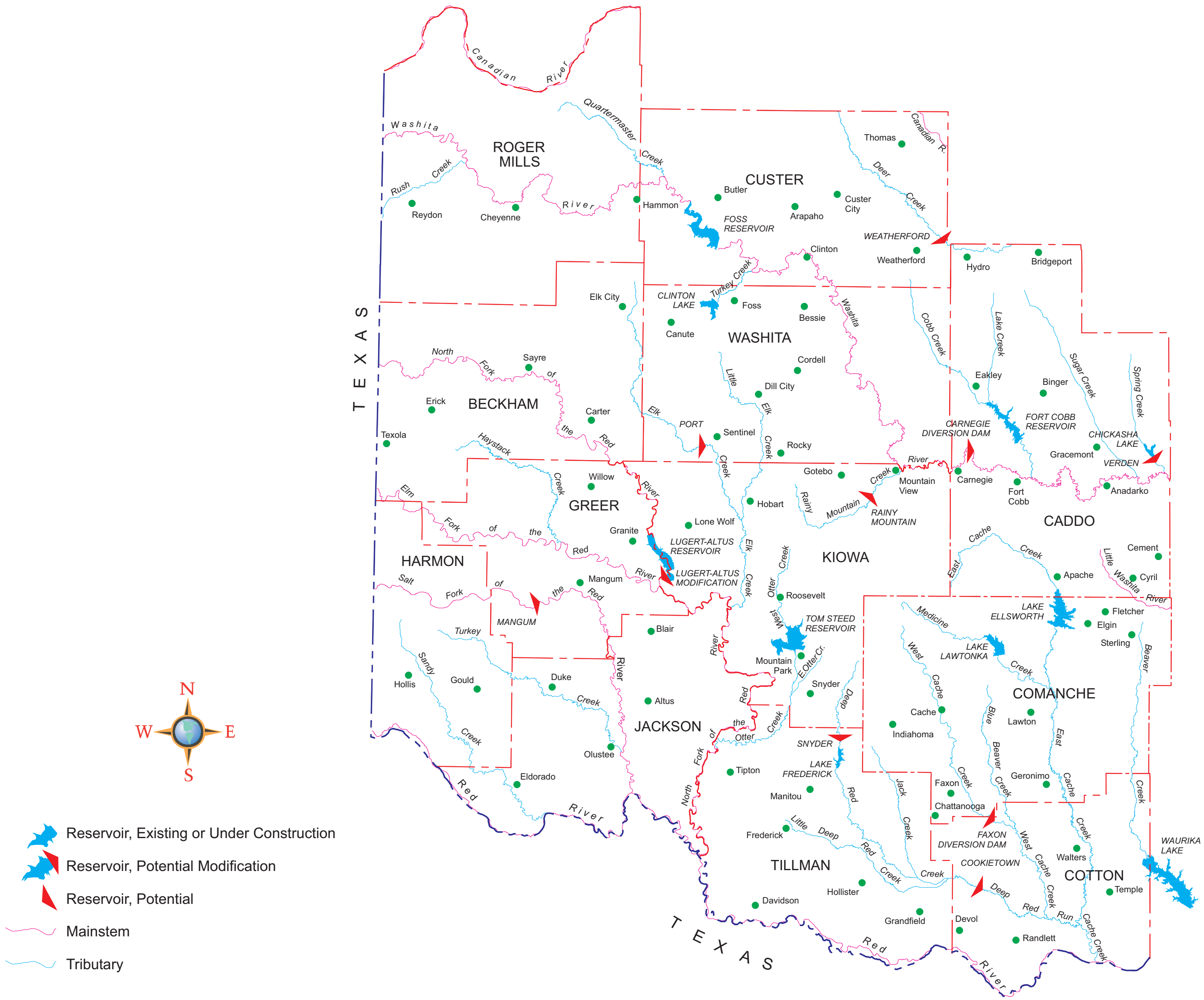
As of June 1994, the OWRB had issued stream water allocation permits totaling 319,598 ac-ft per year from lakes, rivers and streams within the Southwest Planning Region (Table 36).

Table 35
STREAM WATER DEVELOPMENT
Southwest Planning Region

PROJECT	STREAM	PURPOSE*	FLOOD CONTROL STORAGE (acre-feet)	WATER SUPPLY STORAGE (acre-feet)	WATER SUPPLY YIELD (ac-ft/year)
		EXISTING OR UNDER CONSTRUCTION			
Chickasha	Spring Creek	ws, r	---	41,080	---
Clinton	Turkey Creek	ws, r	---	3,980	1,700
Ellsworth	East Cache Creek	ws, r	116,710	65,500 [1]	23,500 [2]
Fort Cobb	Cobb Creek	ws, fc, r, fw	63,730	78,350	9,720 [3]
Foss	Washita River	ws, fc, r, fw, i	180,410 [4]	165,480 [5]	18,000
Lawtonka	Medicine Creek	ws, r	25,665	56,574 [6]	23,500 [2]
Lugert-Altus	North Fork of Red River	ws, fc, r, i	19,600	132,830	47,100 [7]
Tom Steed	West Otter Creek	ws, fc, r, fw	20,310	88,970	16,000
Waurika	Beaver Creek	ws, fc, wq, r, fw, i	---- [8]	---- [8]	27,190 [8]
TOTAL			**426,425**	**632,764**	**139,520**
		POTENTIAL			
Carnegie Diversion Dam	Washita River	w s	---	---	50,000
Cookietown	Deep Red Run	ws, fc, r, i	37,500	208,200	34,700
Faxon Diversion Dam	West Cache Creek	w s	---	---	10,700 [9]
Lugert-Altus Modification	North Fork of Red River	ws, fc, r, i	196,000	204,600	8,200 [10]
Mangum	Salt Fork of Red River	ws, fc, r	---	9,420	3,050
Port	Elk Creek	ws, fc, r	47,700	68,000	14,000
Rainy Mountain	Rainy Mountain Creek	ws, fc, r	66,500	60,000	6,000
Snyder	Deep Red Run	ws, fc, r	11,800	95,000	---
Verden	Spring Creek	ws, r	---	40,000	7,500
Weatherford	Deer Creek	ws, fc, r	55,000	62,000	11,200
TOTAL			**414,500**	**747,220**	**145,350**
TOTAL YIELD					**284,870**

*ws-municipal water supply, fc-flood control, wq-water quality, r-recreation, fw-fish and wildlife, i-irrigation.

[1] 72,500 ac-ft total, including 7,000 ac-ft for sediment reserve.
[2] Exceeds 98% safe yield due to City of Lawton's ability to divert from other sources.
[3] Total water supply yield is 18,000 af/yr, of which 8,280 is allocated to South Central Planning Region.
[4] Includes 3,500 ac-ft of sediment storage.
[5] Includes irrigation storage.
[6] Only 32,300 ac-ft of conservation storage required to develop maximum yield. As a result, an additional 24,274 ac-ft could be used for flood control storage.
[7] Top of irrigation and municipal water supply pool; yield is 20% of dependable yield since primary use is irrigation.
[8] Reservoir located in South Central Region. Total yield is 45,590 af/yr (including 5,040 af/yr of irrigation storage), of which approximately 27,190 af/yr is allocated to Southwest Region via Waurika Master Conservancy District.
[9] Additional yield from diversion to be developed in proposed Cookietown Reservoir.
[10] Additional yield from modification of Lugert-Altus Dam.



OKLAHOMA COMPREHENSIVE WATER PLAN

Figure 30
SOUTHWEST PLANNING REGION

Mapping and Graphics - Oklahoma Water Resources Board

Table 36
WATER RIGHTS
Southwest Planning Region

STREAM WATER ALLOCATIONS
(acre-feet)

COUNTY	Municipal	Industrial	Agricultural	Commercial	Rec, F&W	Power	Other	TOTAL
Beckham	---	100	1,110	---	1,402	---	---	2,612
Caddo	24,140	28	16,189	---	840	1,636	---	42,833
Comanche	40,881	6,548	5,153	18	2,225	---	---	54,825
Cotton	300	---	2,485	---	---	---	---	2,785
Custer	17,350	370	5,488	---	982	---	---	24,190
Greer	---	---	555	---	---	---	---	555
Harmon	---	---	208	---	167	---	2,000	2,375
Jackson	4,800	---	94,853	---	---	---	---	99,653
Kiowa	58,100	---	2,662	---	136	---	---	60,898
Roger Mills	434	95	2,678	---	2,483	---	---	5,690
Tillman	3,400	---	3,078	---	---	---	---	6,478
Washita	2,765	50	13,003	8	878	---	---	16,704
TOTAL	**152,170**	**7,191**	**147,462**	**26**	**9,113**	**1,636**	**2,000**	**319,598**

GROUNDWATER ALLOCATIONS
(acre-feet)

COUNTY	Municipal	Industrial	Agricultural	Commercial	Rec, F&W	Power	Other	TOTAL
Beckham	8,038	4,043	19,879	1,036	325	---	50	33,371
Caddo	6,445	3,220	169,280	153	278	3,697	---	183,073
Comanche	5,804	1,507	14,609	20	---	---	4	21,944
Cotton	4,268	---	4,877	---	---	---	---	9,145
Custer	6,802	11,610	94,636	209	223	---	136	113,616
Greer	1,623	20	19,922	13	---	---	---	21,577
Harmon	1,526	---	66,436	---	---	---	---	67,962
Jackson	670	849	36,171	10	10	---	---	37,710
Kiowa	1,861	178	14,526	194	50	---	---	16,809
Roger Mills	2,042	9,203	134,162	---	60	---	1	145,467
Tillman	3,254	20	42,367	---	---	---	---	45,641
Washita	6,333	5,464	57,152	880	130	---	---	69,959
TOTAL	**48,666**	**36,114**	**674,016**	**2,514**	**1,076**	**3,697**	**191**	**766,273**

Note: Agricultural allocations include Irrigation. Mining included in Industrial.
Source of data: Oklahoma Water Resource Board printout, June 23, 1994.

Groundwater

Southwest Oklahoma overlies seven principal groundwater aquifers -- the Arbuckle-Timbered Hills Group, Rush Springs Sandstone, Blaine Formation, Elk City Sandstone, Ogallala Formation and alluvium and terrace deposits of the Washita River and North Fork of the Red River. Groundwater is the principal supply for most irrigation needs, as well as the major source for many small communities in the region.

The Arbuckle-Timbered Hills Group is a confined, high-porosity limestone, dolomite and conglomerate formation found in portions of Comanche, Kiowa and Caddo Counties, The formation is approximately 6,000 feet thick and well depths are commonly between 100 and 2,800 feet. Well yields range between 25 and 500 gpm. The water is generally soft; however, fluoride concentrations exceed EPA limits and chloride concentrations approach those limits at most locations. The water is generally not suited for most uses.

The Rush Springs Sandstone is a fine-grained sandstone aquifer with some shale, dolomite and gypsum. Within this region, the aquifer outcrops in portions of Caddo, Custer and portions of Washita Counties. Thickness of the formation ranges from 200 feet in the southern end to 330 feet in the north. Well depths are usually 100 to 200 feet and yield between 200 and 600 gpm. The water tends to be of a calcium bicarbonate type and very hard. TDS levels are generally less than 500 mg/L and the water is suitable for most uses.

The Blaine-Dog Creek Shale Formation is found in Greer, Jackson and Harmon Counties. It is an interbedded gypsum, dolomite and siltstone formation usually between 300 and 400 feet thick. Well depths range from 100 to 200 feet with yields between 100 and 500 gpm, although they can exceed 2,500 gpm. The water is of a calcium sulfate chloride type with dissolved solids exceeding 2,000 mg/L. The water is not suitable for municipal or industrial purposes, although it can be used for irrigation on some tolerant crops. The aquifer is recharged by surface runoff into sinkholes and solution openings.

The Elk City Sandstone Formation is a fine-grained sandstone with little or no shale. The formation is thinner and less productive than the Rush Springs Sandstone with yields commonly between 60 and 200 gpm. The formation is found in Washita and Beckham Counties and its water is generally suitable for most uses.

The Ogallala Formation in the Southwest Region underlies portions of Roger Mills and Beckham Counties. The semi-consolidated aquifer consists primarily of fine sands and silt with lesser quantities of gravel and clay and minor beds of limestone and caliche. The saturated thickness of the formation ranges from a few feet to more than 500 feet. Well depths range from 100 to 500 feet with yields between 100 and 800 gpm. Locally, some portions of the formation have high fluoride and chloride concentrations. Overall, the water is of good quality and, although hard, is suitable for most uses.

The major alluvial and terrace deposit aquifers are found around the two major rivers in the region, the North Fork of the Red and Washita Rivers. Wells into those formations yield from 200 to 500 gpm and formation deposits average 70 feet in thickness. The formations consist of silt and clays, downgrading into fine to coarse sand. The water is hard to very hard and of a generally calcium magnesium bicarbonate type. TDS values are usually less than 1,000 mg/L in the Washita River Basin and less than 2,000 mg/L in the Red River Basin. Water levels have generally declined in recent years.

GROUNDWATER DEVELOPMENT

Extensive development of groundwater supplies has occurred in the Southwest Planning Region, with overdevelopment in some areas. This is due, in part, to low rainfall and poor aquifer recharge. Many communities rely on groundwater as their primary supply due to the limited availability of suitable surface water.

GROUNDWATER RIGHTS

As of June 1994, the OWRB had issued groundwater allocation permits totaling 766,273 ac-ft per year from aquifers in the Southwest Planning Region (Table 36).

SUPPLY AND DEMAND ANALYSIS

The Southwest Planning Region's extensive agricultural demand may pose serious water problems in some areas, including Jackson and Tillman Counties, which are projected to have substantial shortages. These problems could be compounded by the current overdevelopment of groundwater in those areas. Water quality is also a problem in the west. Existing reservoirs in the region are fully allocated with no surplus water available. Table 37 indicates the availability of water from existing sources. The long-range projection of M&I water demand in the year 2050 is 125,400 af/yr (111.5 mgd). The agricultural demand of 531,500 af/yr (473 mgd) is projected to be the second highest of any planning region.

