A Summary
of the
<u>Preliminary Plan</u>
for

Proposed Water Resources Development
in the
SULPHUR RIVER BASIN

by the

Texas Water Development Board

June 1966

ERRATA

Listed below are several corrections to be made in the main text of the Preliminary Sulphur River Basin Plan. Please enter them in this copy.

On page 9, paragraph 1, line 3:

(1) Change "2,661,200" acre-feet

to read "2,616,400" acre-feet

On page 11, paragraph 2, line 2:

(1) Change "Sabine River basin"

to read "Sulphur River basin"

On page 23, Table 5 (column 6, line 3):

(1) Change the incremental flood-control capacity for Cooper Reservoir, "131,400" acre-feet

to read "127,500" acre-feet

On page 24, Table 6 (column 2):

(1) Line 2, change "$123,313,000"

to read "$116,800,000"

(2) Line 3, change "$32,500,000"

to read "$31,200,000"

(3) Line 4, change "$13,530,000[2/]"

to read "$13,000,000[2/]"

(4) Line 5, change "$187,343,000"

to read "$179,000,000"

On page 27, line 4 from top of page:

(1) Change "$187,000,000"

to read "$179,000,000"

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FOREWORD

The Sulphur River basin lies largely in Texas and extends for a short distance into Arkansas. It is treated in Texas as a separate river basin although the Sulphur River becomes a Red River tributary in Arkansas. Both the North and the South Sulphur Rivers head in southwestern Fannin County, in northeast Texas, join as the Sulphur River, which flows easterly into Arkansas to empty into the Red River. The Texas portion of the Sulphur River basin contains 3,558 square miles, or 1.4 percent of the area of Texas.

Since the Sulphur River is actually a tributary of the interstate Red River, it is being included in the Red River Compact. Compact commissioners representing the States of Texas, Oklahoma, Arkansas, and Louisiana with a chairman representing the Federal government have been negotiating a Red River Compact. Most details have been worked out, allocations of water agreed upon, and the Compact draft is being reviewed by Federal and State agencies. The final language to incorporate into the Compact is being considered before signing by the Compact Commission. The Compact will then need approval by the Legislatures of each of the States, and by the Congress before it will become effective.

The Sulphur River Conservation and Reclamation District has been created by the State and has been assigned certain planning and development responsibilities. Besides the District, there are also other entities concerned with various phases of water development in designated parts of the basin.

The Texas Water Development Board, in preparing this preliminary Water Resources Development Plan for the Sulphur River basin, has carefully considered the Compact draft, the plans and programs of the various entities active in the basin, and existing water rights.

The primary objective of the basin plan has been first to determine long-range in-basin water requirements and to suggest development of available water resources in the basin to meet such requirements. After all projected in-basin water requirements to 2020 had been fulfilled, consideration was given to development of water-resources surplus to basin needs. The Sulphur River basin plan provides for fulfilling the projected 2020 basin water requirements, along with developing an uncommitted annual basin water yield substantially larger than the projected 2020 basin requirements.

In addition, surface-water projects developed in the Sulphur River basin will allow for export of some 1-1/4 million acre-feet of water annually to out-of-basin areas of need. Over 1 million acre-feet of water will be imported annually into the Sulphur River basin from the Red River and Cypress Creek basins for re-diversion to out-of-basin areas of need.

This preliminary Sulphur River basin plan has been prepared as an integral part of the Texas Water Plan.

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SULPHUR RIVER BASIN

The major upstream branches of the Sulphur River--the North Sulphur River and the South Sulphur River--both head in southwestern Fannin County, Texas, at an elevation of about 700 feet. These streams flow easterly to join at the eastern edge of Hopkins County, a distance of about 55 airline miles, to form the Sulphur River. At this point the streambed elevation is about 320 feet. The Sulphur River continues an easterly course for about 75 miles to the Texas-Arkansas line 10 miles south of Texarkana. Thence, it turns southeasterly for about 15 miles to join the Red River. The streambed elevation at the Texas-Arkansas line is about 190 feet.

The Sulphur River drainage area in Texas is about 130 miles long. It is bounded on the north by the Red River watershed and on the south by the watersheds of the Sabine River and Cypress Creek. The one major tributary to the Sulphur is White Oak Bayou, which enters from the south at the northwest corner of Cass County. The total Sulphur River basin drainage area within Texas is 3,558 square miles, or about 1.4 percent of the total area of Texas.

The Sulphur River basin is within the Coastal Plain geographical province. For water development planning purposes, the Sulphur River basin in Texas has been considered as a single zone, as shown on Plate 1.

WATER RESOURCES

Rainfall and Evaporation

The average annual rainfall in the Sulphur River basin is 45 inches, and the average annual net lake-surface evaporation loss is 19 inches. The rainfall ranges from 42 inches in the west to 49 inches in the east, while the evaporation loss ranges from 8 inches in the east to 30 inches in the west.

Surface Water

Runoff

The historical average annual runoff in the Sulphur River basin in Texas ranges from a maximum of about 700 acre-feet per square mile at the Texas-Arkansas line to a minimum of about 400 acre-feet per square mile at the headwaters in Fannin County. The runoff decreases more or less uniformly from east to west and varies widely from year to year.

The former gaging station, Sulphur River near Darden, Bowie County, Texas, provides the longest record, 33 years (1924-56), of any gaging station in the basin and gives the best index of runoff for the basin as a whole. The drainage area at the Darden station is 2,774 square miles, whereas the drainage area at the Texas-Arkansas line is 3,466 square miles. The average annual runoff at the Darden station for the 33-year period (1924-56) was 1,670,000 acre-feet. The runoff for the maximum year was 4,025,000 acre-feet in 1945, and the minimum year was 353,100 in 1925. The second highest year was 3,468,000 acre-feet in 1950 and the second lowest year was 483,400 in 1956.

Records of streamflow of significant length have been obtained at three other gaging stations in the Sulphur River basin: (1) South Sulphur River near Cooper, Delta County, drainage area 527 square miles, 22 years (1943-64); (2) North Sulphur River near Cooper, Delta County, drainage area 276 square miles, 15 years (1950-64); and (3) White Oak Creek near Talco, Titus County, drainage area 494 square miles, 14 years (1951-64).

During the 22 years of record (1943-64), at the station South Sulphur River near Cooper, the average annual runoff was 259,200 acre-feet, the maximum year was 649,600 acre-feet in 1957, and the minimum year was 48,900 acre-feet in 1956.

During the 15 years of record (1950-64), at the station North Sulphur River near Cooper, the average annual runoff was 160,000 acre-feet, the maximum year was 391,300 acre-feet in 1957, and the minimum year was 61,020 in 1956.

During the 14 years of record (1951-64), at the station White Oak Creek near Talco, the average annual runoff was 293,200 acre-feet, the maximum year was 754,200 acre-feet in 1958, and the minimum year was 49,800 acre-feet in 1956.

The runoff and flood flows from the Sulphur River basin into Arkansas are affected by storage in Texarkana Reservoir 7 miles west of the Texas-Arkansas line. Texarkana Reservoir has a present conservation storage capacity of 145,300 acre-feet, and a flood-control storage capacity of 2,509,000 acre-feet.

Floods

Owing to the channel of the North Sulphur River having been rectified, the floods in this stream have characteristics different from floods in the South Sulphur, Sulphur River below confluence of North and South Sulphurs, and in White Oak Creek.

Floods in the North Sulphur rise and fall rapidly, have high velocity, have greater unit maximum discharges, and cause little if any overflow. Maximum discharge at the station North Sulphur River near Cooper during the period 1950-64 was 42,800 cfs (cubic feet per second) on April 29, 1953, from a drainage area of 276 square miles.

Other than the North Sulphur, the streams in the Sulphur River basin generally have small main channels and wide, timbered flood plains which are overflowed frequently. These characteristics result in floods of longer duration, lower velocities, and smaller maximum unit discharges.

The maximum discharge at the station South Sulphur River near Cooper during the period 1943-64 was 23,800 cfs on April 29, 1953, from a drainage area of 527 square miles.

The maximum discharge at the station White Oak Creek near Talco during the period 1951-64 was 26,600 cfs on April 28, 1958, from a drainage area of 494 square miles. The greatest flood to have occurred at this station since at least 1870 was on March 31, 1945, when the maximum stage reached was 3.4 feet higher than the flood of April 28, 1958.

The maximum discharge at the former station Sulphur River near Darden during the period of record 1924-56 was 157,000 cfs on April 1, 1945, from a drainage area of 2,774 square miles. This flood was the greatest to have occurred at this site since at least 1865.

Quality

The surface water of the Sulphur River basin is of excellent quality with respect to both mineral and organic constituents. Dissolved-solids concentrations in all streams average less than 250 ppm (parts per million). At the daily sampling station on the South Sulphur River near Cooper, the discharge-weighted average concentrations for 6 years, 1959-64, was 140 ppm dissolved solids, 20 ppm sulfate, and 10 ppm chloride. The Sulphur River in Bowie County had the following averages for the period 1964-65: biochemical oxygen demand 3.02 ppm, chlorine demand 4.52 ppm, and dissolved oxygen 5.6 ppm. Upstream, in Red River County, averages for 1964-65 were biochemical oxygen demand 1.9 ppm, chlorine demand 3.1 ppm, and dissolved oxygen 5.5 ppm.

Ground Water

Approximately 5,700 acre-feet of ground water is available annually from the aquifers in the Sulphur River basin. Of this amount, 4,000 acre-feet is from the Carrizo-Wilcox aquifer, shown on Plate 2, and the remainder is from small aquifers, including the Blossom Sand and the Nacatoch Sand.

Although not considered either major or minor aquifers, the Blossom Sand is important as a source of local water supply in Lamar and Red River Counties, and the Nacatoch Sand is similarly important in a narrow strip from east-central Hunt County to southwestern Red River County. The Trinity Group aquifer and the Woodbine aquifer extend into the northwestern part of the basin. Both are at considerable depth and generally have water containing more than 1,000 parts per million dissolved solids. Ground-water development in the Red River basin could affect the quantity available from these two aquifers. (Minor aquifers of importance in other portions of Texas are shown on Plate 3.)

Carrizo-Wilcox Aquifer

The sands of the Carrizo-Wilcox aquifer crop out in the eastern and southern part of the Sulphur River basin. The Carrizo Formation consists of unconsolidated, cross-bedded, fine- to medium-grained sand with small amounts of interbedded fine sand, silt, and clay. Thickness of the Carrizo ranges from 0 to about 100 feet. The Wilcox Group consists principally of unconsolidated, cross-bedded, fine- to medium-grained sand interbedded with light to dark gray clay, lignite, and silt. Individual sand beds are lenticular and grade laterally into clay, lignite, or silt. Thickness of the Wilcox Group ranges from about 450 to 800 feet. Water in the Carrizo-Wilcox outcrop generally is under water-table conditions. Yields from the large-capacity wells average about 60 gallons per minute, but some reach 150 gallons per minute.

