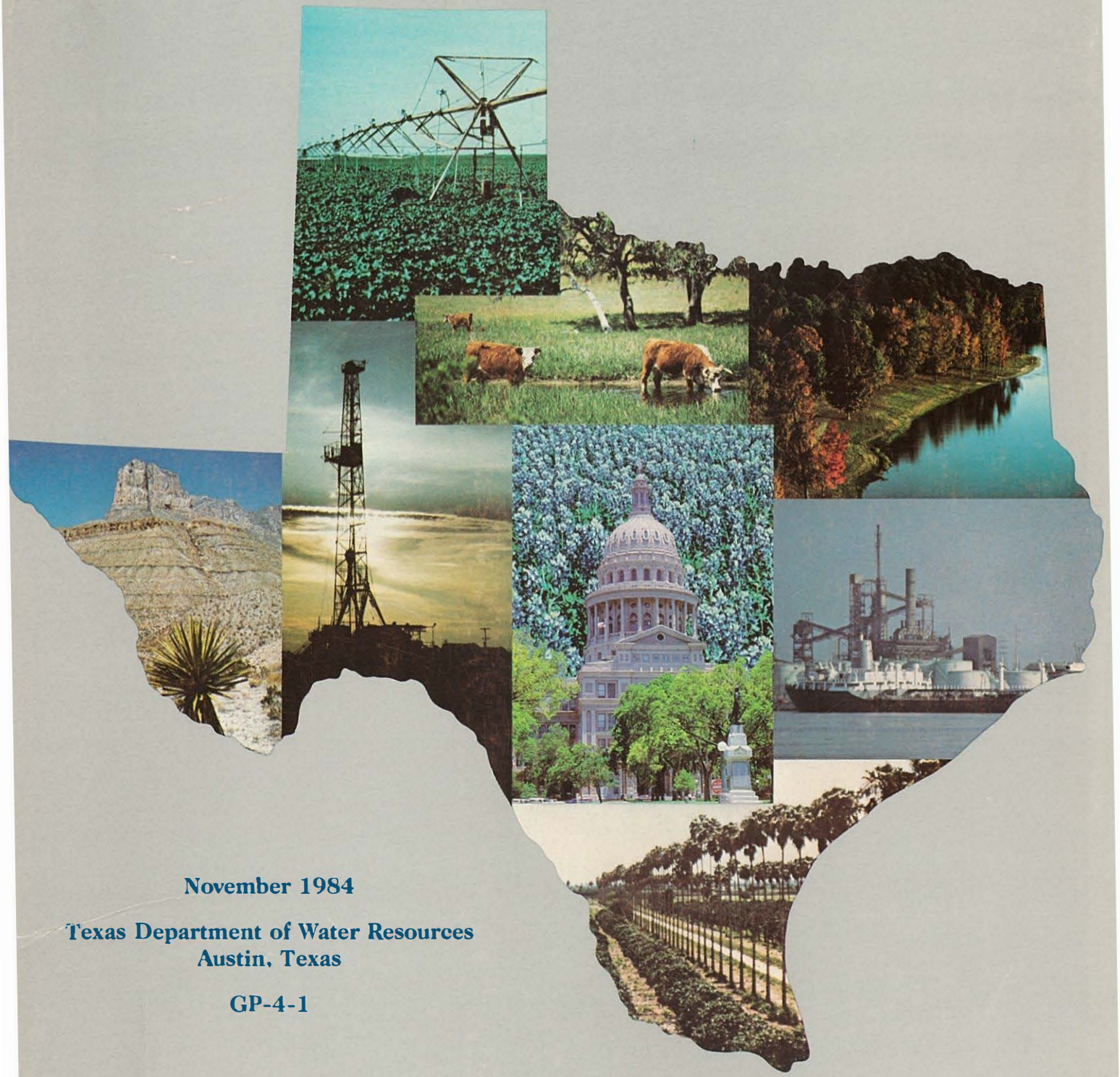
Water For Texas

A Comprehensive Plan for the Future

Volume 1



November 1984

Texas Department of Water Resources
Austin, Texas

GP-4-1

TEXAS DEPARTMENT OF WATER RESOURCES
1700 N. Congress Avenue
Austin, Texas

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The Honorable Bill Hobby
Lieutenant Governor of Texas

The Honorable Gib Lewis
Speaker of the House

The Legislature of the State of Texas

Transmitted herewith is the amended Texas Water Plan which was adopted by the Texas Water Development Board on September 20, 1984 as the official water plan for the State. This amended water plan titled "Water for Texas: A Comprehensive Plan for the Future" has been in preparation since 1981 and is the result of a planning process which included public input through 13 public meetings, interviews with community and professional leaders, a public opinion poll, and nine public hearings.

Volume 1 of the amended plan is an executive summary which sets forth planned actions and policy recommendations. Volume 2 is a technical document which provides details of current water development and use, projected future water supply and wastewater treatment needs, and potentially developable water supplies to meet future water needs in each river and coastal basin of the State.

The planned actions and policy recommendations approved by the Board include actions to be taken by the Texas Department of Water Resources and recommendations to local, State, and federal entities and the Legislature to: (1) implement actions and programs intended to address the problem of inadequate longterm water supplies in certain areas of the State, (2) increase attention to flood protection and floodplain management at the State and local level, (3) maintain strong State involvement in protecting water quality, and (4) address problems associated with the increasing strain being placed upon local entities to cope with water supply, water quality protection, water conservation, flood protection, and other water-related needs.

The People of Texas
Governor of Texas
Lieutenant Governor
Speaker of the House
The Legislature

The accelerated population and economic growth which the State is currently experiencing is imposing severe pressures on the capabilities of local units of government to implement and finance new water supply and wastewater treatment facilities necessary to keep pace with such growth. Actions are needed now to insure that Texas State government is responsive to the needs of all of the citizens.

Respectfully submitted,

Texas Water Development Board

Louis A. Beecherl, Jr. Chairman

George W. McCleskey, Vice-Chairman

Glen E. Roney, Member

W. O. Bankston, Member

Lonnie A. "Bo" Pilgrim, Member

Louie Welch, Member

Charles E. Nemir, Executive Director

Water For Texas

A Comprehensive Plan for the Future

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Section 16.051 of the Texas Water Code directs the Executive Director of the Department of Water Resources to prepare and maintain a comprehensive State water plan for the orderly development and management of the State's water resources in order that sufficient water will be available at a reasonable cost to further the economic development of the entire State. In addition, the Department is directed to amend and modify the plan in response to experience and changed conditions.

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Texas Department of Water Resources
Austin, Texas

GP-4-1

Published and distributed
by the
Texas Department of Water Resources
Post Office Box 13087
Austin, Texas 78711

PREFACE

Presented herein is an amended Texas Water Plan which sets forth planned actions and policies to address future water supply, water quality protection, water conservation, flood protection, and other water-related needs of the State. The history of water resources planning and development in Texas is discussed and the objectives of Texas water planning and the underlying concepts are described. Existing water resources and water uses, projections of future water requirements, and estimates of future water supplies are presented in regional and Statewide perspectives. Potential projects and associated costs to protect water quality, to solve water supply problems, and to meet as many of our future water needs as possible are identified. A companion document, *Volume 2—WATER FOR TEXAS: Technical Appendix,* contains more specific detail about the topics and planning concepts presented herein and also includes an analysis of current water development and use, future water needs, and potentially developable water supplies to meet projected water needs in each river and coastal basin of the State.

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VOLUME I

WATER FOR TEXAS: A Comprehensive Plan for the Future

INTRODUCTION AND BACKGROUND

How much water does Texas have? Is there enough for the people, the economy, and the environment? Will there be enough for future generations? Will it be safe to drink and to use in other ways? These fundamental questions exemplify the need to plan for water development, water conservation, and water quality management in Texas.

State policy explicitly provides for the conservation and development of natural resources. The Texas Department of Water Resources is the agency of the State given primary responsibility for implementing the provisions of the Constitution and laws of the State relating to the conservation and development of water.

State law directs the Executive Director of the Texas Department of Water Resources to prepare and maintain a comprehensive water plan for the orderly development and management of the State's water resources in order that sufficient water will be available at a reasonable cost to further the economic development of the entire State. In addition, the Department is directed to amend and modify the plan as experience and changed conditions require.

Water demands by people, industry, and agriculture, although somewhat seasonal, are continuous from hour to hour and day to day in many cases. In addition, water-using functions and enterprises cannot all be located adjacent to available water supplies. Thus, it is essential to plan, develop, operate, and maintain adequate water storage, water conveyance, water treatment, and wastewater treatment facilities for the existing people and the present economy, as well as to plan for the development of adequate facilities for the future as the population and the economy grow.

PLANNING AND DEVELOPMENT — 1900 TO 1983

Growing water demands and a highly variable climate have caused State government to develop legal and institutional arrangements to meet the water supply and water quality protection needs of the people and the economy. These arrangements include the roles of the private sector, local governments, regional authorities, State agencies, and federal agencies. Major legislative and institutional actions which underlie Texas water administration and planning (except court decisions) are listed below.[1]

In 1904, a constitutional amendment was adopted authorizing the first public development of water resources.

In 1913, the 33rd Legislature passed the first major irrigation act and created the State's first water agency — the Board of Water Engineers — to regulate appropriations of water. This act also created a water rights appropriation system based on a "first in time, first in right" priority.

In 1917, with the adoption of a constitutional amendment, Article 16, Section 59(a) of the Texas Constitution was passed. This article established the State's legal right to regulate and effectuate conservation of natural resources in the State.

In 1931, the 42nd Legislature, in the Wagstaff Act, established for the State the priorities of use that would be followed in the allocation of the State's water resources to various purposes. The preference list provided the following order for all streams in the State with the exception of the Rio Grande: (1) domestic and municipal uses, (2) processing (industrial), (3) irrigation, (4) mining and the recovery of minerals, (5) hydroelectric, (6) navigation, and (7) recreation and pleasure.

In 1944, the Texas Water Conservation Association was formed to provide a public forum for citizen participation in water matters. The Association has continued to the present.

In 1949, an appraisal of Texas water problems was prepared by the U.S. Bureau of Reclamation at the request of Senator Lyndon B. Johnson.

[1]Many water supply, water quality protection, drainage, and water conservation functions are carried out by local and regional units of government and the private sector. The legislation and administrative actions whereby these functions are specifically authorized and operated are voluminous and are not identified or discussed herein.

In 1949, the Texas Legislature enacted legislation which recognized underground water as private property of the landowners and authorized the creation of underground water conservation districts.

In 1952, Governor Allan Shivers appointed a 90-member committee, with J. B. Thomas of Fort Worth as chairman, to examine State water problems.

In 1953, the Thomas Committee recommended State financial assistance to local water projects, reorganization of the Board of Water Engineers, and preparation of a long-range water policy for the State.

In 1953, the Legislature created the Texas Water Pollution Advisory Council, composed of representatives of the Attorney General, State Health Department, Game and Fish Commission, Board of Water Engineers, and Railroad Commission, with the responsibility to focus the State program by coordinating State efforts.

During the period 1954-1956, Texas suffered the most severe drought in history. In approximately the western half of Texas, drought conditions also had prevailed during the preceeding four years and were continuous for seven years.

In 1956, the Federal Water Pollution Control Act (Public Law 84-660), enacted by the 84th Congress, authorized states to receive matching funds to finance pollution control programs and local municipalities to receive grants for up to 30 percent of the cost of the construction of waste treatment plants. The Act also strengthened provisions for federal enforcement of pollution laws.

In 1957, the drought was broken by terribly damaging floods.

In 1957, a legislative act created the Texas Water Development Board, and a constitutional amendment, approved by Texas voters, authorized the Board to administer a Water Development Fund of $200 million to help local communities develop water supplies.

In 1957, the Texas Water Planning Act of 1957, creating a Texas Water Resources Planning Division in the Board of Water Engineers, was enacted in a special session of the legislature.

In 1958, a report titled, "Water Developments and Potentialities of the State of Texas," was prepared as a joint effort by the U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, U.S. Soil Conservation Service, and Texas Board of Water Engineers. Senator Johnson caused the report to be published as Senate Document III, 85th Congress, Second Session.

In 1958, the Board of Water Engineers prepared and presented to the 56th Legislature a report titled "Texas Water Resources Planning at the End of the Year 1958." This report, prepared in response to a mandate in the Texas Water Planning Act of 1957, was essentially an inventory of the State's water resources and included recommendations for a State planning program.

In 1959, the U.S. Study Commission-Texas, created through a Congressional authorization requested by Senator Johnson, began a three-year study of land and water resources in the intrastate river basins of Texas.

In 1961, the 57th Legislature made important changes to State laws affecting water administration. The Board of Water Engineers was reorganized, renamed the Texas Water Commission, and given specific responsibilities for water planning. The Texas Water Pollution Control Board was created, replacing the Texas Water Pollution Advisory Council, and given specific duties and responsibilities including the approval of activities for pollution control work and issuance of waste disposal permits allowing the discharge of waste into State streams. Also, the Board was to promulgate and enforce rules and regulations to abate and prevent pollution, as well as coordinate among the various agencies having pollution control activities. The Board was part of the State Health Department.

In 1961, the Board of Water Engineers, at the request of Governor Price Daniel, prepared and released a report, "A Plan for Meeting the 1980 Water Requirements of Texas." This report, prepared with assistance from river authorities and water conservation districts, was essentially a plan of surface-water development for meeting municipal and industrial requirements to 1980.

In 1962, the U.S. Study Commission-Texas, a Commission of both federal and State representatives authorized by the 1957 Congressional Act, released its report recommending a plan of development for meeting the projected, 50-year water needs of the State. This plan covered only that part of the State lying within and between the Neches River Basin in the east and the Nueces River Basin in the west; that is, it included only rivers and their basins lying exclusively in Texas and excluded rivers flowing interstate, the Canadian, Cypress (Creek), Pecos, Red, Rio Grande, Sabine, and Sulphur.

In 1964, Governor John Connally, reacting to the fact that the U.S. Study Commission's report and other ongoing federal agency studies did not address the entire State, directed the Texas Water Commission to begin immediate development of a comprehensive State Water Plan. Emergency appropriations were made available to the Commission, and additional appropriations for the planning effort were also provided by the Legislature in 1965. In that year, the Legislature also restructured the State water agencies

by transferring the water resource planning functions to the Texas Water Development Board and renaming the Texas Water Commission as the Texas Water Rights Commission.

In 1965, Congress enacted the Water Resources Planning Act (Public Law 89-80) to encourage the conservation, development, and use of water and related land resources on a comprehensive and coordinated basis by federal, State and local governments, and private enterprise. The Act authorized states to receive matching grants for planning and created the Water Resources Council to review or revise these plans and formulate recommendations for the authorization of projects. At the same time, Congress amended the Federal Water Pollution Control Act to require that states adopt water quality standards for all "interstate waters," and failing that, the federal government had the option to do so.

Also in 1965, the U.S. Bureau of Reclamation released its Congressionally authorized planning report entitled the "Texas Basins Project," which recommended a coastal canal project to convey projected surplus water from southeastern Texas to various points of use along the coast, terminating in the Lower Rio Grande Valley.

In 1966, voters approved a constitutional amendment increasing the Water Development Fund to $400 million, expanding the scope of the fund's use, and placing limitations on interbasin transfers of water.

In 1966, the Texas Water Development Board's staff completed and released for public review the "Preliminary Texas Water Plan," which contained proposals for meeting the State's projected water needs through the year 2020, with the exception of the long-range needs of West Texas. In addition to proposing 53 new reservoirs, the preliminary plan envisioned a potential 980-mile long State Water Project, beginning in northeast Texas and culminating in the Lower Rio Grande Valley. During 1966, the Board held 27 public hearings and two public meetings on the preliminary plan. A hearing was held in each of the State's 23 river and coastal basins. Following these hearings, the Board substantially revised the preliminary plan.

In 1967, the Legislature passed the Texas Water Quality Act, creating the Texas Water Quality Board as a separate agency and abolishing the Water Pollution Control Board. Also in 1967, the Texas Water Quality Board adopted water quality standards for all waters in the State in accordance with the Federal Water Pollution Control Act of 1965, as amended, and the Texas Water Quality Act of 1967.

In 1967, the Texas Water Development Board initiated a cooperative program with the U.S. Geological Survey to collect data on the estuaries of Texas.

In late 1968, the Texas Water Development Board released the revised preliminary plan as the Texas Water Plan. In April 1969, the Texas Water Rights Commission conducted a public hearing in Austin on the water rights aspects of the Texas Water Plan. Shortly thereafter, the Commission issued an order finding that existing water rights had been adequately considered, and that the plan had taken into account modes and procedures for equitable adjustment of water rights affected by the plan. Subsequently, the Board formally adopted the 1968 Texas Water Plan as the flexible guide to State policy for the development of Texas water resources. The 1968 Texas Water Plan recommended development of 67 new major (greater than 5,000 acre-feet in capacity) reservoirs and two salt water barriers to meet the projected year 2020 water needs of the State and also provided a conceptual plan for storage, regulation, and distribution of some 12 to 13 million acre-feet of imported water, should it become available. The reservoirs recommended for development in the 1968 Texas Water Plan did not include off-channel reservoirs for condenser cooling in steam-electric power generation plants.

Since the adoption of the Texas Water Plan in 1969, construction of 43 major reservoirs and three reservoir enlargements has increased conservation storage capacity in the State by almost 10 million acre-feet. Of the 43 major reservoir projects completed since 1969, 24 were for water supply, 18 were off-channel cooling ponds for steam-electric power generation, and one project was for natural salt (chloride) control. Two major planning studies which considered the importation of surplus surface waters from outside the State were conducted. These studies indicate that importation is not economically feasible at this time. Presently, there are five major water supply reservoir projects under construction; however, actual construction work on two of these projects has been halted by court order.

The Texas Water Quality Act, amended by the 61st Legislature in 1969, was the basic State statute on water quality and water pollution control. It expressed State policy toward water quality control, created the Texas Water Quality Board, outlined a system of water quality control, coordinated water quality programs among the various State agencies and local governments, and provided a basis for coordinating State water quality programs with the federal government. The Act also included provisions concerning the pollution control authority of other agencies. Membership of the Board included representatives from the Railroad Commission, Texas Parks and Wildlife Department, Texas Water Development Board, and State Department of Health, in addition to three public members appointed by the Governor.

In 1969, the 61st Legislature enacted the Solid Waste Disposal Act to empower the State "to safeguard the health, welfare and physical property of the people through controlling the collection, handling, storage, and disposal of solid wastes." This Act assigned the Texas Water Quality Board jurisdiction for industrial solid waste management, and the State Health Department jurisdiction for management of municipal solid waste, as well as any mix of industrial solid waste routinely collected with municipal wastes. The Act provided that the Water Quality Board be consulted with respect to water pollution control and water quality, and the Department of Health, with respect to public health.

Between 1968 and 1970, the Texas Water Quality Board prepared an Oil Spill Contingency Plan for the State of Texas, which was approved by the Governor in 1970. The plan provided procedures to be followed in notifying the Board, the Governor's Office, other State agencies, and navigation districts in the event of an oil spill within the State. The plan also specified methods for containment and cleanup, communications, prevention of oil spills, and legal action.

In 1971, the 62nd Legislature passed, and the voters of the State approved, a constitutional amendment authorizing the Texas Water Development Board, at the direction of the Texas Water Quality Board, to issue $100 million in bonds for water quality enhancement.

In 1972, Congress amended the Water Pollution Control Act of 1956 with Public Law 92-500. These Federal Water Pollution Control Act Amendments had a significant impact on water quality planning. The Act established programs and interim goals to meet its objective using areawide waste treatment and management plans as its foundation. A broad, basin plan was prescribed in a format that could be easily and continuously updated. The law required the State management programs to specify a continuing planning process to maintain these plans, to be complemented by a facility plan which would develop the requirements for a single treatment plant or service area and lead to the selection, location, and construction of a specific facility to solve the local water quality problem. Less than one year after passage of Public Law 92-500, the State of Texas had produced (under Section 303(e) of that Act) four of the six basin water quality management plans approved nationwide. Plans for the remaining eleven major river basins in the State were completed and approved between 1973 and 1975.

Section 208 of the Act established areawide or regional planning for urban-industrial areas, where such an approach could be more cost-effective and comprehensive. The regulations required the Governor to designate the areas for 208 planning as well as the planning agency, to certify the acceptability of the plan, and to designate the management agency to implement the plan. A formal mechanism for handling the 208 planning process was established in Texas in 1974, when the Governor issued Executive Orders DB-18 and DB-18A in accordance with the Federal Water Pollution Control Act Amendments of 1972.

In 1973, the Board adopted a Continuing Planning Process containing a State strategy designed to meet the objectives of Section 303(e) of the Federal Water Pollution Control Act Amendments of 1972. It contained a Statewide assessment of water quality problems, criteria for developing the construction grant funding list, a schedule of basin planning, and other programs. In addition, the Board published a plan for industrial solid waste management in Texas, based on a survey of existing management practices. This survey was designed to provide new information to facilitate development of new regulations under the Solid Waste Disposal Act. In 1973, the Oil Spill Contingency Plan was also expanded to include spills and accidental discharges of both oil and hazardous substances, in accordance with provisions of the Federal Water Pollution Control Act Amendments of 1972 and revisions to the National Oil and Hazardous Substances Pollution Contingency Plan.

In 1973, the Mississippi River Commission, Corps of Engineers, and Bureau of Reclamation released the results of their studies of the Texas Water Plan, as authorized by a 1966 Congressional Act. The most significant of these reports was their study on the "West Texas-Eastern New Mexico Import Project," as conceptually proposed in the 1968 Texas Water Plan. The federal studies determined that the project was technically feasible, but under existing federal planning criteria it was not economically justified. The report recommended that no further studies be undertaken by Congress at that time.

Between 1972 and 1975, the Water Development Board's staff initiated a number of regional studies of water and related land resources in areas of Texas faced with severe water problems at that time. Studies were undertaken in cooperation with federal, State, and local agencies and the universities. These included a ground-water investigation for the El Paso area, and a comprehensive water supply and demand analysis for the San Antonio-Guadalupe River Basins.

In 1975, the 64th Texas Legislature enacted into law Senate Bill 137 which directed the Board to carry out comprehensive studies of the relationships between freshwater inflows and the biological productivity of Texas bays and estuaries. Reports of results of these studies were forwarded to the Legislature in 1979.

In 1975, the Governor designated eight areas in the State for 208 planning and financial assistance, with regional councils of governments as planning agencies and the Texas Water Quality Board having oversight responsibilities. Later that year, the 208 planning program was extended from urban-industrial areas to cover the entire State. Also in 1975, the Texas Water Quality Board expanded its regulatory program over industrial solid waste through a shipping control ticket or manifest system.

The enactment of the federal Resource Conservation and Recovery Act (RCRA) in 1976 expanded the State role in hazardous waste management. The law provided federal financial assistance to states to develop hazardous waste management programs equivalent to federal requirements and authorized approved states to implement these permitting and enforcement programs in lieu of federal programs. This involved the development of a State plan for solid waste management in Texas, evaluation of industrial solid waste management sites based on State and federal criteria, and development of public awareness and participation programs. In 1977, the Texas Solid Waste Disposal Act was amended to enable the State to assume administration of the RCRA program.

In 1976, Texas voters approved a constitutional amendment that increased the authorization for water quality enhancement funds from $100 million to $200 million. A corresponding amendment to increase the water development fund authorization by $400 million failed to pass.

In 1977, the Texas Water Development Board released a two-volume draft document titled, "Continuing Water Resources Planning and Development for Texas," which incorporated the results of the regional studies initiated in 1972 into a Statewide planning document for use in updating and revising the Texas Water Plan.

In 1977, the three water agencies existing at that time—Water Development Board, Water Rights Commission, and Water Quality Board—were combined by the Legislature, creating the Texas Department of Water Resources. The legislation provided that the former six-member Water Development Board continue as the Board for the new agency. The Water Quality Board was abolished and the Water Rights Commission was replaced by the Texas Water Commission, structured to carry out the judicial functions for the agency. Within this new single agency a multitude of responsibilities, including water resources planning, water quality protection, water rights administration, and water development loan administration, were placed.

Solid waste planning efforts were begun in 1978 with the Governor designating the Texas Department of Water Resources as the responsible agency for industrial solid waste planning activities under RCRA, and the Texas Department of Health as the responsible agency for municipal solid waste. This planning program consisted of data collection; grants administration, policy coordination, and public participation activities to assist in the development of the State Solid Waste Management Plan. The purpose of the industrial solid waste plan is to describe and evaluate the current program and suggest needed modifications. The plan serves as a policy guide for the recovery and reuse of industrial solid wastes, incorporates federal requirements for a State solid waste plan, and provides for the management of hazardous and non-hazardous industrial waste, which includes manufacturing, agricultural, and mining wastes, as well as air and water pollution control residuals.

During 1978 and 1979, most of the initial planning procedures under the 208 program were completed for eight urban-industrial areas as well as the remainder of the State. In 1979, the Governor certified and forwarded to the U.S. Environmental Protection Agency all 208 plans that had been completed. Altogether these comprised the State Water Quality Management Plan, which included local plans developed for wastewater treatment needs as well as specified water quality stream standards, water quality problem areas, waste load evaluations, and needed wastewater treatment and collection systems. The local plans, developed through contractual agreements with local planning agencies such as river authorities and councils of governments and reviewed by local advisory committees, had been approved by the Texas Water Development Board.

In 1979, the Governor issued an executive order designating the Texas Department of Water Resources as the State agency responsible for: coordinating all water quality management planning in the State; making recommendations to the Governor regarding designations; receiving grants for water quality management planning in the State planning area and conducting the planning (except for planning for agricultural/silvicultural nonpoint source pollution controls for which the Texas State Soil and Water Conservation Board was designated); and reviewing designated area plans. Continuing water quality management planning since that time has resulted in the development and approval of four major updating documents (Statewide wastewater facility needs) on an annual basis. Additionally, special studies have been conducted in many areas of the State to develop additional data concerning existing or potential problems identified in the initial 208 planning studies; the majority of these efforts have been through contractual agreements with local planning agencies. The staff of the Texas Department of Water Resources has also undertaken major efforts in the performance of intensive monitoring surveys and water quality

modeling which result in wasteload evaluations which prescribe levels of wastewater effluent quality necessary to maintain stream standards. These ongoing efforts also include the preparation of a biennial water quality inventory for the State and periodic (not less frequently than every three years) review and revision of the State's surface water quality standards.

For the period of 1975 through 1981, federal funding for water quality management planning in the designated areas had been provided through direct grants from the U.S. Environmental Protection Agency to the designated planning agencies (councils of governments). With the passage of the 1981 amendments to the federal Clean Water Act, the water quality management program moved into another phase with the entire program coordinated and funded through federal grants to the Texas Department of Water Resources. Federal funds are distributed, when appropriate, to local planning agencies for necessary studies on a priority basis.

In 1981, the draft State Solid Waste Management Plan was approved by the Texas Water Development Board and later approved by the U.S. Environmental Protection Agency.

In 1981, the Texas Legislature created the Texas Water Assistance Fund, to be administered by the Texas Water Development Board, and appropriated $40 million to this fund. A constitutional amendment (Proposition 4), which would have provided for one-half of the State's excess tax revenues each biennium to be deposited in the Water Assistance Fund, raised the 6 percent ceiling on authorized but unissued State of Texas bonds to 12 percent, and established a water bond guarantee program with $500 million of the general credit of the State was defeated.

In 1983, the Legislature designated the Texas Department of Water Resources as the State's lead agency in oil and hazardous substances spill response and expanded its jurisdiction from coastal areas to the entire State.

In accordance with directives of the Water Resources Development Act of 1976 (P.L. 94-587, Sec. 193), the Secretary of Commerce (acting through the Economic Development Administration), in cooperation with the Secretary of the Army (acting through the U.S. Army Corps of Engineers), and in cooperation with the States of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, Texas, and the private sector, conducted a study of the depletion of the natural resources of the High Plains region that depends upon the Ogallala Aquifer. The objective of the six-state High Plains Ogallala study was the determination of feasible resource development alternatives and recommendations (policies and actions) for assuring an adequate supply of food and fiber for the nation and a continuation of the economic vitality of the High Plains region. A report, with recommendations, was transmitted to Congress in January of 1983 by the six-state High Plains Study Council.

During consideration of Proposition 4 in 1981, criticism was voiced that there was no clear-cut plan which outlined specific water-related projects so that the Legislature and citizens would know which projects would be built with the proposed funds. Following the defeat of the proposition in the general election, the Texas Water Development Board was encouraged to proceed to prepare an amended water plan to be considered by the Legislature — a plan that would be acceptable and would contain the needed information and provisions to assure that needed water supplies are available for Texas to meet projected future requirements and also to contain an adequate financing mechanism to assure implementation of the plan.

A broad-based public involvement program was conducted early in 1982 to obtain citizens' views and ideas regarding Texas water problems and solutions. A comprehensive document was prepared which identified and described basic water policy issues in the State and was widely distributed for public review and comment. Public input was obtained through: (1) 13 public meetings; (2) written comments; (3) personal interviews with community and professional leaders knowledgeable in water matters; and (4) a professionally conducted public opinion poll.

Results were considered by a broad-based Task Force on Water Resource Use and Conservation, appointed by Governor Clements. Approximately 100 water leaders and leading citizens from all parts of Texas worked on this project, including presidents of the regional chambers of commerce — East, West, South, and Rio Grande Valley. The Task Force organized three working committees as follows: (1) Finance; (2) Water Resources Use and Conservation; and (3) Water Importation.

The Task Force Committees developed recommendations to the Governor and the Texas Energy and Natural Resources Advisory Council on the basis of results obtained from the public input program regarding water quality protection, water conservation, public education, environmental protection, water supply development, flood protection, water importation studies, water management, and State participation in water financing. A special committee of the Texas Municipal League also recommended that flood control and sewage treatment needs be included within a revised water plan and that a program of State financial assistance to individual communities, additional research and planning, and public education be emphasized in Texas water planning.

To the extent possible, the work to amend the Texas Water Plan has been based upon the public input and the committee recommendations. Using the latest information available, Department staff have revised and updated projections of population and economic growth for the period 1980 through 2030 for each county (and in the case of population, for most cities) of Texas, with specific projections for intervening points in time. From these projections of population and economic growth, estimates have been derived of the sewage treatment needs and the quantities of water that will be needed for people, industry, agriculture, fisheries, and other purposes in the future. Sewerage systems, water-supply facilities, and major water projects to meet municipal and industrial needs of most areas of the State have been identified both in terms of approximate location and time of construction. The projections and the projects were included in a draft planning report entitled "WATER FOR TEXAS: Planning for the Future" which was released by the Department in February 1983 for the purpose of receiving public input and amending the Texas Water Plan adopted by the Texas Water Development Board in 1969.

Subsequently, eight regional public hearings were held within the State to receive public response to the draft planning report. Public comments and recommendations received at these hearings have been considered in revising the draft planning report. A two-volume document which presents a plan for water conservation, water quality protection, water supply development, and water-related needs of Texas has been prepared. In *Volume 1 — WATER FOR TEXAS: A Comprehensive Plan for the Future,* data, information, planned actions, and policy recommendations are oriented toward regional and Statewide planning perspectives. In Volume 1, references are made to conditions or particular problems specific to a region or local area of the State. These references are used to highlight or exhibit a particular problem or solution and are not meant to be inclusive. The companion document to this Plan, *Volume 2 — WATER FOR TEXAS: Technical Appendix,* is organized and developed to provide more specific detail. Volume 2 contains background information and descriptive discussions of the topics and planning concepts included in Volume 1, along with identification of problems, projections of future water requirements, and estimates of water supplies potentially developable to meet projected demands within each zone of each river basin of the State.

OVERVIEW OF WATER PROBLEMS AND WATER RESOURCES

Water Problems

Rapid population growth and economic development, coupled with a climate in which water resources are scarce, have imposed real and potential water supply problems in many areas within the State. In much of the State today, available storage capacity in existing surface-water reservoirs will barely be sufficient to meet water demands during critical droughts. Additional water supplies will have to be developed to meet growing needs.

Industrialization and population increases have resulted in steadily increasing water requirements and water quality protection needs for the State. Although the trend has been toward urbanization, a significant portion of the State's population still resides in rural areas, and recent trends indicate that the population of these areas is beginning to increase after decades of decline. Rural water systems generally have difficulty in providing dependable, uninterrupted service because they are relatively small in size and the low population density of service areas commonly results in relatively high costs per customer. Drinking water standards promulgated as a result of the Federal Safe Drinking Water Act have been adopted, in part, by the Texas Department of Health. These standards apply to all public water supplies; however, a number of rural and small community systems cannot fully comply with these standards without installing new, expensive, water treatment systems.

Extensive development of ground water has resulted in several problems, some local in nature, while others are more widespread. In the Texas High Plains, the rate of use of water stored in the High Plains (Ogallala) Aquifer far exceeds the rate of natural recharge. In the Houston-Galveston area, large-scale pumpage of ground water has resulted in land surface subsidence and saline water encroachment in localized areas. Problems of water quality, both from natural and man-made causes, are expected to affect the suitability for use of water from portions of most of Texas' subsurface, water-bearing formations in the future.

Water quality problems, both natural and man-made, affect a significant part of the State's surface-water resources. Problems of naturally occurring salinity are particularly severe in the upper reaches of the Red, Colorado, Brazos, and Pecos River Basins and continue to plague development and full beneficial use of water resources in these basins. In these areas, natural pollution, primarily sodium chloride, results from salt springs and salt flats within the drainage areas of the basins. In some areas, this problem has been aggravated to some extent by oil and gas exploration and production activities.

Many of the man-made water quality problems occurring in Texas streams originate from highly populated urban areas which include Dallas-Fort Worth, Houston-Galveston, and San Antonio. The Trinity River below Dallas is dominated by treated sewage effluent during summer

EXPLANATION

1. Upper Rio Grande and Far West Texas Region
2. High Plains and Trans-Pecos Region
3. West Central Texas Region
4. North Texas Region
5. Northeast Texas Region
6. South Central Texas Region
7. South Texas and Lower Gulf Coast Region
8. Southeast Texas and Upper Gulf Coast Region

Figure 1. Major Geographical Regions in Texas

months. A similar situation exists in the San Antonio River below the San Antonio metropolitan area. In the Houston-Galveston metropolitan area, water quality problems are increasing with increasing urban and industrial development.

Serious flooding conditions have at one time or another struck most parts of the State. Flash flooding resulting from high-intensity rainstorms is common and not easily predicted. Also, the flat coastal area is vulnerable both to high tides and to heavy runoff from rainfall associated with tropical storms. In the coastal area, and in other parts of the State, the flat land surface is not particularly amenable to flood control by structural measures.

The potential effects of upstream water development on freshwater inflows to the bays and estuaries are of major concern to the State. Use of the bays for navigation, commercial shell dredging, commercial and sport fishing, oil and gas production, maintenance and propagation of marine life, and diverse recreational use is extensive. These activities make a major contribution to the viability of the State's economy. Estimates of the freshwater inflows needed for estuarine purposes, along with estimates of fresh water needed for other purposes, are included in the amended Plan.

The location of existing water supplies in relation to the areas of water need presents a significant water resource planning problem. In many areas, El Paso, the Texas High Plains, and the Lower Rio Grande Valley, for example, where existing ground-water supplies are beginning to be depleted, or where demands are beginning to exceed current surface-water supplies, there are no supplemental supplies available, except at great distances. This problem is compounded by limited availability and poor characteristics of dam and reservoir sites. Thus, supplemental water supplies, either surface or ground, may have to be transported great distances to meet future demands.