Table 37
SUPPLY AND DEMAND ANALYSIS
Southwest Planning Region
(1,000 ACRE-FEET/YEAR)

SOURCE	Beckham	Caddo	Comanche	Cotton	Custer	Greer	Harmon	Jackson	Kiowa	Roger Mills	Tillman	Washita	TOTAL
							COUNTY						
MUNICIPAL AND INDUSTRIAL COMPONENT													
Clinton	—	—	—	—	—	—	—	—	—	—	—	1.7	1.7
Ellsworth	—	—	23.5	—	—	—	—	—	—	—	—	—	23.5
Fort Cobb	—	8.4	—	—	—	—	—	—	—	—	—	—	8.4
Foss	—	—	—	—	1.2	—	—	—	1.0	—	—	1.2	3.4
Lawtonka	—	—	23.5	—	—	—	—	—	—	—	—	—	23.5
Lugert-Altus	—	—	—	—	—	—	—	4.8	—	—	—	—	4.8
Tom Steed	—	—	—	—	—	—	—	13.0	1.0	—	2.0	—	16.0
Waurika	—	—	23.8	2.6	—	—	—	—	—	—	—	—	26.4
SCS & Municipal Lakes	1.3	22.9	9.9	—	—	—	—	1.3	—	0.1	4.8	4.4	44.6
Groundwater	13.5	10.1	7.3	4.3	19.0	1.7	1.5	1.5	2.3	11.3	3.3	12.8	88.6
M & I Supply	**14.8**	**41.4**	**88.0**	**6.9**	**20.2**	**1.7**	**1.5**	**20.6**	**4.3**	**11.4**	**10.0**	**20.1**	**240.9**
2050 M & I Demand	**6.7**	**9.4**	**61.6**	**3.4**	**8.7**	**2.7**	**1.7**	**20.5**	**2.5**	**1.8**	**2.9**	**3.5**	**125.4**
M & I Surplus/(Deficit)	**8.1**	**32.0**	**26.4**	**3.5**	**11.5**	**(1.0)**	**(0.2)**	**0.1**	**1.8**	**9.6**	**7.1**	**16.6**	**115.5**
AGRICULTURAL COMPONENT													
Foss	—	—	—	—	7.4	—	—	—	3.8	—	—	3.4	14.6
Lugert-Altus	—	—	—	—	—	—	—	42.3	—	—	—	—	42.3
SCS & Municipal Lakes	4.3	12.6	4.1	0.8	15.3	0.7	1.9	0.3	6.6	16.3	3.0	17.0	82.8
Groundwater	19.9	169.3	14.6	4.9	94.6	19.9	66.4	36.2	14.5	134.2	42.4	57.2	674.0
Agricultural Supply	**24.2**	**181.9**	**18.7**	**5.7**	**117.3**	**20.6**	**68.4**	**78.7**	**25.0**	**150.4**	**45.3**	**77.6**	**813.8**
2050 Agricultural Demand	**10.7**	**147.6**	**6.1**	**5.7**	**34.1**	**26.5**	**40.9**	**136.3**	**11.5**	**17.8**	**68.4**	**25.9**	**531.5**
Agricultural Surplus/(Deficit)	**13.5**	**34.3**	**12.6**	**—**	**83.2**	**(5.9)**	**27.5**	**(57.6)**	**13.5**	**132.6**	**(23.1)**	**51.7**	**282.3**
POWER COMPONENT													
Fort Cobb	—	1.3	—	—	—	—	—	—	—	—	—	—	1.3
SCS & Municipal Lakes	—	1.6	—	—	—	—	—	—	—	—	—	—	1.6
Treated Sewage Effluent	—	—	4.0	—	—	—	—	—	—	—	—	—	4.0
Groundwater	—	3.7	—	—	—	—	—	—	—	—	—	—	3.7
Power Supply	**—**	**6.6**	**4.0**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**10.6**
2050 Power Demand	**—**	**5.9**	**5.9**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**11.8**
Power Surplus/(Deficit)	**—**	**0.7**	**(1.9)**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**(1.2)**
TOTALS													
Total Local Supply	**39.0**	**229.9**	**110.7**	**12.5**	**137.5**	**22.3**	**69.9**	**99.3**	**29.3**	**161.8**	**55.4**	**97.7**	**1,065.2**
Total 2050 Demand	**17.4**	**162.9**	**73.6**	**9.1**	**42.8**	**29.2**	**42.6**	**156.8**	**14.0**	**19.6**	**71.3**	**29.4**	**668.7**
Total Surplus/(Deficit)	**21.6**	**67.0**	**37.1**	**3.4**	**94.7**	**(6.9)**	**27.3**	**(57.5)**	**15.3**	**142.2**	**(15.9)**	**68.3**	**396.5**

Water-Related Issues and Problems

Introduction

Presented here are state water issues identified by the Citizens' Advisory Committee and Technical Advisory Sub-Committee as a result of numerous meetings of both groups held from January 1994 through March 1995. The 20-member OCWP Citizens' Advisory Committee brought a grass-roots perspective to the formation of state water management and protection strategies while the Technical Advisory Sub-committee facilitated the involvement of 23 relevant state and federal agencies. The two groups also reviewed updated water use projections for Oklahoma.

This section highlights substantiating discussion of each water issue and/or problem. Prescriptive options developed by the committees to deal with these issues -- i.e., recommendations -- are presented in the following section.

WATER RIGHTS

Stream Water Rights & Administration

While problems related to state water rights management arise from time to time, the general abundance of supply (though unevenly distributed) and relatively strong legal foundation upon which Oklahoma water law is based preclude many potential conflicts surrounding administration of the current system. State laws relating to non-use and forfeiture of water rights generally serve their intended purpose -- i.e., to ensure that Oklahoma's water resources are used beneficially and for the good of the public.

The current system also benefits the state by encouraging small-scale water rights marketing agreements and local transfers which protect often costly investments made in putting state water to beneficial use. Without forfeiture proceedings or related measures to manage and control use, "stockpiling" of rights could result, leading to the inefficient use and development of water resources.

Still, stream water rights and administration could be improved through judicious revision of OWRB regulations. Because original Oklahoma water laws were not specifically designed to promote conservation of supplies, there is room to modify the existing system to maximize efficiency of use. The system could also be improved through more judicious enforcement, expansion of data collection and management programs (including hydrologic studies), and development of educational programs.

It has been argued that the prior appropriation system of water rights may encourage the uneconomic use of water and many question the need for statutes relating to water usage and forfeiture of rights, especially in significantly under-appropriated stream systems where these regulations may encourage permit holders to waste water and deliberately over-report use. Also, in stream systems where relatively little water is available for appropriation, criticism has been directed at lenient schedule of use provisions that allow water resources and rights to be tied up for 50 years or more. In addition, regular permits issued under the current permitting system appropriate stream water on a year-round basis. As a result, the system does not take into account seasonal climatic variations (i.e., regional rainfall totals) or varying seasonal uses of water (for example, increased irrigation during the summer months) which affect immediate water availability.

Few problems exist with current forfeiture and cancellation/reduction laws. However, it is likely that other measures or regulations could be implemented in conjunction with, or in place of, existing laws to better ensure the intelligent and optimum use of Oklahoma's water resources while still protecting prospective water users (for example, allowances for cases where no other user is demanding water on a particular stream). Future efforts to improve this situation will be directed at more accurate accounting of water supply and use and more realistic determinations of "beneficial use" and "present or future need" in permit application proceedings

Currently, the OWRB lacks administrative enforcement authority to prohibit violations of permitted water use and is required to petition district court to impose compliance measures. Such problems hinder enforcement efforts and give added credence to an alternative system that provides financial and other incentives in exchange for compliance.

Finally, as competition increases for water resources, reliable information on the amount of water available for appropriation will be critical to ensure that the optimum amount of water is used to benefit the state's economy. While hydrologic surveys have been completed on virtually all state stream systems, it is essential that these investigations are continually updated. In addition, Oklahoma's current system of water use reporting requires some modification to better facilitate the collection of accurate, dependable data on usage.

Instream Flow Protection

Inadequate instream flow adversely affects all beneficial uses, including aquatic life, recreational activities, aesthetics, hydropower generation and navigation. Low flows can be caused by climatic and hydrologic conditions, diversions or operation of reservoir storage for offstream project purposes. Water quality problems that can result from insufficient streamflows -- many of which could also be addressed through potential watershed management or non-consumptive use permitting initiatives -- include inadequate dilution of point and nonpoint pollution discharges and damaging changes in water temperature and dissolved oxygen levels.

Excessive flows can be equally damaging. High flows may result from natural causes, such as storm events, or man-induced causes, such as reservoir regulation, causing adverse impacts on aquatic life, recreational activities and other instream uses.

Instream flow is indirectly recognized in Oklahoma's laws governing stream water use. However, several provisions in laws relating to water and water rights could provide specific opportunities to assure protection of stream flows. In general, some streamflow is protected by the requirement in the law relating to appropriation permits that prohibits interference with domestic uses. When the Oklahoma Water Resources Board considers appropriation permit applications, it must determine that the proposed appropriation use will not interfere with domestic uses. Board rules provide that for every affected household downstream of the proposed diversion point, it is presumed that 10 acre-feet of water per year is necessary to protect the domestic use of each household, unless there is evidence showing otherwise. This total of domestic use water must be allowed to "flow by" the point of diversion, thereby providing incidental protection for instream uses. Secondly, OWRB rules state that low- flow averages (i.e., "flows available less than 35 percent of the time") will not constitute water available for appropriation.

A mechanism established by the Legislature to provide general protection of instream flows is the Scenic Rivers Act. Under the Act, and for designated "scenic river areas" listed therein, there is a prohibition against state agencies approving plans to construct, operate or maintain any dam without legislative consent. There is an exception for municipal or domestic use, but only when the structure would not interfere with preservation of the free-flowing stream. In addition, the OWRB has implemented low-flow restrictions on the Baron Fork River, one of six scenic rivers in the state.

Many states that follow the appropriation doctrine are facing similar instream flow questions. Some state legislatures have elected to adopt laws specifying flows for specific streams or segments of streams at which no further diversions may take place. Other states have adopted the approach of allowing instream flows for beneficial use for recreation and fish and wildlife protection; these states either allow any person to apply for an instream appropriation or have limited the kind of entity that can apply (such as the state fish and game agency), but only for certain streams. Also, water rights agencies in some states may declare that certain minimum flows are not water available for appropriation on a real-time basis (cubic feet per second) and require that appropriation rights be conditioned accordingly.

A very controversial method to protect instream flows involves the "public trust doctrine." That doctrine has been adopted to address the appropriation of water from a reservoir, declaring that all appropriations -- regardless of their priority dates -- are conditioned on water being available by the public trust to protect that which is owned by the public (i.e., fish and wildlife). Water banking and "donation" of existing water rights toward instream flow protection are additional alternatives.

The Franco case touched upon the use of water in the stream for aesthetics and minimum flows needed for recreation use and whether such uses might be considered reasonable. However, the extinguishment of riparian rights (except domestic use) by Senate Bill 54 in the 1993 legislative session appears to have eliminated the possibility to argue that a riparian rights claim could be used to protect instream flows.

The OWRB has not issued any water use permits expressly for protection of instream flows or instream flow maintenance. It can be argued that allowing water to flow downstream and, eventually, out of state does not promote the Legislature's policy of optimum beneficial use in the state and may not be a "beneficial use" as required under appropriation law. That legal point has never been tested in a court, although there have been several water rights issued for recreation, fish and wildlife uses, most of which are reservoir-related or involve a specific point of diversion.

Establishing minimum instream flows on a particular stream segment is a very difficult and controversial proposition involving numerous biological, hydrological, economical and legal factors. To conscientiously address the instream flow issue, the state must first decide if there is a need to provide waters with additional protection to that currently offered under state law and then, if necessary, develop a methodology for actually determining minimum instream flows. However, if the state resolves to pursue an instream flow protection strategy, it will be imperative to have accurate information on the amounts of water available for appropriation in each stream system. This goal will be contingent upon proper maintenance and expansion of data collection/management programs, especially OWRB hydrologic investigations.

Indian Water Rights

Indian water rights in Oklahoma concern both fundamental sovereignty and water quantity and quality. Indian claims to water rights could have a significant effect on existing state water law as well as the current system of water rights administration and water quality regulation in Oklahoma.

Winters v. U.S., often called the foundation upon which the issue of Indian water rights rests, and subsequent court cases (including U.S. v. Grand River Dam Authority) have generally determined that the federal government's establishment of Indian reservations implicitly reserved relevant water as well as land. In addition, Winters asserts that federal reserved rights cannot be lost by failure to put the associated water to beneficial use. This case law of Indian property rights, which extends to other federally reserved water rights, presents a challenge to any water resource project that involves disturbance of the beds and waters of state rivers, streams or groundwaters to which Native American claims might extend. In addition, the federal Clean Water Act recognizes Indian tribes on the same level as state government entities in development of water quality standards.

As a result, there is a need to resolve Indian and other reserved water rights claims, whether they involve court action or negotiated settlements. However, to date, involved parties have been reluctant to put the issue to a definitive test in state or federal court, primarily due to the potentially damaging financial, legal and political ramifications of litigation. Recent state laws dealing with state-tribal relations have encouraged mutual agreements. Similarly, to avoid potential legal conflicts, it will be essential for the state to work in cooperation with Oklahoma's Indian tribes to resolve related water rights issues. In order to resolve the Indian water rights issue in a non-confrontational manner, it is imperative for the state to first develop a level of trust with the Indian tribes. One of the most effective ways to foster this trust is for state water resource agencies to identify specific projects through which the state and Indian tribes can cooperate, then develop a responsible work plan to complete each project.

Groundwater/Stream Water Relationships

Because nearly all alluvial aquifers in the state discharge to or are recharged by a surface water body, conjunctive use of stream and groundwaters, at least on a case-by-case basis, has potential to augment and conserve state water supplies. Although current state water law does not recognize this hydrologic connection, the Oklahoma Water Resources Board has attempted to consider both stream and groundwater resources when appropriating water in areas where each could be affected.

The natural relationship between groundwater and stream water is extremely complex. The uppermost portion of the water table lies anywhere from a few feet to several hundred feet below land surface. During periods of high streamflow, significant aquifer recharge can occur. During other periods, the discharge of a shallow aquifer into the stream channel can provide a large portion of the water flowing in that stream.

In some areas or during certain periods of time, pumping groundwater from wells may reduce the amount of water flowing in a stream. When water is diverted from a stream for irrigation purposes, deep percolation losses could result in inadequate aquifer recharge. In addition, current Oklahoma groundwater law allows the withdrawal of water from an alluvial aquifer to exceed the recharge rate, possibly leading to the loss or depletion of base flow in an overlying stream.

Conjunctive use of stream and groundwaters could prove valuable in areas where both sources may be in short supply but together constitute sufficient supply to meet anticipated demands. However, while there are benefits to conjunctive stream and groundwater use, their joint management is complex. For example, water used for irrigation is in demand only part of the year while the majority of the streamflow passes downstream the remainder of the year. The maximum benefit would result if excess stream water flowing in the non-growing season could be stored for use when it is needed through artificial recharge or related storage projects.

In areas where stream or groundwater quality is relatively poor and substandard for economical treatment and potable use, it may be possible to blend to an acceptable level, prior to distribution, those poorer quality supplies with higher quality water from alternative sources. This would increase the overall availability of usable water and avoid the development of new and costly supply sources.

A number of different management plans have potential, depending on aquifer and stream characteristics, beneficial use, water need and other circumstances. Whatever management plan is implemented, the impact will affect the rights of all state water users, especially groundwater right holders who are afforded use privileges due to basic statutes related to private property rights. However, regulations that unduly infringe upon private property rights should be avoided to the greatest extent possible.

WATER QUALITY

Groundwater Protection

Although the quality of groundwater in Oklahoma is generally very good, some problems exist in individual groundwater basins. Abandoned, improperly plugged oil, gas and water wells; chemical waste and brine disposal wells; poorly designed sanitary landfills; and nitrates from rural and urban runoff are potential sources of pollution to state groundwaters. Due to these problems, and because increased population and economic pressures have produced greater demands for good quality groundwater, the need to protect groundwater resources is becoming a major state priority.

Successful efforts by the state to protect groundwater supplies include the Well Drillers and Pump Contractors Licensing Program, created to ensure the proper construction and plugging of water wells, and the state Wellhead Protection Program in which local communities voluntarily implement management and contingency plans to reduce or eliminate the risk of polluting local public water supplies. While the licensing program has been effective, studies indicate that inadequate well borings and casings are still allowing numerous contaminants to reach state aquifers. As a result, strengthening of the program may be necessary.

Oklahoma's groundwater basins are assigned to a three-tiered classification system based on their respective current or future economic and ecological value. Basins are designated as either Special Source (groundwaters considered very vulnerable to contamination; basins of exceptional water quality or ecological and environmental importance; or those necessary to maintain an outstanding resource), General Use (capable of being used as a drinking water supply with no treatment or with conventional treatment methods; those which have the potential for agricultural, industrial, recreational or other beneficial uses) or Limited Use (those of poor quality, probably requiring extensive treatment for use as drinking water supply).

The existing comprehensive classification system involving groundwater use, if coupled with an aquifer's specific vulnerability to contamination, could be an effective tool for optimizing groundwater protection efforts. This system would allow the development of a different protection strategy for each aquifer class. In addition, groundwater quality standards (discussed in detail under its respective heading), remediation, permitting requirements and enforcement activities could be designed specifically for each basin or groundwater class. The development of aquifer cleanup standards could further facilitate this protection effort.