About 4,000 acre-feet of water can be developed annually from the Carrizo-Wilcox aquifer in the Sulphur River basin. Ground water in the Carrizo-Wilcox aquifer is chemically suited for municipal and most industrial and irrigation uses. Generally it contains less than 500 parts per million dissolved solids. The basin's ground water generally contains excessive amounts of iron and may require treatment before use for some purposes.

ECONOMIC DEVELOPMENT AND POTENTIAL

Municipal and Industrial

The population of the Sulphur River basin in Texas, which in 1960 was 129,140, is projected to increase to more than 377,000 by the year 2020. Of this, about 261,600 will be in cities and towns with populations greater than 5,000. These projections, obtained for water-planning purposes, include the city of Texarkana, Arkansas because it shares a common water-distribution system with Texarkana, Texas and obtains all of its water supply from the Sulphur River. That part of the city of Paris in the Sulphur River basin is not included, as it receives all of its water supply from the Red River basin and will be included in that basin summary.

Texarkana, Texas, ranks first in the basin in population, presently having more than 30,000. Other major cities in the basin having a 1960 population of 5,000 or more are Commerce and Sulphur Springs. The 1960 populations of these and other municipalities in the basin are compared with their projections for the years 1990 and 2020 in Table 1 below.

Table 1.--Population projections for selected municipalities, Sulphur River basin, Texas

City	Population		
	1960	1990	2020
Clarksville	3,851	4,300	5,600
Commerce	5,789	20,300	37,200
New Boston	2,773	6,500	12,000
Sulphur Springs	9,160	22,800	49,600
Texarkana, Texas	30,218	54,100	99,200
Texarkana, Ark.	19,788	34,000	58,000

The major industrial products in the basin are stone and clay products. Light manufacturing is of some significance, and Texarkana is primarily a manufacturing distribution center. Lumber, vegetables, cotton, and livestock, the chief agricultural products, contribute to lumber mills, meat packing, food processing, furniture manufacture, dairying, and clothing production. It is expected that by 2020 military ordnance and non-manufacturing products will play a prominent role in the economy of the basin.

This basin has excellent possibilities for the establishment of new water-oriented enterprises. Construction of three new reservoirs proposed in the basin plan will add to the potential for growth of recreation and associated enterprises.

Irrigation

Farming in the Sulphur River basin, bountifully supplied with rainfall, is almost completely unirrigated. Only 600 acres was irrigated in 1964, a relatively dry year.

Future irrigation is likely to be confined to small acreages; for production of peanuts, improved pasture, and hay; and served by diversions to individual fields and farms from streams, farm ponds, and other small impoundments. Ground-water usage for irrigation is not anticipated. By 1990 it is estimated that irrigation in the basin will not exceed 7,400 acres. By 2020 the irrigated acreage will be no more than an estimated 14,800 acres.

In this area of relatively high rainfall and lush, moisture-using unirrigated crops and native vegetation, the effects of irrigation on net depletion of basin water yields will be minor, even if more irrigation develops than is anticipated.

EXISTING WATER-SUPPLY DEVELOPMENTS

Surface Water

The surface-water resources of the Sulphur River basin in Texas are, to a great extent, undeveloped. The U.S. Army Corps of Engineers' Texarkana Reservoir, with a total capacity of 2,661,200 acre-feet, is the largest in the watershed. Although constructed primarily for flood-control purposes, the reservoir serves as a source of supply for the cities of Texarkana, Texas, and Texarkana, Arkansas, which operate a common municipal distribution system. River Crest Reservoir, a 7,100 acre-foot off-channel impoundment, is used by Texas Power and Light Company for steam-electric power generating. White Oak Creek, the other major reservoir, is a source of water for the city of Sulphur Springs. The Texas Parks and Wildlife Department has a permit for 2,260 acre-feet per year to maintain a waterfowl management area in the Texarkana Reservoir flood plain. Several cities have small reservoirs for municipal supplies, and there are several irrigation permits.

Construction is scheduled to begin shortly on Cooper Reservoir, on the South Sulphur River, a U.S. Army Corps of Engineers' multiple-purpose project. The Sulphur River Municipal Water District, the North Texas Municipal Water District, and the city of Irving have received approval of applications for permits for appropriations from the conservation-storage pool.

Pertinent data for Texarkana Reservoir are given in Table 5 (page 23).

Ground Water

Ground water is not a major source of water supply in the Sulphur River basin in Texas. In 1960 the total use of ground water amounted to 3,400 acre-feet. The distribution of use was 1,900 acre-feet municipal, 1,400 acre-feet industrial, and 100 acre-feet for irrigation.

Primary developments of ground water have been from the Carrizo-Wilcox aquifer, Blossom Sand, and Nacatoch Sand. The city of Commerce in Hunt County obtains its water supply primarily from the Nacatoch Sand, and several smaller communities are supplied by ground water from these aquifers.

Water Permits, Certified Filings, and Reported Riparian Users

The development of Texas law relating to water rights has been strongly influenced by the State's history. Texas adopted many of the old customs and laws of the Spanish Civil Law System as a natural consequence of Spanish and later Mexican sovereignty over what is now all of Texas and parts of New Mexico, Oklahoma, and Colorado. Water rights appurtenant to lands granted by the Sovereign before 1840 are evaluated under the Spanish Civil Law as modified by the Congress of the Republic of Texas in 1837. Between January 20, 1840, and March 19, 1889, the common law of England governed the character of rights pertaining to land granted by the Republic of Texas, and later by the State. Since 1889, the Texas Legislature has enacted many laws relating to Texas rivers and streams and the use of their public waters.

The Water Act of 1889 declared the unappropriated waters of every river or natural stream within the arid portion of the State to be the property of the public and subject to appropriation for irrigation. In 1895 the permitted use was broadened to include "the construction of water works for cities and towns." As population grew and frequent droughts caused shortages, additional laws were passed. Since 1889, however, most of the new statutes have incorporated language which has preserved the riparian right of a landowner abutting the bed of a stream to utilize the benefit of water flowing past his land. The riparian right has been consistently defended and upheld by Texas courts.

The invention of large, efficient irrigation pumps and the development of a large rice-growing belt along the Coast in southeast Texas led to the need for additional legislation, and in 1913 the Legislature rewrote the irrigation laws and created the State Board of Water Engineers for the purpose of administering water appropriations throughout the entire State. Under the 1913 Statute, a record of all existing appropriations was to be filed with the Board, and these declarations came to be known as "certified filings." All appropriations subsequent to 1913 were to be made by applying to the Board for "permits" to appropriate water. The name of the Board of Water Engineers was changed in 1962 to the Texas Water Commission. It was renamed September 1, 1965, the Texas Water Rights Commission.

The existing applications filed and permits granted for appropriations of water and certified filings in the Sabine River basin in Texas, as compiled by the Texas Water Rights Commission, April 1, 1966, are listed in Tables 7 and 8, respectively (see pages 29 and 31). In addition to names shown in these listings, eight individuals have reported uses of water in the basin as riparian claimants. In the proposed plan to meet future water requirements, consideration has been given to these data and to specific water-permit conditions pertaining to major existing reservoirs.

RELATED ELEMENTS

Water-Quality Problems

Surface water in the Sulphur River basin is of excellent quality with the dissolved-solids concentration averaging less than 250 ppm (parts per million). A moderate supply of ground water of good to excellent quality is available from aquifers in the basin.

At times, decaying vegetation in wooded areas may raise the biochemical oxygen demand and chlorine demand and tend to lower the dissolved oxygen of water in the basin. Trent Creek, in northern Titus County, was contaminated in the Talco area by inflow of salt water from the Talco oil field. However, when considered on a regional basis, no significant water-quality problems are present in the basin.

Flood Damage

Annual flood damages have averaged about $500 to $700 per mile along the main stem of the Sulphur River and $1,200 per mile along White Oak Creek. Cities and towns have sustained flood damage of limited consequence, with minor flooding occurring on the average of at least once a year and major flooding about every 4½ years.

Upon the completion of the Texarkana Dam and Reservoir in 1956, flooding on the Sulphur River below this project was substantially reduced.

Completion of the Cooper Dam and Reservoir will provide considerable additional reductions in flooding below that dam and above Texarkana Reservoir.

Upstream Flood Prevention Program

The upstream flood prevention program of the U.S. Department of Agriculture and administered by the Soil Conservation Service is designed to develop flood-prevention measures on subwatersheds having less than 250,000 acres in drainage area. Flood-prevention projects presently constructed or under construction on 56,700 acres of the Sulphur River basin watershed consist of 24 floodwater-retarding structures. These projects are listed in Table 2. There are no other projects authorized by Congress or in the planning stage. Projects for flood prevention are feasible on 585,800 acres.

Drainage

Drainage is feasible for 106,800 acres in the Sulphur River basin, mostly in the alluvial bottoms and terraces in the Blackland Prairie and East Texas Timberlands. On-farm drainage systems, consisting of proper row direction, land leveling, field drains, and collection ditches are needed for 99,800 acres, of which 31.4 percent is now in cultivation. Group drainage or lateral ditches in connecting farm systems, with required major outlets, will be needed on 53,800 acres. A considerable amount of channel enlargement and levee work has been done by the U.S. Army Corps of Engineers above Bowie County.

Table 2.--Upstream-watershed program, Sulphur River basin, Texas

Subwatershed	Area (acres)	Floodwater-retarding structures			Channel improvement		
		Planned	Completed or contracted		Planned	Completed or contracted	
		(number)	(number)	(percent)	(miles	(miles	(percent)
Constructed or Under Construction							
Auds Creek	31,670	13	13	100	--	--	--
Total	31,670	13	13	100	--	--	--
Plans Authorized By Congress but Not Under Construction							
(None)	--	--	--	--	--	--	--
Total	--	--	--	--	--	--	--
Planning Underway							
(none)	--	--	--	--	--	--	--
Total	--	--	--	--	--	--	--
Feasible for Planning							
Upper South Sulphur	85,000	--	--	--	--	--	--
Central Sulphur	151,040	--	--	--	--	--	--
Upper North Sulphur	220,200	--	--	--	--	--	--
Deport Creek	38,040	--	--	--	--	--	--
Morgan Creek	9,600	--	--	--	--	--	--
Bruton Creek	62,720	--	--	--	--	--	--
Sandy - Hickory	19,200	--	--	--	--	--	--
Total	585,800	--	--	--	--	--	--

MEETING FUTURE BASIN NEEDS

Water-Supply Considerations

General

In determining how the water requirements to fulfill projected needs were to be supplied in the Sulphur River basin in Texas, existing and potential supplies of both ground and surface water were evaluated.

Ground Water

Having estimated the requirements, as a first step the availability and location of ground-water supplies were studied with respect to present use and future needs. Based on this analysis, it was determined that essentially all future water use in this basin can be expected to be supplied from surface-water sources. Ground-water supplies will constitute an unassigned reserve supply, and a supply for users and uses with only small demands.

Surface Water

Surface-water supplies were considered next. Surface water will be obtained by use of water stored in the reservoirs in the basin, by direct diversion from basin streams, or from small upstream and on-farm impoundments.