The major types of water and water-related problems in each of eight major geographic regions of the State (Figure 1) are described below.

Upper Rio Grande and the Far West Texas Region:

1. Water supplies are very limited. The surface-water and ground-water supplies of the Region are shared by Texas, New Mexico, and Mexico. During the past 30 years, the Rio Grande delivered only 65 percent of the water needed for the El Paso irrigation area.

2. High salinity in surface-water supplies due to frequent low flows, and increased salinity of municipal and agricultural return flows is detrimental to crops and cropland.

3. Ground water from the Hueco Bolson deposits is the primary source of municipal and industrial supply. The Bolson is being "mined" and saline water from adjacent saline water-bearing sands is encroaching upon the Bolson.

4. Fresh ground water is projected to meet El Paso's needs through 2010, but at higher costs for pumping and a poorer quality water.

5. Water supply for smaller cities is a problem now.

6. Flash flooding is a major problem.

Major Cities

El Paso

High Plains and Trans-Pecos Region:

1. Surface-water supplies are very scarce, with practically all such supplies already developed and dedicated.

2. The High Plains (Ogallala) Aquifer—the major source of municipal and irrigation water is being overdrafted. At the present time, the Ogallala supplies irrigation water to 4.6 million acres in the Southern High Plains (south of Canadian River) and 1.3 million acres in the Northern High Plains. By the year 2000, it is projected that the Ogallala can supply irrigation water to 7.5 million acres if an effective water conservation program is implemented and 6.0 million acres if effective conservation is not practiced throughout the area. By the year 2030, it is projected that the Ogallala can supply water to irrigate only 1.8 million acres (39 percent of the present acres) and 0.9 million acres (72 percent of present acres) in the Southern and Northern High Plains, respectively, if an effective water conservation program is not implemented.

3. Municipal and industrial water supplies are becoming more difficult to obtain and more expensive as the water table declines. Some major cities of the area will need additional supplies by 1990. Ground water in many areas is higher in fluoride and nitrate concentrations than the U.S. Environmental Protection Agency and the State allow for public consumption under the Federal Safe Drinking Water Act.

4. Localized flooding is a problem throughout the Region.

Major Cities

Odessa
Midland
Lubbock
Amarillo

West Central Texas Region:

1. Surface-water and ground-water supplies are very scarce.

2. Natural salt pollution in the upper reaches of the Red and Brazos River Basins precludes full utilization of the water resources of these basins. Also, leaking oil, gas, and salt water disposal wells and improper disposal of salt water incidental to oil and gas exploration and production have resulted in local contamination of fresh ground- and surface-water supplies.

3. High nitrate concentrations occur in the ground water in some areas due to natural phenomena, locally intensified by septic tanks, cesspools, feedlots, agricultural fertilizers, and cultivation practices. Locally, ground water is higher in fluoride than existing State standards for public consumption under the Federal Safe Drinking Water Act.

4. Major cities will need additional supplies within the next 25 to 30 years. Some smaller cities have experienced water shortages during droughts since 1980, and as a rule have poor quality water (relatively high chloride, fluoride, dissolved solids, and nitrate concentrations).

5. Brush infestation of rangeland and growth of woody species that obtain water directly from the water table or from the soils just above it (phreatophytes) compete with more useful plants for fresh water.

6. Agricultural land practices in some dryland farming areas cause increased infiltration of water directly from rainfall and from surface runoff. This has contributed to soils becoming water logged, highly mineralized, and completely unproductive.

7. Localized flooding is a problem throughout the Region.

Major Cities

Abilene
Wichita Falls

North Texas Region:

1. Surface-water development is near the maximum potential for the Upper Trinity River Basin. Water is being imported from neighboring basins to the east. Potential future surface-water projects to serve the region are located in neighboring basins to the east and the north.

2. Major cities have adequate supplies to meet projected needs until about 2000 to 2010. Cities served by the North Texas Municipal Water District are near critical water supply conditions.

3. Ground-water levels (Trinity Group Aquifer) have been lowered severely; thus, pumping costs are burdensome and will increase.

4. Quality of ground water is deteriorating as water levels decline. Fluoride concentrations of ground water are high. Surface-water quality suffers from high urban use pressures (dissolved oxygen, suspended solids, phosphates, fecal coliform, algal blooms, and aquatic plants).

5. Smaller cities throughout the area do not have adequate supplies to meet growth needs. Many are barely meeting current needs.

6. Major flooding problems exist in the Region.

7. High chloride concentrations in Lake Texoma in the Red River Basin and reservoirs in the middle Brazos River Basin preclude full utilization of the water resources of these basins.

Major Cities

Dallas	Garland	Denton
Fort Worth	Killeen	Plano
Waco	Temple	Richardson
Arlington	Sherman	Irving
Denison		

Northeast Texas Region:

1. Surface-water and ground-water resources are potentially available to meet projected needs, if projects are planned and developed on schedule.

2. Rapid growth due to development and use of lignite reserves is expected.

3. Water and air quality protection and land reclamation from strip mining are potential problems for this area.

4. In many areas, shallow ground water has high concentrations of iron and is acidic, which makes the water undesirable for municipal use and many manu-

facturing processes. These problems generally can be solved by completing wells in deeper water-bearing sands or by expensive treatment of water from shallow wells.

5. Presently, water supplies for many smaller cities are inadequate in both quality and quantity.

6. Flooding problems are present in local areas.

7. Periodically, dissolved oxygen content in streams is low due to low stream flow and low natural reaeration rates.

Major Cities

Tyler
Longview
Texarkana
Marshall

South Central Texas Region:

1. Rapid growth of cities and suburban areas is straining existing water supply and waste disposal facilities and subjecting many citizens to threat of flooding.

2. Development of surface-water projects is needed to firm up municipal supplies and reduce reliance on the Edwards (Balcones Fault Zone) Aquifer in critical drought periods. Increased use of surface water would also assist in maintaining the ecosystems and recreational opportunities of Leona, San Pedro, San Antonio, Hueco, Comal, and San Marcos Springs, and the base flow of streams to the south of the aquifer.

3. Continued protection of the Edwards (Balcones Fault Zone) Aquifer from pollution is essential.

4. Pumping from the Carrizo Aquifer in the Winter Garden area has lowered water levels more than 400 feet since 1930. Poor quality water is encroaching into the aquifer in this area. Pumping costs may soon render this aquifer an uneconomic source of irrigation water.

5. The Guadalupe, San Antonio, and lower Colorado River Basins have potential surface-water projects that can be developed.

6. The upper Colorado River Basin has serious water quality problems due to inflow of saline ground water.

7. The Region has other local salinity problems and flooding problems from locally intense storms.

Major Cities

Austin
San Antonio
San Angelo

South Texas and Lower Gulf Coast Region:

1. The Region has insufficient quantities of surface water and ground water to meet growth needs for all water-using purposes. Surface-water supplies are practically all developed and committed. During extended drought periods, some of the current requirements cannot be met.

2. Soil salinity and drainage problems are present locally.

3. Flooding and storm surge problems exist.

4. Woody species that obtain water from the water table or from the soils just above it (phreatophytes) compete with more useful plants for water.

5. Surface-water quality in the region is generally good, but low dissolved oxygen occurs in some stream segments during summer months.

6. Navigation facilities, channel maintenance, dredge spoil disposal, and bay and estuary protection require continuing management programs.

Major Cities

Brownsville	Laredo	Harlingen
Kingsville	McAllen	Corpus Christi

Southeast Texas and Upper Gulf Coast Region:

1. Land surface subsidence and salt water encroachment result from overdevelopment of ground-water supplies.

2. The Houston and Galveston areas have water supplies to meet growing needs until 1990 to 1995.

3. Smaller cities are having problems from lack of surface-water availability and insufficient treatment, conveyance, and storage facilities.

4. Storm surge flooding and drainage problems are present.

5. Salt water intrusion during periods of low flow in the Brazos, Neches, and Trinity Rivers has the potential

for contaminating the freshwater supply at existing intake facilities.

6. Navigation facilities, channel maintenance, dredge spoil disposal, and bay and estuary protection require continuing management programs.

7. Water quality problems require a continuing management program.

Major Cities

Houston	Victoria	Nacogdoches
Galveston	Bryan	Huntsville
Beaumont	College Station	Orange
Port Arthur	Lufkin	

The conditions described above are illustrative of the types of water problems present in major geographic areas of Texas. However, it is emphasized that each area has significant water resources and water resource facilities that are now being used. These problems have been identified for the purpose of developing and suggesting plans to solve as many of them as possible.

Ground-Water Resources, Development, and Use

More than 50 percent of Texas is underlain by seven major aquifers and sixteen minor aquifers (Figures 2 and 3). Collectively, these aquifers receive an average annual natural recharge of about 5.3 million acre-feet (one acre-foot of water equals 325,851 gallons) and contain about 430 million acre-feet of water in storage that is recoverable using conventional water well technology. Of this total, about 89 percent, or 385 million acre-feet, is in the High Plains (Ogallala) Aquifer. Of the 17.9 million acre-feet of water that Texans currently use annually, about 10.9 million acre-feet is from ground-water sources. Of the 10.9 million acre-feet of ground water used, 11.9 percent, or 1.3 million acre-feet, is for municipal uses; 2.3 percent, or 249 thousand acre-feet, is for manufacturing purposes; 0.5 percent, or 53 thousand acre-feet, is for steam-electric power generation; 1.7 percent, or 183 thousand acre-feet, is for mining; 1.1 percent, or 120 thousand acre-feet, is for livestock watering; and 82.5 percent, or 8.9 million acre-feet, is for irrigation. About 50 percent of municipal water is obtained from ground-water sources. Ground water is used for municipal purposes in all areas of Texas and in practically every county. However, in many areas, the long-term use of ground water is lowering water levels to the extent that major water supply problems are occurring, or are projected to occur, in the foreseeable future.

Surface-Water Resources, Development, and Use

Texas has 15 major river basins and eight coastal basins which have approximately 3,700 designated streams and tributaries and more than 80,000 miles of streambed, 16,000 miles of which are subject to specific numerical water quality criteria established and adopted by the Department of Water Resources in cooperation with the U.S. Environmental Protection Agency (Figure 4). Long-term average annual precipitation ranges from 8 inches in the El Paso area to more than 56 inches in the Beaumont area (Figure 5). Average annual runoff (streamflow) is about 49 million acre-feet. Runoff ranges from about 1,100 acre-feet per square mile at the Texas-Louisiana border to practically zero in parts of the Trans-Pecos Region of far West Texas. From 1940 through 1970, Statewide runoff averaged 57 million acre-feet per year during the wettest period (1940-1950), and 23 million acre-feet per year during the severe drought of the early and mid-1950's.

There are currently 184 major reservoirs (36 federal and 148 non-federal) with 5,000 acre-feet or greater total capacity in Texas (Plate 1). In addition, there are five reservoirs presently under construction (four federal and one non-federal). Conservation storage capacity in existing major reservoirs and those under construction totals about 32.3 million acre-feet. Flood control storage capacity totals about 17.5 million acre-feet. The dependable (firm) water supply—the uniform yield that can be withdrawn annually from conservation storage through extended drought periods—from major reservoirs is about 11 million acre-feet annually. Texans now use about 7.0 million acre-feet (64 percent) of this dependable surface-water supply. A little over 21.7 percent is for municipal uses, 18.2 percent is for manufacturing purposes, 3.9 percent is for stream-electric power generation, 0.8 percent is for mining, 1.8 percent is for livestock watering, and 53.5 percent is for irrigation. A large portion of the remaining 4.0 million acre-feet of dependable surface-water supply is committed through permits and contracts to meet growing municipal and industrial needs of major metropolitan areas of the State over the next 30 years. This supply, however, will not meet all of the projected municipal and industrial needs of many Central, South, North Central, and West Texas cities. It is also projected that many cities in the eastern part of the State will need to develop additional surface-water supplies in the near future.

Water Quality

The quality of State waters has improved significantly during the last decade. Most of this improvement is directly related to the establishment of the Texas Water Quality Management Program and recent advances in wastewater treatment by industries and municipalities. The Department has determined that 244 of the 311 State Water Quality Segments currently comply with applicable stream

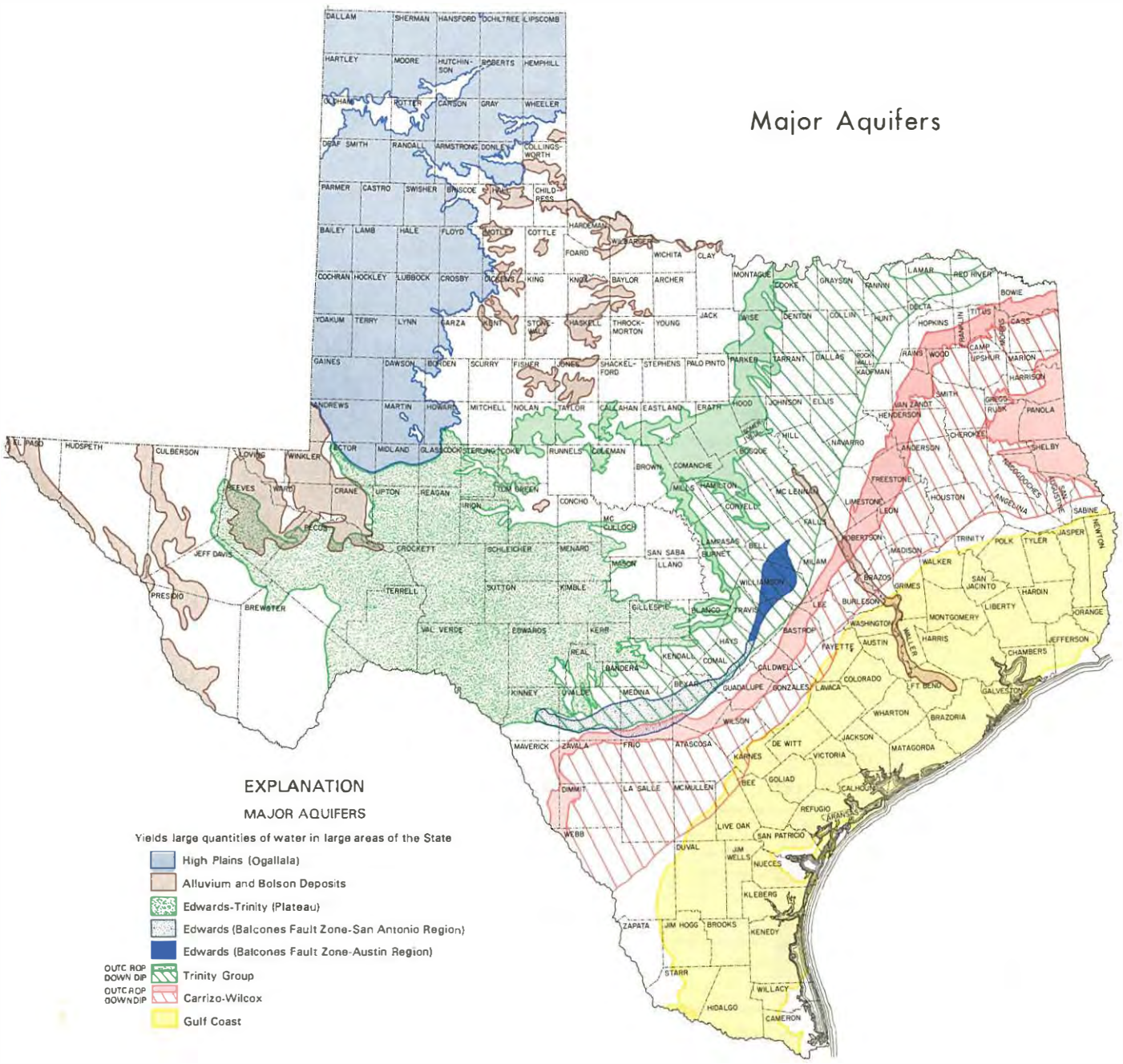


Figure 2. Major Aquifers

standards or will be in compliance after implementation of best practicable treatment plans by local industries and secondary treatment by municipalities. In addition, over 90 percent of the 16,115 stream miles in Texas are compliant with the national goals of "fishable and swimmable" waters (Plate 2).

The Texas Water Quality Management Program is designed to provide basic protection and planning for improvement of the State's waters. In practice, the most important program areas include:

1. The Texas Water Quality Inventory—intensive sur-

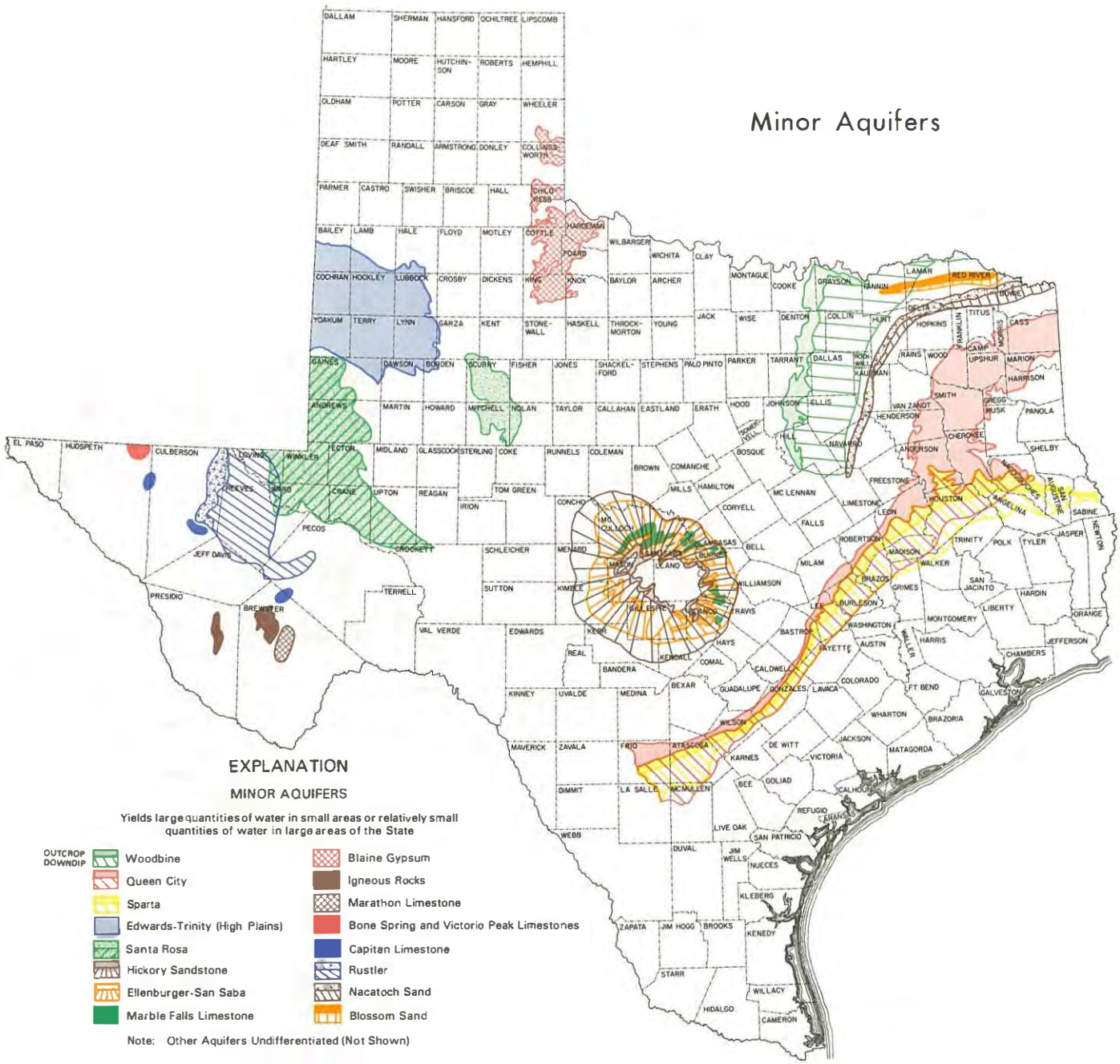


Figure 3. Minor Aquifers

veys and extensive Statewide monitoring of the Water Quality Segments;

2. Statewide and Areawide Water Quality Management Planning—identification of problem areas leads to the development of multi-year management strategies;

3. The Texas Water Quality Standards and Effluent Limitations—surface-water standards and waste discharge permit limits reflect both State and federal laws enacted to protect water supplies;

4. The Permit Process—State permitting of wastewater discharges, waste injection wells, and industrial solid

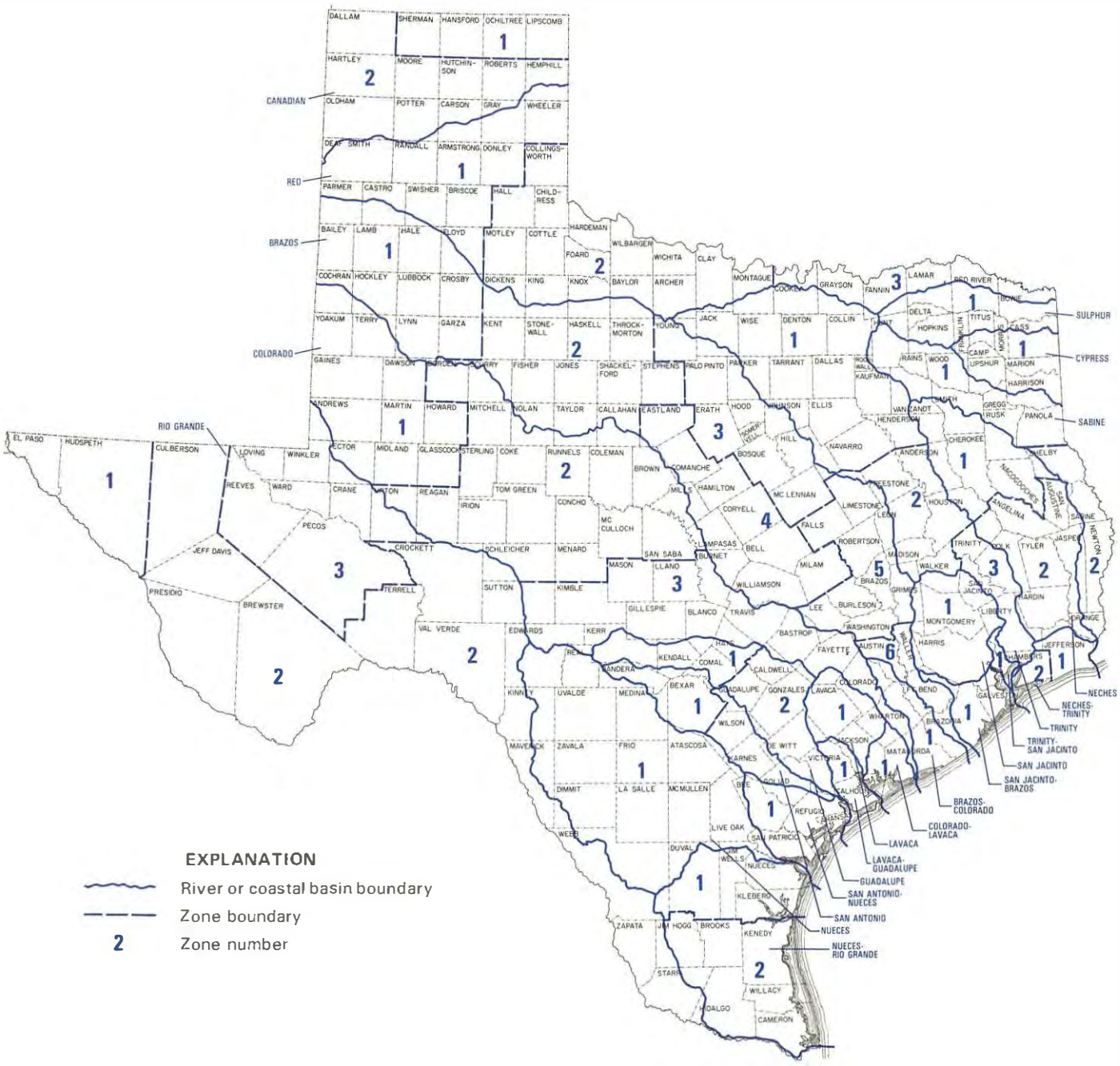


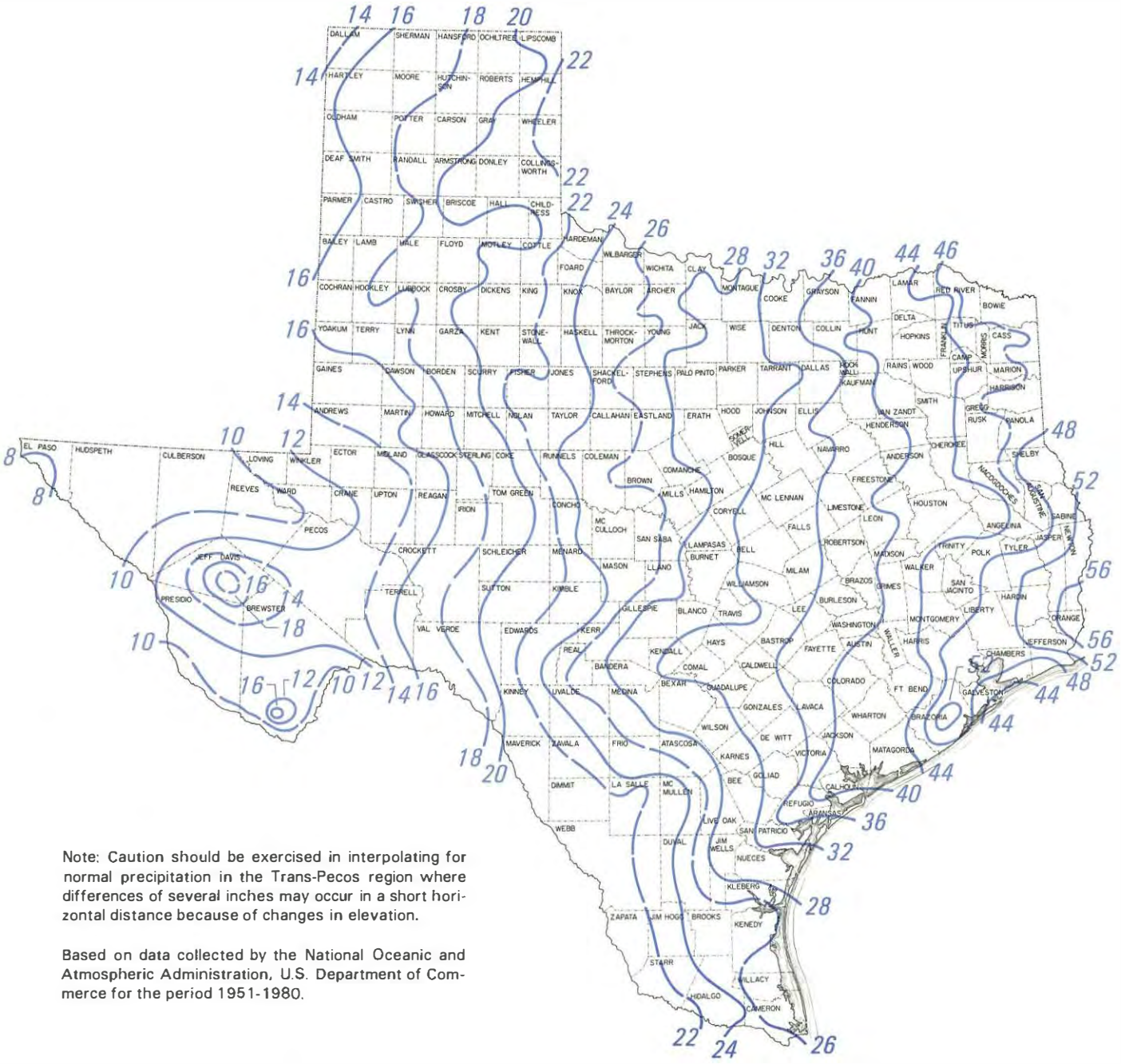
Figure 4. River and Coastal Basins and Zones

waste facilities involves technical review and public hearings where interested persons can be parties to the proceedings and present evidence and positions;

5. Enforcement—a principal tool for compelling adherence to State permits and standards that protect the quality of Texas waters;

6. Construction Grants—planning and financial assistance to local governments constructing wastewater treatment plants improves State water quality and lessens environmental impacts associated with human use; and

7. Hazardous Waste Management—a recently-



Note: Caution should be exercised in interpolating for normal precipitation in the Trans-Pecos region where differences of several inches may occur in a short horizontal distance because of changes in elevation.

Based on data collected by the National Oceanic and Atmospheric Administration, U.S. Department of Commerce for the period 1951-1980.

Figure 5. Normal Annual Precipitation (Inches)

expanded program area that involves hazardous waste disposal permits, underground injection control, "cradle to grave" tracking of wastes, identification and clean-up of abandoned waste sites (federal Superfund actions), and the Texas Oil and Hazardous Substances Pollution Contingency Plan for rapid State response to emergencies and accidental spills.

The federal Resource Conservation and Recovery Act of 1976 directed the development of a national hazardous waste management program by the U.S. Environmental Protection Agency (EPA). The Act also established a procedure whereby the EPA could authorize a state to implement a consistent state program in lieu of the federal program. The Texas Hazardous Waste Management Program satisfies both State and federal requirements, and is being implemented with financial assistance and oversight from the EPA. The Texas Solid Waste Disposal Act defines a hazardous waste as a discarded material of a solid, liquid, semi-solid or contained gaseous form that can cause or

significantly contribute to serious illness or death, or that poses a substantial threat to human health or the environment when improperly managed. Under this State Act, the Department of Water Resources and the Department of Health are, respectively, delegated the responsibilities for management of industrial solid wastes and municipal solid wastes.

The EPA has also awarded the Department's Underground Injection Control Program primary authority to permit, monitor, and enforce regulations associated with such activities as solution mining projects and municipal and industrial waste disposal well operations. The Department has issued over 200 permits for the underground injection of liquid wastes into deep salt water aquifers, and there are currently 140 active permits for these waste disposal (Class I injection well) projects. Industrial wastes disposed of by deep well injection are typically low volume wastes that are not readily amenable to disposal by such methods as incineration or treatment and discharge into the State's waterways. In addition, there are more than 70 brine solution mining projects, 30 uranium mines, 4 sulphur mines, and 3 sodium sulfate mines which together account for more than 200 separate injection wells in Texas that are being permitted under this State program.

The Department has determined that both groundwater and surface-water resources can be adequately protected from contamination (pollution) if the injected fluids are confined to suitable subsurface strata that are not hydrologically connected with useable freshwater aquifers, provided injection pressures are within defined limits and injection wells are properly designed and operated. After permits are issued, the Department is also responsible for monitoring operational compliance of these injection well projects. At present, underground injection wells are being used in Texas for disposal of municipal and industrial wastes, storage of natural gas and petroleum products in subterranean caverns, operation of heat-pump systems, recovery of minerals by solution mining, injection of excess rural (agricultural) and urban runoff, secondary oil and gas recovery, and brine disposal of brines associated with oil and gas production.

Floodplain Management

All of the 254 counties in Texas have been designated by the Federal Emergency Management Agency as having some flood prone areas in which human life and property are subject to flooding risks. Many of the counties and cities have adopted local floodplain management programs in compliance with federal requirements regarding participation in the National Flood Insurance Program (NFIP). As of June 1984, 661 cities, 108 counties, and 12 special purpose districts had chosen to participate in the NFIP. Participation in the NFIP makes flood insurance available to residents presently residing within floodplains in these areas and affords some degree of protection against monetary losses due to flooding. To qualify for the NFIP, political subdivisions must comply with the requirements and criteria of the program. These requirements encourage sound land use by minimizing exposure of property to flood losses.

Bays and Estuaries

Texas has 11 major river basins which are associated with bays and estuaries of primary importance. There are 7 major and several minor estuaries distributed along the 400 miles of Texas Gulf coastline (Figure 6). Texas estuaries are generally characterized as drowned river mouths (the results of an ancient rise in sea level), and are complemented by elongate barrier islands that enclose about 1.5 million surface acres of open water and at least an additional 1.1 million acres of marshes and tidal flats. These coastal environments produce over 100 million pounds per year of seafoods harvested by sport and commercial fishermen. At this level of fishing activity, the total annual impact on the Texas economy is currently about $1.25 billion (1980 dollars). Virtually all of the coastal fisheries species are considered to be estuarine-dependent during at least some portion of their life cycles. The estuaries, in turn, are dependent on freshwater flows from Texas streams and rivers for sediments, nutrients, and a viable salinity gradient that allows inhabiting organisms to survive, grow, and reproduce.

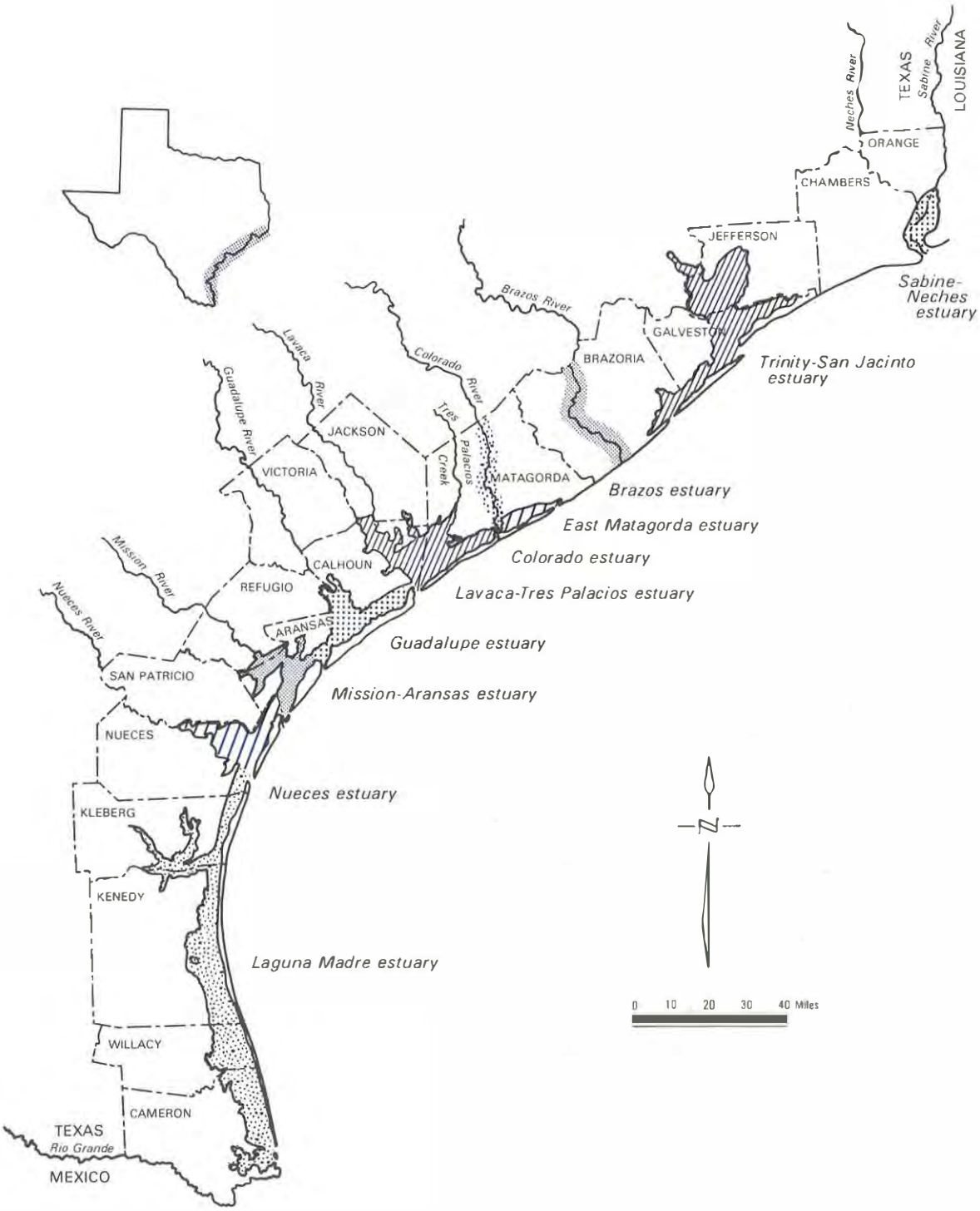


Figure 6. Locations of Texas Estuaries

PLANNING CONCEPTS AND OBJECTIVES

THE GOALS

The objective of water resources planning is to provide a comprehensive State water plan that will serve as a flexible guide to State policy for the development, management, conservation, and protection of water resources for the State. The plan will identify and equitably consider the public and private interests and institutions of the entire State, giving appropriate attention to environmental factors, while promoting economic welfare. The plan, as a flexible guide, will identify alternative strategies for implementation in order to give direction to appropriate private and public institutions in the State to enable them to:

1. Supply in a cost-effective manner sufficient quantities of suitable quality water in each area of the State, as the population and the economy of Texas grow, taking into account the potentially achievable effects of improved water-use efficiency and water conservation;

2. Continuously protect the quality of both surface and ground water in each area of the State, and where practical and feasible, improve its quality; and,

3. Provide protection of human life and public and private property from flooding and flood damage, to the extent that such flood protection can be determined to be economically feasible.