Through its Comprehensive State Groundwater Protection Program guidance document, the U.S. Environmental Protection Agency encourages states to establish groundwater management efforts based on a local understanding of the relative use, value and vulnerability of the underlying groundwater and threat of contamination. The program itself consists of strategic activities that foster more efficient and effective protection of state groundwaters through improved operation of all relevant federal, state and local programs. The Oklahoma Department of Environmental Quality has fostered developed of these activities through the Comprehensive State Groundwater Protection. This effort -- designed to coordinate federal, state and local groundwater protection efforts -- is guided by the relative use, value and vulnerability of groundwater resources, including the relative threat of all actual or potential contamination sources.

The federal program is intended to empower states with the primary role in coordinating all federally funded groundwater programs. However, Oklahoma must ensure that sufficient flexibility is built into its program and the state should prioritize groundwater protection programs and activities to most efficiently utilize limited financial resources. And, although it has its liabilities, risk assessment could have promise in identifying safe, feasible and realistic groundwater protection measures. In addition, to properly address the state's unique groundwater resources and protection needs and recognize the significant climatological and hydrological differences between west and east, Oklahoma should seek to avoid broad-based regulations, especially those which unduly infringe upon individual groundwater property rights.

Information and technical support, rather than regulation, should be the primary emphasis in groundwater protection. Reliable background data, in particular, is essential to implementation of a successful and comprehensive state groundwater protection program. Revival of the state water well monitoring network, discontinued in 1992, or establishment of a comprehensive data collection program could be especially useful in obtaining water quality (as well as quantity) information on state aquifers. While regulatory measures can be effective, public education efforts and best management practices may be the most useful protection tools.

Groundwater Quality Standards

Serving several functions, groundwater quality standards are one of the most important mechanisms to protect groundwater resources. They specify a maximum concentration of a contaminant, describe an acceptable level of quality or define a specific groundwater use. Standards can also be used to establish limits on contaminants in effluent, evaluate ambient groundwater quality, establish a goal for remedial cleanup, trigger enforcement and help establish preventive programs to protect groundwater.

The Oklahoma Water Resources Board is authorized to promulgate standards of quality for waters of the state and to classify water bodies according to their best uses in the interest of the public under conditions the Board prescribes for the prevention, control and abatement of pollution. In accordance with provisions of the Clean Water Act and state statutes, Oklahoma has prepared and adopted water quality standards for stream waters of the state which are updated at least every three years. Formal adoption of groundwater quality standards occurred in 1982. However, unlike stream water quality standards, EPA does not approve or disapprove state groundwater standards.

The standards apply to all fresh groundwater (defined under state law as groundwater with a maximum total dissolved solids concentration of less than 5000 parts per million) in the state. They set forth that groundwater basins with an average yield of at least 50 gallons per minute are designated major groundwater basins. In general, the standards require that groundwater be maintained to prevent alteration of its chemical properties by harmful substances not naturally found in groundwater. This is accomplished by utilizing narrative criteria, 36 numeric standards for organic compounds, and a three-tired classification system based on the resource characteristics of each individual groundwater basin (as discussed under the Groundwater Protection issue). Future efforts to establish the vulnerability of these individual basins could improve this system.

The two principal uses of standards are reactionary and preventive management. If the standard is set at a level where contamination of an aquifer could occur, it becomes a reactionary mechanism that does little to protect groundwater quality, although it may prevent further degradation and initiate cleanup activities. If the standard is set at a more stringent level (an anticipated percentage of the enforcement level), then its breach signals the need for regulatory action to prevent contamination. In basic form, Oklahoma has reactionary groundwater standards. If a listed level is exceeded, it may be considered pollution and corrective action could be required. Numeric standards offer a specific definition of the expected level of protection and serve as an trigger mechanism for preventive or remedial actions. Also, enforcement tends to be more effective when citation to specific numeric limits can be made. However, because there are so many substances in commercial usage, it is impractical to set numeric standards for them all. In addition, it is extremely difficult to gather sufficient information on the health or environmental effects of a contaminant at a specific concentration level in groundwater. Risk assessment has been utilized, on a case-by-case basis, to measure associated threats to human health.

The goal of narrative standards is to establish reference points for judging whether groundwater quality is being protected. While narrative standards afford the state discretion in regulating a discharge, they sacrifice clear enforcement criteria when contamination is suspected. The matter before the state is whether or not existing narrative criteria are sufficient to protect groundwater quality. The current general wording of the standards is sufficient to encourage, though not ensure, groundwater protection.

DRASTIC, developed by the National Water Well Association for EPA, is a mapping system that evaluates the most important factors controlling groundwater pollution potential. These factors include depth-to-water, recharge, aquifer and soil media, topography, impact of the vadose zone media and conductivity. A modified version of the methodology could be used to delineate the varying vulnerabilities of each groundwater class. Based on evaluation of a groundwater basin, different DRASTIC indices could be divided into DRASTIC ranges -- i.e., slightly sensitive (SS), moderately sensitive (MS) and very sensitive (VS). The aquifer class, combined with the DRASTIC pollution vulnerability index, yields the complete classification of an aquifer.

Creation of an organizational framework to separately administer groundwater quality standards, apart from stream water, would not only facilitate stronger protection of state groundwater basins but simplify the rulemaking/revision process of each aspect of water quality standards. However, implementation of groundwater quality standards, as with stream water quality standards, will require reliable background data. Creation of a centralized ambient stream and groundwater quantity and quality monitoring program in Oklahoma would prove invaluable to the administration of both sets of standards. In addition, future standards revisions should consider the significant quality/quantity relationship between stream and groundwater resources.

Oklahoma Water Quality Standards contain a generic non-degradation policy statement defined to include both groundwater and stream water. Adoption of a specific groundwater protection policy statement would at least demonstrate to the public that the state is serious about protecting groundwater resources.

Nonpoint Source Pollution

The contribution of point versus nonpoint pollution sources varies by waterbody, although, in general, nonpoint sources account for the majority of pollutants present in the nation's waters. While federal and state programs have implemented significant controls upon the contribution of point source discharges, relatively little has been accomplished in similarly addressing nonpoint pollution. Throughout the country and especially in Oklahoma, which is sparsely inhabited in comparison to many other states, nonpoint source pollution is receiving significant attention by numerous agencies, special interest groups and the public.

Excessive nutrients and sediment are generally accepted to be one of the most prolific sources of nonpoint pollution, especially to surface waters in both rural and urban areas of Oklahoma. Nutrient pollution has been closely linked to municipal wastewater treatment facilities although it is now recognized that nonpoint sources are probably the most likely source of nutrients, especially in rural states. A recent study that examined the trophic status of small lakes in Oklahoma revealed that more than 50 percent could be classified as eutrophic, indicating a high level of nutrient loading. Given that these lakes are not subject to point source discharges, the nutrient loading is most likely tied to nonpoint sources. In addition, sediment pollution is almost entirely linked to nonpoint sources. In western Oklahoma, numerous streams suffer from the effects of excessive sedimentation.

Oklahoma's Nonpoint Source Assessment document provides an inventory of areas where impairment of beneficial uses has occurred due to nonpoint source pollution and identifies causative agents and their sources. The most frequently identified categories of nonpoint sources include agriculture, silviculture, urban areas, abandoned refineries, rural roads, mine lands, hydrostructure/tailwaters, in-place contaminants, industrial parks, septic systems and recreation.

Oklahoma has established an ambitious approach to nonpoint source management. The Office of the Secretary of Environment serves as the coordinating body for nonpoint source activities conducted under the CWA Section 319(h) Grant Program, which promotes voluntary approaches to nonpoint source pollution control. The Oklahoma Conservation Commission (OCC), which authored the Nonpoint Source Assessment document, serves as the lead technical agency for nonpoint source programs and cooperates with state and local agencies, as well as both major state universities, on individual projects. The OCC also developed the state's five-year plan for implementing Nonpoint Source Management Program projects.

The effectiveness of best management practices (BMPs) and other voluntary water quality improvement efforts has been demonstrated through the relative success of state nonpoint source mitigation projects. However, funding for BMP implementation is relatively meager compared to funds pledged for implementation of point source controls. Oklahoma has received less than three million dollars for nonpoint source controls while hundreds of millions have been allocated toward point source controls. The scarcity of both state and local funds precludes implementation of many nonpoint mitigation projects, which are funded by a 60/40 federal/state cost-share.

Despite the success of individual Section 319 projects, the overall scope of the state's nonpoint source control program is inadequate to address specific problem areas which are often impacted by numerous pollution sources. In addition, although EPA generally encourages the development of innovative practices (such as whole basin/total watershed planning, which must be included to receive priority funding for Section 319 nonpoint source projects), current policy restricts the funding of certain point source reduction practices that have demonstrated past success but involve problem areas which fall outside of Section 319 program eligibility requirements.

The implementation of total maximum daily loads (TMDL's) -- the sum of all point source wasteload allocations and nonpoint source load allocations -- into Oklahoma's water management strategy will provide improved monitoring of nonpoint source pollution. Although it is now recognized that nonpoint sources are an integral part of overall stream loading, the traditional TMDL process has included only point sources. TMDL's are currently being used as a tool to develop nonpoint source management options in Oklahoma's 303(d) priority watersheds. In addition, the Watershed Strategy Committee of the Watershed Nonpoint Source Working Group -- a coalition of numerous state and federal agencies, sub-state planning districts and universities who oversee and coordinate many state nonpoint source activities -- is now developing a TMDL process for use on 319(h) watershed projects.

Assessment of nonpoint source impacts, an integral part of the TMDL process, is very limited under current guidance. Expansion of Section 319 protocols to increase assessment would facilitate more effective prioritization of project areas for demonstration projects. In addition, as state Nonpoint Source Assessments become outdated, efforts should be made to update these documents.

While the voluntary approach to problem-solving is generally preferred -- as compared to regulatory controls -- it is unrealistic to expect this cooperative strategy to be successful, or desirable, in all cases. Individual cost-share burdens, reluctancy to cooperate, expensive controls or the extent of a particular problem may inhibit implementation of voluntary measures. However, in many cases, regulatory and enforcement measures provide the necessary incentive to encourage participation in voluntary programs.

Stream Water Quality Standards

According to Oklahoma law, "the Oklahoma Water Resources Board is authorized to promulgate standards of quality for state waters and classify the waters according to their best uses in the public interest under conditions prescribed for the prevention, control and abatement of pollution." In accordance with provisions of the Clean Water Act and state law, the State of Oklahoma has prepared and adopted water quality standards for intrastate waters. Under these statutes, the OWRB is also authorized to classify the state's waters with respect to their best present and future uses and set water quality standards.

Standards are designed to enhance the quality of Oklahoma's waters, protect their beneficial uses and aid in the prevention, control and abatement of water pollution in the state. Water quality standards have been established for all state waters through the assignment of beneficial uses and the development of criteria designed to protect these beneficial uses. Additionally, the standards assign additional protection to waters whose quality exceeds that necessary to protect beneficial uses and waters which are considered outstanding resources (through an Antidegradation Policy). State-adopted standards and implementation policies must satisfy public participation requirements (including public hearings). They also must be adopted by the Governor and State Legislature and reviewed and approved by the U.S. Environmental Protection Agency, at which point they become effective as federal law. State water quality standards may be revised at any time, but must be updated at least once every three years.

Significant advances have occurred in Oklahoma's Water Quality Standards since the original document was promulgated in 1968. The current document (revised in 1994) contains numerical aquatic life criteria; numerical criteria to protect human health for the consumption of water, fish flesh, and fish flesh and water; dissolved oxygen criteria; narrative aquatic life criteria which prevent acute and chronic aquatic life toxicity; and related criteria designed to protect aquatic life and human health. Additional criteria protect the beneficial uses of state waters: agriculture (including crop irrigation and livestock watering), body contact recreation (swimming and wading), aesthetics, public and private water supply, municipal and industrial process and cooling water, navigation and hydropower.

Oklahoma's Water Quality Standards document continues to evolve and improve. Narrative and numerical criteria to protect human health, wildlife and aquatic life are constantly being added and modified. Specifically, criteria for fish flesh have been developed utilizing risk assessment methodology, a potentially valuable water resource protection tool. Other recent activity in this area includes the addition of metals criteria to protect human health and aquatic life, new wildlife criteria and modifications to existing silver criteria. Oklahoma's Antidegradation Policy recently experienced changes related to stormwater discharges and anticipated language regarding stormwater discharges into Outstanding Resource Waters could affect Oklahoma's current Antidegradation Implementation Policy. The principles involved in the implementation of criteria into discharge permits will continue to be a major area of emphasis, as recently cited in the 1994 Continuing Planning Process (CPP) document. The CPP formalizes the process through which Oklahoma prevents and controls pollution from toxic substances, primarily from point source discharges. Oklahoma has become nationally recognized in this area and will continue to maintain that status by refining mixing zone policies and models and testing and sampling requirements.

Recent work in the area of biological criteria (biocriteria) by other states and EPA is currently being evaluated for broadened inclusion in the standards. This may involve modifications to existing biocriteria -- narrative and/or numerical expressions used to evaluate the structure and health of aquatic communities -- through the delineation of ecoregions and reference streams. Development of biological criteria is being stressed by EPA due to its potential value in water quality management.

The concept of total maximum daily loads (TMDL's) is receiving a great deal of attention nationally. TMDL's are the sum of all point source wasteload allocations and nonpoint source load allocations, with an appropriate safety factor. The implementation of TMDL's into Oklahoma's water management strategy will facilitate the development of more accurate waste discharge permits and improve monitoring of nonpoint source pollution. However, this strategy is very complex and expensive, requiring a significant commitment of both staff and monies. Currently, TMDL implementation is impeded due to the lack of background water quantity and quality information, a situation that will likely worsen due to cut-backs in programs for the collection of ambient water quality data. Creation of a centralized state water quantity and quality monitoring network could also help identify potentially impaired waters and generally ensure that site-specific decisions are made on the basis of reliable data.

Other stream water quality standards issues that should receive consideration and/or refinement in the next decade include measures to protect instream habitat; improved protection of Outstanding Resource Waters; nutrient criteria; measurement of metals criteria (total versus dissolved); groundwater vulnerability assessment and cleanup standards; assignment criteria for Cool Water Aquatic Communities; High Quality Waters and Appendix B areas; criteria which protect the agriculture beneficial use; and default and regulatory flows. In addition, protection of stream waters on a regional or site-specific basis will also be a primary focus of future standards revisions. Proper attention to these matters will be determined, in part, by the significant amount of time and money required by the state in addressing federal mandates. Regardless, future development and implementation of water quality standards must be guided by sound, scientifically-based evidence on individual sites, conditions and species.

WATER & WASTEWATER SYSTEMS

Municipal & Rural Water/Wastewater Systems

Most Oklahomans depend upon either a municipal or rural water system for clean, potable drinking water. According to 1990 census data for Oklahoma, 1,223,121 housing units (87 percent) were on a public or private water supply system, 177,074 (12.5 percent) were on individual wells, and 6,304 households (0.5 percent) obtained water from some other source.

Unfortunately, many water systems in the state suffer from old age, too rapid growth and a variety of related problems which are exacerbated by current funding restraints, unfunded federal mandates and increasingly stringent environmental regulations. An April 1986 report by the Department of Community and Economic Affairs (DECA) on Oklahoma infrastructure revealed that distribution facilities are inadequate in nearly one-half of the municipal and rural water systems in Oklahoma; storage facilities are inadequate in 35 percent of the state's water systems; and more than 26 percent of municipal water systems are operating at greater than 70 percent of capacity.

Forty-four percent of the municipal wastewater plants in Oklahoma, including the majority of cities serving relatively large populations, discharge effluent to waters of the state. These discharges include wastewaters from domestic sources (such as residences and commercial and institutional facilities), industrial operations, infiltration/inflow entering sewer systems, and stormwaters. DECA's report states that almost all Oklahoma municipalities with a population of 10,000 or more operate their own sanitary sewer systems, as do a large majority of cities less than 2,500 in size. However, while virtually all cities of 10,000 or more possess their own storm sewer systems, many smaller cities and rural water districts do not.