The usable surface-water yield of the basin is determined by the location, kinds, and amounts of storage contemplated and by the location and amounts of demands placed on that storage. Yield studies were based on runoff data for the most critical period of record adjusted for future conditions of watershed development up to 2020. The proposed plan has resulted from analysis of storage alternatives, giving due consideration to the relation of various elements of the plan to usable basin yield. Proposed features have been considered in conjunction with existing ones.

Return Flows

Return flows from municipal and industrial use will not constitute an appreciable portion of usable surface-water supplies in the Texas portion of this basin. By 2020 the usable return flows are estimated to total only 16,200 acre-feet. A total of 26,600 acre-feet of return flow will originate downstream from the Texarkana Reservoir and is not recoverable in Texas.

Saline-Water Conversion

Because abundant, low-cost water is available from other sources, saline-water conversion is not anticipated as an aid in meeting projected requirements in the Sulphur River basin, and no community studies of economic feasibility are being made.

Water Quality

Present and projected return flows above the major reservoirs in the Sulphur River basin are not of sufficient magnitude to affect appreciably the quality of water in storage.

Basin Water Requirements

Municipal and Industrial

Future municipal and industrial water requirements were based on projections of population, industrial change, and related elements of the economy that were made especially for planning purposes. Per capita water requirements were developed, based on analyses of present use and use trends.

Table 3 includes the 1960 municipal and industrial water use and estimated requirements for 1990 and 2020 for each city in the basin with a 1960 population of more than 5,000, and for all other cities in the basin, considered as a group "other cities." Table 3 also shows the use of ground and surface water now

Table 3.--Total annual basin ground- and surface-water requirements, Sulphur River basin, Texas

(acre-feet per year)

Zone and city	1960[1]			1990			2020		
	Ground water	Surface water	Total	Ground water	Surface water	Total	Ground water	Surface water	Total
Municipal and Industrial									
Zone 1									
Commerce	700	--	700	--	3,500	3,500	--	7,000	7,000
Sulphur Springs	--	1,100	1,100	--	3,700	3,700	--	9,000	9,000
Texarkana (Texas)	--	17,600	17,600	--	32,800	32,800	--	47,600	47,600
Texarkana (Arkansas)	--	10,800	10,800	--	17,400	17,400	--	28,000	28,000
Other cities	2,600	1,700	4,300	--	6,900	6,900	--	9,300	9,300
Total	3,300	31,200	34,500	--	64,300	64,300	--	100,900	100,900
Irrigation									
Zone 1	100	200	300	--	11,100	11,100	--	22,000	22,000
BASIN TOTAL	3,400	31,400	34,800	--	75,400	75,400	--	122,900	122,900

1/ Irrigation data is for 1964, from irrigation inventory.

supplying these and other needs and additionally the use of surface water proposed for supplying projected needs.

In 1960 a total of 34,500 acre-feet of water was used by the cities and industries of the basin (including 10,800 acre-feet of Sulphur River basin water used by the city of Texarkana, Arkansas). Water for the city of Paris, Texas, partially in the basin, is supplied from the Red River basin, and its water use is not included in the above amount. Ground water furnished 3,300 acre-feet of the total 1960 municipal and industrial requirements.

By 1990 annual municipal and industrial use in the basin is expected to reach 64,300 acre-feet (including 17,400 for Texarkana, Arkansas, but excluding Paris, Texas). By 2020 annual requirements are expected to increase to 100,900 acre-feet (including 28,000 for Texarkana, Arkansas, but excluding Paris, Texas). Surface water alone is expected to be used to supply the 1990 and 2020 requirements. Where recoverable, return flows have been included in the computation of water-supply balances used in planning.

Irrigation

An inventory of irrigation in the 1964 season showed only 300 acre-feet of water being used for irrigation in the basin (100 acre-feet, ground water; 200 acre-feet, surface water).

Irrigation is not expected to become a widespread practice in the Sulphur River basin. The annual irrigation requirement by 1990 is estimated to be 11,100 acre-feet of surface water and by 2020, 22,000 acre-feet.

Future irrigation water requirements are based on anticipation of some increase in need for the irrigation of improved pastures, peanuts, some fruits and vegetables, nursery stock, and specialty crops that can be profitably grown in the basin under irrigation.

Irrigation is assumed to be of non-project type. Water will be diverted directly to individual fields and farms from streams, small upstream impoundments, and on-farm ponds but is reflected in reservoir inflows or by releases from reservoirs.

Flood Control

Texarkana Reservoir, completed in 1956, includes flood-control storage capacity. Under the proposed plan, when Cooper Reservoir is completed, 131,400 acre-feet of its capacity would be used for flood-control storage, in exchange for inclusion of 120,000 acre-feet of water-supply storage in the Texarkana Reservoir. Likewise, when the proposed Naples Reservoir is complete, 701,700 acre-feet of its capacity would be used for flood-control storage, in exchange for inclusion of additional water-supply storage in the Texarkana Reservoir. Stage 1 of the Naples Reservoir would provide an initial exchange of storage capacity of 454,700 acre-feet. In addition, when the Naples Reservoir is completed, 6,800 acre-feet of present Texarkana Reservoir flood-control storage, upstream from the proposed Naples dam, will be inundated by the Naples Reservoir. Thus, after proposed exchanges, Texarkana Reservoir will contain 1,687,714 acre-feet of flood-control storage capacity.

Navigation, Hydroelectric Power, and Mining (Water Flood)

There are no known existing or proposed provisions in the basin for navigation, for hydroelectric power generation, or for water flooding for petroleum production; consequently, no water requirements have been included for these uses within the basin.

Recreation and Fish and Wildlife

Recreational and fish and wildlife needs have been provided for in the plan, where applicable. Water requirements for these uses, however, are generally of a nonconsumptive nature. Except for 2,300 acre-feet annually required for the Texarkana-Bassett Creek Wildlife Management Area water requirements for recreation, fish and wildlife have not been assigned.

Projects Necessary to Meet 2020 Requirements

As previously pointed out, future water requirements are expected to be supplied from surface water that can be developed in various storage facilities, existing and proposed, in the basin. Listed in Table 4 are all of the planned reservoirs (see Plate 4 for locations), the 2020 annual requirements proposed to be served from them, the usable return flows to be expected, and the remaining water yield after all estimated in-basin requirements have been fulfilled.

The in-basin 2020 surface-water requirements will be supplied from the existing and enlarged Texarkana Reservoir and the proposed Cooper Reservoir. These two projects will supply the projected 2020 surface-water requirements of 122,900 acre-feet annually, and will also provide a surplus substantially larger than the projected requirements to meet unforeseen needs.

Table 4.--Surface-water supply projects necessary to meet in-basin and export requirements in 2020, Sulphur River basin, Texas

Projects required to meet in-basin requirements

Reservoir	Status	Annual requirement supplied (acre-feet)	Usable return flow (acre-feet)	Remaining yield (acre-feet)	Estimated date required
Cooper	Authorized	Commerce 7,000	--	--	--
		Sulphur Springs 9,000	--	--	--
		Other Cities 9,300	--	--	--
		25,300	4,700	9,900	
Texarkana	Storage exchange proposed	Texarkana Texas 47,600	--	--	Exchange by 1995
		Texarkana Ark. 28,000	--	--	--
		Local Irrigation 22,000	--	--	--
		Wildlife Use 2,300	--	--	--
		99,900	11,500	239,000	

Projects required to meet basin export requirements by 2020

Reservoir	Status	Annual export (acre-feet)	Estimated date required
Cooper	Authorized	97,800	--
Sulphur Bluff 1	Proposed	118,700	1985
Naples	Proposed	836,300	1990 to 2010
Texarkana	Storage exchange proposed	200,000	Exchange by 1995
Total export..............		1,252,800	

PROPOSED PLAN OF DEVELOPMENT

The proposed plan for development of water resources in the Sulphur River basin includes those features of flood control, drainage, watershed-protection programs, water-quality maintenance, and ground-water utilization previously discussed. The plan also proposes construction of three new storage reservoirs in the basin (Cooper, Sulphur Bluff 1, and Naples) in addition to the existing Texarkana Reservoir. (See Table 5 for location, elevation, capacity, and area data for each.) The authorized Cooper Reservoir is to be constructed as soon as possible consistent with the availability of Federal appropriation. All except Sulphur Bluff 1 Reservoir will contain flood-control storage as well as water-supply storage. Naples Reservoir is planned to be developed in stages.

Of the proposed reservoirs, Cooper Reservoir will be completed first. Sulphur Bluff 1 Reservoir will need to be developed by about 1985, and Stage 1 of Naples Reservoir will be needed by approximately 1990. The conversion of flood-control storage to conservation storage in Texarkana Reservoir will be needed by about 1995. Naples Stage 2 will likely be needed by about 2010. Trans-basin diversion facilities located in the basin will need to be phased to out-of-basin requirements and completion of the in-basin facilities to supply water for export. Table 6 gives the estimated total cost of the planned reservoirs and modifications.

In addition to the in-basin reservoirs named above, facilities are proposed, including necessary pumping installations to transfer water from the Red River and Cypress Creek basins to the Sulphur River basin for trans-basin diversion from Cooper Reservoir to help meet out-of-basin water needs in Texas.

Importation from the Red River basin, needed by about 2000, would amount to 647,000 acre-feet of water per year. Of this amount, 617,000 acre-feet would originate by direct diversion from the Red River, and the remaining

Table 5.--Existing and proposed reservoirs, Sulphur River basin, Texas

Reservoir	Location	Stream	Type Storage	Elevation[1]	Incremental capacity[2] (acre-feet)	Surface area (acres)	2020 yield[3] (acre-feet/year)
Cooper	5 mi. SE of Cooper, Texas	South Sulphur River	Dead[4]	408.0	9,300	--	--
			Water Supply	440.0	273,000	19,280	128,300
			Flood Control	446.2	131,400	22,740	--
Sulphur Bluff 1	4 mi. N of Sulphur Bluff, Texas	South Sulphur River	Dead[4]	370.0	87,220	10,621	--
			Water Supply	401.0	548,171	40,700	264,300
Naples (ultimate project)	1.5 mi. upstream from planned Interstate 30	Sulphur River	Dead[4]	275.0	189,989	25,100	--
			Water Supply	312.0	2,220,011	108,200	836,300
			Flood Control	318.0	701,700	127,400	--
Texarkana[5]	11 mi. SW of Texarkana, Texas	Sulphur River	Dead[4]	220.0	125,819	20,300	--
			Water Supply	240.5	802,881	61,750	327,400
			Flood Control	259.5	1,687,714	119,700	--

1/ Datum is mean sea level.

2/ Values reflect the storage remaining after sediment distribution of 31,580; 25,600; 56,350; and 37,886 acre-feet (between 1953 and 2020) for Cooper, Sulphur Bluff, Naples, and Texarkana, respectively.

3/ Does not include return flows, which are calculated separately.

4/ Dead or inactive pool elevations are provided for to maintain a more efficient head in transporting water westward.