A Texas Water Plan adopted by the Texas Water Development Board is a flexible guide for use by the State, local governments, and the private sector to solve their water problems.

The Texas Department of Water Resources, other State agencies, and federal agencies provide information and technical assistance to local governments and the private sector to solve certain local water-related problems, and can provide limited financial assistance to local governments for these purposes. The Department, other State agencies, and federal agencies also administer regulatory programs pertaining to water quality and water rights, but the State agencies normally do not engage in the construction and operation of water works facilities. Local governments and private establishments, assisted to some extent by federal agencies, must develop detailed water quality protection and water supply project plans, arrange for the necessary permits, obtain financing, and construct and operate water works facilities.

WATER RIGHTS

Formulation of the Texas Water Plan has been based upon these tenets of water rights administration:

1. The Plan will not interfere with vested rights under existing water right permits.

2. For planning purposes, intrabasin needs for all beneficial purposes developing within the ensuing 50-year period will have priority over exportation for out-of-basin demands.

3. Water temporarily surplus to intrabasin requirements and to the satisfaction of existing rights at any time will be conserved and exported to meet out-of-basin needs only under valid permit and contractual agreements.

4. Rights under any new permits as might be held by the Texas Water Development Board will be obtained through full compliance with rules and procedures of the Texas Department of Water Resources.

FEDERAL-STATE-LOCAL RELATIONSHIP

There are several federal agencies and departments with the authority and responsibility to assist states in the development, utilization, and conservation of water. The most notable of these are the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, the U.S. Geological Survey, the U.S. Soil Conservation Service, and the U.S. Environmental Protection Agency. There are ten

State agencies in Texas that have responsibilities to a varying degree for the administration of water law and water policy. Of these, the Texas Department of Water Resources has the major responsibility for managing water resources. However, the political subdivisions at the regional and local levels of government, of which there are more than 2,100 in Texas, actually construct (except for federally constructed multi-purpose reservoirs), operate, and maintain the water supply and wastewater treatment facilities in Texas. In addition, there are about 800 rural water supply corporations, 750 investor-owned public water supply systems, and thousands of private water and wastewater systems operating in Texas.

Implementation of the Texas Water Plan will continue to be a coordinated and cooperative effort of the federal government, the State of Texas, political subdivisions of the State, and private interests, each acting within the scope of its authority and policies, and within the objectives and framework of the Plan. The State will be a major participant, on a partnership basis with the federal government, in assisting local interests with the orderly development of the State water resources. However, it is clear that the State will have to play a greater role in financial assistance in the future than it has in the past due to the trend toward declining federal participation.

INTERSTATE STREAM COMPACTS

The apportionment of water from sources flowing along or across the boundaries of Texas will be made on the basis of the five jointly conceived interstate stream compacts that have been ratified by the states involved and the U.S. Congress.

THE PLANNING HORIZON

The planning horizon for this amended water plan is the period 1980 through 2030, with all important data and projections of annual water requirements and annual water supplies tabulated and listed for the years 1980, 1990, 2000, 2010, 2020, and 2030, respectively. This specification of the 50-year planning horizon is necessary in order to comply with Section 16.052 of the Texas Water Code which provides that for the purpose of planning the basin of origin of any surplus surface waters shall have its projected 50-year water requirements protected from transfer out of the basin except on a temporary interim basis.

THE PLANNING AREAS

Texas has 15 river basins and 8 coastal basins. In accordance with Section 16.051 of the Texas Water Code, each basin is designated as a separate planning area for the purpose of calculating in-basin water supplies and for projecting the 50-year foreseeable future in-basin water requirements. Because of the wide range of hydrologic conditions and water uses within Texas river and coastal basins, each basin has been divided into homogeneous subareas or zones to facilitate presentation of information and planning analyses (Figure 4).

POPULATION AND ECONOMIC GROWTH

In preparing projections of future water requirements, it was assumed that an adequate supply of suitable quality water would not be a limiting factor influencing future population and associated economic growth in Texas. However, the projections are based on the availability of all other resources, including current industries, educational institutions, labor force, capital markets, business atmosphere, natural resources, and state, national, and world markets. Based on different sets of assumptions regarding these generalized resources, a range of scenarios with high and low limits were developed. The projection process thus results in a range of possible values at a given point in time. Because of the long lead times involved in developing a major surface-water supply project, over 20 years at the present time, and because the accuracy of predictions diminishes with time, projections should be revised periodically to reflect changing conditions. Projections should be revised at least every 10 years, and ideally every 5 years, if they are to be acceptable as a basis for planning.

GROUND-WATER AVAILABILITY

The estimate of the ground-water supply capability of each area of the State is based on the assumption that some form of ground-water management program will be instituted in each area of the State where it is prudent to do so. For some areas, it is feasible to allocate ground-water supplies on a safe-yield basis, specifically, in areas where natural recharge is significant and in some areas where ground water can be "mined" from storage without causing harm to the aquifer or to users. Using the safe-yield approach, it is assumed that ground-water supplies to be utilized in many cases in conjunction with surface-water supplies and facilities, particularly where such coordinated operation of water supply facilities would be expected to lower the cost of providing adequate water supplies.

In parts of West Texas and in the High Plains, where natural recharge to aquifers is negligible and ground-water mining is necessary and practical, it is assumed that ground water will be mined at a decreasing future annual rate according to the hydrologic capabilities of the aquifers. Where applicable and feasible, alteration in the areal distri-

bution of pumpage is taken into account in the planning projections. In these areas, significant water shortages are projected to occur, and in certain cases some surface-water supplies would be allocated to reduce the shortages, whenever such surface-water supplies can be feasibly considered as potential sources of water to offset the reduction in supplies of ground water.

SURFACE-WATER AVAILABILITY

Surface-water supplies estimated in the Plan to be available for use and distribution to meet total projected future water needs in the State are based upon quantities that are anticipated to be available during a recurrence of the most critical drought period of record. Supplies available in such drought periods represent the smallest volume of surface-water supplies anticipated to be available for beneficial use. The sources of these supplies include the firm annual yields of reservoirs, direct runoff and spring-flow during the worst year of the critical drought, and municipal and manufacturing return flows upstream of major reservoirs and water diversion points.

The water available from a particular reservoir project is based upon the firm annual yield of the project. The firm annual yield of a reservoir is defined as the maximum quantity of water that can be withdrawn each year, on a dependable basis, during a repetition of the most critical drought of record.

Projected annual return flows from municipal and manufacturing water users are included in water availability projections in the Plan. These return flows are included as a surface-water resource where they could reasonably be expected to be captured for reuse. Return flows from irrigation are estimated but are not considered as a dependable resource for planning future water supply because irrigation return flows of any significance occur only in coastal areas and generally cannot be captured for reuse. However, return flows not recaptured for reuse represent an important freshwater inflow source for Texas bays and estuaries.

PROJECT PRIORITIZATION

On the basis of projections of population and economic growth and associated water needs, water-resource projects considered necessary to meet these needs are specifically identified and described in *Volume 2—WATER FOR TEXAS: Technical Appendix,* in the discussion of problems and needs within each river and coastal basin of the State. These projects, which include well fields, additional or enlarged reservoirs, and new or enlarged water-delivery systems to convey raw water supplies from existing or new sources to areas of current or projected need, are scheduled according to their estimated time of need. In practice, each project will be staged and constructed by local and regional units of government in time to meet water demands as they develop. The merits of each project will be evaluated on a case-by-case basis by the local sponsors and, where appropriate, by the State, considering need, existing statutory water use priorities, and the ability to improve the efficiency of the future use of the water resource in the particular region or locale.

WATER USE CATEGORIES

The major water-using purposes for which future water demands were projected are: municipal and commercial; industrial; steam-electric power; agricultural; and mining. These purposes are defined below.

With the exception of some light manufacturing operations, the municipal and commercial water use category includes the quantity of water used by people in private residences for drinking, cooking, dishwashing, laundry, bathing, toilet flushing, lawn watering, car washing, swimming pools, and other purposes; by business establishments, restaurants, car washes, public offices and institutions (except municipally-owned steam-electric generating plants); and by municipalities for sanitation, maintenance of grounds, fire protection, swimming pools, and other users supplied from municipal systems. Light manufacturing water use is included in the municipal category, in contrast to the industrial use category, since the characteristics of water use—drinking, sanitation, air-conditioning—in these manufacturing firms more closely compare to the characteristics of municipal use than to the characteristics of industrial use.

Water used for industrial purposes is distinguished from water used for municipal and commercial purposes in that it is an integral part of the production process. In addition to drinking and sanitary water uses, industrial water requirements serve such process-specific purposes as cooling, boiler feed, cleaning and washing, pollution control, and extraction and separation of desirable materials from by-products and waste materials. Incorporation of water into the final product also is a major aspect of industrial water demand, especially in the production of food and beverage products.

Steam-electric power plants use large quantities of water to remove heat from their condensers, plus a small quantity of water for boiler feed make-up. Only a small fraction of the condenser cooling water, about, one percent, is actually consumed through evaporation, however, and the remainder is commonly returned to an adjacent cooling pond and subsequently recirculated through the

condensers. In some situations, the condenser cooling water is drawn from a moving body of water—river, reservoir—and thus makes only a single pass through the condensers. In these situations, only the quantity of water evaporated in dispelling the heat absorbed from the condenser is part of steam-electric power generation water requirements. Similarly, in systems using cooling ponds, only the quantity of water evaporated is considered in steam-electric power generation water requirements. With respect to steam-electric power plants which derive cooling and boiler-feed water needs from ground-water sources, the total volume of ground water withdrawn from storage is considered consumed.

Agricultural water use accounts for the water that is used on-farm for irrigation of field, vegetable, and orchard crops and for livestock watering. In irrigated areas supplied from surface-water sources, water losses incurred in transport from the supply source to the farm are also included as a part of the agricultural water requirements.

The principal use of fresh water for mining in Texas is in the recovery of crude petroleum by waterflooding oil-bearing formations. Lesser volumes are used in the production of sand and gravel, in the recovery of minerals other than petroleum to separate useful materials from by-products and waste, and for land reclamation following the surface mining of lignite.

PLANS TO MEET WATER QUALITY PROTECTION AND WATER SUPPLY NEEDS

In order to solve Texas water problems, it will be necessary to protect the quality of existing supplies, increase the efficiency with which water is used, increase the quantity of water supplies where additional supply can be developed, and provide flood protection where possible. Water conservation through increased water-use efficiency in agriculture and industry, reduced per capita use of municipal supplies, and reduction in distribution line leakage can allow existing supplies to meet the needs of a larger number of people and support larger levels of industry and agriculture. However, it is clear that water conservation alone cannot meet all of the growing needs for water. Thus, it will be necessary, where possible, to increase the use of ground water, develop additional surface water, continue the research and development of desalting, ground-water recovery, and weather modification technologies, and consider importing water from outside the State.

The amended Texas Water Plan, as formulated in this report, is an assessment of the future water needs of Texas and proposed actions to meet these needs, where practical. The proposed actions include conservation and reuse, construction of wastewater treatment plants, the development of both ground- and surface-water resources, the development of storage, distribution, and treatment facilities, research, and flood protection. A schedule of proposed facility construction is included in the Plan.

The proposed action program in this Plan is intended to be a flexible guide to the management and development of the State's water resources. The implementation of this plan depends to a large extent upon actions of local and regional interests, such as municipalities, river authorities, water districts, and private enterprises. The Department will be involved in water conservation, water quality protection, water rights administration, and water resources planning; however, the construction, operation, and maintenance of projects must be done by local and regional units of government, and the private sector.

PROJECTIONS—POPULATION AND WATER REQUIREMENTS

Texas population has increased rapidly since 1930 (Figure 7). In each decade growth has been above the national increase, and in the decade of the 1970's the increase was much greater than the national average, 27.1 percent for Texas and 11.1 percent for the Nation. By 1930, the population of the State had risen to 5.8 million, by 1960, to 9.6 million, and by 1980, to 14.2 million. In 1983, the Texas labor force is reported at 7.41 million, with 6.85 million employed. Annual personal income is nearly $175 billion. Texas has developed into a broad-based industrial, service, trades, energy, and agricultural economy. The people, the economy, and the environment must have dependable supplies of suitable quality water in order to survive and to continue to enjoy a favorable level of living.

Projections of population and future levels of manufacturing, energy, and agricultural production were made for counties, and cities as appropriate. High Series and Low Series projections were made for population growth and for each of these major water-use categories. Population projections are based on vital statistics for each Texas county, with different estimates of migration rates into Texas distinguishing the two series. The High Series reflects a continuation, on through the 1980's and the decade of the 1990's, of the high rate of migration into the State experienced during the 1970's. The Low Series reflects a slower rate of migration into the State characteristic of rates of the past three decades. Economic growth projections are based upon the best available data from industry and agriculture, including the outlook for foreign markets and foreign competition in manufacturing. From these population and economic projections, water quality protection and water supply needs in municipal, commercial, and rural-area domestic uses, and manufacturing, agriculture, steam-electric power generation, and mining needs were derived. Corresponding with the High and Low Series projections of population and economic activity, a High and Low Series of water requirements were projected.

In 1980, the reported population of the State was 14.2 million people (Table 1; Figure 7). The largest cities in the State are Houston, Dallas, San Antonio, El Paso, Fort Worth, Austin, Corpus Christi, Lubbock, Arlington, and Amarillo (Table 2). In the High Series population projection, the State population is projected to be 21.2 million in the year 2000, increasing to 34.3 million in 2030 (Table 1). In the Low Series population projection,

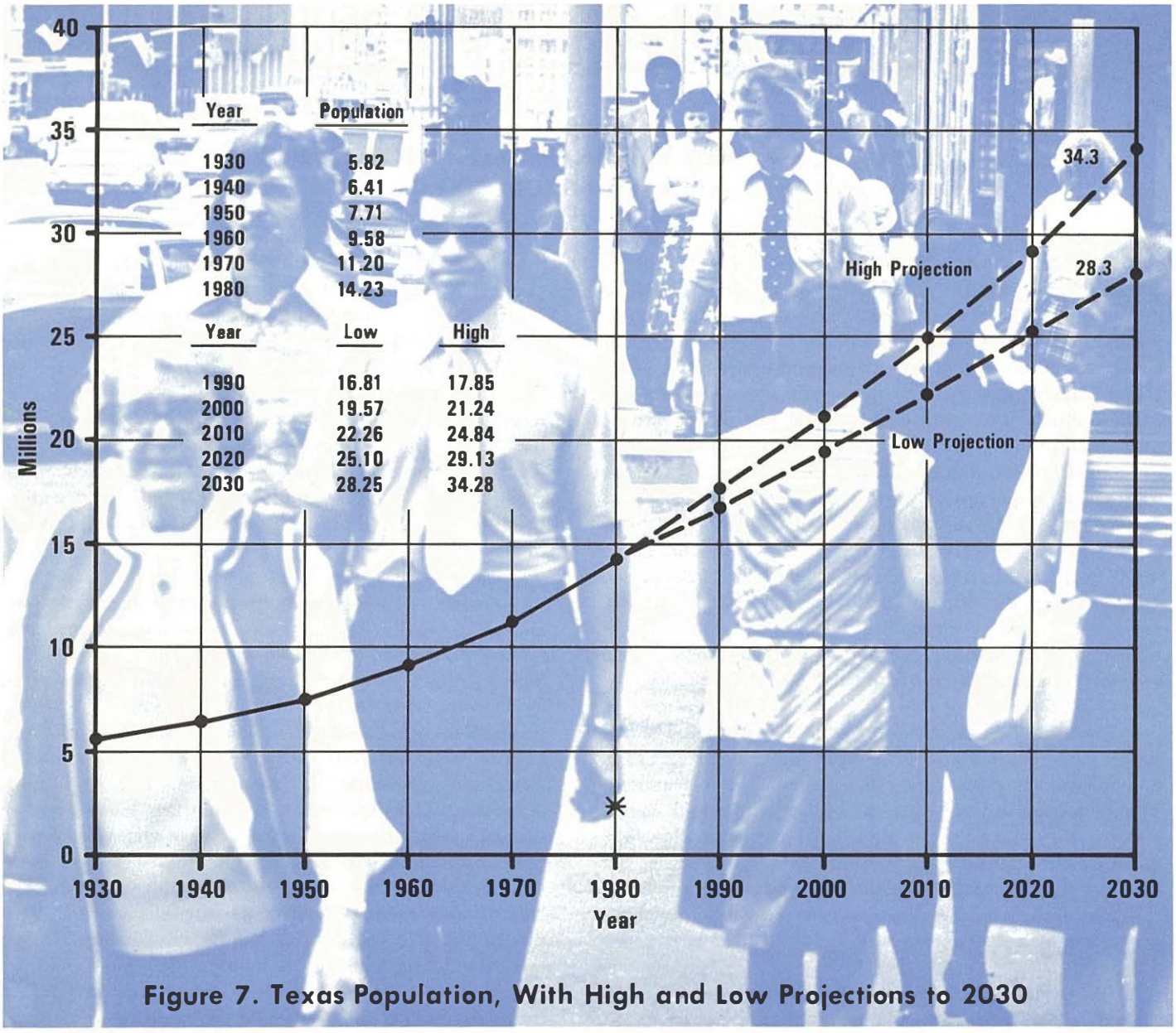


Figure 7. Texas Population, With High and Low Projections to 2030

the State population is projected to be 19.6 million in the year 2000, increasing to 28.3 million in 2030 (Table 1).

Of the total 17.9 million acre-feet of water used in the State in 1980, 15.8 percent was for municipal and domestic use , 8.5 percent was for industrial use, 1.8 percent was for steam-electric power use, 72.5 percent was for agricultural use, and 1.3 percent was used in mining operations.

Municipal and domestic uses in the State totaled 2.8 million acre-feet during 1980. Projections of future municipal and domestic water requirements are based upon population projections and projected per capita water use. Per capita water use estimates are based upon water use data reported by the suppliers of municipal and commercial water within each county, and upon statistical analyses of trends in per capita water use rates through time. Reported municipal and commercial water use shows an upward trend of four gallons per person per decade for the State. Estimates of these trends were made for each city and were applied in the projections through the year 2000. These analyses of per capita water use relate water use to local and regional climatic characteristics and to historical and projected economic factors for the State. Per capita water requirements projected for the High Series take into account the demands that will be placed upon water supply sources and treatment and distribution facilities during drought conditions. Per capita requirements for

Table 1

Reported and Estimated Population and Water Use in 1980 with Projections of Future Population and Annual Water Requirements for 2000 and 2030, Low and High Series, State of Texas

1980	Population[1]	14,227,571	
	Municipal and Domestic[2]	2,813,182	
	Manufacturing[2]	1,519,992	
	Mining[2]	239,076	
	Steam-Electric[2]	330,057	
	Agriculture (Irrigation and Livestock)[2]	12,950,357	
	TOTAL (Water)[3]	17,852,664	
		Low	**High**
2000	Population[1]	19,567,335	21,239,279
	Municipal and Domestic[2]	3,512,065	5,080,510
	Manufacturing[2]	2,407,092	2,717,673
	Mining[2]	267,671	267,671
	Steam-Electric[2]	717,440	816,940
	Agriculture (Irrigation and Livestock)[2]	10,426,908	16,542,538
	TOTAL (Water)[3]	17,331,176	25,425,332
2030	Population[1]	28,254,495	34,276,928
	Municipal and Domestic[2]	5,058,994	8,177,532
	Manufacturing[2]	4,230,531	5,013,989
	Mining[2]	387,128	387,128
	Steam-Electric[2]	1,118,619	1,417,449
	Agriculture (Irrigation and Livestock)[2]	11,385,468	15,350,638
	TOTAL (Water)[3]	22,180,740	30,346,736

[1]Population in number of persons.
[2]Water in acre-feet annually.
[3]In addition, estimated fresh water inflow requirements for Texas' bays and estuaries range from a low (survival limit) of 4.7 million acre-feet annually to a high (enhancement) of 13.6 million acre-feet annually.

the Low Series are for average weather and climate conditions. Per capita water use is not projected to increase after 2000, due primarily to the effects of conservation.

High Series municipal water requirements to meet needs during extended drought conditions are estimated to be 4.2 million acre-feet annually in 1990. For the year 2000, total State municipal water requirements are projected to be 5.1 million acre-feet annually, increasing to 8.2 million acre-feet annually by the year 2030 (Figure 8). Low Series municipal water requirements are projected to be 3.0 million acre-feet in 1990, 3.5 million acre-feet annually by the year 2000, and 5.1 million acre-feet annually by the year 2030.

Table 2
Reported and Estimated Population and Water Use in 1980 for the Largest Cities in Texas with Projections of Future City Population and Annual Municipal Water Requirements for 2000 and 2030, Low and High Series.

1980

City	Population (thousands)	Acre-Feet (thousands)
Houston	1,595.1	354.2
Dallas	904.1	227.7
San Antonio	785.9	183.2
El Paso	425.3	88.9
Fort Worth	385.1	91.8
Austin	345.5	78.6
Corpus Christi	232.0	59.1
Lubbock	174.0	34.7
Arlington	160.1	40.2
Amarillo	149.2	33.0

2000

City	Low		High	
	Population	Acre-Feet	Population	Acre-Feet
	----(thousands)----		----(thousands)----	
Houston	2,055.0	409.7	2,204.3	582.7
Dallas	989.3	212.8	1,032.5	289.1
San Antonio	1,095.3	218.4	1,178.5	311.5
El Paso	684.4	147.2	746.6	160.6
Fort Worth	471.4	87.1	489.0	122.1
Austin	534.5	113.2	594.8	164.6
Corpus Christi	289.4	57.1	299.8	78.6
Lubbock	227.5	44.3	239.7	62.3
Arlington	196.0	37.3	203.3	51.9
Amarillo	167.7	38.0	179.3	52.2

2030

City	Low		High	
	Population	Acre-Feet	Population	Acre-Feet
	----(thousands)----		----(thousands)----	
Houston	2,979.7	594.1	3,576.3	945.4
Dallas	1,312.0	282.2	1,465.9	410.5
San Antonio	1,690.6	337.1	2,174.7	574.9
El Paso	1,081.7	232.6	1,302.3	280.1
Fort Worth	568.7	105.1	626.1	156.4
Austin	774.8	164.0	1,047.0	289.7
Corpus Christi	419.7	82.7	513.0	134.5
Lubbock	299.6	58.4	349.1	90.7
Arlington	236.5	45.0	260.3	66.5
Amarillo	213.3	48.3	249.3	72.6

SOURCE: Texas Department of Water Resources.

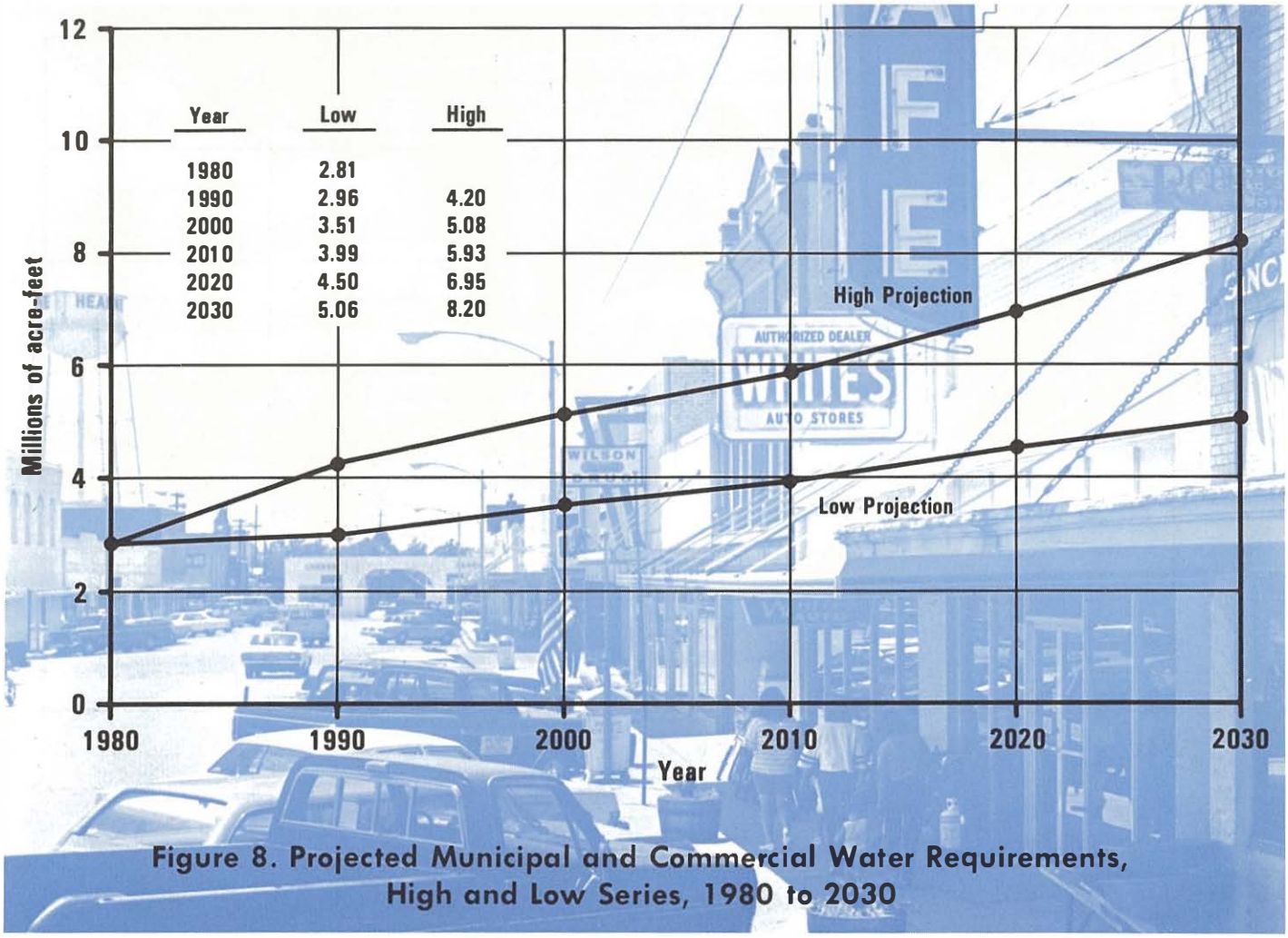


Figure 8. Projected Municipal and Commercial Water Requirements, High and Low Series, 1980 to 2030

Manufacturing industries in the State used 1.5 million acre-feet of water during 1980. Major industries using significant quantities of water include food and beverage products, paper and allied products, chemicals, petroleum refining, and primary metals.

The projections of future industrial water requirements are based upon the growth outlook developed for each of the major industries and upon estimated rates of implementation of industrial water conservation techniques. Manufacturing water requirements in the State are projected to increase by the year 1990 to 2.1 million acre-feet annually, High Series (Figure 9). By 2000, manufacturing water requirements are projected to be 2.7 million acre-feet annually, increasing to 5.0 million acre-feet annually by 2030. The Low Series industrial water requirements are projected to be 2.0 million acre-feet in 1990, 2.4 million acre-feet annually by the year 2000, and 4.2 million acre-feet annually by the year 2030.

In 1980, there existed 50.7 thousand megawatts of steam-electric power generating capacity in the State. Water consumption for power generation totaled 330.0 thousand acre-feet.

Water requirements for steam-electric power generation are based upon projections of future electric power demand, the energy source used for generation, and the specific location of generating capacity. Because of the large, near-surface lignite reserves and the availability of water supplies in the northeastern part of the State, steam-electric power generating capacity is projected to grow significantly in that area. By the year 2000, High Series water requirements for power generation are projected to be 816.9 thousand acre-feet annually (Figure 10). Water requirements for steam-electric power generation in the State are projected to increase to 1.4 million acre-feet annually in 2030. The Low Series water requirements for steam-electric power generation are projected to be 535.3

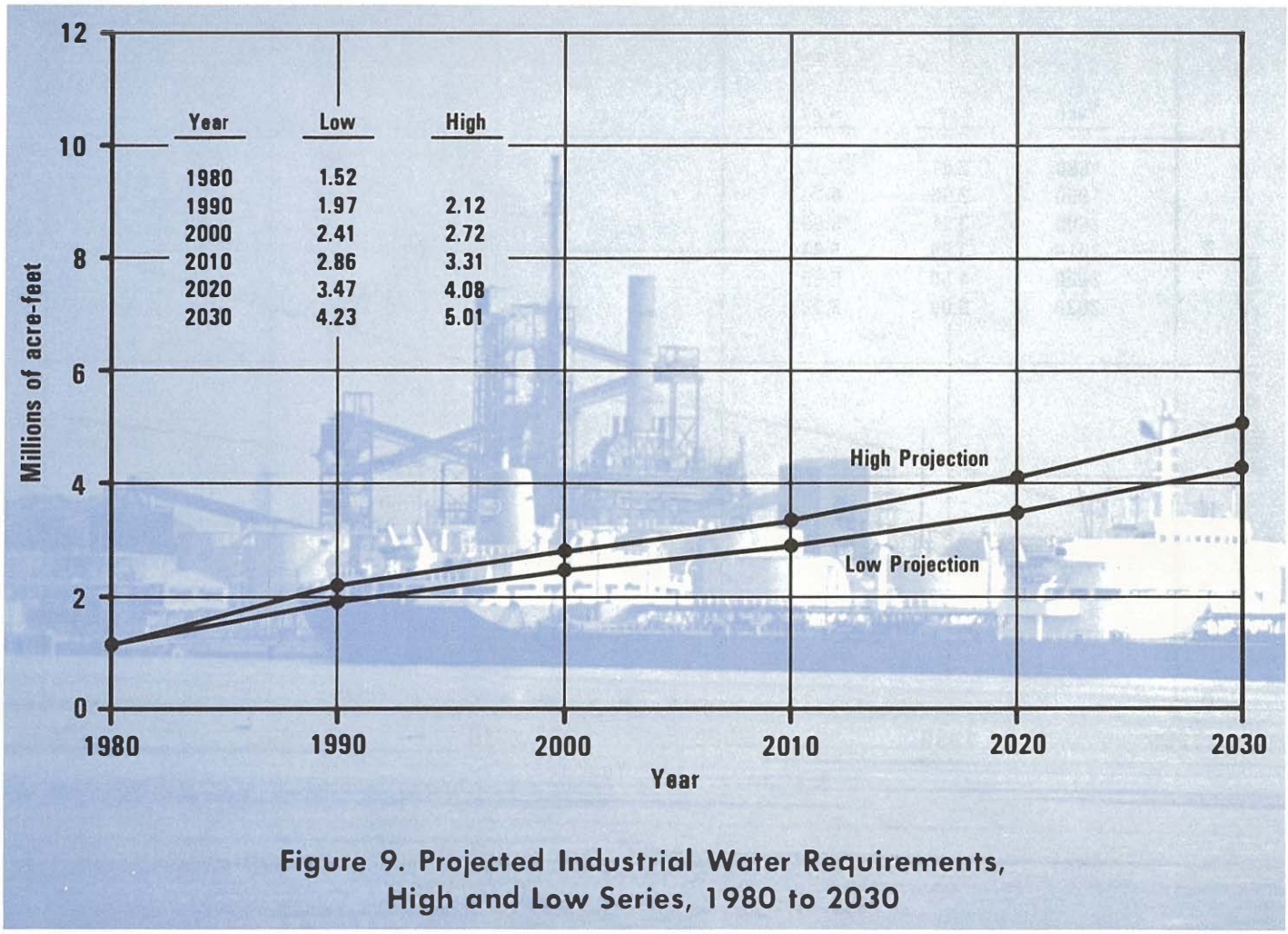


Figure 9. Projected Industrial Water Requirements, High and Low Series, 1980 to 2030

thousand acre-feet in 1990, 717.4 thousand acre-feet annually by the year 2000, and 1.1 million acre-feet annually by the year 2030.

The major irrigation areas in the State are shown in Figure 11. About 12.7 million acre-feet of water was used for irrigation in the State in 1980. In estimating the future water needs of irrigated agriculture, the following factors were considered: the total acreage suitable for irrigation; acreage currently in irrigated production and the 1980 water use per acre; the potential for improvements in irrigation water conservation practices; water costs; the economics of dryland versus irrigated production; and national and international demands for food and fiber. Based on these factors, the High Series water requirements for irrigation were estimated for each decadal period 1990-2030. These estimates of demand represent the quantities of irrigation water that can be used profitably in irrigation farming operations typical to Texas' agricultural conditions, including the different crop types among regions, and taking into account water conservation potentials. A Low Series of irrigation water requirements was calculated by continuing to irrigate in future years the same number of acres irrigated in 1980. In calculating the Low Series water requirements for irrigation in each decade 1990-2030, the number of acres actually irrigated in 1980 was used as the land base, but improvements in irrigation water use (conservation) and shifts in cropping patterns to reflect a more profitable mix of crops were factored into the calculated requirements. These improvements in application rates for water and relative shifts in cropping patterns were adopted from the High Series irrigation water demand estimates.

Statewide irrigation water use is projected for the High Series to be 12.3 million acre-feet in 1990, 16.2 million acre-feet annually by the year 2000, and 15.0 million acre-feet annually by 2030 (Figure 12). The Low Series irrigation water requirements are projected to be 10.2 million acre-feet in 1990, 10.1 million acre-feet annually by the year 2000, and 11.1 million acre-feet annually by the year 2030.