DECA estimated that total water system needs over the period 1985-2000 will be approximately $4 billion while sanitary and storm sewer needs will exceed $3.4 billion. Water user fees -- the principal source of revenue for municipal and rural water/wastewater systems -- are generally insufficient to recover actual costs associated with operations, maintenance and capital. Also, many smaller systems lack a reserve fund to fund minor emergencies and repairs. State and federal grant and loan programs (including the popular State Financial Assistance Program and its source, the Statewide Water Development Revolving Fund) have stepped in to fund numerous system improvement projects. However, due to federal budgetary restrictions and economic difficulties at the state and local level, financing of water/wastewater facility needs will become increasingly difficult. Therefore, investigation of alternative strategies is required to meet current and future infrastructure needs.

Regional systems, where customers from many towns and water districts are served by a common source, are often able to provide the most efficient, economical and reliable water supply. Regionalization can also help lessen the potentially devastating impacts posed by stringent water quality regulations as well as funding constraints. In addition, regional systems promote unity among members and help avoid unnecessary -- though all too common -- disputes over water, typically affording all members an equal say in system operation, maintenance and overall administration. Factors that can impede regionalization include the potential loss of autonomy than can accompany consolidation of systems as well as differences in funding capabilities, system densities, service area size and methods of operation.

The 1980 Oklahoma Rural Water Survey, currently being updated by the OWRB, will be a useful tool in identifying potential regionalization opportunities. The survey contains valuable information to guide the operation, expansion and maintenance of Oklahoma's rural water systems. In addition, the revised data will help facilitate economic development in rural areas by linking sources of water supply to new or expanding businesses and industry.

Privatization of water and wastewater facilities is a way for the private sector to work with local governments in obtaining and/or operating needed facilities. Privatization can take several forms, including "contracting out" the financing and ownership of facilities and providing service through contracts. Some of the advantages of privatization include construction savings, quicker procurement and scheduling activities, risk reduction, operational savings, tax benefits, debt capacity benefits and availability of financing. Disadvantages relate primarily to a perceived loss of control by municipalities, the potential negative aspects of long-term contracts, and uncertainties relating to legal and regulatory issues.

In the early and mid-1980's, several factors contributed to the emergence of privatization as an attractive alternative to traditional methods of providing public services. Federal and state grant funding for public infrastructure facilities had declined significantly while, at the same time, tax laws were passed to make private ownership of certain capital facilities much more attractive. The Economic Recovery Act of 1981 was the first major tax act to encourage capital investment by private investors.

Tax law amendments in 1982 and 1984 specified conditions and constraints on leasing and privatizing activities. However, they still provided a means by which the private sector could profitably enter into a service relationship with public entities. The provisions of the Tax Reform Act of 1986 and the Deficit Reduction Act of 1987 served as further constraints on privatization of water and wastewater treatment facilities since the private sector could no longer utilize the advantages of tax-exempt financing, accelerated depreciation and investment tax credits to cut the costs of environmental infrastructure projects. However, where the private sector has proprietary technologies or is better able to handle risks associated with facility operation, full privatization still occurs, despite the 1986 Tax Reform Act.

Technical assistance is currently available through the Oklahoma Rural Water Association and U.S. Environmental Protection Agency funding to help state communities identify system design, management and consolidation alternatives. Unfortunately, many communities with outdated or insufficient water and/or wastewater systems are reluctant to seek help through the state because of their fear of possible consent orders or related regulatory mandates. An expanded, non-regulatory state technical assistance program could help promote privatization and regionalization, where appropriate, and the implementation of other concepts to stretch financial resources and improve management of Oklahoma's water/wastewater systems.

Financing

The primary state financing provider for community water and wastewater projects is the Statewide Water Development Revolving Fund (SWDRF), created by the State Legislature in 1979 and confirmed by popular vote in 1984. The corpus of the SWDRF provides a reserve for the OWRB's bond issues. Due to the excellent credit ratings on the issues, the Board's bond program offers small borrowers lower interest rates than could be obtained if they marketed their own bonds. Interest earned on the Revolving Fund is the source of funds for the OWRB's emergency grant program. Qualified projects can apply for up to $100,000 in grant money. The program is based on a priority point system, with the type of emergency being the primary factor.

Also, in response to the 1987 amendments to the Clean Water Act, which contain provisions for a transition from the traditional method of direct federal grant awards to communities for assistance in the construction of sewage treatment facilities to a new method of repayable loans, the Legislature more recently established the Wastewater Facility Construction Revolving Loan Account State Revolving Fund (SRF) Program. The Act requires each state to provide a 20 percent match in order to receive Environmental Protection Agency SRF capitalization grant monies. Together, these programs make up the State Financial Assistance Program (FAP), administered by the Oklahoma Water Resources Board.

Other major sources of loans and grants are:

Rural Development (RD) -- (formally Farmers Home Administration)
RD provides funding for both municipal and rural projects related to watershed protection and flood prevention/control; water conservation, development and storage; and water treatment, pollution control and wastewater disposal. To qualify for RD loans or grants, communities or rural areas must have a population of 10,000 or less. While the RD loan program has recently grown stronger, the grant program has not experienced similar growth and grant requirements have become more stringent. Funding levels are expected to remain relatively constant over the next several years.

Oklahoma Department of Commerce (ODOC)
The purpose of the Community Development Block Grant (CDBG) program, administered by the ODOC's Division of Community Affairs and Development, is to assist in developing viable urban communities by providing decent housing, suitable living environment and expanding economic opportunities, primarily for persons of low and moderate income. Grants are provided only to cities and towns under 50,000 in population and counties under 200,000.

Indian Health Service (IHS)
The IHS offers a grant program for water and sewer projects. However, qualifying criteria are very stringent and funded projects are limited to those which benefit significant Indian populations.

There is currently a lack of reliance on individual bond issuances as a source of funding for water systems; only 3.5 percent of municipalities and practically no rural water systems obtain revenue from this source. The absence of debt issuance relative to other revenue sources may be explained by the lack of a market for these issuances, particularly for small municipalities and most rural water districts. Many of these jurisdictions have low credit ratings, or no ratings at all, in the market for local government issuances. Debt issuances from these jurisdictions are regarded as relatively risky, thus resulting in higher interest rates which can price many smaller entities out of the debt market. Also, bonds issued by municipalities in Oklahoma are subject to tax exemption only by the federal government; exemptions for state, as well as federal, taxes would allow local governments to issue bonds at lower interest rates.

Due to the inability of small borrowers to market their bonds at an attractive rate, the OWRB issued pooled revenue bonds with the "pool" consisting of many small borrowers. The advantage to this type of financing is that the ratings on the bond issues are not based on one small borrower, but rather the pool of borrowers. As a result, ratings are much higher and interest rates much lower. In addition, the Board's pooled revenue bonds are double tax exempt, making for an even lower interest rate than could be obtained by an individual borrower.

The Statewide Water Development Revolving Fund, which hundreds of Oklahoma communities have turned to for infrastructure needs, has been utilized for many other purposes (especially Tar Creek remediation and Sardis Reservoir water storage payments) in addition to its original primary function as a water/wastewater project funding source. The remaining balance of the SWDRF has been obligated as the required state match for Oklahoma's SRF Program. It has been estimated that a minimum $8 million recurring annual demand could be placed on the Fund. Complicating this situation, Oklahoma and other states have been forced to assume greater responsibility in both the planning and financing of water resource development projects due to the federal government's recent declining role in this area. Due to the state's significant infrastructure needs, significant capitalization of the Revolving Fund is needed, not only to meet upcoming unfunded federal mandates but to satisfy existing 1987 mandates related to point and nonpoint source discharges, water quality standards and related programs. Also, additional funding will be needed to provide the state match to allow establishment of the federal Drinking Water State Revolving Loan Fund Program. It is anticipated that this loan program will be fully functional and providing drinking water loans by mid-year 1997.

Several dedicated revenue sources have been formally or informally proposed to capitalize the SWDRF so that it can remain responsive to Oklahoma's future water resource development needs. These include water user fees, groundwater and stream water permit renewal fees, a water development fee (similar to the Oklahoma Department of Environmental Quality's solid waste fee), reapportionment of existing taxes (such as the Motor Fuel Special Assessment Fee) and direct legislative appropriation.

RESERVOIR OPERATIONS

Allocation & Control

Within the past four decades, an impressive number of reservoirs and lakes have been constructed in Oklahoma. While smaller lakes primarily serve local water supply and flood control needs, most federal projects are utilized for additional multiple purposes such as flood control, water supply, irrigation, power, navigation, recreation, fish and wildlife and water quality enhancement.

Undoubtedly, some federal reservoirs in the state are not being managed to their full potential or to the maximum benefit of Oklahoma citizens; others may have allocations of storage that are insufficient for water supply or other current or projected needs. Occasionally, the difficult task of operating a reservoir for numerous purposes -- especially in regard to releases for flood control, navigation and hydropower -- leads to conflict and necessitates a reassessment of the current operational plan and project benefits. Exploration of opportunities to enhance the operations and benefits of existing reservoirs will become an increasingly attractive planning option, especially due to the current costs and environmental restraints associated with new project construction.

Although most reservoirs in Oklahoma have been planned, constructed and operated on an individual basis, past experience indicates that implementation of system operating plans can significantly increase the benefits of one or more projects in a particular stream system. These plans can be formulated, especially for larger reservoirs located in the same basin, to achieve a reasonable balance of purposes for which a project is operated and to maximize benefits without significant adverse impacts on aquatic life, recreation or existing water rights holders in a stream system.

Flood control, the primary benefit of the majority of the state's 34 major reservoirs as well as hundreds of upstream detention projects constructed by the SCS/NRCS, is a purpose that has generated considerable controversy in Oklahoma. As demonstrated by numerous flooding disasters throughout state history, intelligent and responsive flood control operation is essential to the safety and economic viability of Oklahoma citizens. Especially in eastern Oklahoma, improvement of existing project operation plans or implementation of system operating plans could likely enhance the overall effectiveness of federal flood control efforts. However, the most significant impact upon flooding problems will be achieved through continuation and strengthening of existing floodplain management and hazard mitigation programs. (Floodplain management strategies are discussed in detail under Floodplain Management -- Floodplain Protection and Preservation.)

Storage reallocation -- in most cases, where a certain amount of storage originally allotted to a specific project purpose is increased, reduced or exchanged with storage set aside for another purpose -- presents an opportunity to place under-utilized storage to a more currently needed beneficial use. Due to the considerable effects that reallocation of a major reservoir can have on operation of that project or an entire stream system, the process may require Congressional review and approval. However, the State of Oklahoma must take all appropriate measures to protect current project benefits as well as the water rights of existing users. A potential deterrent to reallocation is the Corps' current policy which requires water reallocated from existing storage to be repaid at updated, rather than original, construction costs

While there is normally no set priority for federal project purposes, water for water supply, flood control, irrigation or other uses which justify the majority of the project's cost (as well as those which constitute the majority of storage) normally prevails during drought episodes or other temporary water emergencies. Other times, for various reasons, these "primary" project purposes are under-utilized and, as a result, "secondary" (nonconsumptive) uses -- such as recreation or fish and wildlife -- become increasingly important as the project matures. In such circumstances, these uses may require and deserve similar protection as provided to the original, major project purposes. However, state law does not acknowledge protection of such uses through allocation of water rights. It could prove advantageous for the state to study the potential for requiring certain exempt water use interests to obtain appropriate water rights and/or storage for their specific uses.

Regardless of the method desired to maximize reservoir storage and/or uses, reaching consensus among affected parties will remain a critical factor in preventing or solving reservoir operation disputes. At Lake Texoma, where various interests clashed over operation of the lake, an advisory committee of water supply, hydropower, flood control, recreation and fish and wildlife advocates was created to resolve the issue. After considerable study, these parties conceded to a seasonal operation plan which facilitates all reservoir uses and benefits. In addition, at Broken Bow Reservoir, the Oklahoma Water Resources Board, State Department of Wildlife Conservation, Southwest Power Administration and Corps entered into an agency memorandum of understanding that set temporary conservation pool releases to facilitate operation of a downstream trout fishery. Although development of fair and mutually beneficial operation plans can be a difficult and arduous task, these successes demonstrate the value of dialogue, compromise and consensus building in satisfying competing uses in Oklahoma's lakes and reservoirs.

Maintenance & Renovation

Structural, as well as operational, modification is a cost-effective method of maintaining a particular reservoir project, producing additional storage/yield and increasing existing benefits -- especially in light of difficulties related to new construction. Prior to consideration of physical improvements, appropriate measures must be taken to ensure that structural modifications are sound and existing project purposes are maintained.

One maintenance problem that will impact the future beneficial uses of Oklahoma reservoirs, especially as they increase in age, is sedimentation. Studies can identify reservoirs experiencing accelerated sediment loading as well as potential mitigation measures that can stretch the water supply potential of existing projects. A coordinated and expanded state bathymetric mapping program could improve sediment monitoring as well as provide updated information on reservoir yield.

In discussing maintenance and renovation of reservoirs in Oklahoma, it is extremely important to consider the locks, dams and river channel which constitute the McClellan-Kerr Arkansas River Navigation System. Opened for navigation in the early 1970's, the system is vital to the economic development of Oklahoma as well as the entire Arkansas River Basin region. However, recurring low water levels on the Mississippi River have resulted in the loss of considerable revenues through delays to the Waterway's ports, customers and shippers along with increased operation and maintenance costs due to dredging.

Of the waterway's 445 miles, the first 10 miles are dependent upon the Mississippi River's elevation while the remainder of the system is controlled by 17 locks and dams. When the Mississippi water level drops, loaded barges cannot enter or leave the waterway. Consequently, many customers are often forced to ship by other modes of transportation, causing significant losses of time and money. These unnecessary market losses and widespread economic dislocations could be avoided through construction of Montgomery Point Lock and Dam on the White River, the final lock and dam envisioned in the original system plan. Otherwise, the uncertain flow levels of the Mississippi River will continue to make navigation on the McClellan-Kerr increasingly difficult and jeopardize the $1.5 billion already invested in the waterway.

Navigation on the system has also experienced significant periods of high flows in recent years causing disruptions and delays in barge movements. These high-flow conditions result in increased fuel, labor and capital costs due to the additional time required for movements, reduced tow sizes and increased accident rates. The recession of high-flow events also causes periodic delays and blockages due to shoaling. The Arkansas River Basin Study, completed in May 1991, investigated opportunities for improvements to the McClellan-Kerr System. The two primary measures analyzed to address the high-flow problems were increasing the available storage in the basin and/or modifying the system operating plan to more efficiently utilize existing storage.

WATER MARKETING

Water Transfer

Water transfer and marketing, a strategy which allows water to be used where it is needed most or has the greatest economic value, can be beneficial for all of Oklahoma. Because water is a somewhat renewable resource and has value as a commodity, water and water rights/storage transactions can create attractive investment opportunities as well as assist in repaying the debt of many communities who have entered into federal water storage contracts. Other benefits include conservation of supplies, especially during times of drought; protection of habitat for fish and wildlife; and preservation and enhancement of water quality.

The ease in transferring rights under the prior appropriation system facilitates economic transactions that promote optimal development and use of both stream and groundwater resources. If water rights are transferred in an open market, they tend to migrate from the least efficient uses to more efficient and economically productive uses. It appears that the transfer of water rights from decreasing agricultural needs to escalating municipal use will become more widespread, leading to the growing emergence of water markets. However, water rights transactions should be limited to some extent to preserve the social, economic and political diversity of rural areas, especially in Oklahoma where agriculture is of such importance to the economy. Individual marketing projects must be achieved in a manner that balances existing uses and avoids excessive reservoir fluctuations.

The expense, legal complications and political obstacles which frequently accompany large-scale water transfers often preclude those projects. While safeguards, such as the requirement of legislative authority for the interstate transfer of water, help ensure that water transactions are conducted fairly, they may also hinder projects which appear to be beneficial to all involved parties.