5/ Storage allocations are based on net flood storage exchange of 120,000 acre-feet with Cooper and 700,000 acre-feet with Naples. (Texarkana Reservoir is an existing reservoir).

Table 6.--Estimated costs for proposed reservoirs, Sulphur River basin, Texas (1965 Prices)

Reservoir	Total cost
Cooper	$ 18,000,000 1/
Naples	123,313,000
Sulphur Bluff 1	32,500,000
Texarkana	13,530,000 2/
Total	$187,343,000

1/ Final estimate not available. Inclusion of flood-control storage and facilities to permit movement of water into Cooper Reservoir from downstream projects considered.

2/ Includes $4,367,000 for construction features of Naples Reservoir to provide for flood-control-conservation storage exchange.

30,000 acre-feet would represent water available from the yield of the Pecan Bayou Reservoir.

Annual importation from the Cypress Creek basin of 415,000 acre-feet will be needed about 2015. This water would come from the following proposed reservoirs in the amounts indicated: Marshall, 325,000 acre-feet; Titus County, 80,000 acre-feet; and Franklin County, 10,000 acre-feet.

Figure 1 shows diagrammatically how the existing and proposed reservoirs, when fully operative under 2020 conditions, combine to produce water yields in several parts of the basin to serve projected 2020 in-basin requirements, planned exports, and remaining, unassigned yields that can supply additional in-basin or export requirements not included in the presently proposed plan.

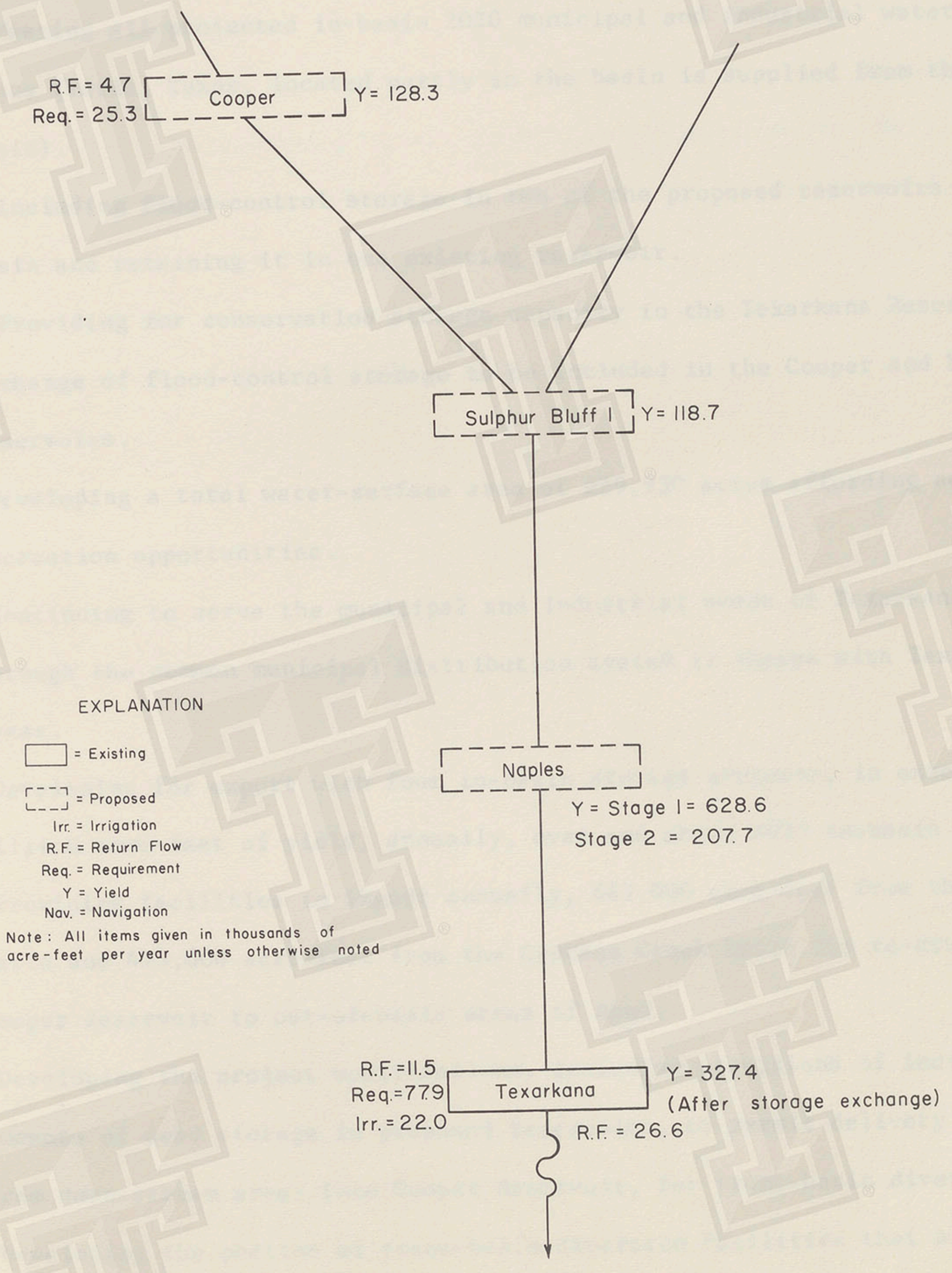
If unforeseen in-basin or out-of-basin needs occur, in excess of 2020 projections the next logical development in the Sulphur River basin would be the Sulphur Bluff 2 Reservoir.

The preliminary Sulphur River basin plan has been prepared as an integral part of the Texas Water Plan. A condensed explanation of the proposed Texas Water Plan is included in this summary following Plate 4; and the associated proposed reservoirs and diversion features are shown on the map (Plate 5), which follows the condensed explanation.

Figure 1

PROPOSED RESERVOIR DEVELOPMENT
SULPHUR RIVER BASIN

Texas Water Development Board



SUMMARIZATION

The proposed basin plan provides for:

Constructing 3 additional reservoirs at an estimated ultimate cost of approximately $187,000,000.

* Meeting all projected in-basin 2020 municipal and industrial water requirements (Paris, Texas, located partly in the basin is supplied from the Red River basin).

* Including flood-control storage in two of the proposed reservoirs in the basin and retaining it in one existing reservoir.

* Providing for conservation storage capacity in the Texarkana Reservoir by exchange of flood-control storage to be included in the Cooper and Naples Reservoirs.

*Developing a total water-surface area of 229,930 acres affording added water-recreation opportunities.

*Continuing to serve the municipal and industrial needs of Texarkana, Arkansas, through the common municipal distribution system it shares with Texarkana, Texas.

*Developing for export with four in-basin storage projects, in excess of 1-1/4 million acre-feet of yield, annually, over and above 2020 in-basin requirements.

*Providing facilities to import annually, 647,000 acre-feet from the Red River basin and 415,000 acre-feet from the Cypress Creek basin for re-diversion from Cooper Reservoir to out-of-basin areas of need.

*Developing the project modifications, including provisions of indicated amounts of dead storage in proposed reservoirs, to permit delivery of water from down-stream areas into Cooper Reservoir, for trans-basin diversion.

*Developing the portion of trans-basin diversion facilities that are situated in this basin, to permit delivery of water, over and above in-basin 2020 requirements, to out-of-basin water areas of need in Texas.

* Operating and maintaining all existing storage facilities for their designated and established purposes.

*Developing an annual unassigned basin water yield of considerably more than the projected 2020 requirements in the basin that can be used to meet future unforeseen needs.

*Incorporating into the basin plan the watershed protection, flood protection, and drainage improvement programs planned to be developed by the U.S. Department of Agriculture in cooperation with the State Soil and Water Conservation Board and local entities.

*Incorporating into the basin plan local protection and other improvements that are planned in cooperation with local entities.

Table 7.--Applications and permits for appropriations of water in the Sulphur River basin, Texas

(As reflected by the records of the Texas Water Rights Commission, April, 1966)

Application No. Date filed Permit No. Date issued	Name Address County Stream	Acres irrigated Acre-feet per year and use Maximum rate of diversion Permitted impoundment, in acre-feet	Remarks
1222 Sept. 19, 1929 1144 Dec. 20, 1929	Annona, City of Annona, Texas Red River Alexander Wright Creek	- - - -	Annona Station. Amended by A1977
1226 Nov. 22, 1929 1149 May 20, 1930	Brooks, Phil Clarksville, Texas Red River Cuthand Creek trib. Sulphur River	- 170.0 - Railway - 161.5	Bagwell Station
2106 Nov. 24, 1958 1929 May 26, 1959	Broseco Ranch Ft. Worth, Texas Morris Murphy	621 1242 - Irr. 5.0 cfs 1455	Date cancelled 7-13-62 Reinstated 5-6-63
2159 July 11, 1960 1966 Sept. 14, 1960	Calabria, Dr. J.C. Dallas, Texas Red River Sand Branch	106 200.0 - Irr. 10.0 cfs 200.0	
1834 Mar. 15, 1954 1709 June 24, 1954	Harvey, Riley W. Annona, Texas Red River Trib. of Sulphur River	30.5 93.9 - Irr. 1.0 cfs 93.9	
1458 Aug. 29, 1944 1364 Sept. 10, 1945	New Boston, City of New Boston, Texas Bowie Holly Branch	- 325.0 - Mun. - 8.0	
2308A Jan. 20, 1964 2084A Mar. 23, 1964	Red River Co. W. C. & I. D. No. 1 Langford Creek Clarksville, Texas Red River Langford Creek Langford Creek	- 1,120 - Ind. 3.0 cfs 1225	Amended to change use to Industrial 6-24-65
1718 June 24, 1951 1591 Dec. 27, 1951	Sulphur Springs, City of Sulphur Springs, Texas Hopkins White Oak Bayou	- 2,000.0 - Mun. - 2,206.0	
1684 Mar. 5, 1951 1563 April 18, 1951	Texarkana, City of Texarkana, Texas Cass and Bowie Sulphur River	- 14,572.0 - Mun. - -	Water is diverted from Texarkana by U.S. Army Corps of Engineers.
2025 Feb. 18, 1957 1563A Mar. 27, 1957	Texarkana, City of Texarkana, Texas Bowie Sulphur River	- 10,428.0 - Mun.; 35,000 - Ind. - -	Amends Permit No. 1563

Table 7.--Applications and permits for appropriations of water in the Sulphur River basin, Texas--Continued

Application No. Date filed Permit No. Date issued	Name Address County Stream	Acres irrigated Acre-feet per year and use Maximum rate of diversion Permitted impoundment, in acre-feet	Remarks
2188 Apr. 10, 1961 1989 July 10, 1961	Texas Parks & Wildlife Comm. Austin, Texas Bowie Sulphur River	- 2,260.0 - Rec. - 2,260.0	
1977 May 28, 1956 1835 July 16, 1956	Texas & Pacific Ry. Co. Dallas, Texas Red River County Alexander Wright	- 225.0 - Mun. - 276.0	Amends Permit No. 1144 by changing use only
1747 Mar. 5, 1952 1617 April 22, 1952	Texas Power & Light Co. Dallas, Texas Red River Sulphur River	- 10,000.0 - Power 75.0 cfs 7,100.0	River Crest Steam Electric Station
2062 Aug. 12, 1957 1896 Oct. 30, 1957	Wolf City c/o Mayor, City Hall Hunt Turkey Creek	- 300.0 - Mun. - 855.0	