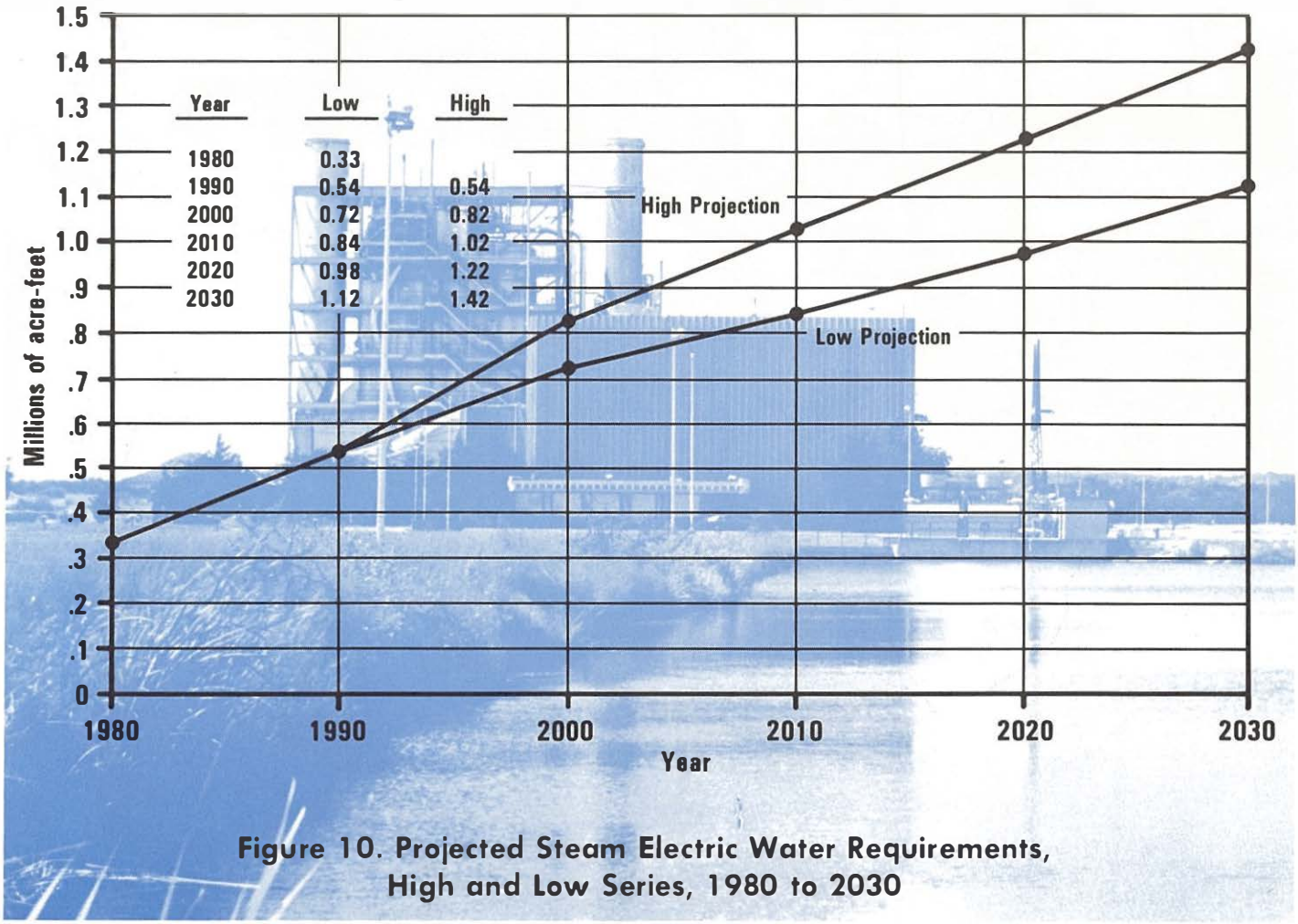


Figure 10. Projected Steam Electric Water Requirements, High and Low Series, 1980 to 2030

Other significant water uses in the State include mining and livestock watering. Mining includes extraction of fuels, metals, nonmetals, and sand and gravel. Estimated mining water use in the State totaled 239.0 thousand acre-feet in 1980. In 1980, livestock water use in the State totaled 243.9 thousand acre-feet. By the year 2000, an estimated 331.7 thousand acre-feet of water will be needed annually for livestock, and is expected to remain at 331.7 thousand acre-feet annually to the year 2030.

The projected freshwater requirements for mining take into account a projected decline in the production of petroleum and natural gas, a significant development of lignite fuels, and increases in demand for construction materials in metropolitan areas. The estimated mining requirements in the State by the year 2000 are 267.7 thousand acre-feet annually, increasing to 387.2 thousand acre-feet annually by the year 2030.

WATER CONSERVATION AND REUSE

The objective of the State's Water Conservation Program is to reduce the quantity of water used in each function or purpose, insofar as is practical, but not to eliminate any uses. In this conception, a water conservation program must be distinguished from a drought-contingency program, discussed elsewhere in this Plan. A drought-contingency program provides procedures for voluntary or mandatory actions, or both, to be put into effect to temporarily reduce the demand placed upon a water supply system during an emergency. Such procedures include conservation, but may include prohibition of certain uses, such as car washing and lawn watering. Conservation, on the other hand, does not eliminate any uses of water, but instead attempts to reduce usage. Conservation can be accomplished through adoption and installation of equipment and practices that result in the efficient initial use of water

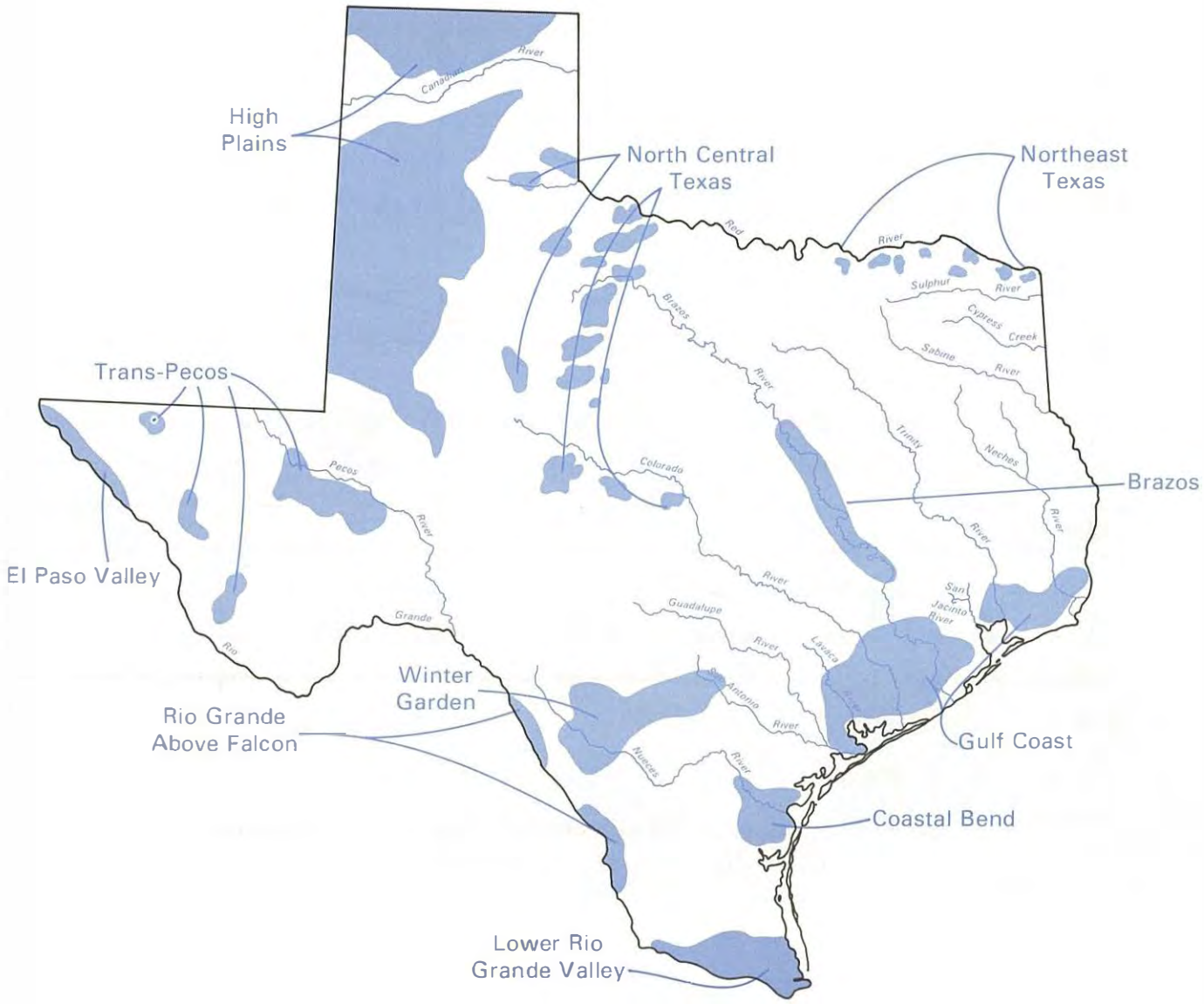


Figure 11. Irrigation Areas in Texas

resources that are available and the reuse of water resources wherever possible.

The water conservation program, including municipal, industrial, and agricultural water conservation, which would accomplish this goal at the State level considers local-level initiatives and requirements as having priority in an overall program. Local geographic, soil, and climatologic variations are considered. Since many of the political subdivisions in Texas have the capability of administering their own programs, and since this is the proper place for such program administration, local governments are assumed to be the primary water conservation agencies. However, many small cities, small water supply corporations, and small irrigation districts may not have the financial capability to establish and promote a water conservation program. Thus, special assistance should be provided to such entities.

Through the planning and management of municipal, industrial, agricultural, and other water uses, it may be possible to reduce waste and improve the efficiency with which water is used. However, improvements in water-use efficiency depend upon the costs of water-

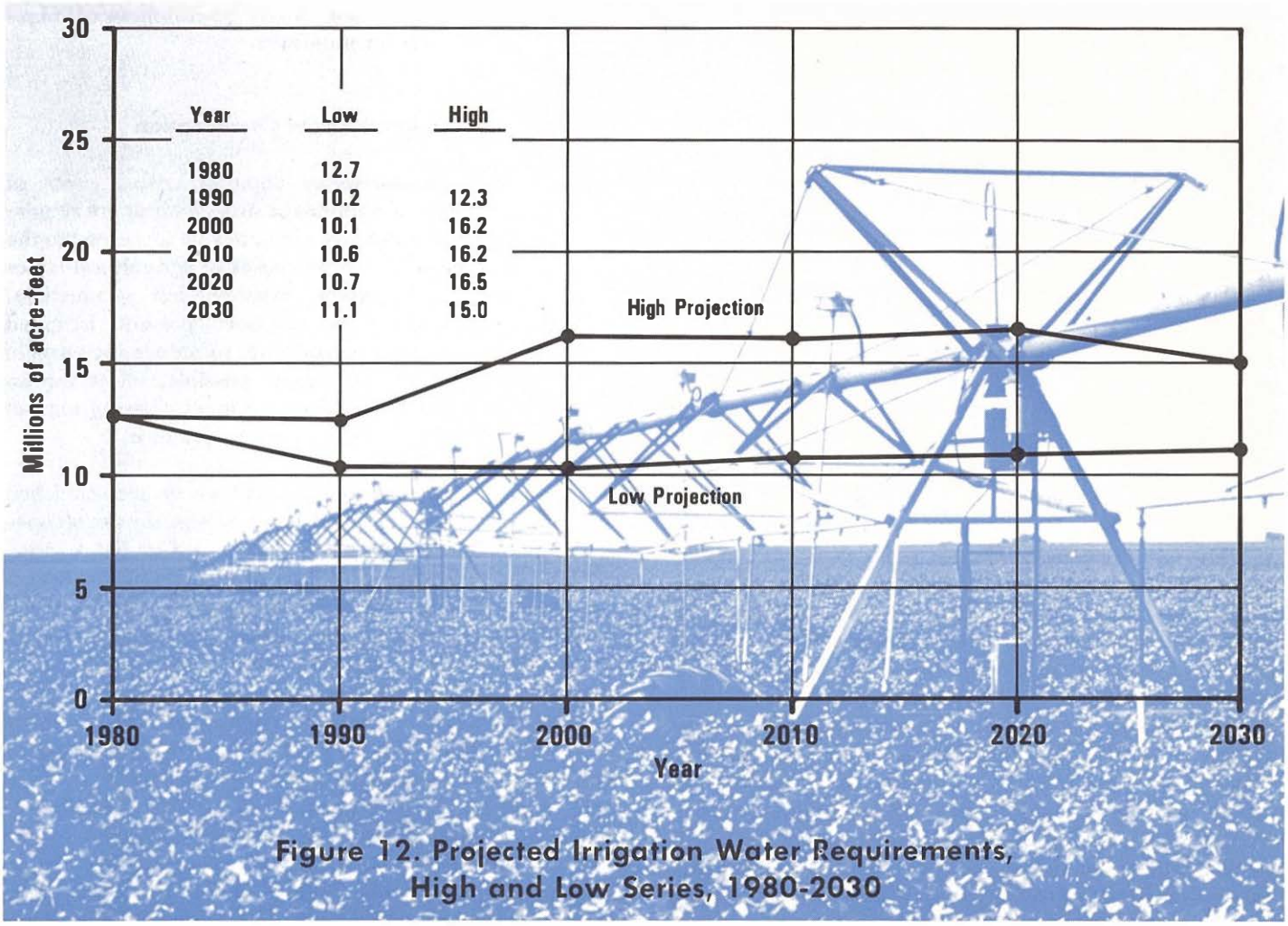


Figure 12. Projected Irrigation Water Requirements, High and Low Series, 1980-2030

saving technologies and incentives to purchase and use such equipment.

Conservation Agencies

Several local water resources associations have been organized to promote the efficient use, development, protection, and management of surface-water and ground-water resources. These include underground water conservation districts, whose purposes are to prevent waste, protect the quality, and conserve ground-water supplies. This is accomplished primarily through regulating the spacing of wells within district boundaries, by enjoining wasteful water management practices such as allowing water to flow into roadside drainage ditches, by promoting the use of tailwater recovery pits, and by public education programs. Ground-water pumping is currently regulated through a permit system in the Harris-Galveston Coastal Subsidence District to prevent or control land subsidence. Control of soil erosion by both wind and runoff of water, along with control of farming and ranching practices that unduly and unnecessarily expose bare soil to the forces of erosion, and the promotion of efficient techniques for use of the State's water resources are the primary responsibilities of the Texas State Soil and Water Conservation Board and local soil and water conservation districts.

Conservation Management Methods

In some areas of the State long-term water supplies can be increased through the joint or coordinated use of ground-water and surface-water supplies. The development and use of supplemental surface-water supplies can serve to reduce the severity of declining ground-water supplies. In addition, the use of treated municipal wastewater for some industrial purposes and for agriculture can reduce the demand for water from original sources and, in effect, can increase the usable supplies of water. Recharging aquifers with treated effluent can increase the supply of ground water in some areas, while the coordinated opera-

tion of reservoirs can increase the dependable supply of surface water in some basins.

Municipal and Commercial Water Conservation

Although water use for municipal and commercial purposes accounts for approximately 15 percent of the total water use in Texas, per capita water use has been increasing at a rate of four gallons per decade since the mid-1960's. At present rates and with projected population growth, municipal and commercial water needs are estimated to increase at least 25 percent by the year 2000 and to double by 2030.

Residential and commercial conservation measures include installation and use of efficient water-using equipment, some changes in life styles, modification of the behavior and habits affecting water use, changes in plumbing codes and subdivision platting, and regulation of water use. Long-range projections of water requirements for municipal and commercial purposes are based upon the assumption that water conservation programs will be adopted in order to reduce the rate of growth in per capita water use. In order to accomplish this, the Texas Department of Water Resources will cooperate with local governments and State and with federal agencies to disseminate water conservation information to the public, encourage water conservation through the news media, and support research and development of water conservation methods. Specific actions and activities to accomplish these general purposes are listed in the recommendations section of the Plan.

Industrial Water Conservation

Industry has reduced water use substantially in response to rising energy costs and the high costs of treating wastewater to conform to effluent and water quality standards. Other potential means of reducing industrial water use involve substituting lower quality water for fresh water for cooling and manufacturing purposes and, in some cases, increasing energy conservation.

Since some of the water conservation methods of private industry are proprietary and therefore are not available for public discussion, the Texas Department of Water Resources water conservation planning efforts will focus on encouraging industry to practice water conservation, and, where possible, recycling and reuse of treated effluent will be encouraged in the administration of water rights and water quality. In addition, the Department will assist in the location of lower quality water that might be substituted for fresh water and will cooperate with industry and other public agencies in the research and development of industrial water conservation measures.

Agricultural Water Conservation

Declining ground-water supplies, rising costs of pumping, and limited supplies of surface water are requiring that irrigation water-use efficiency be increased to the fullest extent feasible. The purposes of agricultural water conservation are to allow existing, but exhaustible, ground-water reserves to support present irrigated acreages for longer periods of time, to reduce the costs of production, and, to the extent possible, allow for an increase in irrigated agriculture to meet growing market demands for food and fiber in future decades.

Significant savings in water use can be accomplished with improvements in conveyance systems, the use of more efficient irrigation application systems, soil moisture monitoring, the development and use of drought-tolerant strains and varieties of crops, use of growth regulators and evaporation suppressants, and brush control. Along with use of water-saving equipment and practices to reduce the quantities of irrigation water applied to crops, appropriate farming practices need to be developed and used to capture and hold rainfall in the soil profile. The capture and retention in the soil profile of rainfall, or reducing runoff from fields, applies beneficially to dryland farming operations as well as to irrigation operations. Furrow diking and conservation tillage are the leading practices currently in use to reduce rainwater runoff, along with control of weeds and brush that use water for no beneficial purpose. In order to realize these potentials, the Department will encourage agricultural water conservation and cooperate with other public and private agencies, institutions, and establishments to expand water conservation research and extension programs. Specific actions to accomplish these general objectives are included in the recommendations of this Plan.

The Department's role in agricultural water conservation will be to promote conservation and disseminate information and materials on irrigation techniques and equipment that are water efficient. Agricultural water conservation work will be done to the extent that resources are available for programs of public information, training, assistance, and demonstrations to local-area soil and water conservation districts, underground water conservation districts, and farmers, and through cooperation and support of other federal, State, and local agencies with related responsibilities. It is in the private sector, however, that most of the actual investment, production, financing, and finally, purchase and use of irrigation water conservation equipment must be made.

PUBLIC EDUCATION AND AWARENESS

Education will play a major role in water conservation, water quality protection, flood protection, and in other important water resources management programs. To the extent that resources will permit, the Department will prepare public information reports, bulletins, illustrations, and pamphlets and will inform the public of the existence and availability of these reports through public announcements and news releases. Specific topics to be emphasized include water quality enhancement and control of water pollution, water conservation practices, equipment and techniques that reduce water use, water supply development programs necessary to meet future needs, and measures to reduce the potential hazards from flooding.

The Department will supply information and coordinate with the Texas Education Agency and other groups to develop educational materials on water-resource related topics for use in Texas public schools. The Department will also cooperate with the Texas Agricultural Extension Service in providing information for use in adult education programs relating to agricultural water conservation (irrigation, dryland, and range), and in applying conservation knowledge to urban water-use problems, such as watering landscape plants and lawns, and in-home modification and management for water conservation. The Department will provide available information and staff assistance to local entities and individuals upon request, to assist them in developing education and public awareness programs.

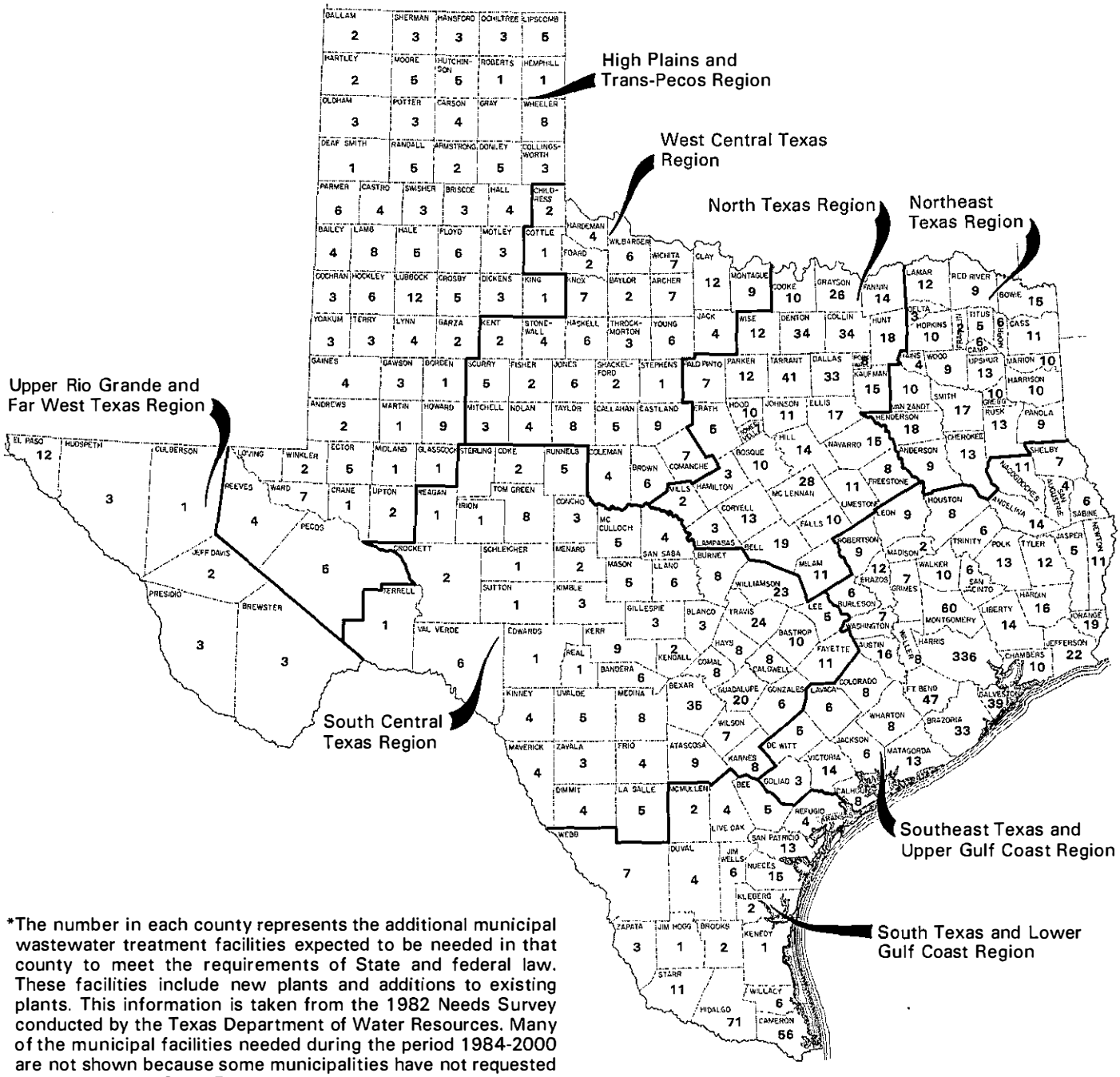
WATER QUALITY PROTECTION

Protection of the quality of existing water supplies is of the highest priority. The State's water quality protection program includes continuous monitoring of water quality in streams; the maintenance of stream standards; waste load allocations to water users having permits to discharge treated effluents into Texas streams; enforcement of wastewater discharge permits; analyses and specification of criteria for new permit applications; assessment of sewage treatment needs for present and future conditions; technical and financial assistance to local units of government to plan, construct, and operate wastewater treatment facilities; administration of programs which regulate the disposal of industrial solid wastes, including hazardous wastes; and administration of programs to clean up oil spills and abandoned hazardous waste sites. The permitting, enforcement, and monitoring programs are in place, as are procedures for cleaning up oil spills and abandoned hazardous waste sites.

The sewage collection and treatment needs are identified, along with time of need and estimated costs, based on data from the Statewide/Areawide Water Quality Management Planning Program, the State/Environmental Protection Agency Needs Survey, the Construction Grant Information and Control System, the Department's Water Quality and Enhancement Loan Records, the Economic Development Administration, the Farmers Home Administration, the Department of Housing and Urban Development, Municipal Advisory Reports, and other Departmental records. Based on these sources of information, it is estimated that by the year 2000 more than 2,300 municipal wastewater treatment facilities, including new construction, rehabilitation, and expansion, will be needed in order to meet the goals of the federal Clean Water Act. Municipal wastewater treatment facilities needed by 2000 for entities who have made application for federal construction grant assistance are shown in Figure 13. There are many other entities who have not applied for such assistance and whose needs are not indicated on Figure 13.

WATER QUALITY ENHANCEMENT

The control of natural salt pollution in the Canadian, Red, and Brazos River Basins as well as the control of salt-water intrusion during periods of low flow in the Brazos, Neches, and Trinity River Basins will result in significant enhancement of the surface-water supplies in these basins. In many areas, natural salt control would improve water quality to levels suitable for municipal water supply. Natural salt pollution affects the entire reach of the Brazos River and causes high dissolved solids concentrations in Possum Kingdom Reservoir, Lake Granbury, and Whitney Reservoir which requires expensive desalinization to make their waters acceptable for municipal water supply. Similar problems occur in the Red River Basin as a result of natural salt sources located in its upper reaches. In the Canadian River Basin, the Lake Meredith Salinity Control Project has been initiated and, if implemented, will help control the natural salt sources which threaten the water quality of that municipal water supply reservoir. Structural measures to control these natural pollution problems have been formulated by various agencies, principally the U.S. Army Corps of Engineers. The cost of the structural controls is significant, and innovative means of financing such projects either through the Corps of Engineers, regional and local interests, or through cooperation with the State should continue to be evaluated. The control of natural salt-water intrusion in various coastal areas by the construction of additional salt-water barriers can eliminate the contamination of freshwater supplies during low flow periods and minimize the need for releases of upstream, stored water supplies as a means to control intrusion. Salt-water intrusion is a particular problem in the Neches, Trinity, and Brazos River Basins.



*The number in each county represents the additional municipal wastewater treatment facilities expected to be needed in that county to meet the requirements of State and federal law. These facilities include new plants and additions to existing plants. This information is taken from the 1982 Needs Survey conducted by the Texas Department of Water Resources. Many of the municipal facilities needed during the period 1984-2000 are not shown because some municipalities have not requested to be put on the Grant Priority List.

Figure 13. Municipal Wastewater Treatment Facilities Needed, 1984-2000

FLOOD PROTECTION

Flood protection measures include flood control storage in reservoirs, channel modification, levee works, and non-structural floodplain management measures such as flood proofing, flood warning systems, and relocation. A wide spectrum of public agencies are responsible for the planning, construction, and operation of both structural and non-structural approaches to flood control. Despite the existence of these flood protection programs, flooding continues to beleaguer Texans and its future impact is expected to increase as both population and economic growth takes place in flood-prone areas.

In the past, flood protection has largely been a local and federal responsibility with very little direct State involvement except in the administration of issuing permits and regulating stream and drainage modification. There are no funds for a Statewide program of flood protection. Federal funds have been provided for flood storage in federally authorized multiple purpose reservoirs and for federally authorized local flood protection facilities on a project by project basis, with the local interests providing lands, rights-of-way, and easements. Under present policy, the federal costs of the flood control components of such projects do not have to be repaid, because flood protection is deemed to be in the national interest. The local share of the costs of federal projects and the financing of locally sponsored flood protection projects is usually provided by local ad valorem property taxes.

The Texas Department of Water Resources is and will continue to be involved in flood protection activities through review and approval of plans for flood protection and drainage works, coordination with local and federal agencies on multi-purpose reservoir projects, and assistance to communities that wish to participate in the National Flood Insurance Program (NFIP). Assistance to communities includes providing information on NFIP requirements, coordinating requests for mapping of flood-hazard areas with federal agencies that do the mapping, and assisting in preparation of floodplain management ordinances which comply with the NFIP and which serve to regulate and control development in the floodplain. The Texas Department of Water Resources also has a research and planning fund program which makes State flood control planning funds available to eligible applicants.

Presently, county authorities only have jurisdiction over unincorporated areas within the 100-year floodplain. This limited authority results in fragmented planning due to the lack of control over projects that are being developed outside the 100-year floodplain but which may contribute to the overall flooding problem.

Existing and currently planned local and federal flood control measures are identified in *Volume 2—WATER FOR TEXAS: Technical Appendix.* Implementation of economically feasible projects in the immediate future will depend in large part upon Congressional appropriations and the ability of local sponsors to contribute their share (which averages about 35 percent) of project costs. In recent years, federal funding for flood protection projects in Texas has been in the $15 million to $17 million range annually.

BAYS AND ESTUARIES

Freshwater inflow needs of the Sabine-Neches, Trinity-San Jacinto, Lavaca-Tres Palacios, Guadalupe, Mission-Aransas, Nueces, and Laguna Madre estuaries have been studied, taking into account: (1) inundation—dewatering process of river delta marshes; (2) biogeochemical cycling of nutrients; (3) estuarine salinity gradients; and (4) production and harvest of fisheries species. The resulting relationships, and their constraints were incorporated into a mathematical programming model to compute estimates of the freshwater inflows needed to meet specified management objectives. The objectives can be varied to produce several different estuarine conditions. The results for three long-term (multi-year average) levels of freshwater needs and one short-term (monthly average) need have been computed (Table 3).

The estimated freshwater inflow needs given in Table 3 are based upon current information about the bays and estuaries of Texas. As additional data become available and the scientific knowledge concerning Texas estuaries increases, the Department will revise these estimates of freshwater inflow needs.

DROUGHT CONTINGENCY PLANNING

One of the principal purposes of comprehensive, long-range water resource planning is to assure that water supplies and facilities will be available to meet water needs during periods of drought, thereby avoiding the hardships and economic losses that result from water shortages. Texas relies primarily upon developed water supplies (ground-water pumpage and reservoir firm yields) to provide sufficient quantities of water for most purposes during drought conditions. Nevertheless, despite the planning for and development of water supplies and delivery systems, some areas do not have sufficient quantities of firm water supplies nor adequate water treatment and distribution facilities to accommodate water demands during moderate to severe droughts. Even the best-equipped systems could experience problems during severe, lengthy droughts. Thus, the Department will continue to provide technical assistance and public information for drought contingency planning as resources permit.

WEATHER MODIFICATION

Efforts to artifically induce or increase precipitation with the use of silver iodide, dry ice, and other means may have potential to increase water supplies in drier areas of the State. While a number of independent research projects indicate that rainfall can be increased as much as 10 percent to 50 percent in the western United States through weather modification activities, in the target area of a cloud-seeding project conducted in West Texas during the 1970's approximately 28 percent more rain occurred than

Table 3

Summary of Estimates of Gaged River Flows Needed for Texas Estuaries Based on Studies by the Texas Department of Water Resources

Estuary	Sabine-Neches	Trinity-San Jacinto	Lavaca-Tres Palacios	Guadalupe	Mission-Aransas[6]	Nueces[7]	Laguna Madre
Average Annual Gaged River Flows[1] (1941-1976)	11.2 million acre-feet	7.09 million acre-feet	2.54 million acre-feet	1.81 million acre-feet	104 thousand acre-feet	575 thousand acre-feet	335 thousand acre-feet
Inundation (flood) Events to Maintain Historic Frequency (median number per year)	2 (Sabine) 3 (Neches)	3 (Trinity)	1 (Lavaca)	5	—	2	—
Alternative I (sustenance)[2]	5.69 million acre-feet	4.61 million acre-feet	1.46 million acre-feet	1.24 million acre-feet	15.5 thousand acre-feet	356 thousand acre-feet	182 thousand acre-feet
Alternative II (maintenance)[3]	(no estimate possible)	4.89 million acre-feet	2.41 million acre-feet	1.62 million acre-feet	19.4 thousand acre-feet	397 thousand acre-feet	285 thousand acre-feet
Alternative III (enhancement)[4]	(no estimate possible)	4.75 million acre-feet	2.45 million acre-feet	1.83 million acre-feet	42.7 thousand acre-feet	550 thousand acre-feet	292 thousand acre-feet
Alternative IV (viability limit)[5]	2.02 million acre-feet	822 thousand acre-feet	808 thousand acre-feet	755 thousand acre-feet	2.80 thousand acre-feet	118 thousand acre-feet	138 thousand acre-feet
Percent of Average Annual Gaged Flow Needed for:							
Alternative I	51%	65%	58%	69%	15%	62%	54%
Alternative II	—	69%	96%	90%	19%	69%	85%
Alternative III	—	67%	98%	100%	41%	96%	87%
Alternative IV	18%	12%	32%	42%	3%	21%	41%

[1]Freshwater inflow to each estuary as measured at the last nontidally affected gage located on each major contributing river.
[2]Estimate based on salinity and inundation needs of each estuary.
[3]Estimate based on salinity, inundation, and fisheries needs to maintain commercial harvests at average levels.
[4]Estimate based on salinity, inundation, and fisheries needs to enhance harvests of selected major commercial species.
[5]Estimate based on monthly limits of bay salinity within which important fish and shellfish can survive, grow and maintain viable populations.
[6]Gaged flow only on Mission River at Refugio.
[7]Gaged Nueces River flow adjusted for diversions at Calallen just above Nueces Delta.

was observed to have occurred in neighboring areas in the same years. Precipitation in both the cloud-seeding target area and neighboring areas was higher than normal during the observation period. Although promising, these techniques are not yet thoroughly proven, and additional research is required to appropriately consider weather modification as a viable method of increasing water supplies. Thus, long-range planning work will encourage and promote research in the field of weather modification, and the Department will provide technical assistance to and coordination of this research as funds allow.

DESALTING

The conversion of brackish and saline water to potable water can produce additional fresh water to meet future demands in some areas of the State. Desalting is currently being utilized to a limited extent in Texas to produce fresh water, primarily for industrial boiler feedwater and for municipal uses. In some areas of Texas, desalting may prove to be the most economical and feasible means to supplement municipal water supplies or to comply with public drinking water standards. In this effort, the Department will continue to monitor state-of-the-art desalting technologies and assist local governments and the private sector in planning and implementing desalting projects as resources permit.

SECONDARY RECOVERY OF GROUND WATER

Additional quantities of fresh water may be obtained from aquifers that are only partially saturated. Such water is known as capillary water and is that water which occurs between the water table and the land surface but which cannot flow into a well under gravitational force alone due to capillary action. This capillary water is the subject of recent and on-going secondary recovery investigations. Preliminary secondary recovery tests, using air injection to

overcome the capillary force, appear to be promising. However, additional research is needed in order to determine the potential for a secondary recovery of ground water and the costs. If economically feasible, secondary recovery may increase recoverable water supplies in the Texas High Plains and other areas having aquifers with water in capillary storage.

WATER SUPPLY DEVELOPMENT

The development and use of ground-water resources and the construction of surface-water storage reservoirs have been and continue to be the primary methods of increasing water supplies. Although water conservation is a viable method of extending water supplies, the development of additional sources, including unconventional sources (e.g., desalinization), will be required to ensure adequate future water supplies. A construction schedule of proposed major ground- and surface-water storage, conveyance, and treatment facilities has been developed to meet future municipal and manufacturing water needs in the State, where feasible. The location and timing of these developments are illustrated in Figures 14 through 17. In addition to those facilities shown in Figures 14 through 17, there are others that will be required after 2005 for which planning and cost estimates are not complete at this time.

Ground-Water Development

The quantity of ground water available for use depends upon the cumulative volume in storage in aquifers, the respective aquifer yield characteristics, and the volumes of natural recharge. Some aquifers can be recharged through the use of recharge dams and injection wells, thus increasing the long-term supplies of areas having such aquifers.