Many states have created "water banks," entities which oversee and control water sales as well as buy available water and storage rights, holding them in trust for potential future users. An Oklahoma water bank could provide for better conservation of water resources and more efficient administration of state water law (such as granting the purchase/loan of portions of water rights, thereby allowing users to avoid reduction or forfeiture of their rights). In addition, the bank could facilitate discussions related to protection of fish and wildlife resources through establishment of minimum lake levels and/or instream flow maintenance. However, above all, Oklahoma requires a coordinated water marketing policy or system to facilitate both the large- and small-scale lease and transfer of water and water rights.

In Oklahoma, only two major transfer projects have been seriously considered -- the statewide transfer plan proposed in the 1980 OCWP and, more recently, an attempt to lease surplus water from the Kiamichi River Basin to North Texas Municipal Water District. The OCWP conveyance plan, although a potential long-range option, has been judged economically unfeasible and updated water projection figures indicate that the major importation of water will not be necessary to meet needs of the state's eight planning regions in the near future. And, although the Kiamichi project yielded to widespread local opposition and substantial political pressure, it brought to light many issues that, if addressed, should benefit future intrastate and interstate transfer efforts.

The statutory definition of "surplus water," set out in 1974 legislation authorizing the original OCWP, is critical to the implementation of individual water transfer projects and in protecting future needs and uses in the area of origin. Determinations of surplus water will also help identify amounts of water needed for future beneficial use in each of Oklahoma's eight planning regions.

HB 2036 requires the OCWP update to review the definition of "excess and surplus water of this state" and consider a procedure for determining this water to ensure that areas of origin will never be made water deficient. Surplus water is currently defined in the Oklahoma Administrative Code as "that amount of water which is greater than the present or reasonably foreseeable future water requirements needed to satisfy all beneficial uses within an area of origin." In fact, one of the major water marketing requirements prior to any long-term agreement for the sale or lease of water is the accurate assessment of local needs -- i.e., a fair and factual definition of surplus water. In regard to the planning horizon utilized for the OCWP, "reasonably foreseeable" is considered to be 50 years because it represents the outer limits of reliable population and water requirement forecasting and it encompasses the minimum life span of most major water supply projects in Oklahoma. However, the most accurate method to determine surplus water in a basin may be on a case-by-case basis.

To ensure future supply for the state's planning regions and to better facilitate future intrabasin water transfers, forecasted estimates of surplus water in Oklahoma must be conservative on available water and liberal on needs. Numerous untapped sources of water throughout the state can be secured and utilized through development of system operating plans, reallocation of reservoir storage, utilization of unneeded sediment storage and administrative actions, such as the cancellation and reduction of unused water rights. However, to be more accurate, future estimates of surplus water could consider the percent of time reservoir storage is reliably available for varying uses. For example, the yield for municipal supply is calculated to be accessible 98 percent of the time while more supply from the same source would be available for irrigation use, but for a lesser percentage of time. As a result, the amount of surplus water available for large-scale transfers could vary according to its proposed use in the receiving area.

WATER SUPPLY AUGMENTATION

Weather Modification

Weather modification is considered by many to be an effective and promising water resource management tool. Interest in enhancing rainfall by artificial means prompted the Oklahoma Legislature to pass the Oklahoma Weather Modification Act. The Act provided for the encouragement and regulation of weather modification activities and, as amended in 1973, assigned the responsibility of its administration to the Oklahoma Water Resources Board.

While moderate success of test programs have proponents convinced of the effectiveness of the technology, others remain skeptical. In an effort to alleviate uncertainties surrounding the use of weather modification technology, the 1980 Oklahoma Comprehensive Water Plan recommended that the Governor and Legislature support the development and implementation of a comprehensive weather modification program for the State of Oklahoma. As a result of this recommendation, the OWRB, Bureau of Reclamation and Texas Water Commission joined forces during the mid-1980's under the Southwest Cooperative Program to demonstrate state-of-the-art cloud seeding technology and its promise in increasing summertime rainfall in the Southern Plains region. Findings from that multiyear effort, combined with more recent results from other programs, suggest that increases in summertime convective rainfall of 10 to 30 percent and reductions in hail loss on the order of 25 to 45 percent are achievable through carefully planned and conducted programs.

Groundwater Recharge

Artificial groundwater recharge -- i.e., diversion of runoff into groundwater basins for storage and later use -- could be an effective tool for managing declining or limited groundwater resources. The technology can lessen pumping costs, provide additional water supplies in times of drought and help utilize stream water that may otherwise be lost during wet years.

In 1984, the Bureau of Reclamation, in conjunction with the U.S. Geological Survey and Environmental Protection Agency, initiated a feasibility study to demonstrate the potential of artificial groundwater recharge technologies in stabilizing and replenishing declining aquifers under a variety of hydrogeologic conditions. The Bureau, in cooperative agreement with 17 western states, selected 21 sites to test various artificial means of supplementing groundwater supplies. As part of this study, the Bureau, Southwest Soil and Water Conservation District and the Oklahoma Water Resources Board are cooperating in a five-year, $2 million effort to recharge the Blaine Aquifer which provides irrigation water to a 1,500 square-mile area in southwest Oklahoma and adjacent parts of Texas. Centered near Hollis, the Blaine Recharge Demonstration Project includes five recharge wells, a recharge dam and 25 monitoring and observation wells. This program supplements an existing, private project, initiated in 1968, of 45 recharge wells operated by the Southwest Soil and Water Conservation District.

A second state groundwater recharge demonstration project, near Woodward, has been proposed to increase water supplies in alluvium and terrace deposits of the North Canadian River. The plan concept involves installation of an underground barrier down-gradient of an existing municipal water well. It is presumed that the barrier dam would increase the production of water from the existing well, resulting in reduced demand on the Ogallala Aquifer.

Reclamation & Reuse

Future water shortages and cost considerations will generate increased pressure to reclaim and recycle wastewater. In many areas of the country, wastewater reclamation -- the reuse of highly treated effluent -- has become an important source of water for landscape and agricultural irrigation, aquifer recharge, industrial cooling, power generation, paper production and food processing. The central issues preventing full utilization and acceptance of reuse techniques include health concerns and the rights to reclaimed water, especially when the water is used to maintain streamflow (i.e., instream flow and/or water quality problems could result in removing effluent from stream systems).

In agriculture, reuse of municipal and industrial effluent for irrigation, as well as the reuse of irrigation tailwater or drain water through installation of pumpback systems or planting of salt tolerant crops, is gaining greater acceptance. In some situations, agricultural return flows are already reused simply because downstream agricultural appropriations depend on upstream return flows. However, salinity buildups and the existence of trace elements can be limiting factors in agricultural recycling. Additional research is needed to determine the possible health and environmental effects of reuse and land application of wastewater.

Industries -- such as food processing, paper manufacturing, and other industries that have a heavy demand for water -- could defray some of the cost of production by selling treatment services to surrounding communities. In addition, significant savings in water use can be accomplished by substituting lower quality reused municipal wastewater for fresh water during the cooling and manufacturing process. In closed cooling systems, water is returned to a tower, pond or lake to be cooled and reused. These cooling lakes can also be used for recreation and fish farming. Another industrial practice involves combining industrial waste flow that requires high nutrients for treatment with municipal wastewater containing those nutrients. Recycling of process water by Oklahoma industries has been limited because of the relative availability and abundance of high quality, generally inexpensive municipal water.

For homeowners, a number of residential on-site water reuse (gray water) systems are technically feasible and environmentally sound. However, this practice is not yet accepted by most household water users.

Chloride Control

Water quality problems, both natural and man-made, affect many of Oklahoma's stream and groundwater resources. Natural dissolved solids and salinity problems, in particular, impede the development and maximum use of water resources in much of western Oklahoma. High concentrations of minerals, primarily chlorides, are emitted into streams from salt springs and salt flats, often rendering both the stream and adjacent alluvium and terrace groundwaters unfit for use. In addition, many of the carbonate aquifers in the region contain naturally occurring salts that impair groundwater quality. In some areas, this problem has been aggravated by oil and gas exploration and production activities.

Chloride control and desalinization have been used with some success to cope with salt contamination. Desalinization, which involves treating salt-concentrated water until it is suitable for beneficial use, is being utilized to treat water at Foss Reservoir, on the salty Washita River. Chloride control does not alter the quality of the water at its source, but rather diverts fresh and usable water around identified salt flats and natural brine springs by means of dikes, dams and retention structures.

The ongoing Red River Basin Chloride Control Project, located in southwest Oklahoma and Texas, is a pilot project authorized by the Flood Control Acts of 1962, 1966 and 1970 and Water Resources Development Act of 1986. In the project region, 10 natural salt source areas contribute some 3,600 tons of salt to the Red River each day. The Arkansas River and its two principal tributaries in north Oklahoma, the Salt Fork of the Arkansas and Cimarron Rivers, also exhibit chloride problems, although a Corps study determined that project to be economically infeasible based on federal resource planning guidelines.

With the Red River Basin Chloride Control Project fully operational, an estimated 65 percent of the chlorides emitted from the 10 major source areas would be controlled. At Lake Texoma, a potentially valuable water supply, water meets the Environmental Protection Agency's dissolved salt standard for municipal water only three percent of the time. It is anticipated that the project would reduce the lake's chloride levels by some 45 percent, making Lake Texoma water useable 94 percent of the time.

Formal study of the Red River chloride situation was initiated in the late 1950's. Actual development of dams, dikes and diversion structures to control an anticipated 65 percent of the chlorides was initiated in 1964 by the U.S. Army Corps of Engineers; operation of the project continues today at full federal expense. The total project cost is estimated to be approximately $262 million with a return on investment (cost-to-benefit ratio) of 1.3 to 1.

To initially determine environmental impacts of the project, numerous studies were conducted by the Corps as part of the final environmental impact statement (FEIS) which was filed with EPA in 1977. Due to changes in project design and in the existing environmental setting, the Corps' Tulsa District reevaluated the project for compliance with current environmental laws and regulations in 1991. They determined that a supplement to the FEIS would be required to assure compliance with the National Environmental Policy Act (NEPA) and other environmental laws. As a result, the District has conducted four additional environmental studies which address various concerns related to the project.

Natural resource agencies and recreational interests have expressed serious concerns regarding construction of the remaining portions of the project. Specific major concerns include the potential impact of decreased chloride concentrations in the Red River basin on primary production and sport fish abundance in Lake Texoma; impacts on federally listed threatened and/or endangered species; potential impacts of selenium concentrations in brine storage lakes; indirect impacts of the project on streamflow and riparian corridors; impacts of flow modification on fishes of the upper Red River; fish and wildlife mitigation features; land use changes at the Area VI disposal site in Oklahoma; and preparation of the FEIS supplement.

A major environmental, as well as economic, concern surrounds the Lake Texoma fishery which contributes some $22.7 million annually to local and state economies in the two-state area. A minimum eight percent decline in the overall sport harvest has been predicted, although further studies of the extent of this particular impact are ongoing. Environmental agencies -- in particular, the U.S. Fish and Wildlife Service and Oklahoma Department of Wildlife Conservation -- have expressed concerns that the Red River Chloride Control Project will adversely affect water quality conditions that have maintained the long-term productivity of Lake Texoma. Increased turbidity in the lake, a condition which could result from the decreased salinity levels, could prove detrimental to the profitable and thriving Texoma striper fishery. Also, increased water withdrawals and consumptive water use, especially in Lake Texoma, could impact national wildlife refuges and state wildlife management areas/parks in the region.

In July 1994, the Corps and USFWS completed a formal consultation which resulted in an agreement that includes a number of measures to conserve and avoid impacts to the Interior least tern, Bald eagle and Whooping crane, although concerns remain about potential changes in the habitats of those species. Impacts to these and other threatened and/or endangered and related sensitive species which occur in the project area are also being re-evaluated.

In addition to potential environmental concerns, increased irrigation resulting from the project could have an adverse cumulative impact on flow within certain segments of the upper Red River during dry periods. However, careful regulation of area water resources, facilitated through information obtained from gaging and monitoring stations established to record changes in flow and water quality, could help diminish this problem.

WATER CONSERVATION

Water Conservation

Water conservation measures have promise to save significant amounts of water and, as a result, forego the need for new water supply construction and development. In the home (including public and private buildings), primary conservation measures include efficient water-using equipment, changes in plumbing codes and, especially, modifications of behavior and habits affecting water use. While revised building codes that require installation of water-saving devices transfer the additional cost from the builder to home buyer, this equipment can provide various economic benefits as well as assist in preserving supplies for future use.

Within the home, about three-quarters of water use occurs in the bathroom where toilets alone consume an estimated 40 percent of all water used. In office buildings, schools and public buildings, toilet flushing is the predominant water use. Substantial water savings can be realized by installing low-flush toilets that use 1.6 gallons of water per flush, as compared to 3.5 to 8.0 gallons per flush for conventional toilets. Toilets using higher volumes of water can also be modified through the installation of certain devices in the tank to reduce the flush volume.

Bathing accounts for 34 percent of water consumed in the home, with 60 percent of this total used in the shower. Many companies manufacture shower heads or adapters that conserve water by reducing the maximum flow rate or producing a low-flow shower spray. Since conventional showers use up to 10 gallons per minute, and showers average five minutes in duration, water use can be reduced up to 70 percent by utilizing a flow control device which reduces the rate of flow to three gallons per minute.

The benefits of water conservation are many. In addition to the obvious benefit of conserving the state's limited and precious water supply, the energy savings achievable through the use of these fixtures and overall consumer cost savings can be substantial. A major concern regarding municipal water conservation measures is the potential financial impact on utility revenues that could result from the sudden, reduced volume of utility revenue when the fixed costs of the utility have to be met regardless of sales. However, phasing-in of conservation programs and practices could address those concerns. The availability of water-efficient fixtures and appliances at costs comparable to more wasteful fixtures, as well as the ease of their use in construction, make a statewide effort governing the sale and use of efficient fixtures and appliances a viable way to achieve substantial in-home water savings. On a larger scale, this particular method of water conservation can help avoid costs associated with development of new supplies and, because of reduced flows, can decrease the price of wastewater treatment. However, full implementation of water-saving plumbing fixture standards could take long to achieve.

Each year, Oklahoma's rural water systems collectively lose millions of gallons of treated drinking water through water line leaks and malfunctioning meters. To address this problem and identify energy and water losses that diminish the profits and efficiency of these smaller systems, the Oklahoma Water Resources Board proposed creation of the Statewide Rural Energy and Water Conservation (Oklahoma Leak Detection) Program. Created in 1993 and funded by $300,000 in federal oil overcharge monies from the U. S. Department of Energy, the program allows the OWRB to offer interest-free loans up to $30,000 for water audits, leak detection surveys and to make associated repairs. The Oklahoma Rural Water Association coordinates those activities. The initial water audit and leak detection survey identifies and assesses water, energy and revenue losses while resulting information determines what projects can most effectively reduce those losses. Eligible entities include rural water districts, non-profit corporations, municipalities and public trusts who provide water service to a maximum population of 10,000. Program funding is scheduled for termination in March of 2003.

The key to water conservation -- applying to in-home as well as agricultural and industrial water use -- is education. The environmental movement of the 1960's and 70's spawned widespread public awareness of environmental problems, especially the importance of conservation and protection of our water resources. Today, citizens are aware of the benefits in preserving, protecting and conserving valuable stream and groundwaters and they are equipped with the knowledge necessary to make intelligent decisions regarding water use and protection. However, there remains a need to develop and foster additional respect for Oklahoma's water resources through education of adults as well as children.

Although education is important, perhaps the most powerful incentive for conservation is price. The price of water should reflect the actual costs of the water itself, plus costs associated with treatment and distribution. In far too many communities, however, water is practically a free resource with its price bearing little resemblance to the actual cost of treatment and delivery -- a fact which often escapes the citizen consumer. Furthermore, small-volume users typically pay much more by volume than do large users and there is little incentive to industry, a major water user, to conserve.