Table 8.--Certified filings for appropriations of water in the Sulphur River basin, Texas

(As reflected by the records of the Texas Water Rights Commission, April, 1966)

Application No. Date filed Permit No. Date issued	Name Address County Stream	Acres irrigated Acre-feet per year and use Maximum rate of diversion Permitted impoundment, in acre-feet	Remarks
665 June 18, 1914 June 30, 1914 Book 4, pp. 373-374	Gordon Country Club Paris, Texas Lamar Prairie or Allen Creek	- West Paris Station 10 - Railway (Gordon Lake) - 125	
656 June 27, 1914 June 30, 1914 Book 4, pp. 365-366	New Boston, City of New Boston, Texas Bowie Tributary of Red River	- - Railway - 12.0	

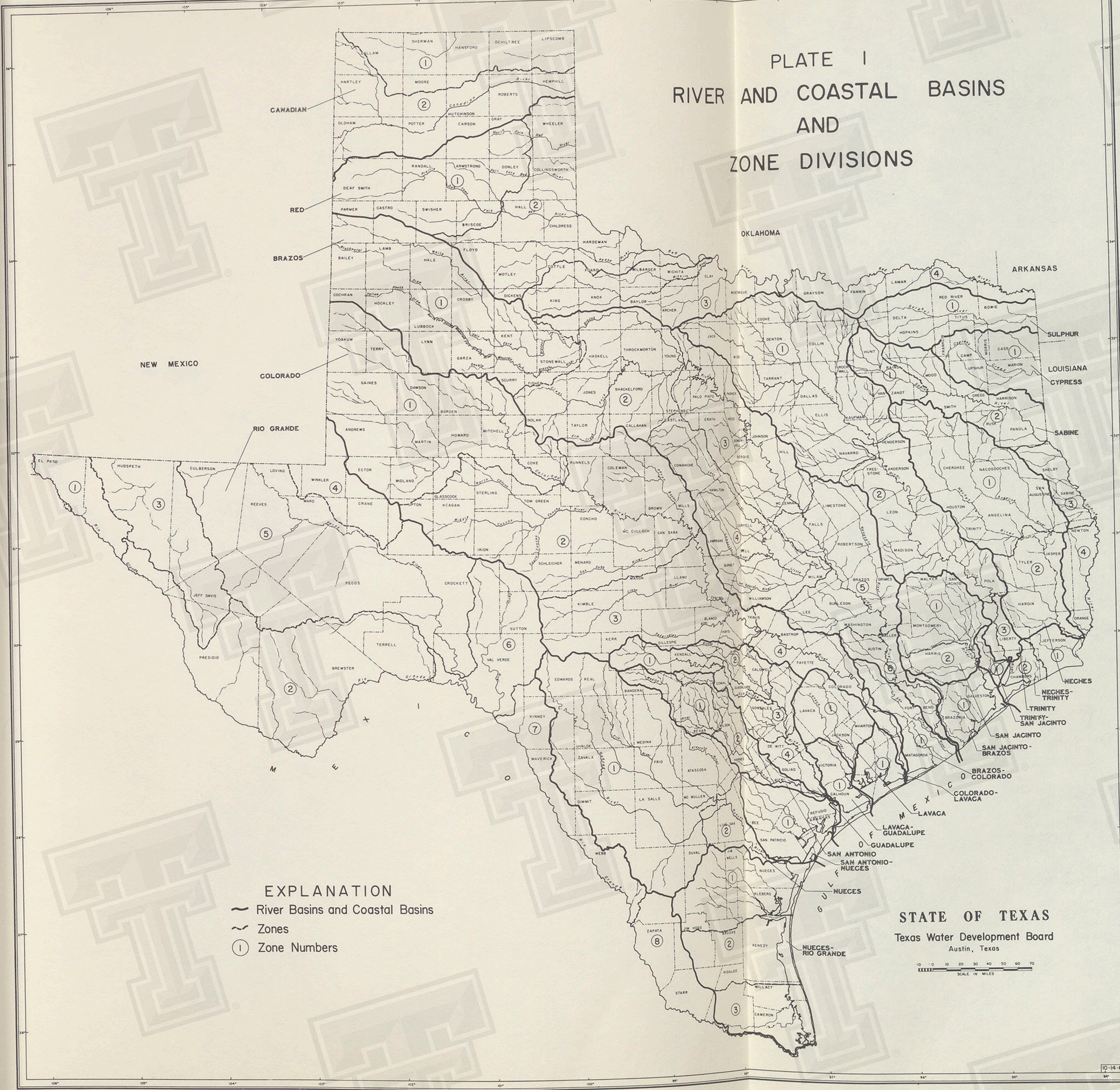


PLATE I
RIVER AND COASTAL BASINS
AND
ZONE DIVISIONS
EXPLANATION
River Basins and Coastal Basins
Zones
1 Zone Numbers
STATE OF TEXAS
Texas Water Development Board
Austin, Texas
SCALE IN MILES
NEW MEXICO
OKLAHOMA
ARKANSAS
LOUISIANA
MEXICO
GULF OF MEXICO
CANADIAN
RED
BRAZOS
COLORADO
RIO GRANDE
SULPHUR
CYPRESS
SABINE
NECHES
NECHES-TRINITY
TRINITY
TRINITY-SAN JACINTO
SAN JACINTO
SAN JACINTO-BRAZOS
BRAZOS-COLORADO
COLORADO-LAVACA
LAVACA
LAVACA-GUADALUPE
GUADALUPE
SAN ANTONIO
SAN ANTONIO-NUECES
NUECES
NUECES-RIO GRANDE
10-14-65

PLATE 2
MAJOR AQUIFERS IN TEXAS

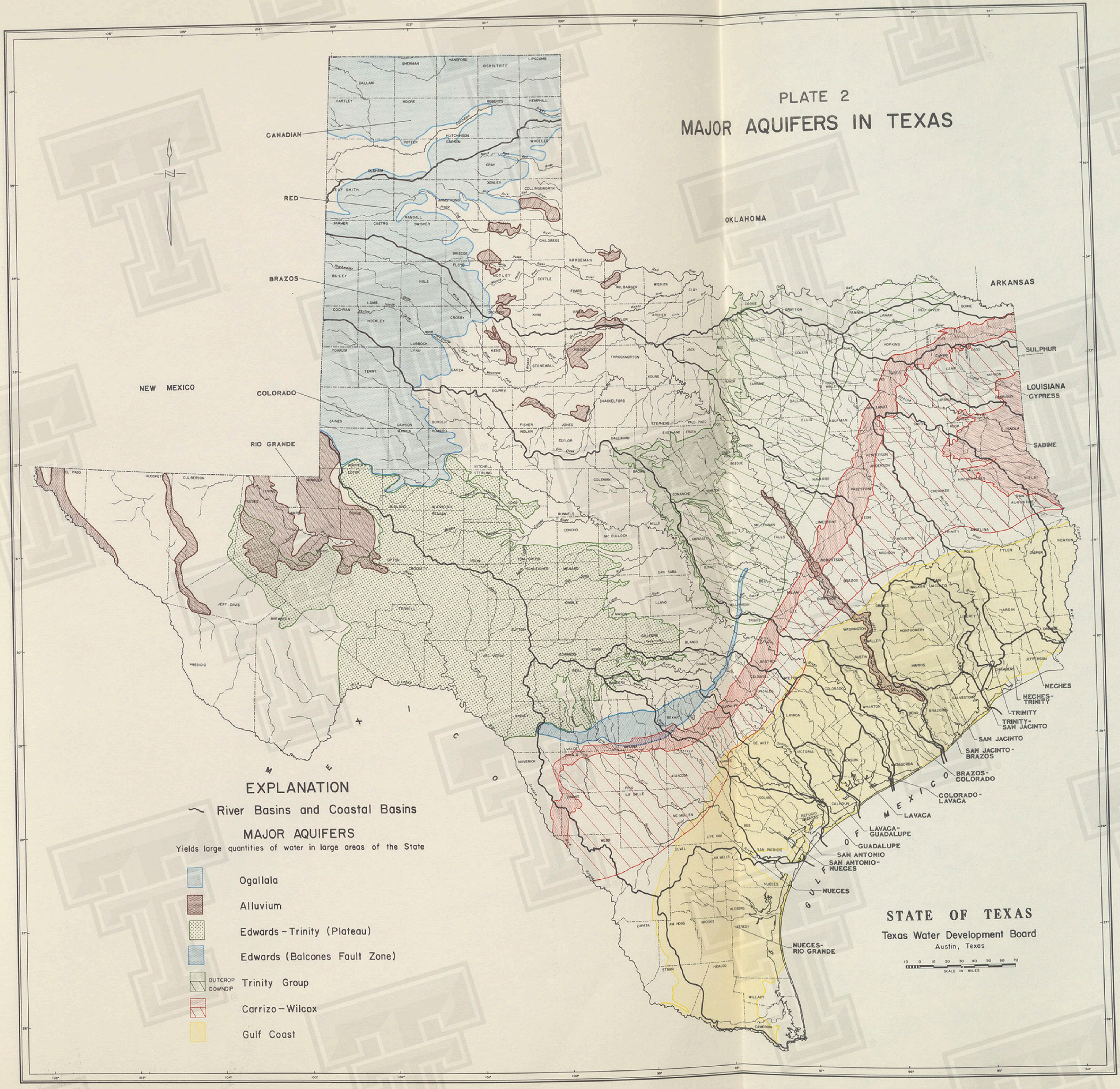
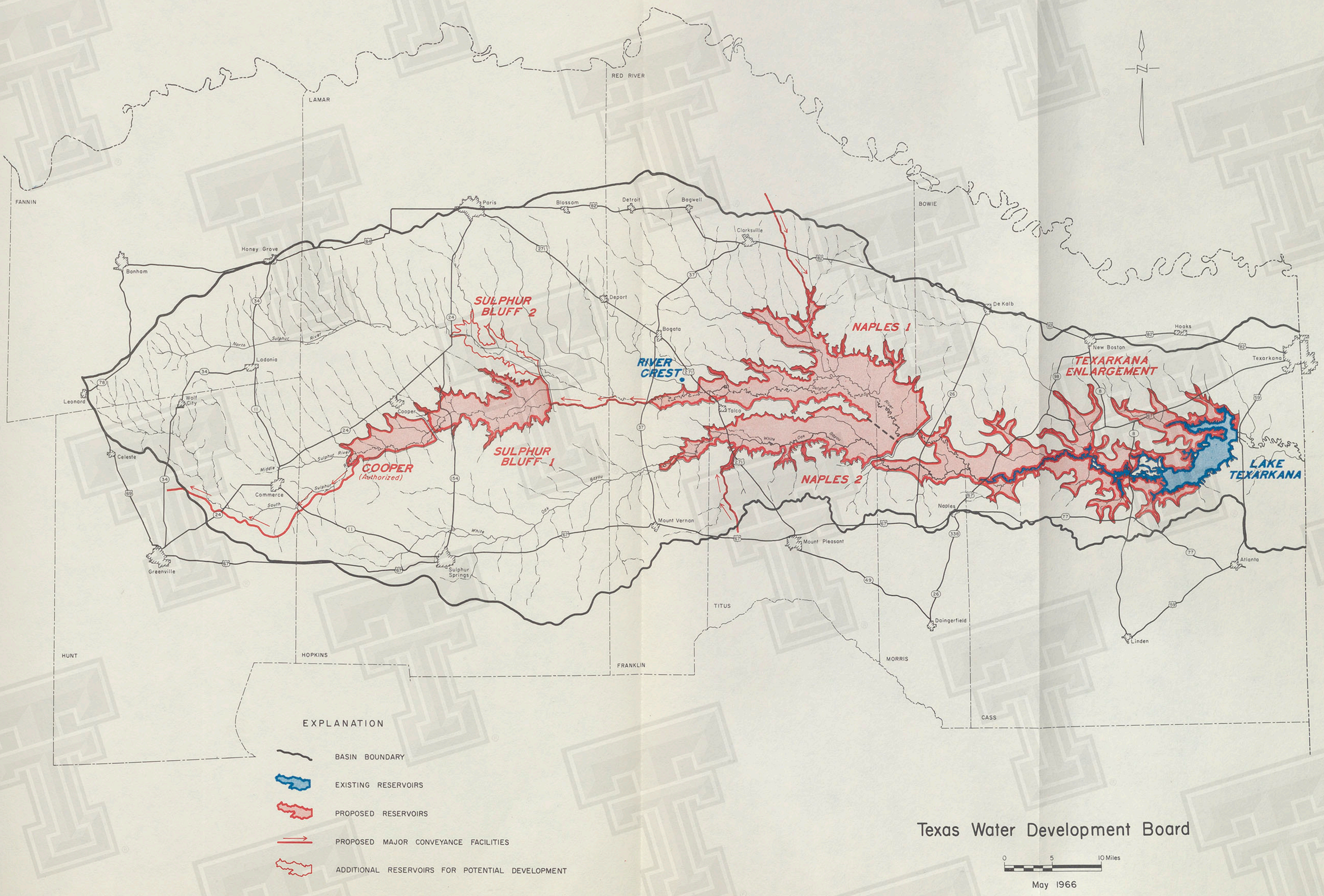