Ground water presently is providing 61 percent of the water used in the State. Like surface-water supplies, ground-water resources are unevenly distributed across Texas, and aquifers are recharged at unequal rates. In some areas of the State, notably the High Plains, ground water occurs in large quantities but rates of natural recharge are so low that the available ground water is being pumped at rates that far exceed recharge. Other areas of the State, the Edwards (Balcones Fault Zone) Aquifer, for example, have limited volumes of ground water available but have high recharge rates such that water withdrawn from storage is replaced rapidly during high rainfall periods. Over the whole of Texas, however, the continued long-term development and use of ground water is limited by the fact that more ground water is being removed than is being replaced by natural recharge. Nonetheless, ground water will continue to be a very important source of water in the future.

In planning to meet the future water requirements in Texas, it is anticipated that approximately 4,500 new municipal wells will be required between 1984 and the year 2005 (Figure 14). This estimated number of wells does not account for additional wells developed privately for industrial purposes nor does it include an estimate of new irrigation wells needed during this period. The projected number of wells to be drilled in each aquifer for municipal supply is based upon projected ground-water requirements for municipal uses in each area of the State and the capabilities of the respective aquifers to meet local area water demands.

Many of the new wells that will be developed for meeting municipal requirements will be in areas where extensive pumping of ground water has not yet occurred. Others will be replacement wells or supplementary wells, since in some areas the lowering of ground-water levels will require that a larger number of wells per unit of area be drilled in order to obtain the water available in the aquifers.

Surface-Water Development

About 64 percent of the dependable yield of Texas reservoirs is being used to meet current needs; the remainder is committed to expanding municipal and industrial needs of the next 20 to 30 years in areas which can be served by these supplies. These uncommitted supplies, however, will not meet the projected future needs within their respective areas, with a few exceptions, and cannot meet all future needs in neighboring and more distant locations.

Past and present planning efforts have identified approximately 65 potential major reservoir project sites (Plate 1). Of this total, 19 are authorized federal projects and 46 are planned State/local projects. About 5.3 million acre-feet per year of additional dependable surface-water yield and capturable treated sewage return flows (4.3 million acre-feet of yield and 1.0 million acre-feet of capturable return flows) could be developed with construction of all 65 potential reservoir projects. However, lands within some sites suitable for reservoirs are being converted to uses that could conflict with future water development.

Surface-water development needs were determined for each area by comparing estimates of the currently-available supplies of ground and surface water with projected future water needs given by the High Series projections. Areas identified as having projected future shortages were examined to determine if available water resources in the local area could be used to meet the shortage. Where locally-available supplies were determined to be insufficient, more distant sources that are projected to be surplus to the future 50-year needs of the

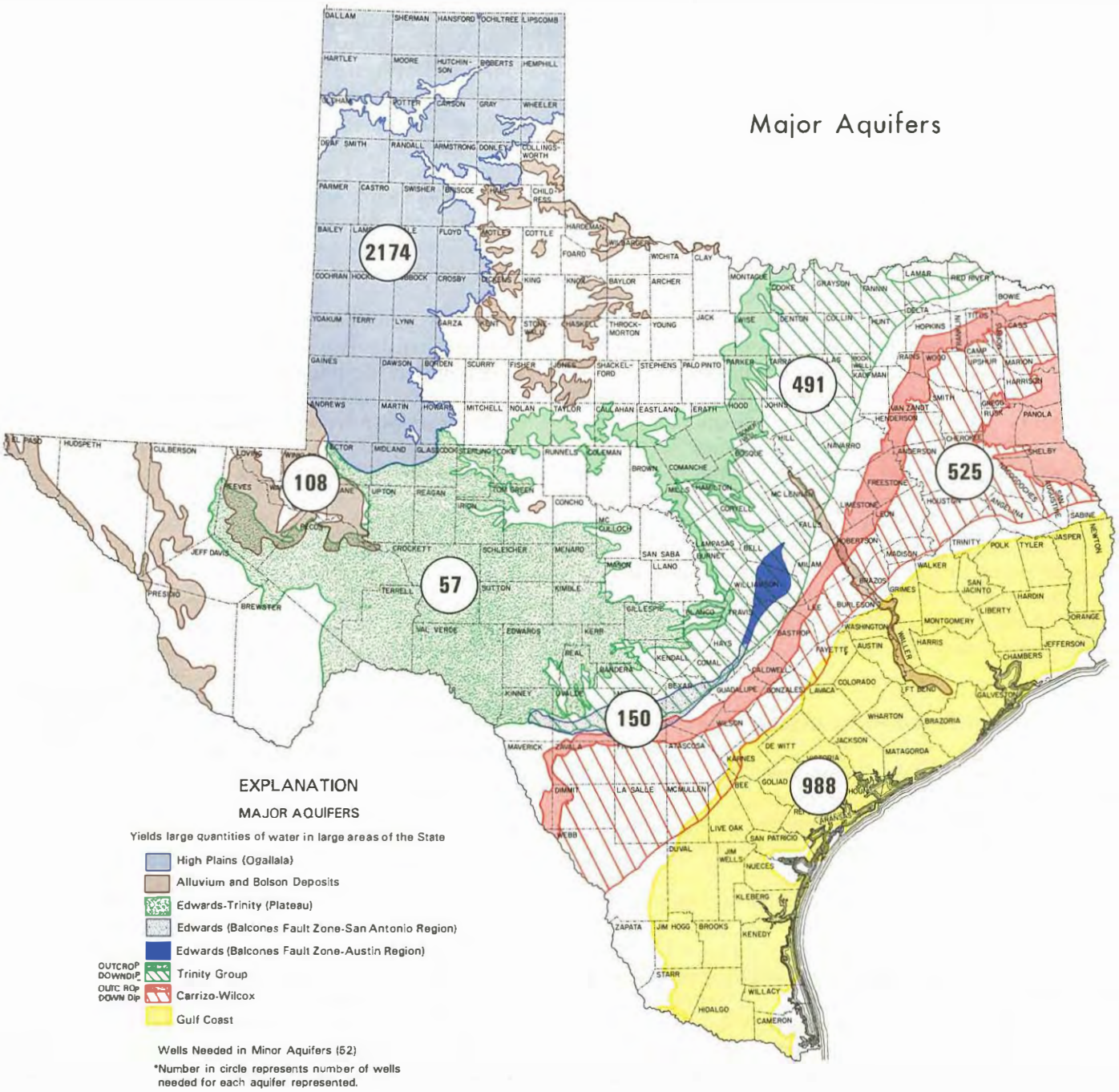
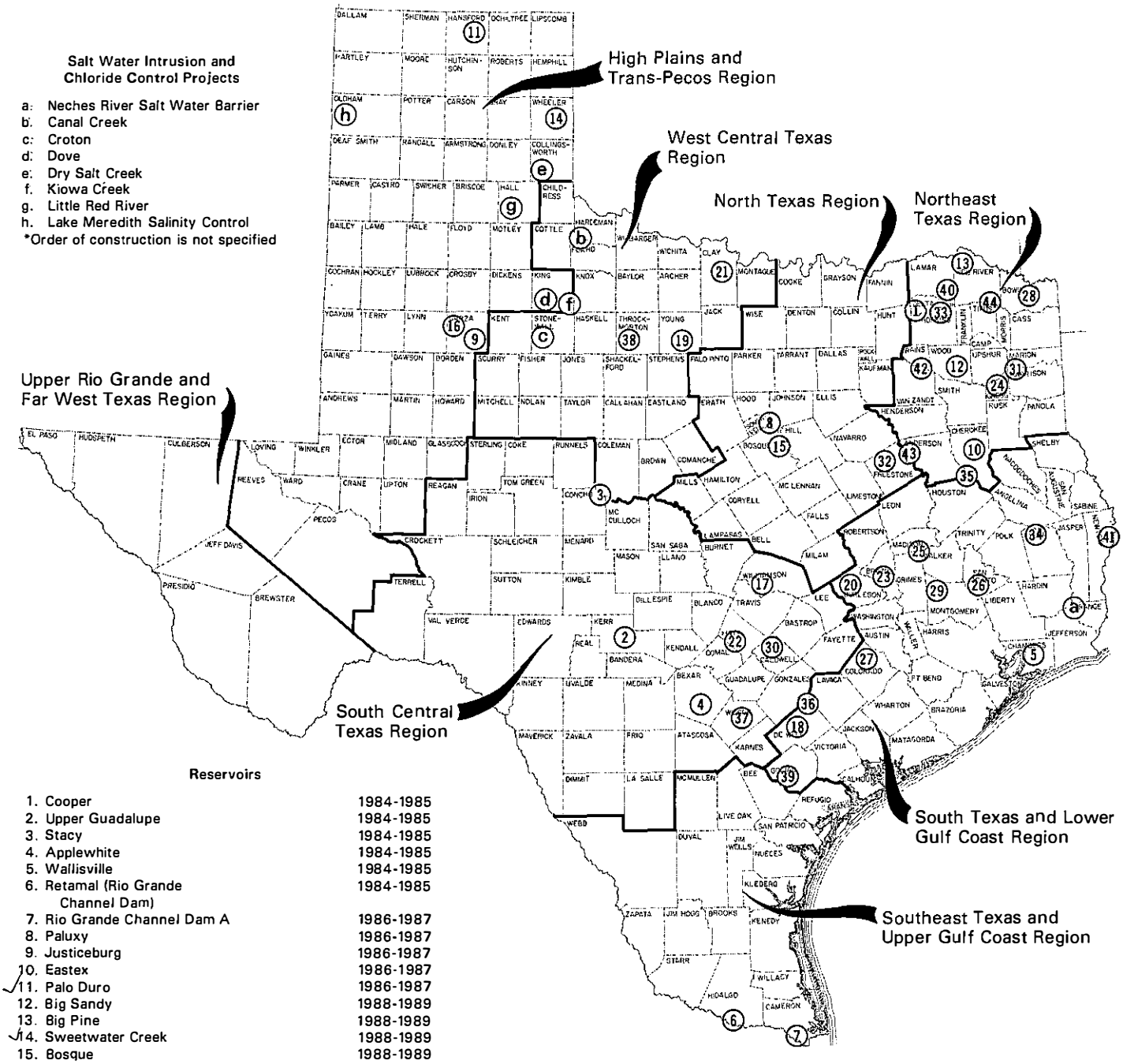


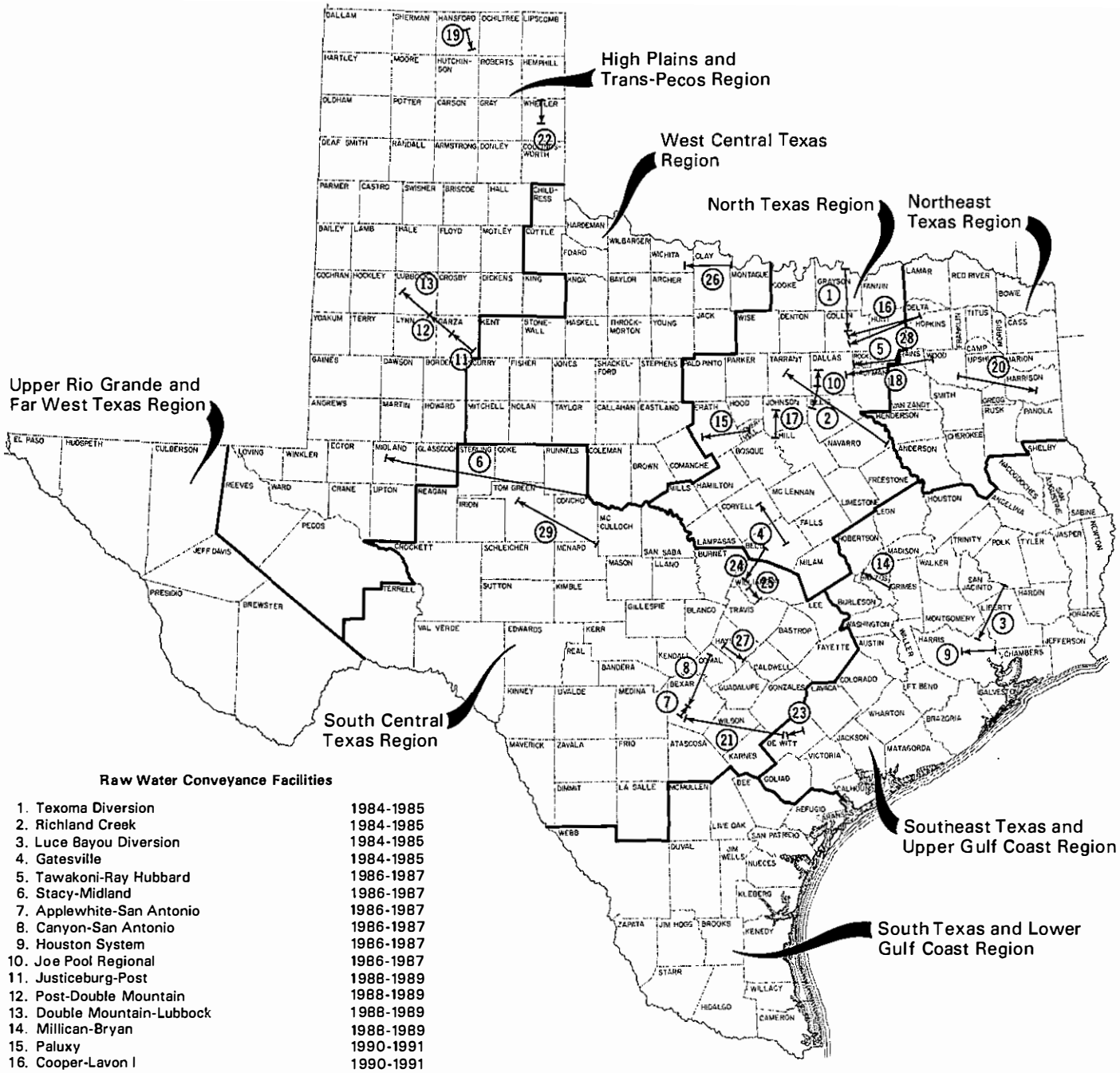
Figure 14. Municipal Wells and Facilities Needed, 1984-2005



Reservoirs

1. Cooper	1984-1985	31. Little Cypress	2002-2003
2. Upper Guadalupe	1984-1985	32. Tehuacana	2004-2005
3. Stacy	1984-1985	33. George Parkhouse I	2004-2005
4. Applewhite	1984-1985	34. Rockland	2004-2005
5. Wallisville	1984-1985	35. Weches	2010-2019
6. Retamal (Rio Grande Channel Dam)	1984-1985	36. Cuero	2010-2019
7. Rio Grande Channel Dam A	1986-1987	37. Cibolo	2010-2019
8. Paluxy	1986-1987	38. Breckenridge	2010-2019
9. Justiceburg	1986-1987	39. Goliad	2010-2019
10. Eastex	1986-1987	40. George Parkhouse II	2010-2019
11. Palo Duro	1986-1987	41. Bon Weir	2020-2030
12. Big Sandy	1988-1989	42. Carl Estes	2020-2030
13. Big Pine	1988-1989	43. Tennessee Colony	2020-2030
14. Sweetwater Creek	1988-1989	44. Marvin Nichols I	2020-2030
15. Bosque	1988-1989		
16. Post	1988-1989		
17. South Fork	1990-1991		
18. Lindenau	1990-1991		
19. South Bend	1990-1991		
20. Caldwell	1990-1991		
21. Ringgold	1994-1995		
22. Clopton Crossing	1994-1995		
23. Millican	1994-1995		
24. Prairie Creek	1994-1995		
25. Bedias	1996-1997		
26. Cleveland	1996-1997		
27. Colorado Coastal Plains	1996-1997		
28. Liberty Hill	1998-1999		
29. Lake Creek	2000-2001		
30. Lockhart	2002-2003		

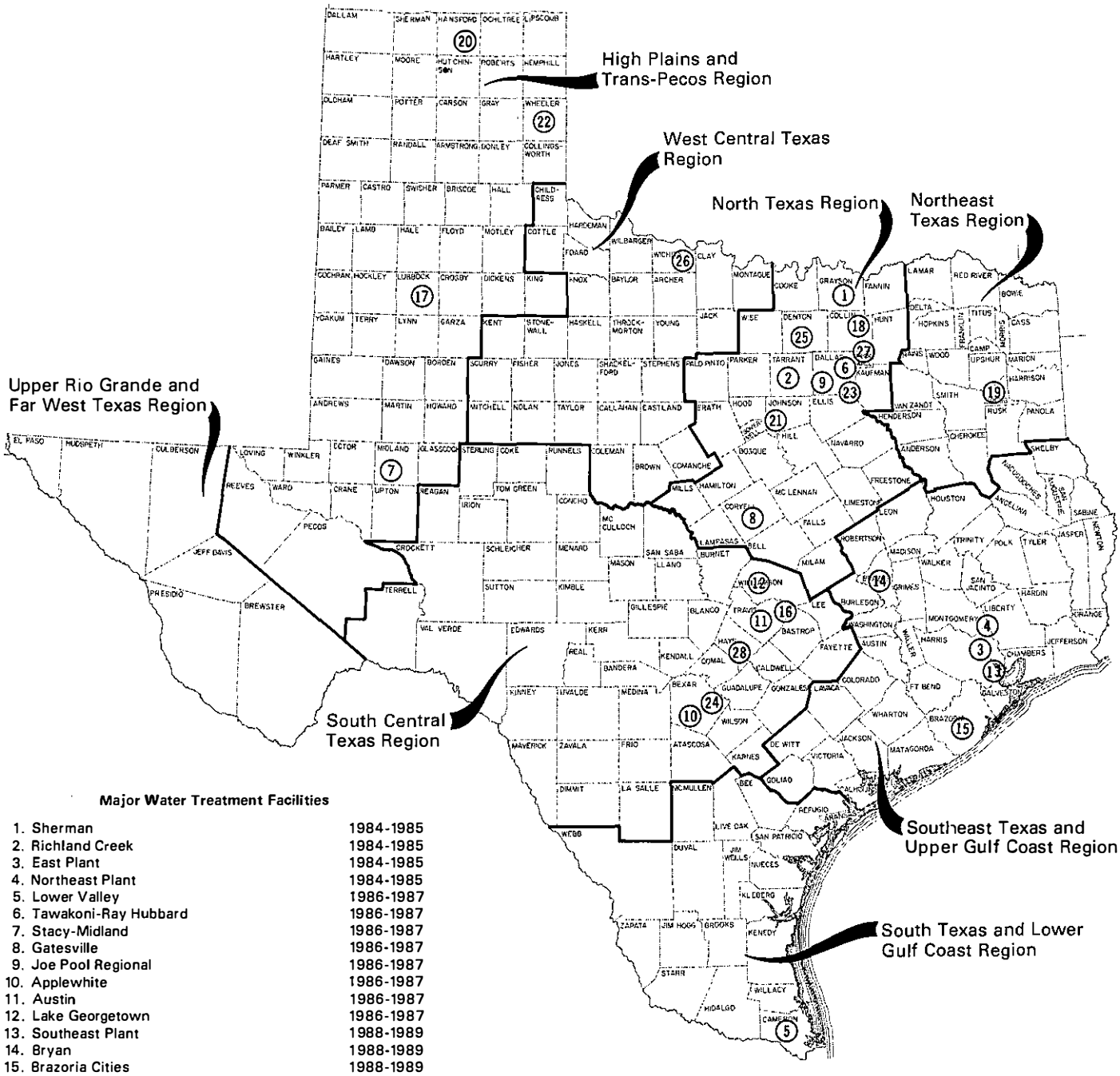
Figure 15. Reservoirs, Salt Water Intrusion, and Chloride Control Projects Needed, 1984-2030



Raw Water Conveyance Facilities

1. Texoma Diversion	1984-1985
2. Richland Creek	1984-1985
3. Luce Bayou Diversion	1984-1985
4. Gatesville	1984-1985
5. Tawakoni-Ray Hubbard	1986-1987
6. Stacy-Midland	1986-1987
7. Applewhite-San Antonio	1986-1987
8. Canyon-San Antonio	1986-1987
9. Houston System	1986-1987
10. Joe Pool Regional	1986-1987
11. Justiceburg-Post	1988-1989
12. Post-Double Mountain	1988-1989
13. Double Mountain-Lubbock	1988-1989
14. Millican-Bryan	1988-1989
15. Paluxy	1990-1991
16. Cooper-Lavon I	1990-1991
17. Whitney-Cleburne	1990-1991
18. Lakefork-Dallas	1990-1991
19. Palo Duro	1992-1993
20. Big Sandy-Marshall	1992-1993
21. Lindenau-Applewhite	1992-1993
22. Sweetwater-Wheeler Co.	1992-1993
23. Lindenau Diversion	1994-1995
24. Stillhouse Hollow-Lake Georgetown	1994-1995
25. South Fork-Round Rock	1994-1995
26. Ringgold-Wichita Falls	1998-1999
27. Clopton Crossing-San Marcos	2000-2001
28. Cooper-Lavon II	2002-2003
29. San Angelo (construction date has not been determined)	

Figure 16. Major Raw Water Conveyance Facilities Needed, 1984-2005



Major Water Treatment Facilities

1. Sherman	1984-1985
2. Richland Creek	1984-1985
3. East Plant	1984-1985
4. Northeast Plant	1984-1985
5. Lower Valley	1986-1987
6. Tawakoni-Ray Hubbard	1986-1987
7. Stacy-Midland	1986-1987
8. Gatesville	1986-1987
9. Joe Pool Regional	1986-1987
10. Applewhite	1986-1987
11. Austin	1986-1987
12. Lake Georgetown	1986-1987
13. Southeast Plant	1988-1989
14. Bryan	1988-1989
15. Brazoria Cities	1988-1989
16. Austin	1988-1989
17. Double Mountain	1990-1991
18. Cooper-Lavon I	1990-1991
19. Prairie Creek	1990-1991
20. Palo Duro	1992-1993
21. Paluxy	1992-1993
22. Wheeler	1992-1993
23. Lake Fork-Dallas	1992-1993
24. Applewhite II	1994-1995
25. Denton	1998-1999
26. East Wichita Falls	1998-1999
27. Cooper-Lavon II	2000-2001
28. San Marcos	2000-2001

Figure 17. Major Water Treatment Facilities Needed, 1984-2005

river basins in which such sources are located, were identified as potential supplies to offset these shortages. In addition to those projects determined to be needed by this allocation of water supplies to projected demands, other specific projects were identified which could be selected based upon the plans of local interests. Where local interests have indicated that they would develop alternative projects, those projects are included in the proposed surface-water development plan.

The surface-water allocation procedure described above resulted in the scheduling of 44 of the 65 potential major reservoir projects over the period 1990 through 2030 (Figure 15). Conveyance works and raw water treatment facilities for which construction should be initiated before the year 2005 are indicated in Figures 16 and 17. Planning for conveyance works and raw water treatment facilities beyond the year 2005 is incomplete. Many of the projects projected for construction and operation by 1990 will not likely be operational by that time; however, these projects or their equivalent alternatives will be needed should there occur a repetition of the critical drought of historical record. The projected High and Low Series water demands and the projected water supplies are indicated in Figure 18. The timing of construction of the facilities indicated in Figures 15, 16, and 17 could be delayed if population growth, growth in the economy, and the effects of water conservation follow more closely the Low Series estimates of future water demands. For projects scheduled after 2000, this delay could be 10 to 15 years.

ALLOCATION OF WATER SUPPLIES TO REGIONAL DEMANDS

In spite of the additional major reservoirs proposed for the 1980-2030 period, some areas of the State are projected to have significant water shortages within the next 50 years. Water for municipal and industrial purposes will be available from existing and proposed sources for the major metropolitan areas, with the exception of the Lower Rio Grande Valley and El Paso. These areas are projected to have significant shortages.

Water available for irrigated agriculture will be insufficient to meet projected needs in many areas of Texas. These areas include the Texas High Plains, Trans-Pecos, Lower Rio Grande Valley, Winter Garden, and Middle Gulf Coast (Figure 11).

The projected High and Low Series water demands and the projected water supplies in each of eight major geographic regions of the State are shown and discussed below. The water needs and supplies referenced are totals for a region. Localized shortages and surplus supplies occur within each region, and these are discussed in more detail in *Volume 2—WATER FOR TEXAS: Technical Appendix.*

Upper Rio Grande and Far West Texas Region

In 1980, the water supply in the Upper Rio Grande and Far West Texas Region totaled approximately 631 thousand acre-feet (Figure 19). Ground water supplied about 362.0 thousand acre-feet, or 57.4 percent of this total. The remaining 269.0 thousand acre-feet represents the surface-water supply available to the Region in 1980 from the Rio Grande Project, return flows below El Paso, and direct diversions from the Rio Grande in Presidio County.

Ground water will continue to be a major source of water in the Upper Rio Grande and Far West Texas Region. However, water use from ground-water sources in the Region is projected to peak in the year 2010 at the 396.3 thousand acre-feet estimated annual supply and decline to 145.9 thousand acre-feet estimated annual supply by the year 2030.

The surface-water supply available to the Upper Rio Grande and Far West Texas Region in the future is projected to average approximately 180.0 thousand acre-feet annually. Of this quantity, 128.7 thousand acre-feet per year represents the average annual allotment from the Rio Grande Project, based on the last 30 years of record. Return flows below El Paso at the El Paso-Hudspeth County line are estimated to be about 38.5 thousand acre-feet per year. The remaining 12.8 thousand acre-feet is the estimate of local (nonproject) surface water available to the Region, primarily from the Rio Grande in Presidio County.

Projections of water needs and available water supplies in the Upper Rio Grande and Far West Texas Region over the ensuing 50-year period indicate that in each decade from 1990 through 2030 the Region will experience increasing water deficits. The annual water shortage is projected to increase from 86.6 thousand acre-feet in 1990 to about 618.4 thousand acre-feet in 2030. The majority of these shortages will be in irrigated agriculture. Municipal and industrial needs in the Region can generally be met through the year 2010. However, after 2010 declining ground-water supplies, along with projected increased demands, could result in shortages of water for municipal and industrial uses. The water deficit for municipal and industrial purposes is projected to be approximately 43.1 thousand acre-feet annually in 2020, increasing to about 237.5 thousand acre-feet annually by the year 2030.

Water resources within the Region needed to augment the existing water supplies available to the Region are limited. The importation of surface-water supplies from other areas of the State, that are projected to be surplus to the future 50-year needs of the river basins in which such

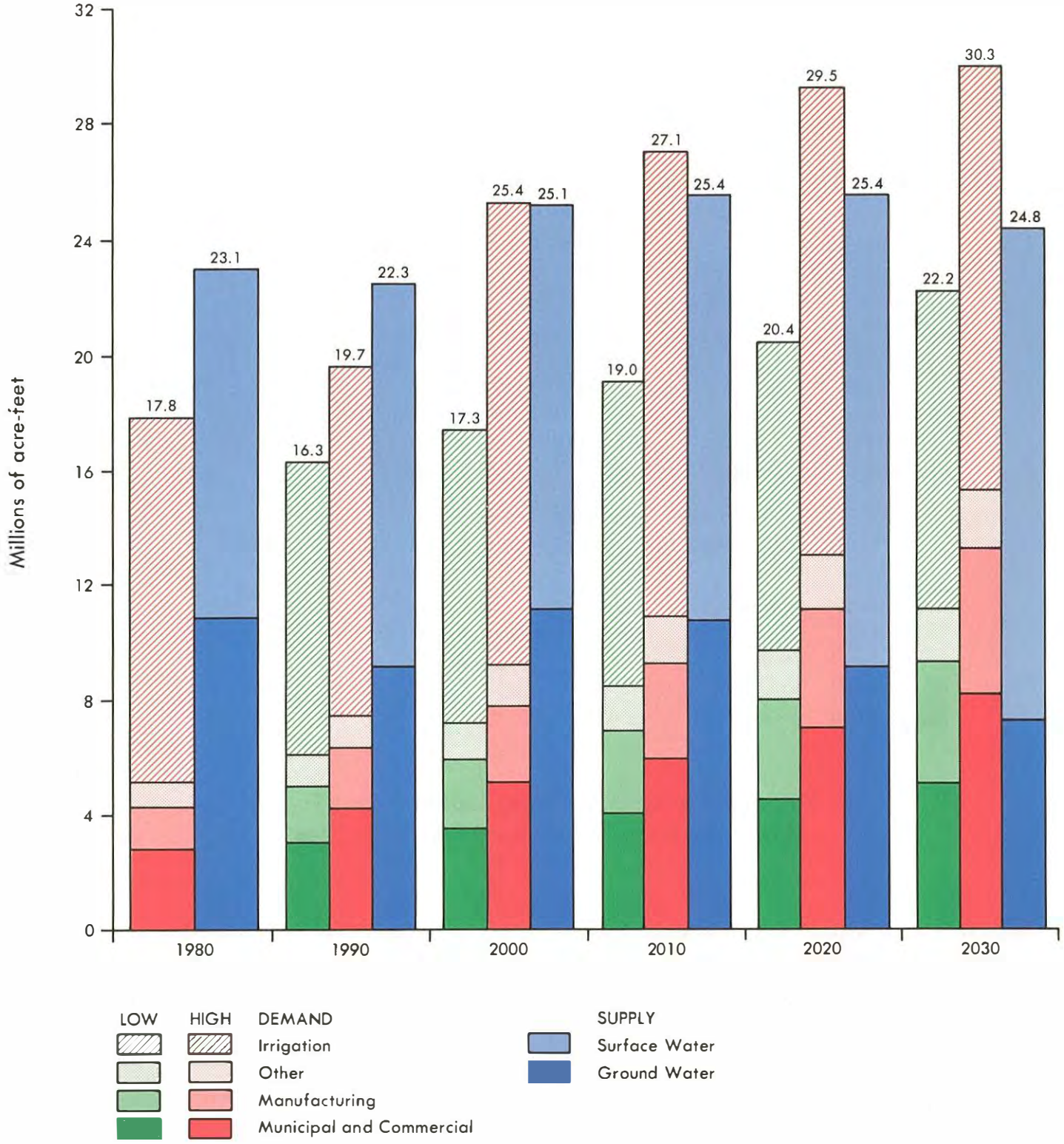


Figure 18. Projected Water Demand and Supply Texas

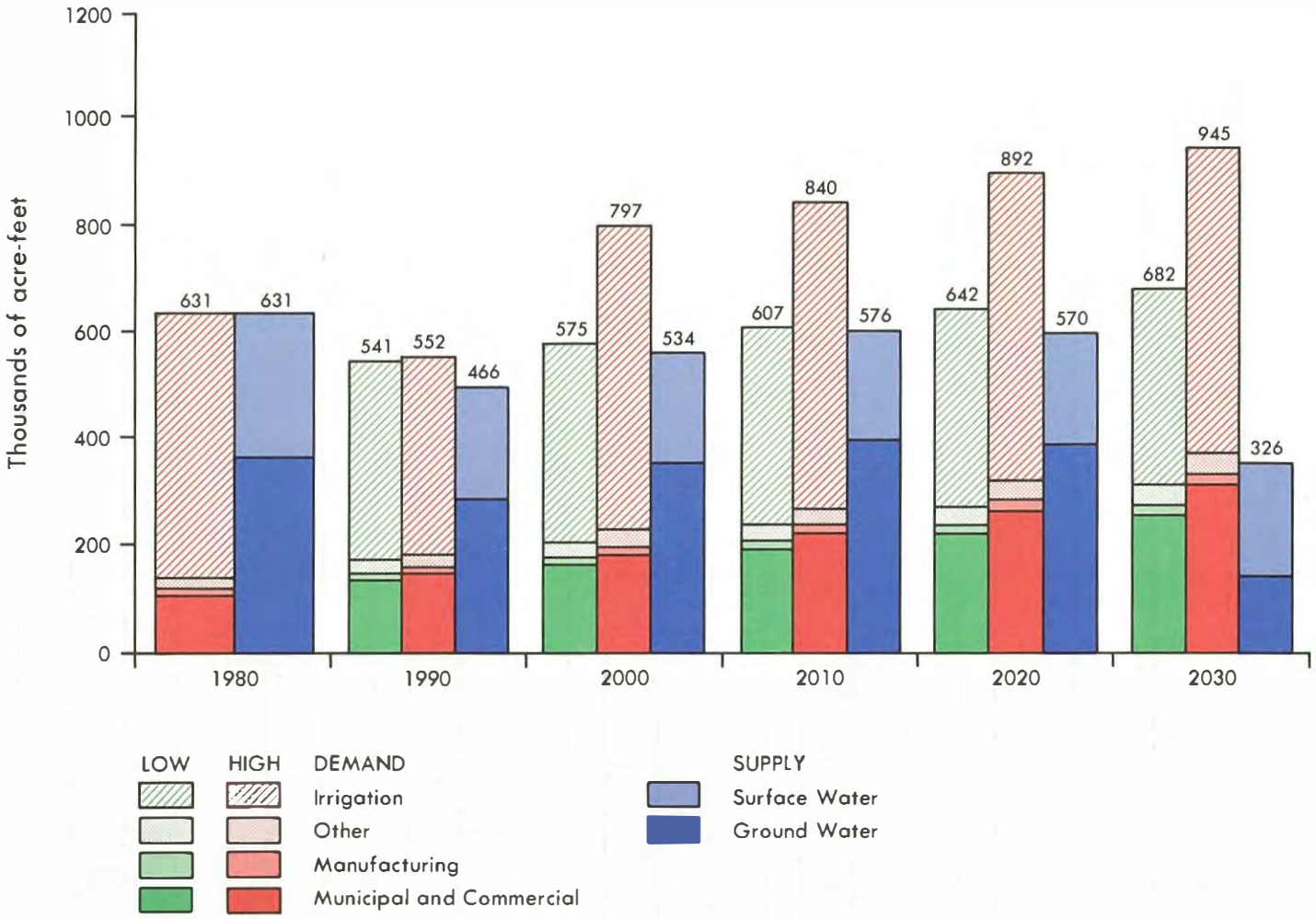


Figure 19. Projected Water Demand and Supply Upper Rio Grande and Far West Texas Region

supplies are located, appear to be prohibitively expensive due to the great distances and lifts that would be involved.

The City of El Paso faces potentially severe water shortages by 2030 due to overdrafting of the City's groundwater supplies. Surface-water supplies are fully committed to permit holders in the Rio Grande Project. The City is aggressively pursuing municipal water conservation to reduce demands, and is implementing artificial recharge programs to increase future supplies. The long-term solution to the City's water needs, however, will lie in acquiring additional water sources. To that end, El Paso is seeking ground water in southern New Mexico and is involved in litigation with that state.

High Plains and Trans-Pecos Region

In 1980, the water supply in the High Plains and Trans-Pecos Region was approximately 7.97 million acre-feet (Figure 20). Ground water supplied about 7.65 million acre-feet, or 96 percent of this total. The remaining 0.32 million acre-feet represents the dependable annual supply currently available to the Region from surface-water sources.