The general function of prices is to assert checks and balances on production and consumption in an economy. In this role, prices have two functions: to discourage excessive consumption of a commodity and to induce the desired supply of that commodity. Prices can play this role not only in the private sector of the economy, but also in regulating the production and consumption of certain commodities produced by governments and local entities. The price of water generally represents the amount necessary to cover a utility's capital and operating costs, including allowances for rehabilitation and replacement. The typical rate structure is the declining block rate system under which there is a charge per gallon for the first block of use which is greater than the charge per gallon for the next higher use category. In effect, the declining rate system subsidizes the larger user at the expense of the small user and is often used to attract industry to an area. However, under this system, there is little incentive to conserve.

It is the pricing of this additional amount of water that has potential for conservation because most of it is used for less critical tasks such as lawn watering. Increasing the price of the initial block will increase revenue but not discourage use. Increasing block rates are more effective. As larger quantities are used, the consumer has to pay an increased cost. Increasing the price of additional blocks -- at least to reflect the full incremental cost of delivery -- may alter use patterns in cases where water is priced below this level.

WATER RESOURCE PLANNING

Basin/Watershed Management

The traditional data-gathering approach to water resource management and planning has been controlled by political, rather than geographical, considerations -- and for good reason. The observance of political boundaries facilitates the flow of information and data from the source entity (such as the U.S. Census Bureau) to water resource agencies who require and depend upon this information to administer numerous state and federal programs.

Today, however, it can be argued scientifically that watersheds constitute the most sensible hydrologic unit within which to manage stream water resources and, especially, protect and enhance water quality. The majority of current watershed management studies are (and likely will be) driven by the nature of the individual problem at hand. Undoubtedly, increased attention to nonpoint source pollution will result in unprecedented incorporation of watershed management techniques.

Watershed management tools can be used to identify holistic cause-and-effect water quality relationships, link upstream uses or problems to downstream effects, develop reasonable water cleanup plans and educate the public. By cutting costs and focusing limited staff and resources on the most important water quality problems, basin-wide watershed management enables a state to protect waters in a more effective and consistent manner. Adoption of watershed management approaches in Oklahoma could also facilitate elimination or consolidation of the many time-intensive federal reporting, or "list-making," requirements. Similarly, a strategy to manage groundwater could be based upon the unique characteristics of a specific basin or aquifer. Coordination of geographic-based water planning includes components of planning and implementation, data collection and dissemination, information and research, and public education and information.

While numerous federal and state agencies (such as the Oklahoma Water Resources Board, U.S. Geological Survey, U.S. Environmental Protection Agency and Natural Resources Conservation Service) currently utilize various aspects of watershed planning and management, many recognize conflicting watershed boundaries. For example, the OWRB, through its stream and groundwater management and permitting programs, conducts studies of water availability in state stream systems and groundwater basins. Water quality standards and related studies are implemented on a primarily local, watershed-oriented basis while Oklahoma's interstate stream compacts recognize large river basins. However, more recent water resource planning activities have emphasized political boundaries. Population, economic and other societal information that is critical to water resource planning must be compiled with consideration for municipal, county and state boundaries -- an approach that limits the institution of watershed planning which recognizes natural geographic boundaries. This political/geographical overlap has traditionally posed problems for water resource planners who must extrapolate redundant, and often incomplete, water quality/quantity data.

A holistic water resource planning and management approach is needed to merge political and geographical differences. Recently, EPA provided the state with funds to develop a Whole Basin Protection Approach (WBPA) Implementation Plan for addressing water pollution on a watershed basis. This effort will include delineation and prioritization of watershed planning units as well as methods for synchronizing National Pollution Discharge Elimination System (NPDES) permits, nonpoint source implementation activities and related pollution prevention programs.

Geographic information systems (GIS) technology -- which involves the use of computers for mapping, management and analysis of spatial information -- exhibits much promise in watershed management. These systems possess capabilities for the encoding, storage, processing and display of computerized maps and images. Geographic information systems are beginning to emerge in Oklahoma and most other states. A consensus among state and federal agencies of watershed planning boundaries would greatly facilitate the exchange of information within the state GIS program.

Drought Preparedness

Drought, which is all too frequent in Oklahoma, has serious social, economic and environmental repercussions. Particularly damaging to the state's agricultural industry, drought has been characterized as a "creeping phenomenon," making an accurate prediction of either its onset or end a difficult task. To most observers, it seems to start with a delay in the timing (or a failure) of the rains normally expected. A major problem in responding to drought lies in the fact that it has a different meaning to different people, largely dependent on their particular background and interest. Essentially, there are meteorological, agricultural, hydrologic and socioeconomic droughts, all relating to some shortfall in water.

Critical to determinations of drought's probability, however uncertain, is the existence of a system to facilitate the long-term, reliable and continuous monitoring of hydrometeorological conditions. According to a 1991 National Research Council report, which discussed the importance of identification and analysis of hydrologic extremes (including both drought and flood), "Estimation of the severity and interval of likely recurrence for this drought [the 1985-86 drought in the southeastern U.S.] was made possible by the availability of high-quality hydrometeorological records maintained continuously for a site since 1934. An even longer precipitation record, 110 years, was located for a nearby station. Whereas the drought was the most severe in the 53-year record, the 110-year record revealed five periods of even less rainfall before 1934. This information substantially altered the interpretation and implications of the 1985-86 drought, showing it to be a much more common event than first considered."

Past efforts in Oklahoma to deal with episodes of drought, both on the state and local level, is best described as crises management. The state must recognize that planning for Oklahoma's critical and emergency water resource needs should not be carried on only during times of drought crises.

Wetlands Protection & Management

Wetlands protection and management is one of the most divisive water policy issues and, as a result, federal regulation of wetlands has experienced numerous recent changes. Developers and farmers have protested the various wetland rules and regulations as being onerous land use requirements while environmentalists insist that more regulatory action is needed to sufficiently protect wetlands. The state must develop balanced policies that bridge the gap between these interests.

Because no individual entity has either the mandate or resources to provide adequate wetlands protection in Oklahoma, wetlands conservation and management are the shared responsibilities of numerous federal, state and local agencies as well as conservation organizations, private corporations, landowners and special interest groups. However, in May 1990, the State Legislature directed the Oklahoma Conservation Commission to prepare a wetlands management strategy for the state in cooperation with numerous state and federal agencies, including the U.S. Environmental Protection Agency, which has granted funds to states for wetlands conservation planning purposes. Also on the federal level, the National Academy of Sciences has been directed by Congress to review the wetlands definition and delineation issue.

Because the wetlands issue has such potential to influence private, state and federal land ownership and administration in Oklahoma, development of wetlands management strategies should be a cooperative effort that assures wetlands protection while balancing economic concerns and interests.

Endangered Species

The Endangered Species Act (ESA) was passed in 1973 "...to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, to provide a program for the conservation of such endangered and threatened species, and to take such steps as may be appropriate to achieve the purposes of [several International] treaties and conventions." The ESA, which has been amended several times since initial passage, provides for a comprehensive approach to identifying species in need of special attention, conserving species and the habitats upon which they depend and recovering species to the point of delisting.

Congressional policy states "...that all Federal departments and agencies shall seek to conserve endangered and threatened species and shall utilize their authorities in furtherance of the purposes of [the ESA]." Furthermore, the ESA requires that federal agencies shall, in consultation with the U.S. Fish and Wildlife Service, ensure that any action authorized, funded or carried out by such agency does not jeopardize the continued existence of any listed species or result in the destruction or adverse modification of designated critical habitat. However, many environmental organizations and agencies believe that federal and state agencies have failed to fully consider the potential impact of individual water resource development projects and related activities on endangered/threatened species.

Nationwide, more than 800 species of plants and animals have been listed as threatened or endangered under authority of the ESA. In Oklahoma, 21 species are currently listed, with one presently proposed for addition. Because the life cycles of many threatened/endangered species in Oklahoma depend, at least in part, upon the aquatic habitats provided by state streams, rivers, lakes or ponds, these species can be profoundly affected by changes in water levels, flows and quality. While both the ESA and Oklahoma Water Quality Standards (through the state's Antidegradation Policy) provide protection to state species classified as threatened or endangered by the U.S. Fish and Wildlife Service, development of water projects or use of water within key river basins may adversely affect critical habitat or otherwise impede plans for species recovery. However, while conflicts between water's environmental value and agricultural, urban and other uses of water could potentially result in expensive and time-consuming litigation and/or prohibit implementation of important water projects, to date, the ESA has been a factor in the development of only one water project in Oklahoma (Lukfata Reservoir, in southeast Oklahoma).

Recently, the U.S. Fish and Wildlife Service proposed to list the Arkansas River shiner-- a small fish peculiar to much of the Arkansas River Basin which has disappeared from over 80 percent of its historic range -- as an endangered species. There are unanswered questions related to decline of the shiner and past water development. On the other hand, there is concern regarding the possible effects the listing may have on future water development and use (including implementation of potential low flow requirements and restrictions on groundwater pumping) in the Canadian River, North Canadian River and Cimarron River Basins. Reliable, long-term hydrologic information will be required to resolve this and future issues related to wise water management and protection of endangered/threatened species.

In some surrounding states, judicial decisions related to the needs of federally-listed species have resulted in changes in the administration of stream and groundwater resources. In response to the U.S. Court of Appeals, the Texas State Legislature has ruled that enforcement of the ESA has priority over the groundwater rights of Texas landowners when the two are in conflict. This major water rights decision in Texas merits careful examination for its applicability to Oklahoma and accentuates the fact that the sometimes competing needs between environmental and non-environmental water uses must be given serious consideration by the state when formulating the wide range of water management options.

FLOODPLAIN MANAGEMENT

Floodplain Protection & Preservation

In the wake of the 1993 Mississippi River flood, the federal government has made a renewed effort to promote floodplain management, including investigation of options to return floodplains to their natural condition, and prevent recurring flood problems. Oklahoma should keep abreast of federal activities in this area as well as continue current floodplain management efforts related to the National Flood Insurance Program (NFIP), federal Hazard Mitigation Grant Program (HMGP) and related programs that have resulted in reduced flood damages throughout the state.

Since Oklahoma joined the NFIP in 1975, the program has been directly responsible for mitigating state flood losses and associated costs. Currently, 358 communities, including 47 counties, have enrolled in the NFIP. However, 16 counties and 79 cities and towns not participating in the program have been identified as having flood hazard areas; 20 additional non-participating counties are unmapped, yet most are suspected of possessing flood-prone areas. Expansion of state mapping efforts, in cooperation with the federal government, could improve this situation, especially considering that increased development in many regions has caused significant alterations in federally-delineated, 100-year floodplain elevations.

While the Hazard Mitigation Grant Program has provided much-needed assistance to many Oklahoma communities in decreasing future flood losses, many elect not to participate due to the program's required 25 percent match. Identification of a funding mechanism that would assist communities with the required cost-share money could provide a boost to program participation. In addition, cities and towns with frequent flooding problems should be encouraged to participate in hazard mitigation planning efforts prior to disasters rather than during post-disaster recovery periods. Improved education, training and planning is needed to reduce the flood risk at the local level and prevent repetitive flood damage.

The availability of long-term and reliable hydrometeorological data is just as important to flood planning as it is to drought planning and other water resource management efforts. For example, precise delineation of the 100-year floodplain relies, to a great extent, upon accurate and accessible streamflow data, especially estimates of extreme discharge and stage (elevation of the water). Also, the existence of a real-time monitoring network, utilizing U.S. Geological Survey stream gage information, is vital to development of effective flood forecasting and warning systems, such as that implemented by the City of Tulsa. In this regard, there is a need to update and improve the current USGS stream gaging network as well as perform maintenance on individual stream gages throughout the state.

Other methods through which state and/or local governments could reduce flood damage and mitigate related hazards include stormwater management planning; development of alternative methodologies for determining flood elevations; improved enforcement; increasing public awareness and education; implementation of state Geographic Information Systems; and investigation of a system that limits future development where a high ratio of impervious to pervious land exists.

PROBLEM MEDIATION & ARBITRATION

Water Resource Dispute Resolution

Activities surrounding the utilization and protection of water are frequently debated and many times litigated. As a result, resolution of disputes involving these issues is growing in importance. Through consensus building techniques, a knowledgeable facilitator, perhaps one authorized state agency, can bring affected parties to the table to air concerns in a non-litigation setting. Such a mechanism -- as currently employed by the Oklahoma Water Resources Board in its effort to mediate disputes involving the state's rural water systems -- could produce an atmosphere conducive to problem-solving and one that avoids costly and lengthy litigation which many times results in undesirable results for all involved parties.

Other potential avenues to solve water use and management disputes include creation of a state arbitration panel and implementation of advisory committees to increase awareness and understanding among parties involved in individual disputes. In addition, there is a need for the state to reevaluate current water law and policy to ensure that it is set forth in a clear and concise manner.

Local Empowerment

Citizens in many areas of the state believe that state regulation of water quantity and quality, especially groundwater, should be curtailed to the greatest extent possible and that the role of the state in addressing water problems should be as facilitator and educator, rather than as manager. Empowerment of local entities with decision-making responsibilities through creation of groundwater management districts (such as those implemented in the State of Kansas), watershed management districts and related organizations, if done responsibly, could benefit water management agencies as well as local water users who are directly impacted by regulation of their water resources. However, local leaders must be equipped with sufficient equipment and education to make informed decisions and agree to be held accountable for those decisions.

In addition, increased accountability at the local level would undoubtedly short-circuit many potential water resource disputes and problems -- relieving both the frequently back-logged state court system of unnecessary legal cases and involved parties of the exorbitant costs of litigation. As unfunded federal mandates continue to increase and emphasize the need for local (as well as state) funding sources for water/wastewater projects, the role of local governments in the control and management of stream and groundwater resources will similarly evolve. Finally, current and upcoming funding restraints will necessitate a comprehensive review and prioritization of water quality and quantity management programs in which the state participates, then possible elimination of those programs deemed to be redundant and/or wasteful.

Interstate Water Disputes

Resolution of interstate water issues and problems is currently facilitated through the four existing interstate stream compacts to which Oklahoma is a party. These compacts are important to Oklahoma to assure receipt of adequate surface flows/releases from upstream states. Generally, the compacts provide a means of working out problems between states in an orderly manner, preventing the likelihood of litigation in most cases. Recently, the Arkansas-Oklahoma Arkansas River Compact Commission has begun to address some water quality issues, along with traditional water quantity matters, and the Red River Compact Commission has already established a standing environmental committee.

Groundwater basins, like their stream watershed counterparts, often extend beyond the geographic outline of a state's boundaries. Through formation of groundwater compacts with neighboring states, Oklahoma could not only improve the planning, development and management of shared groundwaters, but be part of a forum to facilitate the resolution of conflicts involving groundwater allocation, pollution and related problems. However, any interstate groundwater agreement or compact must be in harmony with state water policy, applicable laws and the public interest.

DATA COLLECTION & MANAGEMENT

Stream Gaging Network

In order for the state to manage its water resources, appropriate data must be properly collected and analyzed. According to the National Research Council, which discussed the role of data collection in 1991, "Detection of hydrologic change requires a committed, international, long-term effort and requires that the data meet rigorous standards for accuracy... The absence of supporting facts does not lead to understanding and can result only in conjecture."

While the U.S. Geological Survey has collected stream gage data nationwide since 1888, the State of Oklahoma has participated with the federal agency in cooperative stream gaging programs since 1935. The USGS provides federal matching funds for one-half the program cost, enabling state, local and tribal agencies to acquire reliable streamflow data. The Oklahoma Water Resources Board, as the primary state cooperator in the program, depends heavily on this data to determine amounts of water available for use. In addition, there are numerous communities and organizations in Oklahoma -- including the National Weather Service, Federal Emergency Management Agency and many state and local disaster agencies -- who currently use the program's real-time data for flood forecasting, flash flood warnings, regulation of reservoir discharge and emergency management.