PLATE 3
MINOR AQUIFERS IN TEXAS
NEW MEXICO
OKLAHOMA
ARKANSAS
LOUISIANA
MEXICO
GULF OF MEXICO
CANADIAN
RED
BRAZOS
COLORADO
RIO GRANDE
SULPHUR
CYPRESS
SABINE
NECHES
NECHES-TRINITY
TRINITY
TRINITY-SAN JACINTO
SAN JACINTO
SAN JACINTO-BRAZOS
BRAZOS-COLORADO
COLORADO-LAVACA
LAVACA
LAVACA-GUADALUPE
GUADALUPE
SAN ANTONIO
SAN ANTONIO-NUECES
NUECES
NUECES-RIO GRANDE
EXPLANATION
River Basins and Coastal Basins
MINOR AQUIFERS
Yields large quantities of water in small areas or relatively small quantities of water in large areas of the State
OUTCROP
DOWNDIP
Woodbine
Queen City
Sparta
Edwards-Trinity (High Plains)
Santa Rosa
Ellenburger-San Saba
Hickory
Note: Bone Spring-Victorio Peak and Blaine Aquifers not shown on map
STATE OF TEXAS
Texas Water Development Board
Austin, Texas
SCALE IN MILES

PLATE 4

SULPHUR RIVER BASIN



PROPOSED TEXAS WATER PLAN:

WATER FOR TEXAS

A Plan For The Future

WATER FOR TEXAS

A Plan For The Future

Prepared By

Texas Water Development Board

TEXAS WATER DEVELOPMENT BOARD

Mills Cox, Gay Hill, Chairman
Marvin Shurbet, Petersburg, Vice Chairman
Robert Gilmore, Dallas, Member
Milton Potts, Livingston, Member
Groner Pitts, Brownwood, Member
W. E. Tinsley, Austin, Member

Joe G. Moore, Jr., Executive Director
John J. Vandertulip, Chief Engineer

The Texas Water Plan as summarized in this brochure is preliminary and should be examined within the context of the following:

1. The Plan, which will be adopted tentatively by the Texas Water Development Board in the fall of this year, will include consideration, analysis, and evaluation of testimony presented at twenty-seven basin hearings to be held between June 20 and August 26.
2. The full report, numbering in excess of 400 pages, is in its first draft, and this brochure is a summary of that draft.
3. A large number of alternatives have been considered but other suggested alternatives which meet objectives of the Plan will be considered by the Board.
4. The reservoirs suggested to meet water requirements to 2020 can not all be constructed simultaneously. They must be scheduled in time, and the inclusion of a suggested reservoir should not be construed locally as a commitment to build that reservoir first.
5. Not every possible water supply source is included in the Plan. Other reservoirs can be constructed within the river basins for local purposes so long as they contribute to the optimum development of the basin's water supply.
6. Under the Plan as presently proposed, there remains undeveloped or uncommitted surface water supply sources in the eastern basins which could provide some two million acre-feet of water subject to disposition as the people of Texas may determine.

Joe G. Moore, Jr.
Joe G. Moore, Jr.
Executive Director

May 22, 1966

Mr. Mills Cox
Chairman, Water Development Board

Dear Mr. Cox:

The Consulting Advisory Panel has reviewed the draft of the proposed Texas Water Plan.

The Panel considers that:

1. The planning concepts followed by the staff are sound;

2. Available alternatives have been examined and considered;

3. The recommendations for proposed development are ready for release for public hearing and are endorsed by the Panel.

When the public hearings are concluded and the Board has given full consideration to the information developed in the hearings, the Panel will advise further with the Board concerning the critical importance of continuing studies by a highly competent staff in the implementation of the Plan.

Chairman,
Consulting Advisory Panel

DEFINITIONS OF TERMS

Acre-foot (feet)--A term used in measuring the volume of water, equal to the quantity of water required to cover one acre one foot in depth; it is equivalent to 43,560 cubic feet or 325,851 U.S. gallons.

Surface Water--Water that flows or rests upon the surface of the earth. It may occur in either liquid or solid state.

Evaporation--The process by which water or other liquid passes from a liquid state to vapor--the gaseous state.

Ground Water--Subsurface water occupying the saturation zone, from which wells and springs are fed. In a strict sense the term applies only to water below the water table.

Streamflow--A term used to designate water that is flowing in a stream channel.

Water Supply--A general term for the sources of water for public or private uses.

Aquifer--A geologic formation, a group of formations, or a part of formation that is water bearing; use of the term is usually restricted to those water-bearing units capable of yielding water in sufficient quantity as to constitute a usable supply.

Aquifer, Major--One that yields large quantities of water in large areas of the State.

Aquifer, Minor--One that yields large quantities of water in small areas or relatively small quantities of water in large areas of the State.

Phreatophyte--A plant that habitually obtains its water supply from the zone of saturation, either directly or through the capillary fringe.

Precipitation--The total measurable supply of water of all forms of falling moisture, including dew, rain, mist, snow, hail, and sleet; usually expressed as depth of liquid water on a horizontal surface in a day, month, or year, and designated as daily, monthly, or annual precipitation.

Recharge--The process by which water is added to an aquifer, either by natural or artificial means.

Runoff--That portion of the earth's available water supply that is transmitted through natural surface channels. In the general sense, it is defined as that portion of precipitation which is not absorbed by the deep strata but finds its way into the streams after meeting the persistent demands of evapotranspiration including interception and other losses.

Sediment--Any material carried in suspension by water, which would settle to the bottom if the water lost velocity.

Storage, Conservation--Water impounded for later release for consumptive uses, such as domestic, municipal, industrial, and irrigation.

Storage, Dead--Storage below the lowest outlet level of a reservoir and not susceptible to release.

Storage, Flood-control--Storage of water during floods to be released later as rapidly as channel capacities permit.

Storage, Sedimentation--Storage of sediment deposited in a reservoir accumulatively over a certain period of time.

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WATER FOR TEXAS - A PLAN FOR THE FUTURE

PLANNING TO MAKE DEVELOPMENT POSSIBLE

What is the Plan

The comprehensive Texas Water Plan is a flexible proposal for the protection, conservation, development, redistribution, and administration of water resources to meet water needs for all purposes throughout the State to the year 2020 and beyond. The Plan proposes a method of implementation in accordance with the statutory directive that the Plan be developed with "regard for the public interest of the entire State...in order that sufficient water will be available at reasonable cost to further the economic development of the entire State."

Why a Plan

How is the Plan different from other water plans for Texas? Why is it needed when bookshelves are already lined with earlier water plans? Primarily, it is different because for the first time the entire State was examined in the light of water availability and requirements projected into the next century. It is different because these projections were prepared by objective research techniques on the basis of carefully acquired data. It is different because for the first time ground water is given extensive attention. It is different because water requirements for quality control and recreation are considered. It is different because new techniques were used to analyze saline-water conversion and reuse of water for selected purposes. It is different because it proposes the means to implement the Plan's components, and because an economic analysis was made of alternatives. And it is different because it is predicated on the continuing function of planning as a responsibility of the State.

The Plan is needed to place Texas in a position to judge the merits of proposed Federal projects so profound in potential impact that they could, in fact, commit the direction of Texas water resource and economic development for the next century. It is needed to place the State of Texas in a position to moderate local and regional competition for water resources. And it is needed to move the State toward its objectives of continued growth, and the satisfaction of every citizen's just desire for an equitable share of the State's natural resources.

How the Plan was Made

The Plan was begun by the Texas Water Commission in August 1964. The planning function was subsequently assigned to the Texas Water Development Board effective September 1, 1965. It was developed through the concurrent accumulation and analysis of a wide range of information by the staff of the State's water agencies, cities, local water authorities, leading colleges and universities, consultants, and Federal agencies.

The Plan was geared to the optimum utilization of the State's water resources to meet projected needs for water for all purposes. Surface water, underground water, return flows, low quality water, and desalted brackish water were included in studies of the total available supply. Possibilities of importing water into Texas from other states and even other countries were explored, and those explorations continue with respect to a water supply for West Texas. Each project in the Plan was selectively phased to the year 2020 to serve municipal, industrial, irrigation, mining, hydroelectric-power, navigation, and recreation needs, as well as requirements for preservation of the bays and estuaries. Water use for quality management in streams and in the bays was considered, in addition to fish and wildlife needs. Recreational and aesthetic enjoyment of water resources was considered.