In the High Series projections, the High Plains and Trans-Pecos Region is projected to have a local area water shortage for irrigated agriculture of 1.17 million acre-feet annually before 1990, and this shortage is projected to

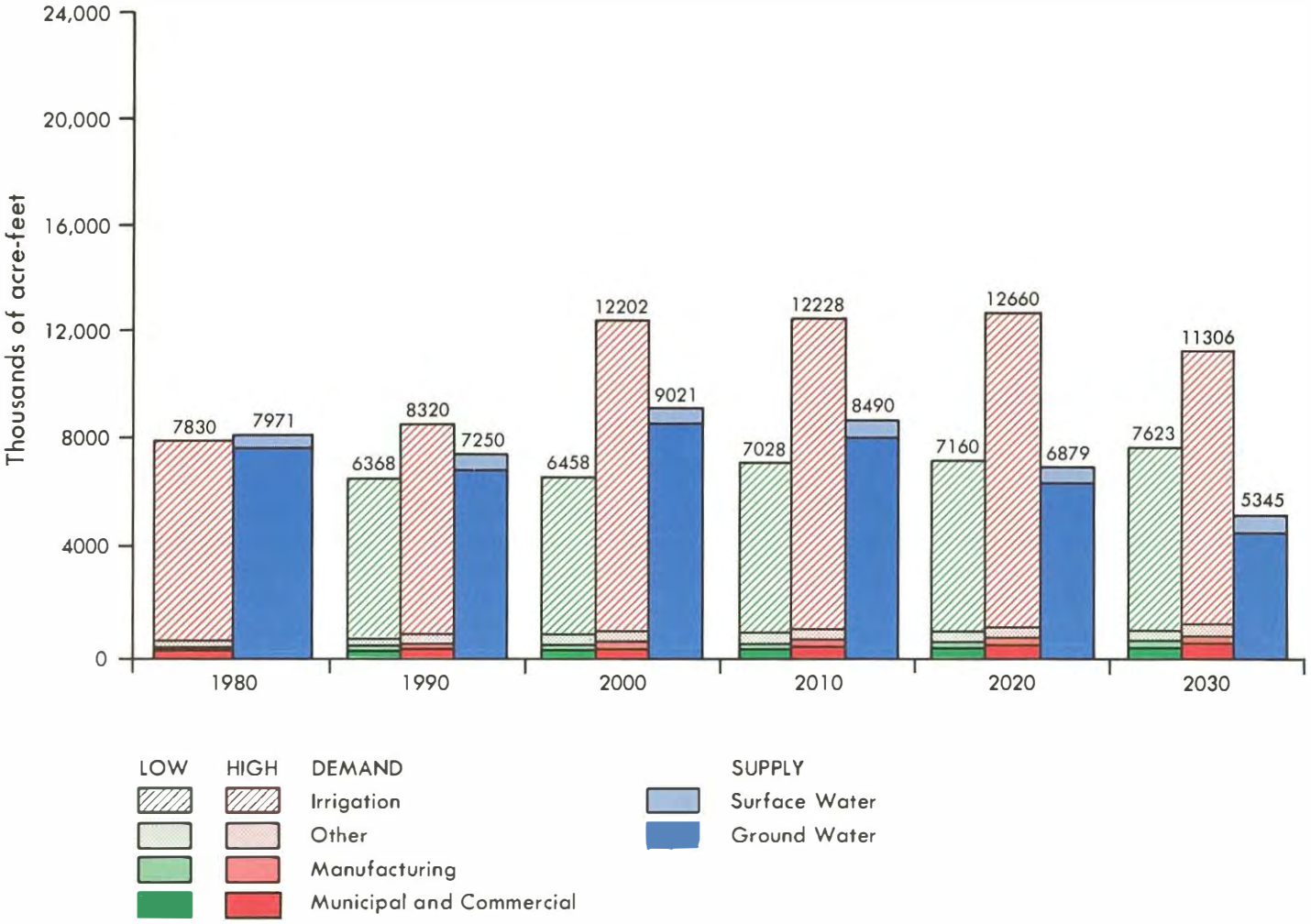


Figure 20. Projected Water Demand and Supply High Plains and Trans-Pecos Region

increase thereafter. The shortage is estimated to be approximately 3.2 million acre-feet annually by 2000 and 5.94 million acre-feet annually by 2030. The declining ground-water supply from the High Plains (Ogallala) Aquifer, along with projected long-range growth opportunities for irrigated agriculture, are the reasons for the projected shortage. Ground-water usage in the Region is projected to increase to about 8.6 million acre-feet per year by the year 2000; locally available ground-water supplies are projected to decline through 2030 to about 4.8 million acre-feet per year, while total water demands are projected to increase by 2030 to more than 11.3 million acre-feet per year. A potential supply to meet part of these shortages may be available through secondary recovery of capillary water in the High Plains (Ogallala) Aquifer. Further research is being conducted to determine the cost and feasibility of the technique. The development and importation of sufficient surface-water resources to offset this shortage of water for irrigated agriculture appears to be prohibitively expensive at the present time. In addition, such surpluses do not exist within Texas. Thus, a source of surplus water will have to be obtained from outside the State. Future planning will continue to explore alternatives for solving water supply problems of the West Texas area, including possible importation of surplus water from other states and water conservation methods.

Municipal and industrial needs in the Region through the year 2030 are projected to be met by the development of additional municipal well fields and the construction of additional surface-water reservoirs. Justiceburg, Sweetwater Creek, Palo Duro, and Post Reservoirs are proposed

for development in the Region to supply municipal and industrial water. In the adjacent South Central Texas Region, Stacy Reservoir in the Colorado River Basin is proposed to supply water to the High Plains and Trans-Pecos Region (Figure 15). With these developments, surface-water sources will be capable of supplying approximately 397.6 thousand acre-feet of water per year to the Region by the year 2000, increasing to about 505.6 thousand acre-feet annually by the year 2030.

Six major water conveyance facilities are needed in the Region by the year 2005 in order to transport water from planned supply sources to points of use (Figure 16). After the year 2005, additional or expanded water conveyance facilities will be needed. Planning for these facilities is incomplete.

Four major raw water treatment facilities will be needed in the Region before the year 2005 (Figure 17). Planning for additional or expanded water treatment facilities in the Region after the year 2005 is incomplete.

The continued suitability of water from Lake Meredith for municipal and industrial purposes is threatened by natural salt (chloride) contamination as a result of the flow of brine from an artesian aquifer upstream of Lake Meredith. The Lake Meredith Salinity Control project is needed to protect the water quality in Lake Meredith from further deterioration.

West Central Texas Region

In 1980, the water supply in the West Central Texas Region was approximately 595.0 thousand acre-feet (Figure 21). Ground water supplied about 222.0 thousand acre-feet or 37.3 percent of this total. The remaining 373.0 thousand acre-feet represents the dependable annual supply currently available to the Region from surface-water sources.

Ground-water resources are scattered in the West Central Texas Region, and in much of the Region well yields are low. In some areas, ground water contains high nitrate and fluoride concentrations which make the water undesirable for municipal use without very expensive treatment. Consequently, the location of usable ground water in relation to the location of demand for such water results in a condition such that ground water is estimated to supply only about 175.9 thousand acre-feet of the annual demand in the Region by 1990, increasing to 192.8 thousand acre-feet annually by the year 2000, then declining to 182.5 thousand acre-feet annually by 2030.

Surface-water resources are also rather scarce in the Region. Natural salt pollution in the upper regions of the Red and Brazos River Basins has prevented the full utilization of these resources in the Region. A number of salt control structures have been proposed by the U.S. Army Corps of Engineers to prevent natural sources of salt pollution from continuing to contaminate fresh surface-water resources in the Region.

In order to meet projected needs for municipal and manufacturing purposes in the Region through the year 2030, the development of additional reservoirs and implementation of natural salt pollution control projects will be needed (Figure 15). Ringgold, South Bend, and Breckenridge Reservoirs are proposed for development in the Region to supply municipal and industrial water. With these developments, surface-water sources in the Region will be capable of supplying approximately 468.2 thousand acre-feet annually by the year 2030. This quantity of supply includes recapturable municipal and manufacturing treated return flows in the Region that are projected to be 8.5 thousand acre-feet annually in 1990, increasing to 9.6 thousand acre-feet annually in the year 2000 and 15.1 thousand acre-feet annually by the year 2030.

The West Central Texas Region is projected to have sufficient water resources through the year 2030 to meet anticipated water needs for municipal and manufacturing purposes, with only minor local shortages, if additional surface-water supplies are provided by the construction of Breckenridge, South Bend, and Ringgold Reservoirs, or alternative reservoirs. Natural salt pollution control will be required to make the water supply in the proposed South Bend Reservoir of acceptable quality for municipal use. However, irrigated agriculture is projected to incur shortages beginning in 1990. These shortages are estimated to be 143.0 thousand acre-feet annually in 1990, increasing to 186.5 thousand acre-feet annually by the year 2030.

One major water conveyance facility (Figure 16) and one major raw water treatment facility (Figure 17) are needed in the Region by the year 2005. Planning for additional or expanded water conveyance and raw water treatment facilities after the year 2005 is incomplete.

North Texas Region

In 1980, the water supply in the North Texas Region was approximately 1.97 million acre-feet (Figure 22). Ground water supplied about 168.0 thousand acre-feet or 8.5 percent of this total. The remaining 1.8 million acre-feet represents the dependable annual supply currently available to the Region from surface-water sources.

Ground-water levels have been lowered significantly in some areas in the Region and the quality of the ground water is deteriorating with the decline of water levels.

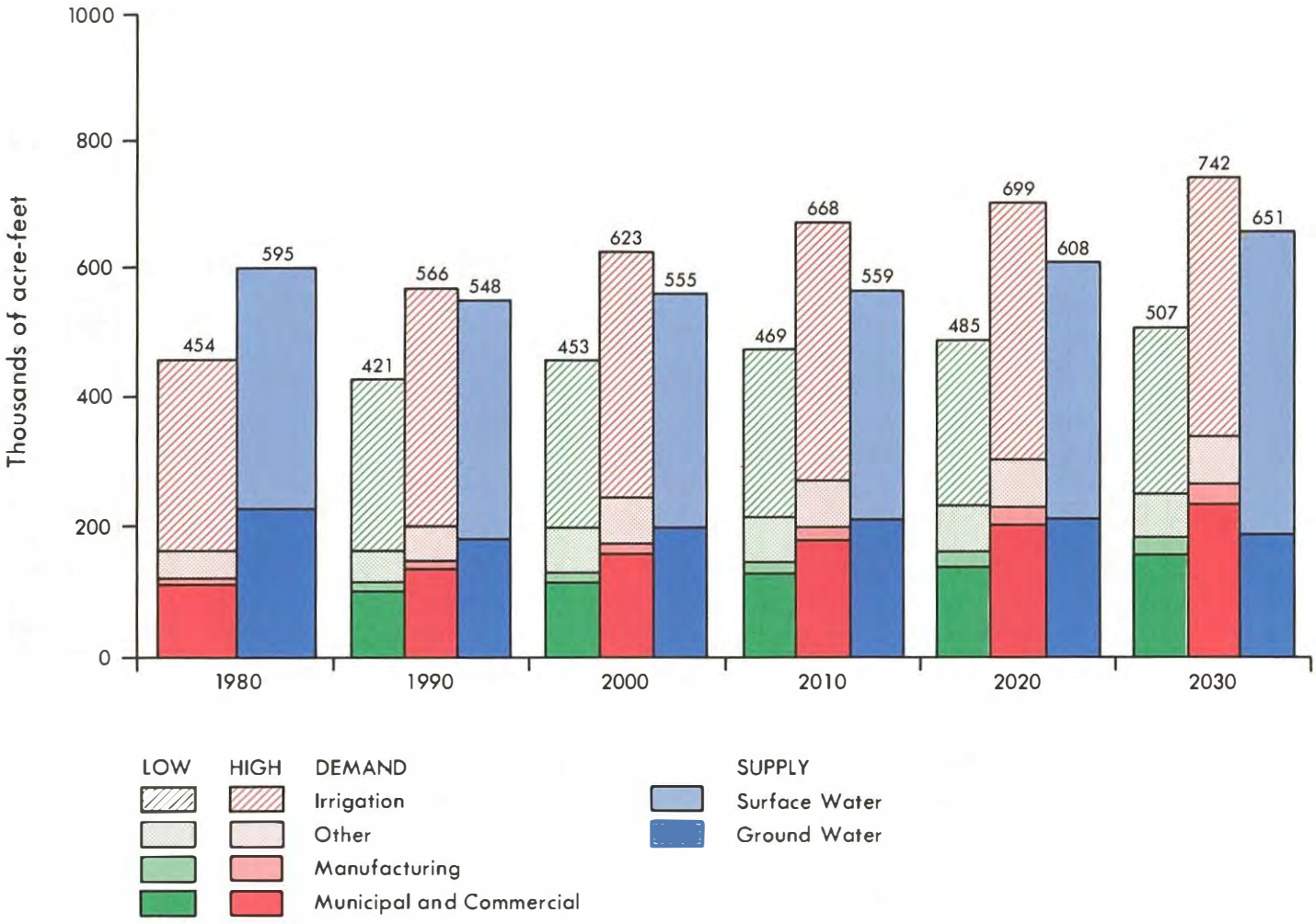


Figure 21. Projected Water Demand and Supply West Central Texas Region

Consequently, the location of usable quality ground water in relation to the location of demand for such water results in a condition such that ground water is estimated to supply only about 85.0 thousand acre-feet of the annual demand in the Region by 1990, increasing to 94.3 thousand acre-feet by the year 2000, and declining to 93.6 thousand acre-feet by 2030.

The projected water resources in the North Texas Region and the surface-water projects proposed to be developed in the adjacent Northeast Texas Region to supply the Region (Figure 15) are estimated to be sufficient to meet the regional municipal and manufacturing needs through 2030. Water available by 1990 from existing reservoirs plus that from reservoirs under construction is anticipated to be in excess of the regional needs through the year 2010.

Paluxy, Tehuacana, Bosque, and Tennessee Colony Reservoirs are proposed for development in the Region as well as an enlargement to the existing Lake Waco to supply municipal and industrial water. The Tennessee Colony project could be developed before 2010 if the project is reduced in size and conflicts with lignite mining are resolved. In the adjacent Northeast Texas Region, Cooper, Parkhouse I and II, and Nichols I Reservoirs in the Sulphur River Basin and Big Sandy and Carl Estes Reservoirs in the Sabine River Basin are potential projects that could supply water to the North Texas Region. Reallocation of water supplies in Lake Belton, currently committed to users out-

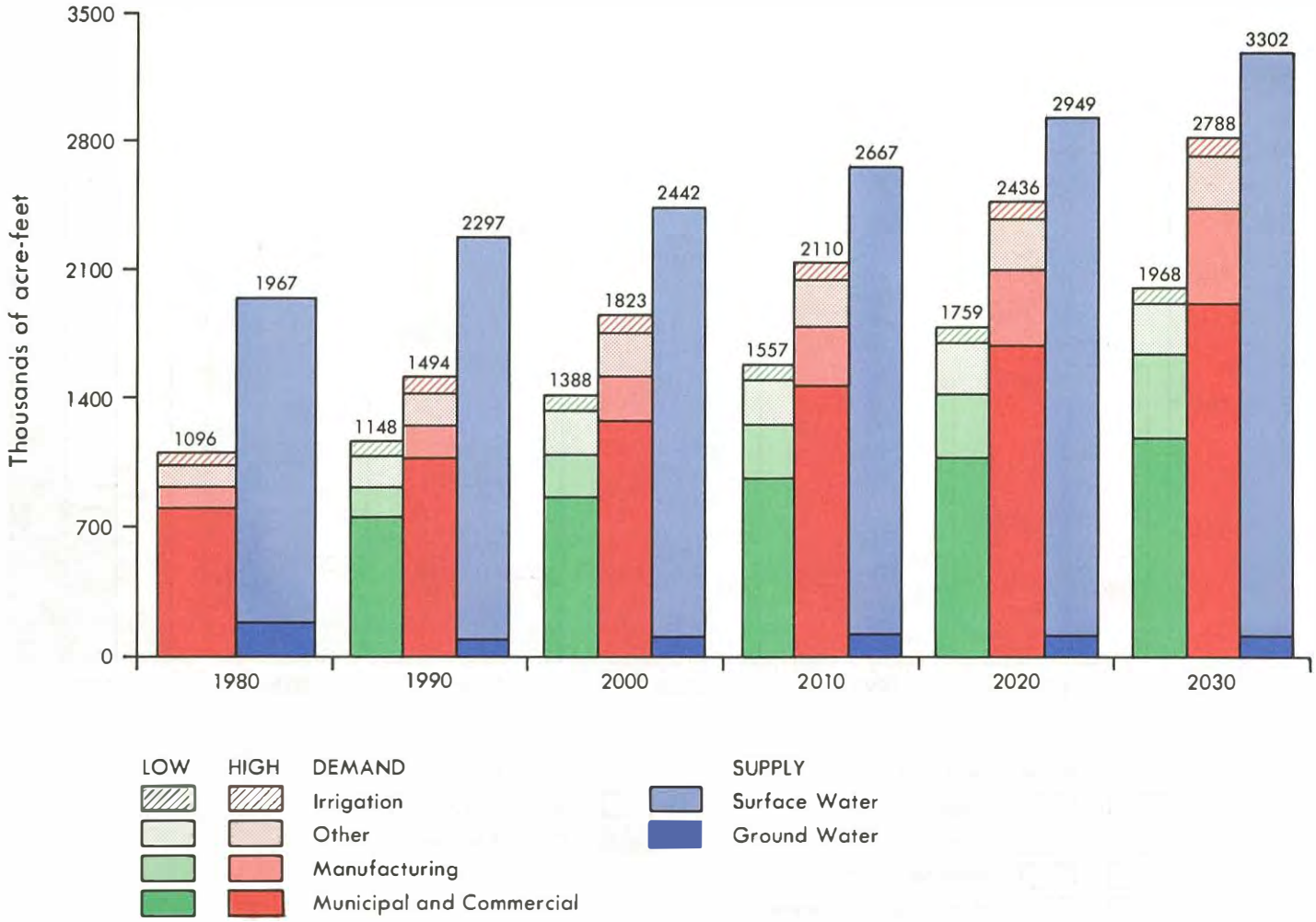


Figure 22. Projected Water Demand and Supply North Texas Region

side the Region, to local users in Bell and Coryell Counties can be accomplished by the development of additional water resources in the Brazos River Basin.

An annual water surplus of approximately 618.7 thousand acre-feet is projected for the Region in 2000. The projected annual water surplus for the Region will decrease to approximately 513.7 thousand acre-feet in 2030. Annual usable municipal and manufacturing return flows within the Region are projected to be 165.4 thousand acre-feet in 1990 and 208.1 thousand acre-feet in 2000. By 2030, the reusable return flows are anticipated to be 371.3 thousand acre-feet per year.

Eleven major water conveyance facilities are needed for the Region by the year 2005 in order to transport water from existing and planned supply sources to points of use (Figure 16). After the year 2005, additional or expanded water conveyance facilities will be needed. Planning for these facilities is incomplete.

Ten major water treatment facilities will be needed in the Region before the year 2005 (Figure 17). Planning for additional or expanded water treatment facilities in the Region after the year 2005 is incomplete.

Northeast Texas Region

In 1980, the developed water supply in the Northeast Texas Region was approximately 1.32 million acre-feet (Figure 23). Ground water supplied about 91 thousand

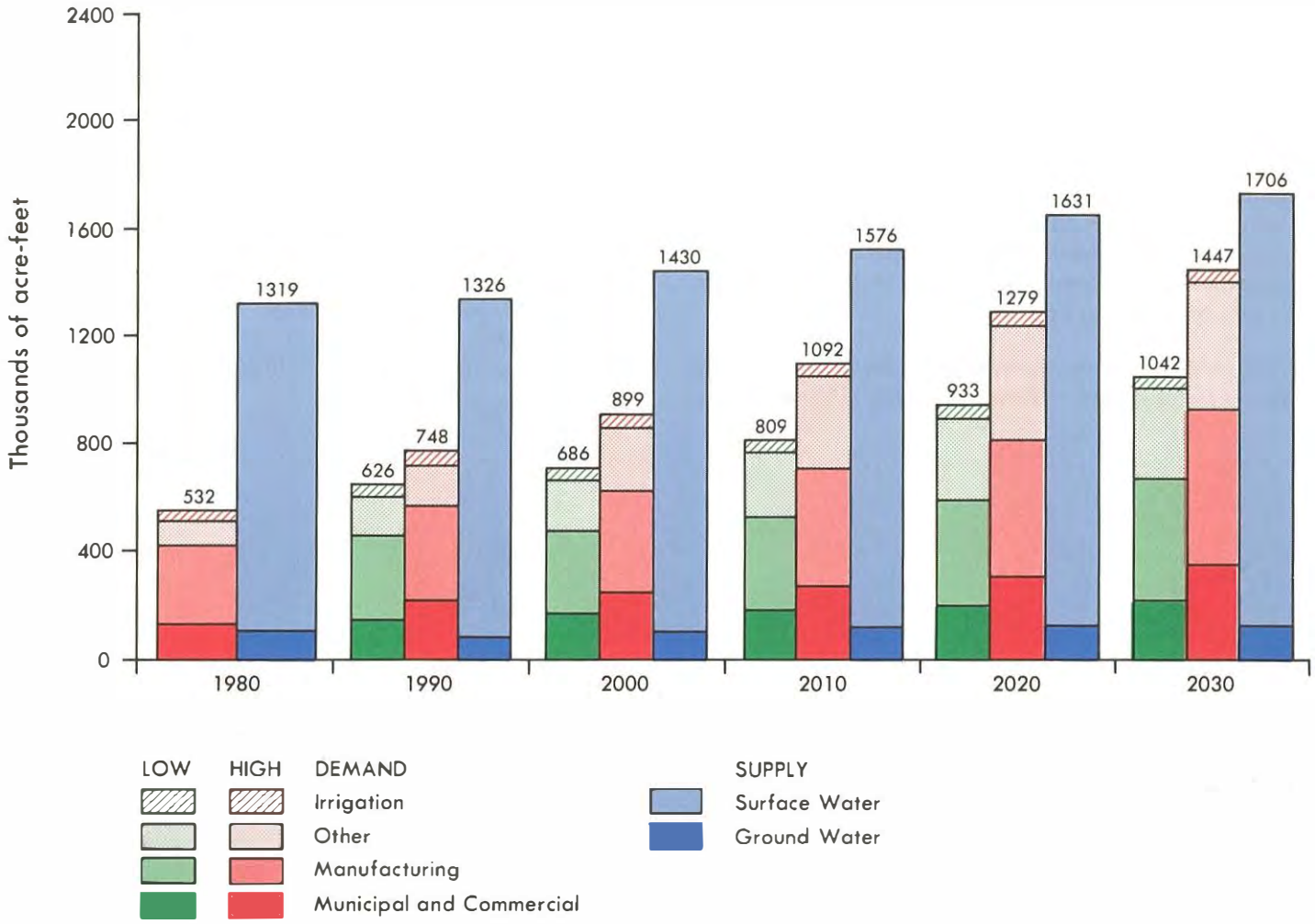


Figure 23. Projected Water Demand and Supply Northeast Texas Region

acre-feet, or 6.9 percent of this total. The remaining 1.23 million acre-feet represents the dependable annual supply currently available to the Region from surface-water sources.

In many areas of the Northeast Texas Region, shallow ground water has a high concentration of iron and is acidic, which makes the water undesirable for municipal and most industrial uses. Consequently, the location of usable quality ground water in relation to the location of demands for such water results in a condition such that ground water is estimated to supply only about 73.4 thousand acre-feet of the annual demand in the Region by 1990, increasing to 89.1 thousand acre-feet annually by the year 2000, and 119.6 thousand acre-feet annually by 2030.

In order to meet projected needs for municipal and manufacturing purposes in the Region through the year 2030, the development of additional reservoirs will be necessary (Figure 15). Based upon proposed development, surface-water sources in the Region can be capable of supplying approximately 1.34 million acre-feet per year by the year 2000, increasing to about 1.59 million acre-feet per year by the year 2030. The surface-water supplies include reservoir firm yields and recapturable return flows in the lower Red, Sulphur, Cypress, and upper Sabine River Basins. Annual recapturable return flows in the Region are projected to be 267.6 thousand acre-feet annually by the year 2000, increasing to 326.4 thousand acre-feet annually by the year 2030.

Overall, if additional reservoir projects are constructed, the Region is projected to have a surplus of surface-water supplies through 2030. Included in this projected surplus is a portion of the water developed in the Region for export to the Dallas-Fort Worth area for municipal and manufacturing needs. The regional water surplus is estimated to be approximately 530.8 thousand acre-feet per year by the year 2000 and 259.8 thousand acre-feet per year by 2030. Shortages in municipal and manufacturing supplies are not projected to occur in the Region under the proposed plan of development.

One major water conveyance facility (Figure 16) and one major raw water treatment facility (Figure 17) are needed in the Region before the year 2005. Planning for additional or expanded water conveyance and treatment facilities after the year 2005 is incomplete.

South Central Texas Region

In 1980, the water supply in the South Central Texas Region was approximately 1.7 million acre-feet (Figure 24). Ground water supplied about 902.0 thousand acre-feet, or 53 percent of this total. The remaining 798.0 thousand acre-feet represents the dependable annual supply currently available to the Region from surface-water sources.

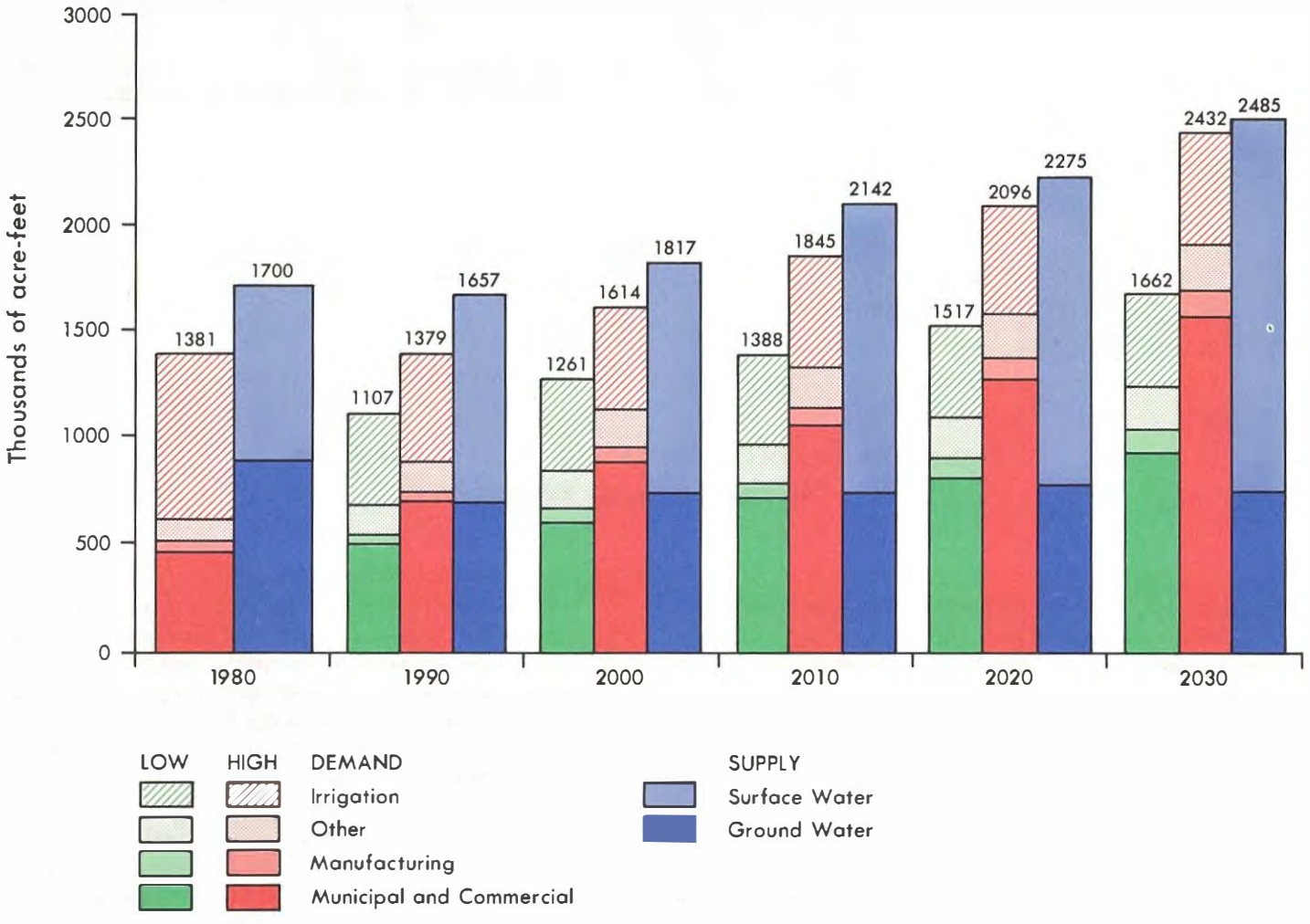


Figure 24. Projected Water Demand and Supply South Central Texas Region

Future ground-water supplies in the South Central Texas Region are based on the quantity of ground-water pumpage that can be sustained without causing severe water level declines, saline water encroachment, and cessation of flows from San Marcos Springs in the Guadalupe River Basin. The location of ground-water supplies with respect to the demand for such supplies results in a condition such that ground water is estimated to supply only about 694.7 thousand acre-feet of the annual demand in the Region by 1990, increasing to 734.9 thousand acre-feet annually by the year 2000, and 746.4 thousand acre-feet annually by 2030.

In order to meet projected needs for municipal and industrial purposes in the Region, the development of additional reservoirs will be necessary (Figure 15). Upper Guadalupe, Stacy, Applewhite, South Fork, Cloptin Crossing, Lockhart, and Cibolo Reservoirs are proposed for development in the Region to supply municipal and industrial water. In the adjacent Southeast Texas and Upper Gulf Coast Region, Lindenau, Cuero, and Goliad Reservoirs are proposed for development to supply municipal and industrial water to the San Antonio, Corpus Christi, and Victoria areas. Based upon proposed development, surface-water sources in the Region will be capable of supplying approximately 1.08 million acre-feet per year by the year 2000, increasing to about 1.74 million acre-feet per year by the year 2030. This includes usable municipal and industrial return flows that are projected to be about 24.5 thousand acre-feet annually in the year 2000, increasing to about 88.3 thousand acre-feet annually by the year 2030.

Overall, if additional reservoir projects are constructed, the Region will have sufficient water supplies to meet projected municipal and industrial needs through the year 2020 with only minor localized shortages during an extended drought period. However, after the year 2020 significant shortages of water for municipal and industrial purposes in the Williamson County area are projected to occur due to the extensive growth projected in that area. Studies are currently underway by local, regional, and State agencies to meet this anticipated need. Particularly, local cities are working with the Brazos River Authority to evaluate alternative supply sources. Planning is in progress for additional reservoir development in the Brazos River Basin that will allow some existing supplies in Stillhouse Hollow Reservoir, currently committed to downstream users in the lower Brazos River Basin, to be reallocated to municipal and industrial users in Williamson County. For planning purposes, it is assumed that South Bend and Caldwell reservoirs will be constructed by the Brazos River Authority to provide for such a reallocation. Shortages of water for irrigation, primarily in the Winter Garden area (Figure 11) are projected to be about 91.3 thousand acre-feet annually in 1990, increasing to 97.6 thousand acre-feet annually by the year 2000, and 169.2 thousand acre-feet annually by the year 2030.

Six major water conveyance facilities are needed in the Region by the year 2005 in order to transport water from existing and planned supply sources to points of use (Figure 16). After the year 2005, additional or expanded water conveyance facilities will be needed. Planning for these facilities is incomplete.

Six major raw water treatment facilities are needed in the Region before the year 2005 (Figure 17). Planning for additional or expanded water treatment facilities in the Region after the year 2005 is incomplete.

South Texas and Lower Gulf Coast Region

In 1980, the water supply in the South Texas and Lower Gulf Coast Region was approximately 1.77 million acre-feet (Figure 25). Ground water supplied about 61.6 thousand acre-feet, or 3.5 percent of this total. The remaining 1.71 million acre-feet represents the dependable annual supply currently available to the Region from surface-water sources.

The annual ground-water use in the Region is projected to be about 66.2 thousand acre-feet in 1990, increasing to 72.0 thousand acre-feet by the year 2000, and 95.6 thousand acre-feet by 2030.

The existing surface-water supplies in the South Texas and Lower Gulf Coast Region are practically all committed. Small amounts of additional surface water for municipal and industrial purposes could be developed from two proposed channel dams on the Rio Grande at Retamal and Brownsville. In addition, the proposed Goliad Reservoir in the adjacent Southeast Texas and Upper Gulf Coast Region can supply water for municipal and industrial purposes in the Corpus Christi area (Figure 15).

With these developments, surface-water sources in the Region will be capable of supplying approximately 1.75 million acre-feet annually by the year 2000, increasing to about 1.87 million acre-feet by the year 2030. These surface-water supplies include recapturable return flows that are projected to be about 48.5 thousand acre-feet annually by the year 2000 and about 165.8 thousand acre-feet annually by the year 2030.

The Region is projected to incur significant water shortages before 1990 with increasing quantities of shortage thereafter. Approximately 200.0 thousand acre-feet of these annual shortages is in irrigated agriculture. The municipal and industrial shortages in the Region are estimated to be 131.7 thousand acre-feet annually by the year

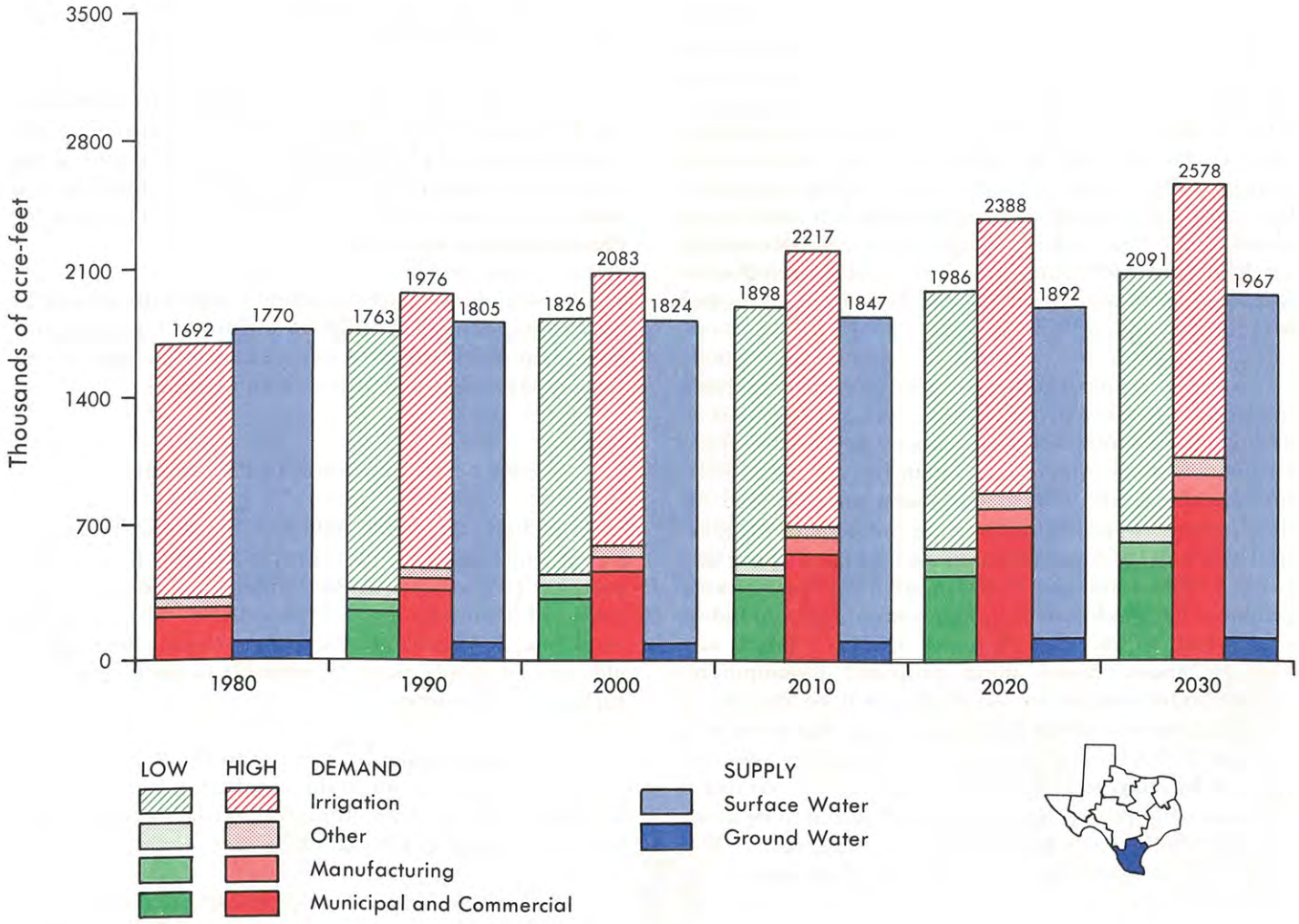


Figure 25. Projected Water Demand and Supply South Texas and Lower Gulf Coast Region

2000, increasing to 437.4 thousand acre-feet annually by 2030. The large majority of these municipal and industrial shortages are in the Lower Rio Grande Valley where limited additional supplies of ground and surface water are available to meet the needs of rapid growth.