USGS stream gaging data is also used in Oklahoma to provide valuable information related to floodplain development; water supply forecasting, planning and research; construction and design of bridges and dams; and facilitation of interstate stream compacts to which the state is a party. In addition, during periods of extensive drought, real-time data can be valuable in monitoring diversions of water. This is especially critical in areas of direct diversion for irrigation when users desire water at essentially the same time.

Water Well Measurement

The state water well measurement program was initiated in 1937 by the U.S. Geological Survey and, since 1950, has been conducted jointly by the USGS and Oklahoma Water Resources Board. The objective of the annual statewide effort is to gather historical records of groundwater level fluctuations and, from them, predict water use trends and future availability of groundwater supplies. Specifically, resulting data is utilized by the OWRB in determining the maximum annual yields of state groundwaters.

Although most of the wells in the network are irrigation wells, those supplying municipal, industrial and domestic water are also included. Typically, some 1,200 wells are measured throughout the state. Because of the great reliance on groundwater for irrigation in the Panhandle and to facilitate cooperative federal/state efforts to track water level changes in the Ogallala Aquifer, more than 200 wells are measured in Texas, Cimarron and Beaver Counties. Some wells are equipped with instrumentation that provides a continuous record while others are measured by hand. Because depletion of groundwater is a serious problem in some areas of the state, well measurement and monitoring will provide the state and local landowners with the necessary information to better manage this resource.

Water Quality Sampling & Monitoring

Water quality monitoring, including observance of biological communities, is an integral tool in determining the current status of stream and groundwater resources and effectively managing their future use. Monitoring provides a means to identify the presence and extent of contamination, recognize regional trends and correlate known contamination problems with suspected health problems.

State water quality sampling activities are directed by several state agencies, including the Conservation Commission, Water Resources Board, Department of Health, Department of Environmental Quality and Department of Wildlife Conservation. These agencies receive assistance from federal agencies (especially the U.S. Geological Survey), state universities and citizens.

Historically, the majority of water quality data on Oklahoma's stream water resources has been obtained through the National Stream Quality Accounting Network, maintained and primarily funded through the USGS for more than a decade. However, insufficient funding has resulted in the abandonment of many state water quality monitoring stations which are part of this and other federal programs. The nine remaining USGS stations are scheduled to be discontinued when the National Stream Quality Accounting Network comes to a close. The two water quality sites funded through the USGS Benchmark network will likely continue.

In addition to USGS efforts, DEQ maintains a statewide ambient trend monitoring network. The network, in place since the mid-1970's, once contained 100 stations throughout Oklahoma which were sampled on a monthly basis. Unfortunately, the program has not been maintained and no ambient water quality data is presently collected for the network.

As part of a separate program, the OWRB conducts sampling studies on numerous publicly-owned lakes with assistance from federal Clean Lakes Program grants. Through the State Lake Water Quality Assessment Program, approximately 120 of Oklahoma's largest lakes are sampled at least once every five years to determine their trophic status. In addition, more than 80 smaller urban lakes are periodically sampled by OWRB staff or "Oklahoma Water Watch" program citizen volunteers. This valuable program provides physical, chemical and biological data for use in identifying pollution problems, recommending solutions and implementing restoration measures. Reservoir water quality information is also gathered by the Oklahoma Department of Wildlife Conservation through its fish monitoring efforts.

The USGS, OWRB and other state and local agencies also cooperate in water quality monitoring programs on specific projects and the USGS monitors surface waters for additional federal programs, such as the National Water Quality Assessment (NAWQA). However, NAWQA monitoring sites are normally established for a specific purpose and may not be entirely useful for state ambient water quality data needs.

Although Oklahoma contains more than 3,500 generally recognized waterbodies, less than 500 have been assessed for water quality. While sampling of all stream waters is unrealistic, additional sampling stations are required for the state to establish an adequate database for planning activities and the monitoring of pollution control measures. A regional approach to sampling would allow for determination of baseline water quality without monitoring of individual resources. Oklahoma requires a plan -- perhaps established in conjunction with, or as a result of, coordinated state watershed planning efforts -- for determining what waterbodies should be measured, the location of sampling points and frequency of assessment.

Biological assessment techniques augment and enhance traditional measures of water quality which have historically focused upon chemical analysis. Biological assessment can establish reference criteria upon which regional assessments of water quality conditions may be based and can provide long-term information on conditions at individual sites to enable monitoring of quality over time. This form of assessment can also detect the effects of those chemicals that are either no longer present or are not normally tested for in routine analysis. In addition, tissue analyses of specimens from the biological community can detect chemicals that are accumulated or magnified at levels below what can be detected through conventional analytical procedures. Finally, analysis of the biological community enables rapid screening of water quality so that resources can be directed where they are needed most.

In 1983, the OWRB began an extensive annual groundwater quality sampling program of 21 major groundwater basins in the state. The purpose of the program was to obtain ambient, or natural, groundwater quality data in an effort to characterize the basins in Oklahoma. The program was refined to include only wells on which information about well construction, location and surrounding land use is available. Individual water samples were analyzed by the State Department of Health laboratory for a wide range of metals and chemical pollutants.

The monitoring network, discontinued several years ago, was designed to obtain water quality data over large representative areas for the major state aquifers. However, while providing good areal coverage and potential trends over time for aquifers with the greatest use, the network neglected many small aquifers used for domestic supplies as well as specific areas that may have been experiencing significant water quality degradation. These deficiencies should be corrected in the event the sampling program is reinstated.

The USGS has also sampled and analyzed water from approximately 25,000 wells and springs in Oklahoma. These data have been collected primarily through special projects, including cooperative efforts with the OWRB.

In addition to past and present water quality monitoring and sampling programs, water quantity programs -- such as the state's well measurement and stream gaging efforts -- provide valuable information vital to development of accurate and effective waste discharge permits and related water quality considerations.

Because of the number of state agencies with legislatively assigned responsibilities for water-related issues, coordination of water quality monitoring activities has been a historical problem in Oklahoma. Communication between agencies, including development of uniform methods of collecting samples, would ensure the consistency and effectiveness of individual water-related sampling programs Coordination would eliminate or reduce duplication in project identification and planning, as well as in information gathering and analysis. Taken one step further, development of a centralized stream and groundwater monitoring network and/or expansion of current programs could provide more reliable background data with which to improve administration of the state's various water management programs.

Oklahoma Mesonetwork/Next Generation Weather Radar

The Oklahoma Mesonetwork (MESONET) is part of a recent initiative to place timely and highly useful weather information in the hands of state citizens. A joint effort between the University of Oklahoma and Oklahoma State University, MESONET consists, in part, of 111 automated observing stations located throughout Oklahoma's 77-county area that continuously monitor a number of important weather and soil conditions.

Every 15 minutes, data observed over five-minute intervals are relayed from each remote station to a central processing site which receives, quality controls, stores and disseminates the observations, as well as value-added products, to a large statewide community of users -- all within minutes of each observation.

MESONET, in conjunction with the National Weather Service's Next Generation Weather Radar (NEXRAD) program's network of operational doppler radar systems, has facilitated remarkable improvements in remote sensing of the environment. These radars provide high-resolution data and products which, in the past, have been available from only a few research meteorological radars during limited time periods. This new partnership enables MESONET users to access additional cutting-edge, value-added weather products.

Beneficiaries of MESONET data include water resource planners, farmers, ranchers, foresters, educators, transportation officials, emergency management officials, energy officials, meteorologists, weather sensitive businesses and the general public. Because MESONET has been designed for a variety of purposes and utilizes several mechanisms to disseminate information, the Oklahoma Mesonetwork may represent one of the most significant improvements ever in environmental data collection.

Water Resource Data Management

The current wealth of water resource information available from state and federal agencies, municipalities, universities and other research centers, and related sources is invaluable in the administration and management of Oklahoma's stream and groundwaters. Unfortunately, much of this data is widely scattered and exists in a variety of formats. Consequently, procurement of this data by a single individual, agency or organization is often difficult, expensive and time-consuming.

Establishment of a central depository for water resource data would be very costly and inefficient. A more viable approach would be to establish a central contact station with the ability to access water related data banks at all relevant state and federal agencies. The creation of a state water resource computer network and data bank, available to all participating water agencies, would facilitate the more efficient, economical and responsive administration of Oklahoma's water resources. Utilization and/or expansion of the Internet system could be a promising tool to access and disseminate water resource data.

Geographic information systems (GIS) -- which involve the use of computers for mapping and analysis of spatial information -- are a promising tool in the research, planning and management of water and other natural resources. GIS possesses various capabilities for the encoding, storage, processing and display of computerized maps and images and the manipulation of socioeconomic data which is vital to holistic water resource planning. Currently, more than one dozen state agencies and academic institutions are working independently to implement GIS technology in Oklahoma. However, only a small portion of the existing data is available for use beyond the agency or institution where it was developed and costs to create system data sets are far in excess of the costs of hardware and software. Recent legislation established a council of agencies and universities whose mission is to develop a strategy to implement a state GIS and coordinate state GIS efforts.

Recommendations

Stream Water Rights and Administration

The Oklahoma Water Resources Board should, within current statutory guidelines, seek to emphasize conservation and efficient use of stream water resources through improvement of the current system of water rights forfeiture/reduction and schedule of use. The OWRB should consider:

- allowances for a permit suspension period, rather than actual cancellation of water rights, if a concerted effort is demonstrated to market the rights;
- forfeiture exemptions for conserved water, perhaps through allowing water users to use, sell or lease the water they conserve;
- establishment of more stringent limitations on the state's schedule of use provision, unless a significant investment is made, to prevent delays in putting water to beneficial use; and
- implementation of administrative fines for failure to report water use or falsification of water report forms.

The OWRB should, within current statutory guidelines and accounting for the inherent inefficiencies associated with the various types of water systems, provide for the proper enforcement of conservation measures where excessive waste takes place through leaks, evaporation or other problems occurring during the use and distribution of permitted water.

The OWRB should study the implementation of a permitting system to account for seasonal changes in water availability, including development of guidelines for seasonal or monthly allocations and withdrawals that could free-up additional sources of water.

The Oklahoma Water Law Advisory Committee should explore potential OWRB rule revisions and/or statutory amendments that would provide for:

- more realistic and fair determinations of "beneficial use" and "present or future need" in cases of water rights adjudications; and
- assessment of administrative fines for flagrant or repeated violations of permit limits.

The OWRB should implement a system to periodically check the accuracy of reported water use and consider the implementation of requirements to emphasize accountability for water, perhaps through threat of perjury (including potential development of affidavit report forms) or initiation of water use metering for right holders who knowingly falsify or consistently fail to file reports of water use.

The OWRB should complete and provide for continuous update of hydrologic surveys to accurately determine the amount of water available in Oklahoma's rivers and streams.

The OWRB should improve education of permit holders regarding water use and conservation through agency-sponsored public workshops and related efforts involving direct interaction with the public.

Instream Flow Protection

The Oklahoma Water Resources Board should work with other appropriate state and federal environmental and natural resource agencies to develop an implementation strategy that provides instream flow protection for the state's designated scenic rivers.

The OWRB and Oklahoma Department of Wildlife Conservation should work with the U.S. Army Corps of Engineers, Bureau of Reclamation and Grand River Dam Authority to ensure that existing and modified reservoir releases are managed to provide dissolved oxygen concentrations that maintain or improve downstream conditions for aquatic life and recreation.

Indian Water Rights

The Oklahoma Water Resources Board should request the Oklahoma Water Law Advisory Committee and selected tribal representatives to explore Indian water rights and quality issues in Oklahoma. Specifically, the group should:

- study formation of a permanent committee consisting of local, state, federal and Indian representatives to address appropriate water rights issues;
- develop a mutually acceptable negotiation system or process to fairly resolve current and future water rights issues; and
- identify water resource projects warranting cooperative action.

The State Legislature should consider appointing qualified Indian representatives to appropriate boards, commissions and other governing bodies of the State of Oklahoma.

Groundwater/Stream Water Relationships

The Oklahoma Water Resources Board should:

- identify and quantify impacts that can result from the interaction between groundwaters and stream waters, especially the quality and quantity effects of groundwater withdrawal on stream water base flow;
- identify the potential benefits of the joint management and conjunctive use of state stream and groundwater supplies and develop potential management schemes which consider opportunities for watershed planning; and
- identify specific areas or watersheds/basins that could potentially benefit from conjunctive management and promote the formation of local advisory committees to guide management programs.

Groundwater Protection

The Oklahoma Water Resources Board should initiate studies to establish individual aquifer classifications based upon each aquifer's vulnerability to contamination.

Appropriate state environmental and natural resource agencies should adopt and implement a flexible, comprehensive state groundwater utilization plan that:

- prioritizes groundwater protection/utilization programs and activities; and
- avoids regulations which unduly infringe upon individual property rights while protecting legitimate public interests.

Appropriate state environmental and natural resource agencies should evaluate the use of risk assessment methodology as a groundwater protection and cleanup tool.

The OWRB should coordinate efforts of appropriate state and federal environmental and natural resource agencies, universities and organizations to establish a comprehensive state water quantity and quality data collection program to monitor the condition of Oklahoma's stream and groundwater resources.

Appropriate state environmental and natural resource agencies should encourage state communities utilizing groundwater as a major water supply source to participate in voluntary state programs to protect local groundwater supplies.

Groundwater Quality Standards

The Oklahoma Water Resources Board, through the Water Quality Standards process, should further develop and upgrade Oklahoma's groundwater quality standards as both a protection and cleanup tool. Consideration should be given to:

- development and implementation of numeric groundwater quality standards;
- development of a narrative standards statement prohibiting discharges of pollutants which result in contamination that could impair human health;
- use of risk assessment methodology;
- development and implementation of realistic, site-specific cleanup criteria to guide remediation of polluted groundwaters;
- further development of the groundwater classification system through adoption of a vulnerability mapping program utilizing DRASTIC or other appropriate methodology;
- creation of an organizational framework allowing the OWRB to separately administer stream and groundwater quality standards;
- the quality/quantity relationship and interaction between stream and groundwater resources; and
- adoption of a specific groundwater protection policy statement that indicates what type of protection (i.e., non-degradation, limited degradation and differential protection policy statements) the state will implement or achieve.

The OWRB should coordinate efforts of appropriate state and federal environmental and natural resource agencies, universities and organizations to establish a comprehensive state water quantity and quality data collection program to monitor the condition of Oklahoma's stream and groundwater resources.

Nonpoint Source Pollution

The State Secretary of Environment should:

- encourage implementation of innovative nonpoint source reduction and management practices while also stressing use of proven measures;
- assure that state programs incorporate an adequate level of watershed planning, best management practice design, water quality monitoring and assessment of progress;
- assure that state projects are focused on identified nonpoint source priority areas;
- study implementation of a comprehensive state program that accentuates voluntary nonpoint source control measures through development and implementation of appropriate management plans for operations which manage nonpoint pollution sources; and
- encourage development of technical assistance programs that promote establishment of pollution prevention plans by landowners.

Stream Water Quality Standards

The Oklahoma Water Resources Board should:

- increase efforts to implement water quality standards, especially biological criteria and total maximum daily loads, on a watershed basis, including additional protection for Outstanding Resource Waters;
- utilize the input of appropriate environmental and natural resource agencies to evaluate the use of risk assessment methodology as a water resource protection and cleanup tool; and
- bring together appropriate state and federal environmental and natural resource agencies, state universities and other involved organizations to assess current state efforts related to the collection and dissemination of water resource data and determine the need for a centralized ambient stream and groundwater quantity and quality monitoring network in Oklahoma. The OWRB should then submit study findings and recommendations to the Governor and State Legislature.

Oklahoma's Congressional Delegation should encourage the federal government to:

- limit federally mandated actions and promote promulgation of water quality standards by individual states to allow states greater flexibility in addressing state-identified priorities and regional and/or local standards issues;
- continue refinement of the Total Maximum Daily Loads concept; and
- require water quality standards implementation procedures that consider not only criteria and permit development, but also field validation of discharge permits which protect human health and aquatic life.