Correlary studies were made of major and minor drainage; hurricane protection; waste-water disposal; streamflow augmentation; estuary quality control; algae growth; undesirable water vegetation; seepage; pollution from oil-field brines; evaporation suppression in ponds and reservoirs; land subsidence along the coastal area; tidal interchanges and surging action in bays and estuaries, affecting channel capacity and egress and ingress of marine life; flood-plain delineation for maximum floods of record; upstream flood-prevention programs showing the development of and additional need for the Soil Conservation Service programs; flood damage for selected reaches in the State; and other special studies.

Problems associated with the diversion or transportation of water from a river basin to another area of Texas were considered in view of the present and future development, economy, general welfare, and water requirements of affected areas. In planning exchanges of water, determinations of availability of excess water were based not only on the projected water requirements of the basins of origin for the Plan's 50-year period, but also provided substantially for possible additional future requirements.

The legal and institutional impacts of the Plan were examined. Existing water rights were considered. Interstate compacts and treaties have been honored.

Who has Made the Plan

Governor John Connally set the stage for development of the Texas Water Plan in August of 1964 when he wrote:

> I am increasingly concerned about drouth conditions in Texas and progress of our efforts to develop adequate sources of water for all our State. I'm sure the members of the Texas Water Commission share this concern with all our citizens.

The Bureau of Reclamation and the Corps of Engineers have proposed broad water development projects for Texas far beyond the plans of the Texas Water Commission report, "A Plan for Meeting the 1980 Water Requirements of Texas." In my opinion, these plans fall short of satisfying the water needs for all of Texas.

Furthermore, the Congress is presently considering a federal water pollution control bill which will supplant state authority in this field. I have long been concerned that the State exercise its responsibility in all areas of water conservation and development. The recently enacted Water Resources Act of 1964 does provide an opportunity for state participation in federal water research programs.

As you know, it is my responsibility, with the help of the Texas Water Commission, to review major federal projects and formally approve or disapprove them on behalf of the State. I cannot properly evaluate some proposed federal projects without a longer-range State Water Plan for Texas.

Therefore, by authority granted me under Article V, Section 22, House Bill 86, 58th Texas Legislature (The General Appropriations Act), I hereby request the Texas Water Commission to use any available moneys appropriated under that Act to begin at once to develop a comprehensive State Water Plan. In the public interest and to aid the economic growth and general welfare of the State, I urge that you explore all reasonable alternatives for development and distribution of all our water resources to benefit the entire State, including proposals contained in preliminary reports of the federal agencies.

In addition to the Texas Water Commission and the Texas Water Development Board, who were assigned primary responsibility for development of the comprehensive Texas Water Plan, other State agencies have participated in its formulation. The Texas Water Rights Commission, State Department of Health, Parks and Wildlife Department, the Texas Highway Department, the State Archeologist, the Planning Agencies Council - Texas, the Texas Railroad Commission, have all contributed valuable time, information, and judgment during the Plan's development.

The river authorities, water districts, cities, and local political entities with an interest in water, have diligently contributed to the State's water-development program to assure the Plan's compatibility with the best interests of all parts of the State.

The State's colleges and universities, especially Texas A & M University, The University of Texas, and Texas Technological College, have made available their vast research capabilities in water and land resource development and management.

Private groups, businesses, and industrial and agricultural associations contributed staff, information, and advice essential to the successful completion of the Plan.

Consultants have participated in the study and analysis of major elements of the Plan.

Federal agencies concerned with water development in Texas have been both considerate and helpful during the planning process. Project proposals, ready for submission for authorization to the Congress, have been voluntarily withheld pending completion of the Texas Water Plan, to permit their evaluation within the Plan's framework. The vast resources of these agencies, both in staff potential and in collected information, have been available as needed.

METHODS AND SOLUTIONS

Planning Concepts

Principles and concepts guiding the formulation of the Plan express the social, economic, and political values essential to natural resource development.

Conceptually, the Plan recognizes that water planning--and the selection between alternative development patterns--has a profound impact on the State, and that the State's leadership in water planning is required to assure the equitable distribution of available supplies.

It has been designed to achieve the maximum benefit from the responsible coordination of the functions of State, local, and Federal agencies.

Water-quality management was recognized as an integral part of planning--both as a constraint on meeting future water needs where quality conditions are impaired, and as an obligation where streamflow is nearing complete control.

The exercise of State leadership to determine the course of water development requires the discharge of certain responsibilities. Thus, the State must participate financially in the construction, operation, and maintenance of some elements of planned water storage and conveyance facilities if it is, in fact, to guide that course through the Plan. The State's investment in these facilities is protected by the Plan's proposal that both the cost of water in reservoirs and the cost of transportation to areas of use be paid by the user and those who benefit directly from its distribution and use.

Projections of Water Requirements

Resource development planning is the prudent response of an organized society to provide for present and future needs. Projections of water requirements are prepared on the basis of many complex factors of future growth and change. The Plan's flexibility will provide for a continuing assessment of these changes so that development keeps pace with actual needs.

Estimates of future population and water requirements for municipalities and industries, as these requirements are met by the Plan, were developed by the Texas Water Development Board in cooperation with the Bureau of Business Research of The University of Texas, and from information provided through a detailed industrial use questionnaire completed by industries throughout the State.

Future agricultural water requirements were prepared by the Texas Water Development Board, based on an inter-disciplinary study by Texas A & M University of the irrigation potential throughout the State.

Water needs for secondary recovery by the petroleum industry were based on reports from consultants, and from the Texas Mid-Continent Oil and Gas Association estimates.

Table 1.--Municipal and industrial water requirements by basin

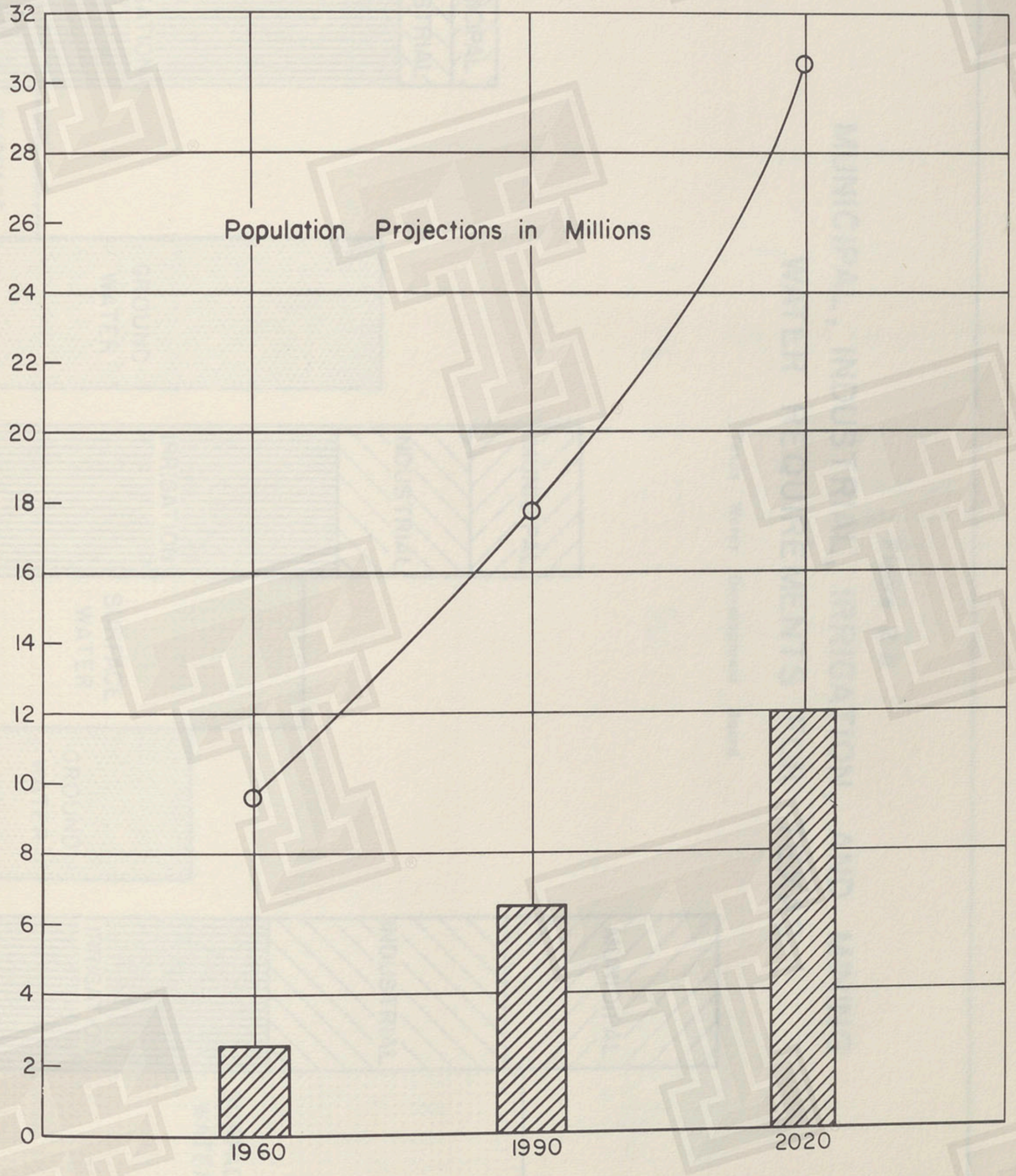
(in acre-feet)

Basin	1960			1990			2020		
	Mun.	Ind.	Total	Mun.	Ind.	Total	Mun.	Ind.	Total
Canadian	38,204	79,973	118,177	100,000	169,900	269,900	148,000	223,200	371,200
Red	43,240	26,212	69,452	94,200	78,800	173,000	172,100	118,700	290,800
Sulphur	10,366	24,118	34,484	27,100	37,300	64,400	55,500	45,500	101,000
Cypress	11,403	46,084	57,487	22,700	81,700	104,400	41,800	111,700	153,500
Sabine	23,301	69,168	92,469	55,200	346,100	401,300	131,200	755,600	886,800
Neches	30,047	120,852	150,899	88,000	353,200	441,200	202,000	668,000	870,000
Neches-Trinity	16,324	96,695	113,019	47,200	341,000	388,200	108,600	703,100	811,700
Trinity	282,830	119,887	402,717	728,900	196,500	925,400	1,394,300	300,300	1,695,100
Trinity-San Jacinto	5,677	42,367	48,044	12,400	75,300	87,700	29,600	122,500	152,100
San Jacinto	176,799	248,801	425,600	445,300	792,600	1,237,900	914,600	1,522,800	2,437,400
San Jacinto-Brazos	36,693	104,197	140,890	93,200	254,500	347,700	217,900	415,300	633,200
Brazos	131,034	93,087	224,121	300,400	159,400	459,800	557,000	233,500	790,500
Brazos-Colorado	5,713	21,698	27,411	12,900	53,300	66,200	32,500	87,400	119,900
Colorado	103,303	40,927	144,230	243,300	94,000	337,300	459,300	145,200	604,500
Colorado-Lavaca	1,576	4,521	6,097	4,000	35,900	39,900	7,800	80,800	88,600
Lavaca	3,239	2,203	5,442	6,400	8,500	14,900	10,600	16,300	26,900
Lavaca-Guadalupe	2,010	39,213	41,223	6,400	124,000	130,400	12,400	233,900	246,300
Guadalupe	19,885	23,862	43,747	48,800	41,200	90,000	102,700	59,000	161,700
San Antonio	99,783	20,925	120,708	231,900	48,200	280,100	369,200	78,000	447,200
San Antonio-Nueces	7,082	6,739	13,821	15,700	12,600	28,300	30,600	18,100	48,700
Nueces	13,543	6,370	19,913	25,400	14,100	39,500	44,800	22,300	67,100
Nueces-Rio Grande	104,900	59,083	163,983	213,300	147,100	360,400	420,400	240,600	661,000
Rio Grande	90,275	26,167	116,442	180,100	46,300	226,400	331,900	70,400	402,300
State total	1,257,227	1,323,149	2,580,376	3,002,800	3,511,500	6,514,300	5,794,800	6,272,700	12,067,500