Studies by the Department have evaluated the possibility of transporting surplus surface waters from other areas of the State to the Lower Valley area. These studies have indicated that such supplies would be relatively expensive, and local interests have pursued less expensive short-term alternatives for the acquisition of water for municipal and manufacturing use, such as the purchase of irrigation water rights and improvements to conveyance facilities within the area.

No major water conveyance facilities are planned for the Region before the year 2005. Planning for such facilities after the year 2005 is incomplete. A major raw water treatment facility is planned in the Lower Rio Grande Valley for the 1986-1987 period (Figure 17). Planning for additional or expanded water treatment facilities in the Region after the year 2005 is incomplete.

Southeast Texas and Upper Gulf Coast Region

In 1980, the water supply in the Southeast Texas and Upper Gulf Coast Region was approximately 7.2 million acre-feet (Figure 26). Ground water supplied about 1.5

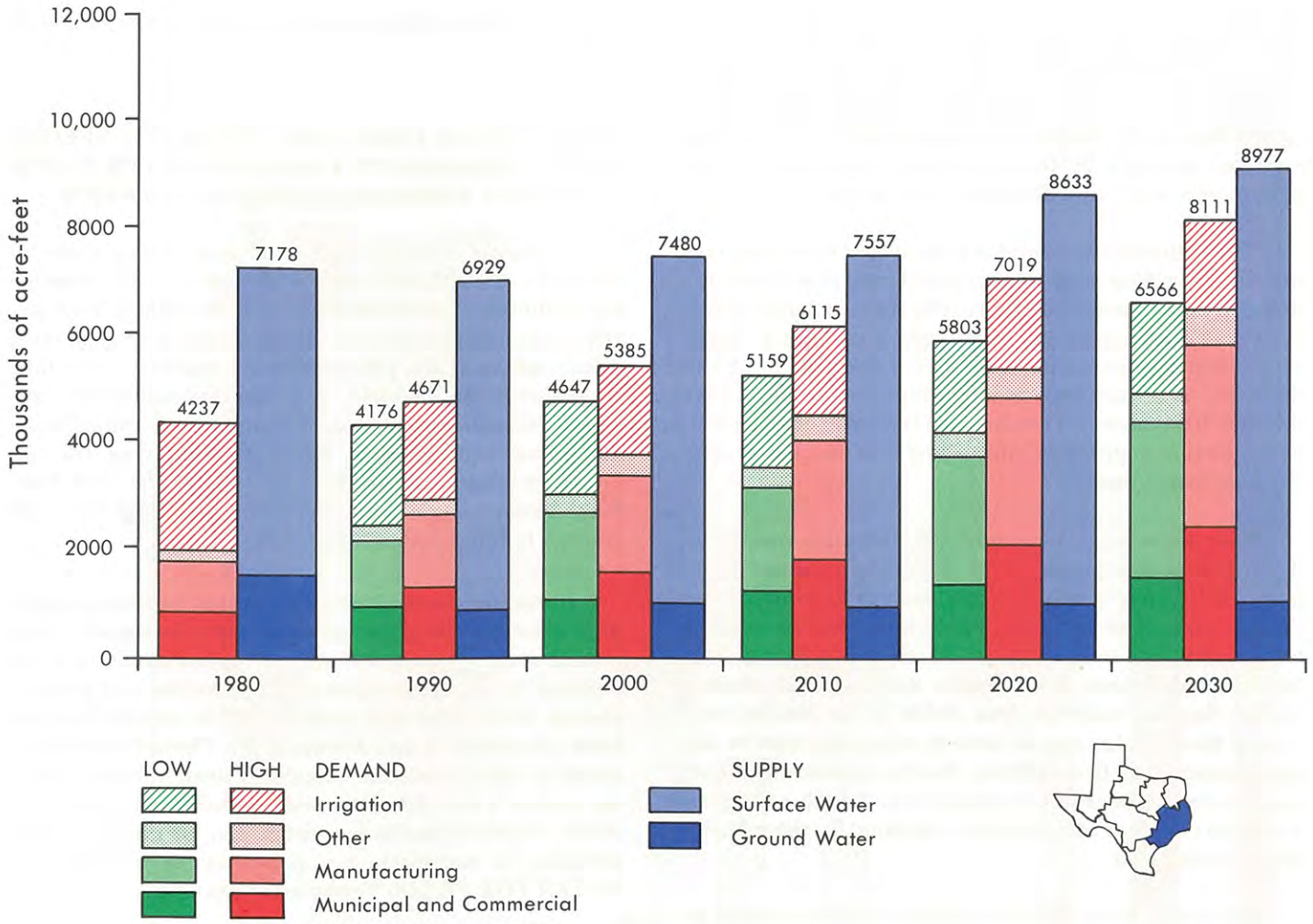


Figure 26. Projected Water Demand and Supply Southeast Texas and Upper Gulf Coast Region

million acre-feet (20.8 percent) of this total. The remaining 5.7 million acre-feet represents the dependable annual supply currently available to the Region from surface-water sources.

Water users in this Region must become increasingly dependent upon surface-water supplies due to the necessity to manage more carefully ground-water pumpage in some areas, primarily from the Gulf Coast Aquifer, to prevent further land subsidence and saline water encroachment. Consequently, the location of ground water in relation to the location of demand for such water results in a condition such that ground water is estimated to supply only about 836.0 thousand acre-feet of the demand annually in the Region by 1990, increasing to 909.5 thousand acre-feet annually by the year 2000, and 1.05 million acre-feet annually by 2030.

In order to meet projected needs for municipal and manufacturing purposes in the Region, the development of additional reservoirs will be necessary (Figure 15). Wallisville, Millican, Caldwell, Lindenau, Cleveland, Colorado Coastal Project, Lower Lake Creek, Rockland, Goliad, Bedias, and Bon Weir Reservoirs are proposed for development in the Region to supply municipal and industrial water. Based upon proposed development, surface-water sources in the Region will be capable of supplying approximately 6.6 million acre-feet per year by the year 2000, increasing to about 7.9 million acre-feet per year by the year 2030.

Overall, the Region is projected to have a surplus of surface-water supplies through 2030. This surplus is due to projected surplus reservoir firm yields in the Sabine and Neches River Basins and to projected increased return

flows from the metropolitan areas of Dallas and Fort Worth that would be recapturable in the lower Trinity River Basin. These return flows are estimated to be over 1.5 million acre-feet per year by the year 2030. Annual recapturable return flows in the Region are projected to be 1.4 million acre-feet annually by the year 2000, increasing to 2.2 million acre-feet annually by the year 2030.

The regional water surplus is estimated to be approximately 2.1 million acre-feet per year by the year 2000 and 867.0 thousand acre-feet per year by the year 2030. However, irrigated agriculture is projected to have a water supply shortage increasing from 227.0 thousand to 285.0 thousand acre-feet per year during the period 1990 through 2030 period. This shortage is a result of an anticipated decline in ground-water supplies in the coastal area southwest of Houston.

Four major water conveyance facilities are needed in the Region before the year 2005 in order to transport water from existing and planned supply sources to points of use (Figure 16). After the year 2005, water will be needed from additional sources to avoid shortages in the San Jacinto and Brazos River Basins and adjacent coastal basins. Surplus reservoir firm yields in the Neches and Sabine River Basins can be used to offset shortages in the San Jacinto and Brazos River Basins. Additional major conveyance facilities will be needed to convey these surplus waters to points of use; however, planning for these facilities is incomplete.

Five major water treatment facilities will be needed in the Region before the year 2005 (Figure 17). Planning for additional or expanded water treatment facilities in the Region after the year 2005 is incomplete.

During periods of low flow and high water withdrawals, salt water from the Gulf of Mexico intrudes up the Neches River in sufficient quantity to contaminate fresh water supplies diverted from the river at Beaumont, Texas. Construction of the Salt Water Barrier project at Beaumont would permanently eliminate this problem.

WATER IMPORTATION

Because there is no single solution to the water needs and problems of the State, water importation will continue to be considered by the Department as one of several alternatives to increase water supplies. Importation studies and planning by the Department will consider only those floodwaters determined to be in excess of the future needs of any potential import source area. Importation studies will assess the need, consider the feasibility, and analyze the environmental impacts and economic costs of any such project.

ESTIMATES OF COSTS AND FINANCING NEEDED FOR WATER QUALITY PROTECTION AND WATER SUPPLY PURPOSES IN TEXAS—1984-2005

Estimates of capital facility costs have been made for reservoirs and chloride control structures, water conveyance and treatment facilities, wells and related facilities, and wastewater treatment works. These estimates were calculated in 1983 prices, without regard for the time construction would begin, and then inflated to the estimated time of construction at a compound annual inflation rate of eight percent. For each facility type, the cost estimates have been tabulated and charted for each State fiscal biennium for both the 1983 costs and the eight percent inflated costs (Figure 27).

In addition, estimates are presented for those proportions of total funding that are expected to be supplied from federal sources, the proportions that are expected to be supplied by local and regional governments, and the proportion of financial assistance that will be needed from the State (Appendix A and Appendix B). These detailed estimates of cost include the cost data shown in Figure 27 for the period 1984-2005, as well as estimates to the year 2030. Project-specific cost estimates, for projects where planning is complete, are presented in *Volume 2—WATER FOR TEXAS: Technical Appendix.*

The estimates of project costs do not include estimates of required capital for privately financed or owned water supply or wastewater treatment facilities, nor do they include the capital costs that would be incurred by a subdivision developer in providing water or sewer services to new residences. Cost estimates are not included for some major raw water treatment, water conveyance, and wastewater treatment facilities that will be needed but for which planning is incomplete at this time, nor for facility capital costs for publicly owned, local water distribution systems, some new wastewater collection lines, smaller water treatment plants, and other similar facilities in cities or districts that do not qualify for federal financial participation or for assistance from the Texas Water Development and Water Loan Assistance Funds under "hardship" criteria.

Since 1956, federal funds have been appropriated and awarded as grants to the states to allocate to local governments for the construction of domestic wastewater treatment facilities. While these grants currently provide 75 percent of construction costs of eligible projects, this share will be reduced to 55 percent beginning October 1, 1984,

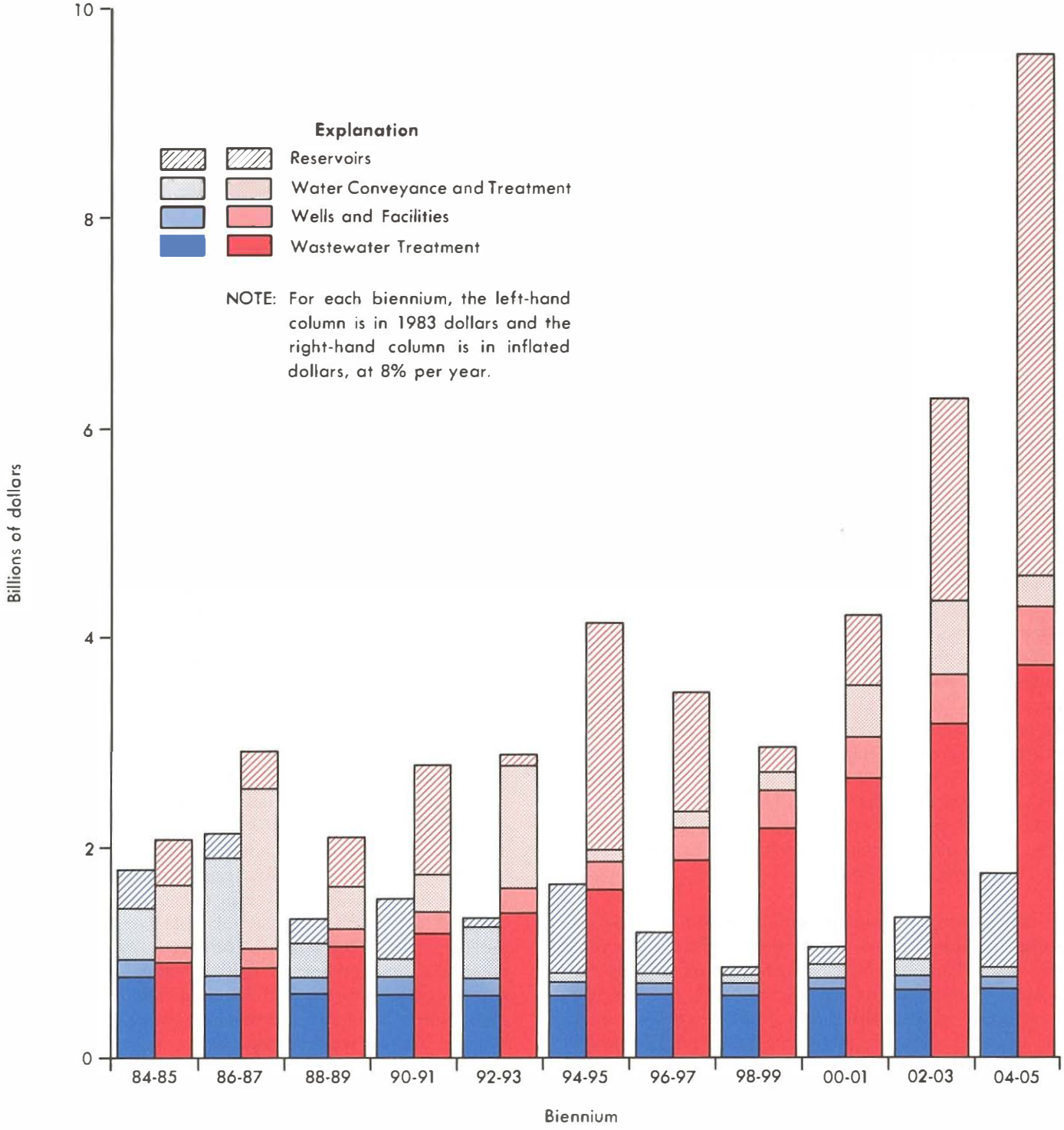


Figure 27. Water Quality and Water Supply Capital Cost Estimates 1984-2005

and possibly totally eliminated by 1990. Given the anticipated reduction in federal funding for water management programs and the requirements to meet water quality standards, local and State governments will be forced to assume a larger share of these costs.

Local governments borrow funds for water quality protection and water supply purposes through the sale of general obligation bonds backed by their respective taxing authorities, and through the sale of revenue bonds backed by the expected income from the sale of water and sewage treatment services. This type of financing depends upon the credit ratings of the respective governments and authorities. The better the credit rating, the lower the interest rate.

In the cost estimates presented in Appendix A and Appendix B, the form of "State financial assistance" is not specified. Such assistance could be in the form of loans, loan insurance, loan guarantees, acquisition of a part of the conservation storage in major reservoir projects by the State, or a combination of these methods. Acquisition of storage in large projects by the State is needed in order to assure optimum development of scarce project sites and thereby make additional water supplies available to meet projected future needs. The source of funding for State financial assistance could be any one of several means, or a combination of two or more means, including a State bond program, appropriations for direct loans, appropriations into a reserve fund which would be used to guarantee local bonds, constitutionally authorized use of a specified quantity of the State's full faith and credit to guarantee local bonds, or a dedicated tax. However, State financial assistance, in addition to that presently authorized through the Water Development and Water Quality Enhancement Loan Programs and the Water Assistance Fund, would require additional legislation.

Rural water supply corporations, as non-profit organizations, cannot qualify for loans or grants from either of the State water financing funds mentioned above. While the Farmers Home Administration (FmHA) of the U.S. Department of Agriculture has provided funding in the past, this type of funding assistance is declining and will be reduced further in the future. If these organizations become eligible for State financial assistance, the demand for State funds will increase further as the quantity of federal funds declines.

Furthermore, monies are needed for additional basic and applied research and planning in order to improve the techniques and technologies of water resources management.

Approximately 200 separate new collector, interceptor, and sewage treatment projects will be required throughout Texas over the period 1985-1989, with several times that number needed between 1990 and 2000 (Figure 13). An additional 44 wastewater projects are fundable in 1984 or are on the Department's contingency projects list and are anticipated to be funded in 1984. For those municipalities that are expected to obtain their future supply of water from ground-water sources, approximately 4,500 new wells will have to be developed between 1984 and 2005. Twenty-nine major water conveyance facilities will be needed by the year 2005 to transport raw water from sources of supply to points of use, and 28 new, major raw water treatment facilities will be needed between 1984 and 2005. Planning for such facilities for the period 2006-2030 is not complete. In order to meet future water supply requirements, 32 reservoirs, two channel dams, one salt water barrier, and seven natural salt (chloride) control projects need to be started between 1984 and 2005 (See Figures 13 through 17).

The estimated total capital requirement for publicly financed projects needed during the 1984-2005 time period is $16.1 billion in 1983 dollars (Figure 27). Wastewater treatment facilities account for $7.4 billion of the $16.1 billion total required, reservoir and chloride control projects account for $4.3 billion, with the remaining $4.4 billion needed for conveyance and water treatment facilities and for wells. Inflated at an annual rate of eight percent, estimates of facility capital costs total $43.6 billion for the period 1984-2005. Of this total, wastewater treatment facilities account for $20.7 billion, reservoir construction accounts for $13.4 billion, with the remaining $9.5 billion for water conveyance and water treatment facilities and for wells (Figure 27).

PLANNED ACTIONS AND POLICY RECOMMENDATIONS

In previous sections of the Water Plan, an overview of the water resources problems in Texas from a Statewide perspective has been presented. The rapidly growing and changing population and economy of Texas, the driving forces underlying utilization of water resources, have been characterized. Plans and means designed to address the existing and potential future water problems in Texas have been specified. Included are institutional and technical criteria for increasing water-use efficiency and methods for augmentation of existing water supplies from unconventional sources where additional ground- and surface-water supplies are not available or where there is a cost advantage in developing unconventional sources of water. Unconventional sources of water supply include reuse of treated effluent by industry and agriculture, use of "gray" water for certain municipal and commercial purposes, and desalinization of brackish or slightly to moderately saline water. Estimates have been made of: the quantities of additional water supplies that can be developed from surface- and ground-water sources; the capital expenditures needed to develop these supplies; and the capital requirements for transmission lines and raw water treatment facilities needed to transport, treat, and deliver suitable quality water to municipal, commercial, and industrial users. Also, estimates have been made of the capital outlays needed to develop sufficient wastewater treatment facility capacity to accommodate the needs of a growing population and economy, and to prevent a deterioration in the quality of the State's ground- and surface-water resources.

This section of the Plan sets forth actions proposed for the Texas Department of Water Resources and recommendations to local, State, and federal entities and the Legislature, which are directed toward expanding programs already in place and currently operational within the Texas Department of Water Resources, and also toward new programs for the Department that will direct certain resources and activities into new areas. These recommendations are intended to address the problem of inadequate long-term raw water supplies in certain areas of the State, the need for continuing and increasing State involvement in protecting water quality, and problems associated with the increasing financial strain upon local entities to provide the necessary capital for wastewater treatment facilities to prevent deterioration of water quality. Implementation of these recommendations would increase activities by the Department designed to address general water resource problem areas that have been identified in the long-range planning process.

WATER CONSERVATION AND PUBLIC EDUCATION

Water conservation must be given increased emphasis in the State's water supply development and water management programs. A balanced approach is needed which gives consideration both to water conservation opportunities and to those needs that can only be satisfied through the development of additional supplies. Preceding sections of the Plan provided a general discussion of the role intended for water conservation in long-range water resource planning. Here, specific actions and activities are recommended for the water conservation and public education programs of the Department.

Municipal and Commercial Water Conservation

In order to increase municipal and commercial water conservation, the Department of Water Resources will cooperate with local governments and State and federal agencies to disseminate water conservation information to the public, encourage water conservation by the public, encourage water conservation through the news media, and support research and development of water conservation methods through the following actions:

1. The Department will provide staff assistance for developing and implementing water conservation programs by cities, water supply districts, river authorities, and other entities as appropriate.

2. The results of conservation and reuse activities of cities and the results of research by universities and other agencies engaged in water conservation research will be obtained and such information will be made available to the public.

The Department recommends biennial appropriations for municipal and commercial water conservation programs in the amount of $400 thousand. Activities of the municipal and commercial water conservation program will include the following:

1. The Department will conduct one-day workshops for members of city planning staffs in each of the 24 regional planning areas of the State. In these

workshops, methods for increasing municipal and commercial water conservation will be identified. Procedures for developing municipal and commercial water conservation programs appropriate for each region will then be presented.

2. Technical assistance in the development of municipal and commercial water conservation programs will be provided to approximately 100 cities and water districts and authorities that have experienced difficulties or that are projected to experience difficulties in meeting demands placed on their water supply systems.

3. Water conservation pamphlets, brochures, flyers, and other materials will be prepared for distribution to the public.

Industrial Water Conservation

Water conservation methods utilized by private industry are generally proprietary. The Department, however, needs to be informed of industry efforts aimed at reducing the quantities of water used in manufacturing processes, especially attempts to reduce use of potable water, as these reductions affect Department estimates of future water requirements for industrial purposes. Estimates of the potential to use recycled water within industrial facilities, or available treated effluent, will be defined and incorporated in the methodology used to project future industrial water needs.

Agricultural Water Conservation

In order to accomplish the objectives of an agricultural water conservation program, and to realize the water-saving potential from such a program, the Department will promote agricultural water conservation and cooperate with other public and private agencies, institutions, and establishments to expand water conservation research and public information programs through the following actions:

1. The Department recommends biennial appropriations in the amount of $2.0 million from which financial assistance can be provided to local soil and water conservation districts and local underground water conservation districts in each of the major irrigation areas of Texas for the acquisition of irrigation system efficiency testing equipment and technical staff support.

2. The Department recommends biennial appropriations in the amount of $500,000 with which to develop a program, whereby local-area irrigation technicians can be trained to perform system efficiency tests, and to prepare exhibits and conduct demonstrations of practical on-farm uses of irrigation water conservation equipment and techniques.

3. Agricultural water conservation information will be disseminated, as broadly as possible, through a public information program.

4. Increased federal and State funding for research to study the effects of brush control on water yields and enhanced production of desirable vegetation in representative physical regimes in Texas will be supported.

5. The effectiveness of the existing Statewide efforts for agricultural water conservation will be increased by supporting increased funding for existing programs of other agencies (Texas State Soil and Water Conservation Board and local soil and water conservation districts, underground water conservation districts, Texas Agricultural Extension Service, Texas Agricultural Experiment Station, universities, and agencies of the United States Department of Agriculture) which have programs in research, education, extension, technical assistance, and financial assistance for agricultural water conservation.

6. Programs which need additional efforts will be evaluated and, where appropriate, funds will be expended from the Research and Planning Fund (or other funds) for these programs not funded by other agencies.

The Department's role in agricultural water conservation will be to: promote conservation; disseminate information and materials on irrigation techniques and equipment that are water efficient; provide training, assistance, and demonstrations to local-area soil and water conservation districts, underground water conservation districts, and farmers; and continue to provide cooperation and support to other federal, State, and local agencies with related responsibilities. It is in the private sector, however, that most of the actual investment, production, financing, and finally, purchase and use of irrigation water conservation equipment, must be made.

Public Education

From the Recommendations of the Governor's Task Force on Water Resources Use and Conservation (September 2, 1982), the following statement generally describes

the need and role for a program in public education in water resource-related and flood-protection problems in Texas:

> "Successful resolution of complex water resource problems is often dependent upon the degree of public understanding of the problem and the degree of public support for the solution. Given the importance of effective public participation in finding and implementing solutions to water resource problems, the State should actively support education and technical assistance efforts that will enhance the public's understanding of water resource problems and issues. The State, working with local and regional government, should assist in the development of and provide funding for curricula and educational materials and technical assistance in water conservation, water reuse and recycling, water quality management, water supply development, environmental management, and flood protection."

In particular, education will play a major role in water conservation and flood protection programs. Therefore, the Department will request that the Legislature appropriate funds with which to initiate and implement water conservation and public education programs.

WATER FINANCING

Water facilities financing is influenced by growth of the local population, financial conditions of the area, level of available federal funding, and age and condition of the water and wastewater systems in place. Department surveys of need and analysis of future growth in population indicate increased burdens upon local financing for water projects. Federal programs that provide funding for water supply, wastewater treatment, and flood control are being reduced, including a reduction in U.S. Environmental Protection Agency grants for construction of wastewater treatment facilities. In the future, many areas in the State will need additional assistance in financing such projects. The State currently has established programs for assistance to hardship cases, primarily small jurisdictions without the capability to sell bonds at reasonable rates of interest.

Other State programs which provide loans for water supply development and water quality enhancement, and the acquisition of storage in reservoir projects, are also in place, but are not adequately funded. Therefore, it is recommended that:

1. Legislation be enacted proposing a constitutional amendment to increase the bonding authority of the existing Water Development Fund by $600 million, $200 million of this increase to be dedicated to water quality enhancement projects and $400 million to water development projects. Of the $400 million, $200 million should be used in the storage acquisition program of the Water Development Fund.

2. Legislation be enacted proposing a constitutional amendment to create a bond insurance (guarantee) program to which the State pledges its general credit in an amount not to exceed $250 million to insure (guarantee) the payment of principal and interest on bonds or other obligations issued by cities, special governmental districts and authorities, and other political subdivisions of the State for use for water development, water conservation, or water quality enhancement. Through enabling legislation, such a guarantee can be leveraged to provide several times the $250 million in funding capability.

3. Legislation be enacted that proposes a constitutional amendment to initiate a water conservation program for agriculture by establishing at least $50 million in State bonding authority for a fund to be used for loans to agricultural interests to finance water conserving irrigation equipment. Future expansion of this bonding authority should be considered when the program proves successful.

4. Legislation be enacted proposing a constitutional amendment to create one or more special loan funds in the State treasury for use for or in aid of water development, water conservation, water quality enhancement, or flood control and drainage or any combination of those purposes. It is further recommended that after passage of such a constitutional amendment, appropriations be made to any of the special funds to carry out the purposes specified. The constitutional amendment should provide that appropriations to a special loan fund not be considered appropriations for purposes of Article VIII, Section 22(a) of the Texas constitution.

5. The Legislature appropriate $50 million per biennium into the existing Water Assistance Fund to (a) accelerate acquisition of reservoir storage space by the State as a measure to permit construction of reservoirs at their optimum capacity in order to provide long-range regional needs including any storage costs that are necessary for environmental purposes of Statewide significance, and to (b) provide additional financial assistance to combinations of local entities for development of regional water supply and wastewater collection and treatment systems.

6. The Legislature appropriate $5 million per biennium into the Water Assistance Fund to fund research and flood protection planning to the extent that projects funded from this appropriation complement and extend related projects funded by other agencies--State, federal, local, as well as private entities.

7. Legislation be enacted proposing a constitutional amendment to remove the hardship condition (e.g., the inability to finance proposed projects through the sale of bonds in commercial channels at reasonable interest rates) as a requirement for financial assistance through the Water Development Fund in order to provide funding for regional water and wastewater systems.

8. Legislation be enacted which will allow water conservation studies and the costs of regional facilities planning to be eligible items for financial assistance through the Water Development Fund program.

WATER QUALITY MANAGEMENT

Significant water quality problems are present in many areas adjacent to and downstream of urban centers because municipal development and population growth have overloaded existing sewage treatment and collection facilities. In addition, poor operation and maintenance of wastewater treatment plants continue to cause localized water quality problems. In some cases, regionalization of planning, implementation, management, and operation of wastewater systems could improve water quality protection. Also, there is increasing concern over the generation, management, and disposal of hazardous wastes. Therefore, it is recommended that:

1. Legislation be enacted authorizing the Department of Water Resources to levy administrative penalties for violations of the Texas Water Code, Department rules, waste discharge permits, solid waste permits, and underground injection control permits.

2. Legislation be enacted authorizing the collection of fees and/or taxes associated with the generation and/or disposal of hazardous waste to provide funds for State management of hazardous wastes.

3. Legislation be enacted to amend the Texas Water Code to require, as a matter of State policy, that water users discharge their treated wastewaters for subsequent reuse, except where the Water Development Board adopts special "no discharge" rules or where waste discharge permits specifically provide for land application of wastewaters.

4. Legislation be enacted to amend the Texas Water Code, as appropriate, to strengthen existing statutes authorizing the Department to require the regionalization of wastewater systems, where such systems can be demonstrated to be appropriate and cost effective.

MANAGEMENT OF FRESHWATER INFLOWS TO BAYS AND ESTUARIES

Freshwater inflow is an essential factor in maintaining the biological productivity of estuarine systems, which include about 2.6 million acres of the Texas Gulf Coast. The bays and estuaries of Texas are dependent upon freshwater inflows for nutrients, sediments, and a viable salinity gradient that allows inhabiting organisms, such as the economically important fish and shellfish species, to survive, reproduce, and grow.

Although studies of Texas bays and estuaries have been carried out during the past decade, the data base available for these studies do not represent a sufficiently long period of time, nor are the related laboratory studies of sufficient breadth, to completely and reliably establish the effects of, and needs for, freshwater inflow. Estuarine science is relatively new and many ecological processes have not been completely described nor are they completely understood. Therefore, it is recommended that the Legislature enact legislation authorizing the Executive Director of the Texas Department of Water Resources to develop an estuarine management plan for each major Texas bay and estuary, and provide sufficient funding through 1991 for the Department to continue to carry out bays and estuaries research and planning.

PRESERVATION OF RESERVOIR SITES

Between the time that a reservoir site is selected and construction is initiated, the value of land and improvements escalates due to market forces. Land values in Texas have increased at a rate of about 10 percent per year during the last two decades, faster than the general inflation rate. Protection of reservoir sites from commercial development and inordinate price increases will require new legal and public policy approaches. Any actions will directly impact the traditional emphasis upon protection of rights of landowners in areas outside of municipalities. Proposed actions must include proper mechanisms for reservoir site designation and preservation and ways to mitigate local tax

effects of such actions, among other concerns. Therefore, it is recommended that:

1. Legislation be enacted to create a State Reservoir Site Development Easement System within the Texas Department of Water Resources, whereby limited eminent domain power would be used to restrict specified parcels of land, that are geographically and hydrologically suitable for water supply storage projects, from certain kinds of land use during the time before reservoir construction begins. Types of alternative uses of land that would be precluded would be those that involve the erection of major facilities which eventually would require purchase and relocation, or other public uses that would preclude reservoir construction. The owners would retain title and use of the lands in all other respects.

2. Legislation be enacted to create a Reservoir Site Acquisition Fund to be administered by the Texas Water Development Board for purposes of preserving future reservoir sites.

3. The Legislature appropriate $100 million in each successive biennium to the Reservoir Site Acquisition Fund to compensate landowners for easements and land options to secure lands for reservoir site preservation.

GROUND-WATER MANAGEMENT

Extensive development and use of ground water in Texas has resulted in several types of problems, some local in nature, others more widespread. In West Texas, the rate of use of water from the High Plains (Ogallala) Aquifer for agriculture and other purposes far exceeds the rate of natural recharge, and along parts of the Gulf Coast, large-scale pumpage of ground water has resulted in land surface subsidence, saline water encroachment, and fault activation. Problems of water quality, both from natural and man-made causes, affect the suitability of water that is available from portions of most of Texas' aquifers. Moreover, ground water, unlike surface water, is the property of the overlying landowner and its use is subject to very few limitations.

With proper modification of Texas law and water management practices, conjunctive use, defined as "use of water from ground and surface sources, separately or in combination, in such a manner that the availability of these sources for future supplies is maximized," has the potential for increasing available water supplies in the State. It is recommended that the Texas Water Code be amended to allow the Texas Water Commission to hold hearings for the purpose of designating additional ground-water conservation districts, where such districts are deemed appropriate to address local area problems. Upon completion of such hearings, the Texas Water Commission would be empowered to call a local election in a potential district area for the purpose of determining if a local district should be created. The Texas Water Development Board should be given the authority to set minimum standards for operation and management of local ground-water districts.

Legislation should be considered that provides for State management of ground water in problem areas in which residents fail to join existing districts or to establish such districts.

INSTREAM FLOW MANAGEMENT

Water resource planners are faced with the dilemma of providing adequate supplies of water to meet man's needs and the preservation or maintenance of sufficient streamflows to meet identified instream flow needs. Problems associated with the instream flow needs include identification of the particular uses, quantification of the need for such uses, and designating the appropriate entity and, where appropriate, the financial responsiblity for providing waters for instream flows. Few of the existing instream uses are specifically identified in the Texas Water Code, Section 11.023, list of beneficial uses of State water. Those listed have a low priority of use. Should existing and future reservoir projects be required to make releases specificially for maintenance of instream flows, the dependable yields of the projects will be reduced. Flow requirements for many of the instream flow uses relating to maintenance of fish and wildlife habitat have not been quantified for most Texas streams. If reservoir operators are required to make releases over and above the amounts normally necessary to meet contractual commitments and/or senior downstream water rights, the unit cost of water for municipal, industrial, and agricultural users will increase. Therefore, it is recommended that:

1. The Texas Water Commission continue to grant water rights permits subject to conditions that downstream water rights are protected, as appropriate.

2. The Texas Water Commission continue to issue waste discharge permits predicated upon the ability of the discharger to meet effluent standards sufficient to protect established stream quality criteria.

3. Where potential future instream flow problems can be identified, reservoir development and methods of operation be considered on a case-by-case basis and appropriate solutions implemented. If potential solutions include the

pass-through of all or a portion of the baseflows of streams, or releases from reservoir storage, then the water appropriation permits for the reservoirs should specify such requirements.

MITIGATION

Development and management of the State's water resources will inevitably result in both beneficial and adverse impacts to other natural resources. At issue is the balance point for an acceptable trade-off between the maintenance of natural habitats, meeting the needs of the people, and compensation for unavoidable losses to the natural system. Methodologies for determining the nature and degree of impact are complicated and studies often require an inordinate quantity of time and funds to complete. Current procedures utilized by the U.S. Fish and Wildlife Service consider only adverse impacts to fish and wildlife and their habitat and do not include the beneficial impacts of newly created open water habitats resulting from reservoir projects. The cost of mitigative measures may be substantial for some projects, and financial responsibilities for providing such measures must be determined. In many cases, the compensatory lands recommended for mitigation will be removed from the areas' tax base, placing a greater tax burden on the local population. Therefore, it is recommended that:

1. The Department of Water Resources with assistance from the Texas Parks and Wildlife Department and other agencies, as appropriate, evaluate each nonfederal water development project with respect to the need for mitigation of potential damages or losses of fish and wildlife habitat resulting from implementation of the project. In the evaluation process, enhancements and benefits to fish and wildlife as well as adverse effects and losses would be considered. Where the Texas Water Commission determines that there will be significant net adverse impacts as a result of issuing a permit for the project, the Commission require appropriate mitigation of those net impacts as a condition of the permit.