Municipal & Rural Water/Wastewater Systems

The State Legislature should capitalize the Statewide Water Development Revolving Fund to a level that will help ensure a continuing source of funding for water/wastewater system projects which will result in a higher quality infrastructure system for economic development and environmental protection activities.

The Oklahoma Water Resources Board and State Department of Commerce should identify and implement incentives through which state financial assistance programs can encourage local interest and cooperation in regional planning projects.

The OWRB and State Department of Environmental Quality -- in cooperation with the Oklahoma Municipal League, Oklahoma Rural Water Association and other appropriate agencies and organizations -- should develop a coordinated technical assistance strategy to promote interest in regionalization among local water/wastewater systems and encourage cooperation among potential regional entities. The strategy should define appropriate state, local and federal roles in regional water system planning -- establishing the state as a facilitator of regional planning activities and as the primary source of information (especially through the updated Oklahoma Rural Water Survey and local needs assessments) on municipal and rural water/wastewater systems -- and emphasize improved education of local water system decision-makers.

The OWRB, Department of Environment Quality, State Department of Commerce and other appropriate state and federal environmental/financing agencies should initiate a cooperative effort to promote privatization opportunities and assist in establishment of private/public partnerships, where appropriate, that will minimize regulation and result in decreased costs for governmental services.

Financing

The State Legislature should capitalize the Statewide Water Development Revolving Fund to a level that enables the Fund to meet Oklahoma's annual recurring water development needs.

The Oklahoma Department of Commerce should ensure that the Community Development Block Grant program continues to provide priority funding to water and wastewater projects that pose a serious or immediate threat to the health or welfare of citizens.

Oklahoma's Congressional Delegation should encourage the federal government to establish funding levels sufficient to satisfy upcoming Clean Water Act mandates and provide states with the maximum flexibility possible to administer state Revolving Fund programs.

Allocation & Control

The Oklahoma Water Resources Board, Corps of Engineers, Bureau of Reclamation, Natural Resources Conservation Service and other appropriate federal, state and local entities, should initiate a cooperative effort to improve and enhance the various benefits of state reservoirs through:

- evaluation of individual project operations in basins throughout the state to identify where system operating plans could be implemented or existing plans improved; and
- pursuit of cost-effective opportunities for storage reallocation in existing projects.

Oklahoma communities should participate in floodplain management and flood prevention opportunities offered under the Hazard Mitigation Grant Program, including channel improvements, construction of dikes and other diversion structures, acquisition/relocation projects, and the return of land to the floodplain and/or its natural state.

The Oklahoma Congressional Delegation should amend the Water Resources Development Act of 1986 so that reallocation of storage is based on original construction costs, as provided in the Water Supply Act of 1958.

The OWRB, Corps of Engineers and other appropriate state and federal agencies should study the potential for establishing a system to manage and administer important non-consumptive water uses, such as navigation, fish and wildlife and recreation. Consideration should be given to obtaining water rights or storage and entering into memoranda of agreement for these uses.

The OWRB, Corps of Engineers, Bureau of Reclamation, Natural Resources Conservation Service and other appropriate federal, state and local entities should develop a mechanism -- such as creation of advisory committees, consisting of representatives of appropriate water uses, or development of agency memorandums of understanding -- - to facilitate the implementation of modified system operating plans, where needed, and address disputes related to reservoir operations.

Maintenance & Renovation

The Oklahoma Water Resources Board, Corps of Engineers, Bureau of Reclamation, Natural Resources Conservation Service and other appropriate federal, state and local entities should undertake appropriate studies -- including preliminary cost/benefit estimates -- to identify potential reservoir candidates for physical modification.

The OWRB, Oklahoma Department of Transportation, State Legislature and Oklahoma's Congressional Delegation should continue to support construction of Montgomery Point Lock and Dam by the U.S. Army Corps of Engineers with a scheduled completion date of September 2001.

Water Transfer

The State Legislature and Oklahoma Water Resources Board should review existing water statutes and identify barriers to water marketing and measures that could be instituted to better facilitate voluntary water marketing and transfers and protect affected parties, including negotiations with the federal government to avoid purchasing reservoir storage at updated costs.

The OWRB should develop a state water marketing and transfer policy, including guidelines to accomplish individual marketing projects. The policy should strongly consider problems and issues identified by the OWRB in its effort to lease surplus Kiamichi River Basin water, including:

- satisfying, to the greatest extent possible, public concerns on mitigating potential impacts on local economic development;
- protecting the most locally important uses of the transferred water; and
- providing compensation, such as payments in lieu of ad valorem taxes (existing statutes provide for this form of restitution), to the area of origin.

The OWRB should study the feasibility of creating a state water bank to:

- locate and purchase sources of available or surplus water rights and storage;
- evaluate all opportunities for water importation and transfer;

- coordinate the sale and/or loan of available supplies and water rights to prospective customers, including transfers through the establishment of regional systems; and
- coordinate efforts to educate the public on water transactions.

The OWRB should identify and investigate methods to utilize untapped sources of usable water in Oklahoma through:

- development of system operating plans;
- reallocation of reservoir storage;
- utilization of sediment storage;
- administrative actions, such as the cancellation and reduction of unused water rights;
- greater consideration of reservoir storage yield that will vary according to proposed use in the receiving area; and
- consideration of additional reservoir project construction.

Weather Modification

The Governor and State Legislature should identify the state's need for (and subsequent role in) a carefully focused, multi-year cloud seeding demonstration program to determine the ultimate utility of weather modification as a water resource management tool.

Groundwater Recharge

The Oklahoma Water Resources Board should initiate a comprehensive study to identify additional potential artificial recharge areas in the state, including a detailed assessment of the Blaine Recharge Demonstration Project.

The OWRB, through the Water Law Advisory Committee, should review state water rights and water quality laws to determine what, if any, additional legislation is needed to address the various water rights and quality considerations of artificial recharge.

Reclamation & Reuse

The State Department of Health and/or Department of Environmental Quality should take an active role in establishing guidelines for the safe and authorized use of recycled wastewater, identifying programs where reuse should be automatically considered as an alternative, investigating technological opportunities for efficient water reuse and examining the effects of an expanded reuse program which considers the effects of water withdrawals on downstream users.

The Oklahoma Water Resources Board should develop measures to encourage water suppliers and individual permit holders to implement conservation/management plans -- including consideration and use of return flows and treated effluent -- to reduce consumptive use of stream and groundwaters.

Chloride Control

Until potential environmental impacts are resolved, Congress should not support full implementation of the Red River Chloride Control Project, as presently designed.

Water Conservation

The State Legislature should promote statewide water conservation by:

- encouraging cities, water supply districts and other entities to develop and implement water conservation programs that include the addition of water-saving plumbing fixtures and household appliances in new construction and as replacements for existing fixtures;
- incorporating water conservation policy goals into all appropriate activities and programs of state government; all agencies responsible for constructing, leasing, or maintaining state facilities and property should be directed to use water-conserving plumbing fixtures and devices, water efficient landscape practices and other programs to maximize water use efficiency; and
- providing appropriate funding to affected state agencies to retrofit existing state facilities with water-conserving devices.

- The Governor and State Legislature should create a permanent funding source to allow continuation of the Oklahoma Leak Detection Program.

The Oklahoma Water Resources Board and Oklahoma Rural Water Association should facilitate public education efforts to encourage participation in the Oklahoma Leak Detection Program by rural communities and water districts.

The State Secretary of Environment should appoint a task force of appropriate state agencies to develop a state water conservation plan that incorporates all aspects of public, agricultural and industrial water use. The plan should identify educational opportunities as well as potential incentives to encourage conservation.

The OWRB, Rural Development, Oklahoma Department of Commerce, Indian Health Service and other appropriate funding entities should consider incorporating incentives for development of individual water system conservation plans into their requirements for water/wastewater project financial assistance.

The OWRB and other appropriate state agencies should study establishment of a technical assistance program to assist industries in implementing water conservation measures.

The OWRB should continue to promote information among water suppliers regarding price structuring options, including the increasing block rate structure, that promote conservation while recognizing the socioeconomic requirements of Oklahoma communities. This effort should be expanded to include improved public education regarding the factors that determine the "true" cost of water (i.e., costs associated with delivery, treatment, etc.).

Basin/Watershed Management

All appropriate state and federal water resource agencies should develop and implement watershed planning and management strategies by:

- delineating uniform, manageable watershed planning boundaries, such as those currently recognized by the U.S. Geological Survey, that incorporate distinct hydrologic units of both stream and groundwater resources;
- identifying and incorporating methodologies that facilitate the evolution of local, state and federal water resource programs to a watershed management approach;
- studying creation of local watershed management organizations for problem-solving and issue resolution; and
- coordinating implementation of Geographical Information System technology at the local, state and federal level.

Drought Preparedness

The Secretary of Environment should appoint a State Water Resource Drought Coordinator to coordinate federal, state and local drought response efforts in Oklahoma. The State Drought Coordinator should be charged with developing a comprehensive drought preparedness plan for mitigating the effects of drought episodes in Oklahoma. Such an effort should include the investigation of:

- a monitoring/early warning system -- including the development and implementation of drought indices that signal the onset and/or varying stages of drought -- to provide information about the timing and severity of drought episodes;
- techniques to assess the probable impacts of prospective drought episodes;
- approaches to coordinating governmental activities including information exchange and drought declaration/revocation criteria and procedures;
- assistance programs with pre-determined eligibility and implementation criteria;
- financial/research resources needed to implement drought assessment and response activities; and
- educational programs designed to promote drought mitigation/ preparedness among the economic sectors most impacted by drought.

Wetlands Protection & Management

State and federal environmental and natural resource agencies should continue efforts to develop a state comprehensive wetlands protection and management strategy that includes:

- defining wetlands;
- designating beneficial uses of wetlands;
- identifying and inventorying wetlands within Oklahoma;
- identifying measures to mitigate losses of wetlands, protect wetlands and manage them on a watershed or hydrologic unit basis;
- developing standards for critical wetlands;
- recommending measures to ensure the protection of landowner property rights while protecting legitimate public interests; and
- defining the roles of appropriate state agencies in wetlands protection and management.

Endangered Species

Appropriate state and federal environmental and natural resource agencies should facilitate increased public involvement in the Endangered Species Act administration and decision-making process.

The Oklahoma Water Resources Board should ensure that future state water quality standards revisions consider the comments and policies of other state and federal environmental and natural resource agencies to achieve a reasonable and environmentally-sensitive balance between protection of endangered and threatened species, economic concerns, consumptive water uses and related considerations.

The Oklahoma Department of Wildlife Conservation and other appropriate state and federal environmental and natural resource agencies should improve coordination, during the planning stages, in assessing the effect of existing and potential water resource development on the state's endangered and threatened species. This effort should include identification of the status of rare, threatened and endangered species in proposed project areas and development of measures to avoid potential adverse impacts.

Floodplain Protection & Preservation

The Oklahoma Water Resources Board and State Office of Civil Emergency Management should establish a committee -- including representatives of the Oklahoma Conservation Commission, Oklahoma Department of Environmental Quality, Office of the State Secretary of Environment and other appropriate agencies -- to consider the need for a unified statewide flood control plan that addresses such issues as National Flood Insurance Program community participation, Community Rating System participation, flood hazard mitigation, dam safety, floodplain mapping, wetlands protection, and related floodplain protection/preservation measures.

The State Legislature should consider enactment of:

- a state Emergency Disaster Response and Recovery Act to facilitate state response to major flooding and other natural disasters; and
- legislation to mitigate the effects of stormwater diversion projects on the regulatory floodplain, including damages to adjacent property resulting from diverted runoff.

The OWRB and Office of Civil Emergency Management should encourage Oklahoma communities to:

- develop and maintain a priority list of eligible hazard mitigation projects;
- participate in pre-disaster planning efforts;
- create a training program, with state assistance, for community officials to educate their residents on flood disaster preparedness;
- develop local stormwater management plans;
- strengthen enforcement of local ordinances;
- develop and implement responsible flood alert systems; and
- consider, where possible, enactment of ordinances requiring an appropriate increase in local base-flood elevations.

Water Resource Dispute Resolution

The Oklahoma Office of Personnel Management should develop and offer training in dispute resolution to all Environment Cabinet agencies.

The Office of the Secretary of Environment should:

- evaluate the Administrative Procedures Act and other applicable Oklahoma laws to identify any impediments to the use of dispute resolution techniques in resolving water resource disputes; and
- direct all agencies under the Environment Cabinet to promulgate rules of procedure for alternative dispute resolution methods in their respective areas of jurisdiction.

Local Empowerment

The Oklahoma Water Resources Board should facilitate creation of a task force of citizens and appropriate agencies to reassess state, federal and local roles in water resource management to identify areas which could facilitate greater control of water resources by local entities and increased local input into state administration of Oklahoma's stream and groundwaters.

The State Secretary of Environment should form a citizens-based task force to assess the relative value and effectiveness of state and federal water quality and quantity management programs.

Interstate Water Disputes

The State of Oklahoma should continue to utilize interstate stream compacts as a major vehicle to address and resolve interstate stream water problems with neighboring states. Specifically, the Oklahoma Water Resources Board should:

- review the provisions of each of the four interstate stream compacts to ensure that they sufficiently respond to Oklahoma's water resource needs;
- explore the potential for addressing interstate environmental and water quality issues, including project construction, under the compacts; and
- propose necessary changes in the compacts to the appropriate state and federal legislative bodies.

The State of Oklahoma should cooperate with neighboring states to investigate establishment of interstate groundwater compacts to resolve potential future disputes involving shared groundwater resources.

Stream Gaging Network

The Oklahoma Water Resources Board, U.S. Geological Survey and other appropriate state and federal agencies, communities and individuals should seek to improve the efficiency and effectiveness of the state stream gaging program. This effort should include:

- identification and encouragement of partnerships and other measures to help defray costs associated with the state stream gaging network;
- identification of opportunities to improve education on the value of stream gage data and the benefits it provides to water resource managers and the general public; and
- a determination of the benefits of program expansion or potential integration into a state stream and groundwater quantity and quality monitoring network.

The State Legislature should continue financial support of current stream gaging programs so that agencies can better manage water resources, especially during periods of drought.

Water Well Measurement

The Oklahoma Water Resources Board and U.S. Geological Survey should:

- update and restrict the state water well measurement network to those with known, reliable information on construction history, depth of completion and location;
- re-evaluate the distribution of wells included in the network and refine the network accordingly;

- refine measurement procedures to improve accuracy of the well measurement program, such as testing selected wells periodically to determine their response to water level changes; and
- ensure that all water well measurement information is readily available and published on a regular basis.

Water Quality Sampling & Monitoring

The Oklahoma Water Resources Board should identify and recommend to the State Legislature a mechanism -- which operates in concert with the federal Clean Lakes Program -- to fund water quality assessment of Oklahoma lakes.

The OWRB should bring together appropriate state and federal environmental and natural resource agencies, state universities and other involved organizations to assess current state efforts related to the collection and dissemination of water resource data and determine the need for a centralized ambient stream and groundwater quantity and quality monitoring network in Oklahoma. The OWRB should then submit study findings and recommendations to the Governor and State Legislature.

Oklahoma Mesonetwork/Next Generation Weather Radar

All appropriate state and federal water resource agencies and entities should work closely with MESONET project leaders to explore opportunities for additional data collection activities and value-added products applicable to water resource management activities. These agencies and entities should also identify measures to improve delivery and dissemination of MESONET data.

MESONET supporters should coordinate efforts to provide public education on the availability, use and access of the system.

Water Resource Data Management

The Oklahoma Water Resources Board should form a committee consisting of representatives of the State Department of Environmental Quality, Oklahoma Conservation Commission, U.S. Geological Survey, Bureau of Reclamation, U.S. Army Corps of Engineers and other appropriate state and federal environmental and natural resource agencies to investigate options -- including possible use of the Internet system -- to create, fund and manage a coordinated water resource computer network and data bank that is compatible with the state Geographic Information System. This committee should also coordinate public education efforts related to availability and accessibility of water resource data.

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