2. The Department coordinate with public agencies having responsibility and authority for fish and wildlife management early in the planning stages.

3. Legislation be enacted to provide that the costs of mitigation be borne by the direct beneficiaries of water development projects; and where a public benefit from mitigation is identified, the State assume financial responsibility.

FLOOD PROTECTION

Flooding is a serious problem in Texas, resulting in loss of life and millions of dollars in damages annually to urban and rural areas, industry, transportation, and public utilities. Even with flood protection programs, damages from flooding will continue to increase along floodplains and in coastal areas, if these areas are selected for residential and business locations. Commonly, however, people do not perceive or consider the risk of flooding, and flood-prone areas continue to be developed to accommodate population and economic growth. It should, therefore, be the policy of the State to assume greater responsibility for the planning and financing of structural and nonstructural flood protection programs. Therefore, it is recommended that:

1. Legislation be enacted that provides the necessary additional, but limited authority for counties, on a local option basis, to establish and enforce development and drainage design standards in unincorporated areas for flood control purposes.

2. Legislation be enacted to establish flood control assistance financing through special loan funds (see "Water Financing" section of the policy recommendations).

3. Legislation be considered that provides for disclosure of floodplain status in contracts for sale of real estate.

MULTI-STATE WATER PLANNING

In some areas of Texas, there is unappropriated surface water which remains to be developed. In several areas of the State, however, little, if any, significant potential water supply sources remain undeveloped. Where potential supply remains to be developed, it may not be sufficient to meet future requirements of the area, even after giving full consideration to the effects of water conservation in the projections of future needs. Water supplies in other parts of the State are, to a large extent, limited to ground-water resources which are finite and exhaustible. For many municipalities, and for irrigated agriculture in the High Plains, ground water is the only source of supply and this supply is being gradually depleted. El Paso and other areas within the Rio Grande Basin also will need water from new sources, sources not available in the basin. Therefore, it is recommended that:

1. A multistate water resources planning committee be established, by legislation or by Executive

Order of the Governor, to initiate and carry on discussions and coordination with neighboring states relative to identification and development of sources and methods for augmenting water supplies on a regional level after existing supplies are fully committed.

2. Funds be appropriated to the Department to provide necessary staff and support to the multi-state water resources planning committee.

3. Water importation into the State in coordination with other states should continue to be considered by the Department in long-range water planning, as appropriate. Importation studies and planning by the Department should consider only those floodwaters determined to be in excess of the future needs of any potential import source area. Importation studies should assess the need, consider the feasbility, and analyze the environmental impacts and economic costs of importation projects.

WATER RESOURCES RESEARCH AND PLANNING STUDIES

Research and development of new technology to increase the usefulness of Texas' water resources and to solve water problems are essential to Statewide water resources planning and to the general welfare of the State. Major types of research needed include technical, legal and institutional, economics, and planning. The Department will work with federal agencies, local water resource agencies, business, industry, universities, and private citizens to coordinate the research and development of technology in these areas.

FUTURE AMENDMENTS OF THE TEXAS WATER PLAN

Section 16.056 of the Texas Water Code provides that "the Board shall amend or modify the plan as experience and changed conditions require. The water plan presented herein is the first official revision of the Texas Water Plan which was adopted as the official water plan for the State in 1969, over 15 years ago. During this 15 year period, there has been a tremendous influx of persons into Texas, a sizeable rearrangement of population within Texas from rural areas to urban centers, and a shift in economic activity from the traditional sources in agriculture and oil and gas production into broadly based manufacturing and microcomputer technology. At the same time, an increasing public awareness of the environment has resulted in the emergence of new issues and additional State and federal legislation, regulations, and administrative requirements which have affected the manner in which development and management of Texas' water resources has been carried on.

This amended Texas Water Plan has taken these factors into consideration. As time passes and conditions continue to change, it will again become necessary to re-evaluate goals, projections of water needs, and decisions about water supplies, water quality management, flood protection, and other water-related problems and issues. Planning must keep pace with an evolving economy, changing public attitudes, advancing water use technology, and ever-changing local, State, and federal initiatives. Therefore, it is recommended that the Texas Water Plan be officially amended at least every five years.

APPENDIX A

Summary of Estimated Capital Costs for Future Water Quality Protection and Water Development, with Estimates of Funding Needed by Local, State, and Federal Governments for Wastewater Treatment and Municipal and Industrial Water Supply Facilities.*

	Estimated Capital Costs, in Millions of Dollars[1]											
	1984 - 1985				1986 - 1987				1988 - 1989			
Type of Facility	Federal	Local	State	Total	Federal	Local	State	Total	Federal	Local	State	Total
1. Wastewater Treatment (Hardship)	—	—	64	64	—	—	50	50	—	—	50	50
2. Wastewater Treatment (all others)	185	400	152	737	185	323	87	595	185	323	87	595
3. Wells and Facilities (Hardship)	—	—	13	13	—	—	12	12	—	—	12	12
4. Wells and Facilities (all others)	0	82	15	97	0	82	16	98	0	81	15	96
5. Major Raw Water Treatment	0	226	0	226	0	361	93	454	0	209	0	209
6. Major Water Conveyance	0	244	1	245	0	514	161	675	0	33	33	66
7. Water Supply Facilities (Hardship)	—	—	50	50	—	—	48	48	—	—	48	48
8. Reservoir and Chloride Control[2]	86	226	56	368	11	192	56	259	0	161	97	258
Subtotal (Hardship)	—	—	127	127	—	—	110	110	—	—	110	110
Subtotal (all other)	271	1,178	224	1,673	196	1,472	413	2,081	185	807	232	1,224
SUBTOTAL	271	1,178	351	1,800	196	1,472	523	2,191	185	807	342	1,334
Research and Planning	—	—	5	5	—	—	5	5	—	—	5	5
TOTAL	271	1,178	356	1,805	196	1,472	528	2,196	185	807	347	1,339
Rural Water Supply												
Applications	57	—	—	57	—	—	—	—	—	—	—	—
Preapplications	0	—	—	0	85	—	—	85	—	—	—	—

	Estimated Capital Costs, in Millions of Dollars[1]											
	1990 - 1991				1992 - 1993				1994 - 1995			
Type of Facility	Federal	Local	State	Total	Federal	Local	State	Total	Federal	Local	State	Total
1. Wastewater Treatment (Hardship)	—	—	50	50	—	—	50	50	—	—	50	50
2. Wastewater Treatment (all others)	0	322	273	595	0	322	273	595	0	322	273	595
3. Wells and Facilities (Hardship)	—	—	12	12	—	—	12	12	—	—	12	12
4. Wells and Facilities (all others)	0	80	14	94	0	79	14	93	0	77	14	91
5. Major Raw Water Treatment	11	35	16	62	0	64	2	66	0	0	0	0
6. Major Water Conveyance	0	39	38	77	0	236	198	434	0	25	25	50
7. Water Supply Facilities (Hardship)	—	—	48	48	—	—	48	48	—	—	48	48
8. Reservoir and Chloride Control[2]	38	437	118	593	12	35	0	47	38	625	150	813
Subtotal (Hardship)	—	—	110	110	—	—	110	110	—	—	110	110
Subtotal (all other)	49	913	459	1,421	12	736	487	1,235	38	1,049	462	1,549
SUBTOTAL	49	913	569	1,531	12	736	597	1,345	38	1,049	572	1,659
Research and Planning	—	—	—	—	—	—	—	—	—	—	—	—
TOTAL	49	913	569	1,531	12	736	597	1,345	38	1,049	572	1,659
Rural Water Supply												
Applications	—	—	—	—	—	—	—	—	—	—	—	—
Preapplications	—	—	—	—	—	—	—	—	—	—	—	—

*See Footnotes at end of Appendix A.

APPENDIX A—Continued

Summary of Estimated Capital Costs for Future Water Quality Protection and Water Development, with Estimates of Funding Needed by Local, State, and Federal Governments for Wastewater Treatment and Municipal and Industrial Water Supply Facilities.*

Type of Facility	Estimated Capital Costs, in Millions of Dollars[1]											
	1996 - 1997				1998 - 1999				2000 - 2001			
	Federal	Local	State	Total	Federal	Local	State	Total	Federal	Local	State	Total
1. Wastewater Treatment (Hardship)	—	—	50	50	—	—	50	50	—	—	50	50
2. Wastewater Treatment (all others)	0	322	273	595	0	322	273	595	0	332	283	615
3. Wells and Facilities (Hardship)	—	—	12	12	—	—	12	12	—	—	12	12
4. Wells and Facilities (all others)	0	76	13	89	0	76	13	89	0	76	13	89
5. Raw Water Treatment	0	0	0	0	0	0	0	0	0	27	38	65
6. Water Conveyance	0	0	0	0	0	0	0	0	0	6	6	12
7. Water Supply Facilities (Hardship)	—	—	48	48	—	—	48	48	—	—	48	48
8. Reservoir and Chloride Control[2]	12	328	53	393	38	15	23	76	12	113	39	164
Subtotal (Hardship)	—	—	110	110	—	—	110	110	—	—	110	110
Subtotal (all others)	12	726	339	1,077	38	413	309	760	12	554	379	945
SUBTOTAL	12	726	449	1,187	38	413	419	870	12	554	489	1,055
Research and Planning	—	—	—	—	—	—	—	—	—	—	—	—
TOTAL	12	726	449	1,187	38	413	419	870	12	554	489	1,055
Rural Water Supply												
Applications	—	—	—	—	—	—	—	—	—	—	—	—
Preapplications	—	—	—	—	—	—	—	—	—	—	—	—

Type of Facility	Estimated Capital Costs, in Millions of Dollars[1]											
	2002 - 2003				2004 - 2005				2006 - 2007			
	Federal	Local	State	Total	Federal	Local	State	Total	Federal	Local	State	Total
1. Wastewater Treatment (Hardship)	—	—	50	50	—	—	50	50	—	—	50	50
2. Wastewater Treatment (all others)	0	343	292	635	0	343	292	635	0	343	292	635
3. Wells and Facilities (Hardship)	—	—	12	12	—	—	12	12	—	—	12	12
4. Wells and Facilities (all others)	0	76	14	90	0	78	14	92	0	80	14	94
5. Major Raw Water Treatment	0	0	0	0	0	0	0	0	0	0	0	0
6. Major Water Conveyance	0	51	51	102	0	0	0	0	0	99	99	198
7. Water Supply Facilities (Hardship)	—	—	48	48	—	—	48	48	—	—	48	48
8. Reservoir and Chloride Control[2]	38	186	186	410	12	484	423	919	0	0	0	0
Subtotal (Hardship)	—	—	110	110	—	—	110	110	—	—	110	110
Subtotal (all other)	38	656	543	1,237	12	905	729	1,646	0	522	405	927
SUBTOTAL	38	656	653	1,347	12	905	839	1,756	0	522	515	1,037
Research and Planning	—	—	—	—	—	—	—	—	—	—	—	—
TOTAL	38	656	653	1,347	12	905	839	1,756	0	522	515	1,037
Rural Water Supply												
Applications	—	—	—	—	—	—	—	—	—	—	—	—
Preapplications	—	—	—	—	—	—	—	—	—	—	—	—

*See Footnotes at end of Appendix A.

APPENDIX A—Continued

Summary of Estimated Capital Costs for Future Water Quality Protection and Water Development, with Estimates of Funding Needed by Local, State, and Federal Governments for Wastewater Treatment and Municipal and Industrial Water Supply Facilities.*

	Estimated Capital Costs, in Millions of Dollars[1]											
	2008 - 2009				2010 - 2011				2012 - 2013			
Type of Facility	Federal	Local	State	Total	Federal	Local	State	Total	Federal	Local	State	Total
1. Wastewater Treatment (Hardship)	—	—	50	50	—	—	50	50	—	—	50	50
2. Wastewater Treatment (all others)	0	343	292	635	0	407	358	765	0	407	358	765
3. Wells and Facilities (Hardship)	—	—	12	12	—	—	12	12	—	—	12	12
4. Wells and Facilities (all others)	0	81	15	96	0	85	16	101	0	85	16	101
5. Major Raw Water Treatment	0	0	0	0	0	10	0	10	0	10	0	10
6. Major Water Conveyance	0	99	99	198	0	47	10	57	0	47	10	57
7. Water Supply Facilities (Hardship)	—	—	48	48	—	—	48	48	—	—	48	48
8. Reservoir and Chloride Control[2]	0	0	0	0	0	105	105	210	0	105	105	210
Subtotal (Hardship)	—	—	110	110	—	—	110	110	—	—	110	110
Subtotal (all other)	0	523	406	929	0	654	489	1,143	0	654	489	1,143
SUBTOTAL	0	523	516	1,039	0	654	599	1,253	0	654	599	1,253
Research and Planning	—	—	—	—	—	—	—	—	—	—		
TOTAL	0	523	516	1,039	0	654	599	1,253	0	654	599	1,253
Rural Water Supply Applications	—	—	—	—	—	—	—	—	—	—	—	—
Preapplications	—	—	—	—	—	—	—	—	—	—	—	—

	Estimated Capital Costs, in Millions of Dollars[1]											
	2014 - 2015				2016 - 2017				2018 - 2019			
Type of Facility	Federal	Local	State	Total	Federal	Local	State	Total	Federal	Local	State	Total
1. Wastewater Treatment (Hardship)	—	—	50	50	—	—	50	50	—	—	50	50
2. Wastewater Treatment (all others)	0	407	358	765	0	407	358	765	0	407	358	765
3. Wells and Facilities (Hardship)	—	—	12	12	—	—	12	12	—	—	12	12
4. Wells and Facilities (all others)	0	87	17	104	0	88	18	106	0	88	18	106
5. Major Raw Water Treatment	0	10	0	10	0	10	0	10	0	10	0	10
6. Major Water Conveyance	0	47	10	57	0	47	10	57	0	47	10	57
7. Water Supply Facilities (Hardship)	—	—	48	48	—	—	48	48	—	—	48	48
8. Reservoir and Chloride Control[2]	0	105	105	210	0	105	105	210	0	105	105	210
Subtotal (Hardship)	—	—	110	110	—	—	110	110	—	—	110	110
Subtotal (all other)	0	656	490	1,146	0	657	491	1,148	0	657	491	1,148
SUBTOTAL	0	656	600	1,256	0	657	601	1,258	0	657	601	1,258
Research and Planning	—	—	—	—	—	—	—	—	—	—	—	—
TOTAL	0	656	600	1,256	0	657	601	1,258	0	657	601	1,258
Rural Water Supply Applications	—	—	—	—	—	—	—	—	—	—	—	—
Preapplications	—	—	—	—	—	—	—	—	—	—	—	—

*See Footnotes at end of Appendix A.

APPENDIX A—Continued

Summary of Estimated Capital Costs for Future Water Quality Protection and Water Development, with Estimates of Funding Needed by Local, State, and Federal Governments for Wastewater Treatment and Municipal and Industrial Water Supply Facilities.

Type of Facility	Estimated Capital Costs, in Millions of Dollars[1]											
	2020 - 2021				2022 - 2023				2024 - 2026			
	Federal	Local	State	Total	Federal	Local	State	Total	Federal	Local	State	Total
1. Wastewater Treatment (Hardship)	—	—	50	50	—	—	50	50	—	—	50	50
2. Wastewater Treatment (all others)	0	489	440	929	0	489	440	929	0	489	440	929
3. Wells and Facilities (Hardship)	—	—	12	12	—	—	12	12	—	—	12	12
4. Wells and Facilities (all others)	0	92	19	111	0	92	19	111	0	94	19	113
5. Major Raw Water Treatment	0	0	0	0	0	0	0	0	0	0	0	0
6. Major Water Conveyance	0	0	0	0	0	0	0	0	0	0	0	0
7. Water Supply Facilities (Hardship)	—	—	48	48	—	—	48	48	—	—	48	48
8. Reservoir and Chloride Control[2]	0	154	143	297	0	154	143	297	0	154	143	297
Subtotal (Hardship)	—	—	110	110	—	—	110	110	—	—	110	110
Subtotal (all other)	0	735	602	1,337	0	735	602	1,337	0	737	602	1,339
SUBTOTAL	0	735	712	1,447	0	735	712	1,447	0	737	712	1,449
Research and Planning	—	—	—	—	—	—	—	—	—	—	—	—
TOTAL	0	735	712	1,447	0	735	712	1,447	0	737	712	1,449
Rural Water Supply Applications	—	—	—	—	—	—	—	—	—	—	—	—
Preapplications	—	—	—	—	—	—	—	—	—	—	—	—

Type of Facility	Estimated Capital Costs, in Millions of Dollars[1]											
	2026 - 2027				2028 - 2029				2030			
	Federal	Local	State	Total	Federal	Local	State	Total	Federal	Local	State	Total
1. Wastewater Treatment (Hardship)	—	—	50	50	—	—	50	50	—	—	25	25
2. Wastewater Treatment (all others)	0	489	440	929	0	489	440	929	0	245	220	465
3. Wells and Facilities (Hardship)	—	—	12	12	—	—	12	12	—	—	6	6
4. Wells and Facilities (all others)	0	97	20	117	0	97	20	117	0	49	10	59
5. Major Raw Water Treatment	0	0	0	0	0	0	0	0	0	0	0	0
6. Major Water Conveyance	0	0	0	0	0	0	0	0	0	0	0	0
7. Water Supply Facilities (Hardship)	—	—	48	48	—	—	48	48	—	—	24	24
8. Reservoir and Chloride Control[2]	0	154	143	297	0	154	143	297	0	77	72	149
Subtotal (Hardship)	—	—	110	110	—	—	110	110	—	—	55	55
Subtotal (all other)	0	740	603	1,343	0	740	603	1,343	0	371	302	673
SUBTOTAL	0	740	713	1,453	0	740	713	1,453	0	371	357	728
Research and Planning	—	—	—	—	—	—	—	—	—	—	—	—
TOTAL	0	740	713	1,453	0	740	713	1,453	0	371	357	728
Rural Water Supply Applications	—	—	—	—	—	—	—	—	—	—	—	—
Preapplications	—	—	—	—	—	—	—	—	—	—	—	—

[1]Project costs in 1983 dollars are shown for the biennium in which it is estimated construction would be initiated.

[2]The Brazos River Authority (BRA) plans to finance BRA projects through the sale of revenue bonds, but would borrow from a State loan fund to pay interest during the first ten years on BRA bonds sold to finance construction of Millican Reservoir and the three chloride control projects in the Brazos River Basin. The BRA would then repay the State with interest. The estimates of State financial assistance include the following amounts (in millions of dollars) required by BRA, assuming 8 percent interest on the BRA bonds: 1994 = $3; 1995 = $3; 1996 = $42; 1997 = $42; 1998 = $45; 1999 = $45; 2000 = $45; 2001 = $45; 2002 = $48; 2003 = $48; 2004 = $45; 2005 = $45; 2006 = $9; 2007 = $9; 2008 = $6; 2009 = $6; 2010 = $6; 2011 = $6; 2012 = $3; 2013 = $3; 2014 = $3; 2015 = $3.

APPENDIX B

Summary of Estimated Capital Costs for Future Water Quality Protection and Water Development, with Estimates of Funding Needed by Local, State, and Federal Governments for Wastewater Treatment and Municipal and Industrial Water Supply Facilities (costs inflated at 8 percent).*

Type of Facility	Estimated Capital Costs at Time of Construction, in Millions of Dollars[1]											
	1984 - 1985				1986 - 1987				1988 - 1989			
	Federal	Local	State	Total	Federal	Local	State	Total	Federal	Local	State	Total
1. Wastewater Treatment (Hardship)	—	—	64	64	—	—	68	68	—	—	79	79
2. Wastewater Treatment (all others)	185	467	218	870	185	439	186	810	185	512	248	945
3. Wells and Facilities (Hardship)	—	—	13	13	—	—	16	16	—	—	19	19
4. Wells and Facilities (all others)	0	96	19	115	0	112	22	134	0	128	24	152
5. Major Raw Water Treatment	0	264	0	264	0	491	127	618	0	331	0	331
6. Major Water Conveyance	0	285	1	286	0	699	219	918	0	50	50	100
7. Water Supply Facilities (Hardship)	—	—	50	50	—	—	66	66	—	—	76	76
8. Reservoir and Chloride Control[2]	100	264	64	428	16	262	75	353	0	254	152	406
Subtotal (Hardship)	—	—	127	127	—	—	150	150	—	—	174	174
Subtotal (all other)	285	1,376	302	1,963	201	2,003	629	2,833	185	1,275	474	1,934
SUBTOTAL	285	1,376	429	2,090	201	2,003	779	2,983	185	1,275	648	2,108
Research and Planning	—	—	5	5	—	—	5	5	—	—	5	5
TOTAL	285	1,376	434	2,095	201	2,003	784	2,988	185	1,275	653	2,113
Rural Water Supply												
Applications	57	0	0	57	—	—	—	—	—	—	—	—
Preapplications	0	0	0	0	85	—	—	85	—	—	—	—

Type of Facility	Estimated Capital Costs at Time of Construction, in Millions of Dollars[1]											
	1990 - 1991				1992 - 1993				1994 - 1995			
	Federal	Local	State	Total	Federal	Local	State	Total	Federal	Local	State	Total
1. Wastewater Treatment (Hardship)	—	—	93	93	0	0	108	108	—	—	126	126
2. Wastewater Treatment (all others)	0	597	504	1,101	0	696	589	1,285	0	812	686	1,498
3. Wells and Facilities (Hardship)	—	—	22	22	—	—	26	26	—	—	30	30
4. Wells and Facilities (all others)	0	147	27	174	0	170	31	201	0	194	35	229
5. Major Raw Water Treatment	21	63	29	113	0	139	5	144	0	0	0	0
6. Major Water Conveyance	0	73	70	143	0	510	428	938	0	62	62	124
7. Water Supply Facilities (Hardship)	—	—	89	89	—	—	104	104	—	—	121	121
8. Reservoir and Chloride Control[2]	70	808	218	1,096	25	76	0	101	96	1,572	374	2,042
Subtotal (Hardship)	—	—	204	204	—	—	238	238	—	—	277	277
Subtotal (all other)	91	1,688	848	2,627	25	1,591	1,053	2,669	96	2,640	1,157	3,893
SUBTOTAL	91	1,688	1,052	2,831	25	1,591	1,291	2,907	96	2,640	1,434	4,170
Research and Planning	—	—	—	—	—	—	—	—	—	—	—	—
TOTAL	91	1,688	1,052	2,831	25	1,591	1,291	2,907	96	2,640	1,434	4,170
Rural Water Supply												
Applications	—	—	—	—	—	—	—	—	—	—	—	—
Preapplications	—	—	—	—	—	—	—	—	—	—	—	—

*See Footnotes at end of Appendix B.

APPENDIX B—Continued

Summary of Estimated Capital Costs for Future Water Quality Protection and Water Development, with Estimates of Funding Needed by Local, State, and Federal Governments for Wastewater Treatment and Municipal and Industrial Water Supply Facilities (costs inflated at 8 percent).*

Type of Facility	Estimated Capital Costs at Time of Construction, in Millions of Dollars[1]											
	1996 - 1997				1998 - 1999				2000 - 2001			
	Federal	Local	State	Total	Federal	Local	State	Total	Federal	Local	State	Total
1. Wastewater Treatment (Hardship)	—	—	147	147	—	—	171	171	—	—	200	200
2. Wastewater Treatment (all others)	0	947	800	1,747	0	1,105	934	2,039	0	1,328	1,129	2,457
3. Wells and Facilities (Hardship)	—	—	35	35	—	—	41	41	—	—	48	48
4. Wells and Facilities (all others)	0	223	39	262	0	259	46	305	0	303	53	356
5. Major Raw Water Treatment	0	0	0	0	0	0	0	0	0	107	153	260
6. Major Water Conveyance	0	0	0	0	0	0	0	0	0	24	24	48
7. Water Supply Facilities (Hardship)	—	—	141	141	—	—	165	165	—	—	192	192
8. Reservoir and Chloride Control[2]	35	963	155	1,153	130	52	78	260	47	454	154	655
Subtotal (Hardship)	—	—	323	323	—	—	377	377	—	—	440	440
Subtotal (all other)	35	2,133	994	3,162	130	1,416	1,058	2,604	47	2,216	1,513	3,776
SUBTOTAL	35	2,133	1,317	3,485	130	1,416	1,435	2,981	47	2,216	1,953	4,216
Research and Planning	—	—	—	—	—	—	—	—	—	—	—	—
TOTAL	35	2,133	1,317	3,485	130	1,416	1,435	2,981	47	2,216	1,953	4,216
Rural Water Supply Applications	—	—	—	—	—	—	—	—	—	—	—	—
Preapplications	—	—	—	—	—	—	—	—	—	—	—	—

Type of Facility	Estimated Capital Costs at Time of Construction, in Millions of Dollars[1]											
	2002 - 2003				2004 - 2005				2006 - 2007			
	Federal	Local	State	Total	Federal	Local	State	Total	Federal	Local	State	Total
1. Wastewater Treatment (Hardship)	—	—	233	233	—	—	271	271	—	—	317	317
2. Wastewater Treatment (all others)	0	1,596	1,364	2,960	0	1,862	1,591	3,453	0	2,172	1,855	4,027
3. Wells and Facilities (Hardship)	—	—	56	56	—	—	65	65	—	—	76	76
4. Wells and Facilities (all others)	0	356	63	419	0	424	76	500	0	504	92	596
5. Major Raw Water Treatment	0	0	0	0	0	0	0	0	0	0	0	0
6. Major Water Conveyance	0	238	238	476	0	0	0	0	0	673	673	1,346
7. Water Supply Facilities (Hardship)	—	—	224	224	—	—	260	260	—	—	304	304
8. Reservoir and Chloride Control[2]	177	863	863	1,903	64	2,633	2,299	4,996	0	0	0	0
Subtotal (Hardship)	—	—	513	513	—	—	596	596	—	—	697	697
Subtotal (all other)	177	3,053	2,528	5,758	64	4,919	3,966	8,949	0	3,349	2,620	5,969
SUBTOTAL	177	3,053	3,041	6,271	64	4,919	4,562	9,545	0	3,349	3,317	6,666
Research and Planning	—	—	—	—	—	—	—	—	—	—	—	—
TOTAL	177	3,053	3,041	6,271	64	4,919	4,562	9,545	0	3,349	3,317	6,666
Rural Water Supply Applications	—	—	—	—	—	—	—	—	—	—	—	—
Preapplications	—	—	—	—	—	—	—	—	—	—	—	—

*See Footnotes at end of Appendix B.

APPENDIX B—Continued

Summary of Estimated Capital Costs for Future Water Quality Protection and Water Development, with Estimates of Funding Needed by Local, State, and Federal Governments for Wastewater Treatment and Municipal and Industrial Water Supply Facilities (costs inflated at 8 percent).*

Type of Facility	Estimated Capital Costs at Time of Construction, in Millions of Dollars[1]											
	2008 - 2009				2010 - 2011				2012 - 2013			
	Federal	Local	State	Total	Federal	Local	State	Total	Federal	Local	State	Total
1. Wastewater Treatment (Hardship)	—	—	370	370	—	—	431	431	—	—	503	503
2. Wastewater Treatment (all others)	0	2,533	2,164	4,697	0	3,515	3,085	6,600	0	4,100	3,598	7,698
3. Wells and Facilities (Hardship)	—	—	89	89	—	—	104	104	—	—	121	121
4. Wells and Facilities (all others)	0	599	111	710	0	731	140	871	0	853	163	1,016
5. Major Raw Water Treatment	0	0	0	0	0	122	0	122	0	122	0	122
6. Major Water Conveyance	0	673	673	1,346	0	549	120	669	0	549	120	669
7. Water Supply Facilities (Hardship)	—	—	355	355	—	—	414	414	—	—	483	483
8. Reservoir and Chloride Control[2]	0	0	0	0	0	1,235	1,233	2,468	0	1,235	1,233	2,468
Subtotal (Hardship)	—	—	814	814	—	—	949	949	—	—	1,107	1,107
Subtotal (all other)	0	3,805	2,948	6,753	0	6,152	4,578	10,730	0	6,859	5,114	11,973
SUBTOTAL	0	3,805	3,762	7,567	0	6,152	5,527	11,679	0	6,859	6,221	13,080
Research and Planning	—	—	—	—	—	—	—	—	—	—	—	—
TOTAL	0	3,805	3,762	7,567	0	6,152	5,527	11,679	0	6,859	6,221	13,080
Rural Water Supply Applications	—	—	—	—	—	—	—	—	—	—	—	—
Preapplications	—	—	—	—	—	—	—	—	—	—	—	—

Type of Facility	Estimated Capital Costs at Time of Construction, in Millions of Dollars[1]											
	2014 - 2015				2016 - 2017				2018 - 2019			
	Federal	Local	State	Total	Federal	Local	State	Total	Federal	Local	State	Total
1. Wastewater Treatment (Hardship)	—	—	586	586	—	—	684	684	—	—	798	798
2. Wastewater Treatment (all others)	0	4,783	4,197	8,980	0	5,578	4,895	10,473	0	6,507	5,709	12,216
3. Wells and Facilities (Hardship)	—	—	141	141	—	—	164	164	—	—	192	192
4. Wells and Facilities (all others)	0	1,021	200	1,221	0	1,211	240	1,451	0	1,413	279	1,692
5. Major Raw Water Treatment	0	122	0	122	0	122	0	122	0	122	0	122
6. Major Water Conveyance	0	549	120	669	0	549	120	669	0	549	120	669
7. Water Supply Facilities (Hardship)	—	—	563	563	—	—	657	657	—	—	766	766
8. Reservoir and Chloride Control[2]	0	1,235	1,233	2,468	0	1,235	1,233	2,468	0	1,235	1,233	2,468
Subtotal (Hardship)	—	—	1,290	1,290	—	—	1,505	1,505	—	—	1,756	1,756
Subtotal (all other)	0	7,710	5,750	13,460	0	8,695	6,488	15,183	0	9,826	7,341	17,167
SUBTOTAL	0	7,710	7,040	14,750	0	8,695	7,993	16,688	0	9,826	9,097	18,923
Research and Planning	—	—	—	—	—	—	—	—	—	—	—	—
TOTAL	0	7,710	7,040	14,750	0	8,695	7,993	16,688	0	9,826	9,097	18,923
Rural Water Supply Applications	—	—	—	—	—	—	—	—	—	—	—	—
Preapplications	—	—	—	—	—	—	—	—	—	—	—	—

*See Footnotes at end of Appendix B.

APPENDIX B—Continued

Summary of Estimated Capital Costs for Future Water Quality Protection and Water Development, with Estimates of Funding Needed by Local, State, and Federal Governments for Wastewater Treatment and Municipal and Industrial Water Supply Facilities (costs inflated at 8 percent).

	Estimated Capital Costs at Time of Construction, in Millions of Dollars[1]											
	2020 - 2021				2022 - 2023				2024 - 2025			
Type of Facility	Federal	Local	State	Total	Federal	Local	State	Total	Federal	Local	State	Total
1. Wastewater Treatment (Hardship)	—	—	931	931	—	—	1,086	1,086	—	—	1,267	1,267
2. Wastewater Treatment (all others)	0	9,117	8,186	17,303	0	10,634	9,548	20,182	0	12,403	11,137	23,540
3. Wells and Facilities (Hardship)	—	—	224	224	—	—	261	261	—	—	304	304
4. Wells and Facilities (all others)	0	1,718	349	2,067	0	2,004	407	2,411	0	2,375	488	2,863
5. Major Raw Water Treatment	0	0	0	0	0	0	0	0	0	0	0	0
6. Major Water Conveyance	0	0	0	0	0	0	0	0	0	0	0	0
7. Water Supply Facilities (Hardship)	—	—	894	894	—	—	1,042	1,042	—	—	1,216	1,216
8. Reservoir and Chloride Control[2]	0	3,904	3,624	7,528	0	3,904	3,624	7,528	0	3,904	3,624	7,528
Subtotal (Hardship)	—	—	2,049	2,049	—	—	2,389	2,389	—	—	2,787	2,787
Subtotal (all other)	0	14,739	12,159	26,898	0	16,542	13,579	30,121	0	18,682	15,249	33,931
SUBTOTAL	0	14,739	14,208	28,947	0	16,542	15,968	32,510	0	18,682	18,036	36,718
Research and Planning	—	—	—	—	—	—	—	—	—	—	—	—
TOTAL	0	14,739	14,208	28,947	0	16,542	15,968	32,510	0	18,682	18,036	36,718
Rural Water Supply Applications	—	—	—	—	—	—	—	—	—	—	—	—
Preapplications	—	—	—	—	—	—	—	—	—	—	—	—

	Estimated Capital Costs at Time of Construction, in Millions of Dollars[1]											
	2026 - 2027				2028 - 2029				2030			
Type of Facility	Federal	Local	State	Total	Federal	Local	State	Total	Federal	Local	State	Total
1. Wastewater Treatment (Hardship)	—	—	1,478	1,478	—	—	1,724	1,724	—	—	1,006	1,006
2. Wastewater Treatment (all others)	0	14,467	12,990	27,457	0	16,875	15,151	32,026	0	9,842	8,836	18,678
3. Wells and Facilities (Hardship)	—	—	355	355	—	—	414	414	—	—	241	241
4. Wells and Facilities (all others)	0	2,860	598	3,458	0	3,335	698	4,033	0	1,945	408	2,353
5. Major Raw Water Treatment	0	0	0	0	0	0	0	0	0	0	0	0
6. Major Water Conveyance	0	0	0	0	0	0	0	0	0	0	0	0
7. Water Supply Facilities (Hardship)	—	—	1,418	1,418	—	—	1,654	1,654	—	—	965	965
8. Reservoir and Chloride Control[2]	0	3,904	3,624	7,528	0	3,904	3,624	7,528	0	1,952	1,812	3,764
Subtotal (Hardship)	—	—	3,251	3,251	—	—	3,792	3,792	—	—	2,212	2,212
Subtotal (all other)	0	21,231	17,212	38,443	0	24,114	19,473	43,587	0	13,739	11,056	24,795
SUBTOTAL	0	21,231	20,463	41,694	0	24,114	23,265	47,379	0	13,739	13,268	27,007
Research and Planning	—	—	—	—	—	—	—	—	—	—	—	—
TOTAL	0	21,231	20,463	41,694	0	24,114	23,265	47,379	0	13,739	13,268	27,007
Rural Water Supply Applications	—	—	—	—	—	—	—	—	—	—	—	—
Preapplications	—	—	—	—	—	—	—	—	—	—	—	—

[1]Project costs are inflated from 1983 to January 1 of the second year of the biennium in which it is estimated construction would be initiated.

[2]The Brazos River Authority (BRA) plans to finance BRA projects through the sale of revenue bonds, but would borrow from a State loan fund to pay interest during the first ten years on BRA bonds sold to finance construction of Millican Reservoir and the three chloride control projects in the Brazos River Basin. The BRA would then repay the State with interest. The estimates of State financial assistance include the following amounts (in millions of dollars) required by BRA, assuming 8 percent interest on the BRA bonds: 1994 = $6; 1995 = $6; 1996 = $105; 1997 = $105; 1998 = $113; 1999 = $113; 2000 = $113; 2001 = $113; 2002 = $124; 2003 = $124; 2004 = $118; 2005 = $118; 2006 = $34; 2007 = $34; 2008 = $26; 2009 = $26; 2010 = $26; 2011 = $26; 2012 = $15; 2013 = $15; 2014 = $15; 2015 = $15.