Figure I A

POPULATION PROJECTION AND MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS

Texas Water Development Board



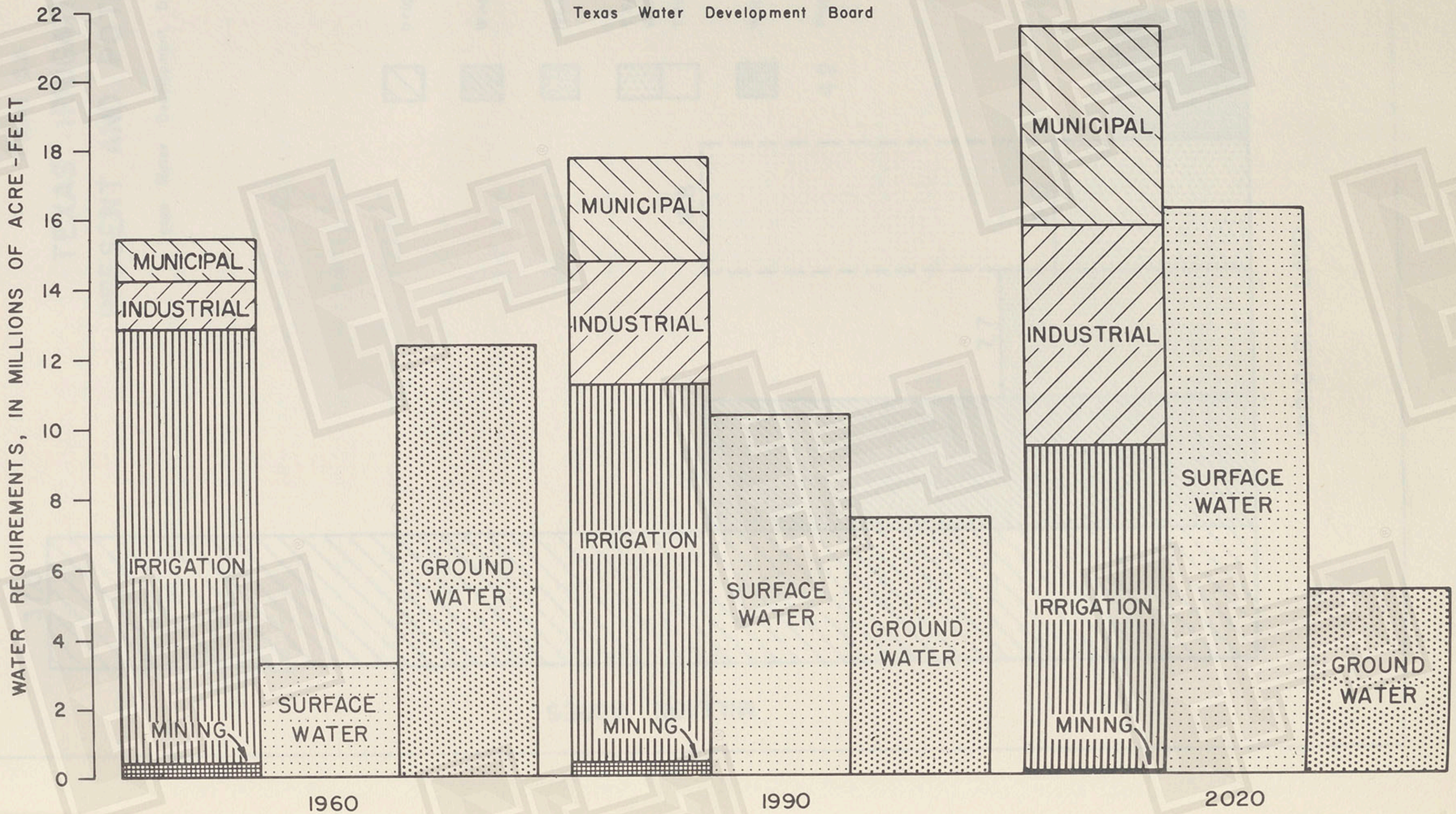
Municipal and Industrial Water Requirements in Millions of Acre Feet

State of Texas

Figure 2 A

MUNICIPAL, INDUSTRIAL, IRRIGATION, AND MINING WATER REQUIREMENTS FOR TEXAS

Texas Water Development Board



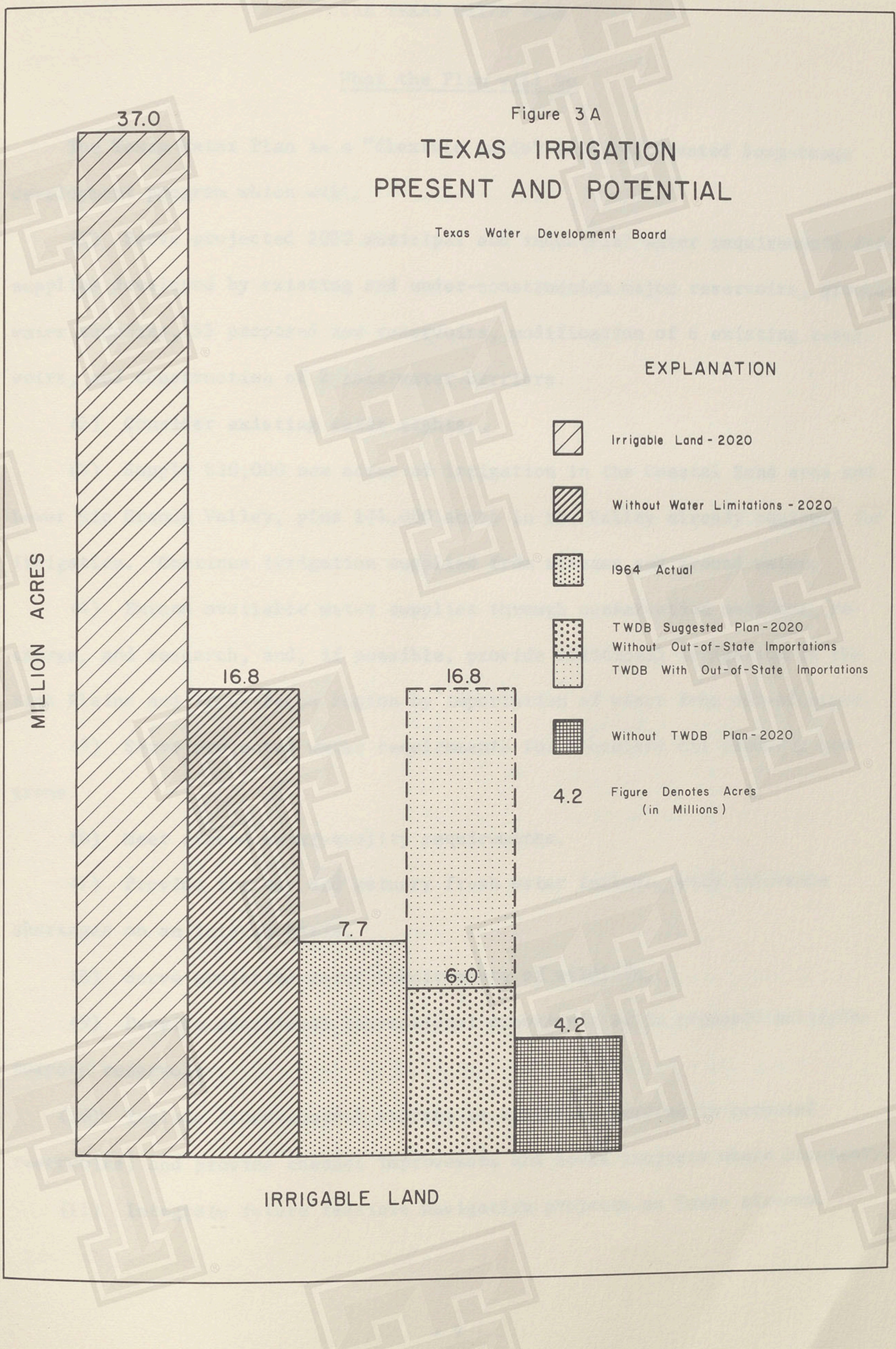


Figure 3 A

TEXAS IRRIGATION
PRESENT AND POTENTIAL

Texas Water Development Board

THE TEXAS WATER PLAN

What the Plan will Do

The Texas Water Plan is a "flexible guide" to a coordinated long-range development program which will:

(1) Serve projected 2020 municipal and industrial water requirements from supplies developed by existing and under-construction major reservoirs, ground-water supplies, 53 proposed new reservoirs, modification of 6 existing reservoirs, and construction of 2 salt-water barriers.

(2) Consider existing water rights.

(3) Supply 830,000 new acres of irrigation in the Coastal Bend area and Lower Rio Grande Valley, plus 174,000 acres in the Valley already equipped for irrigation. Continue irrigation supplied from streams and ground water.

(4) Extend available water supplies through conservation measures, recharge, and research, and, if possible, provide additional irrigation in the High Plains and Trans-Pecos region by importation of water from out-of-state.

(5) Serve projected water requirements for secondary oil recovery programs.

(6) Meet stream water-quality requirements.

(7) Provide for bay and estuary fresh water inflows, with tolerable shortages on an interim basis.

(8) Serve projected water requirements of wildlife.

(9) Provide additional recreational opportunities in proposed multiple-purpose reservoirs.

(10) Include flood-control storage as a project purpose in proposed reservoirs, and provide channel improvement and levee projects where necessary.

(11) Integrate future feasible navigation projects on Texas streams.

(12) Include additional upstream watershed programs on 17,584,560 acres for erosion control and land treatment, plus 2,510 additional floodwater-retarding structures, and 1,193 miles of additional channel improvement.

(13) Include needed drainage projects for wetlands.

(14) Support projects to alleviate natural pollution.

(15) Support hurricane protection projects along the Gulf Coast.

(16) Provide a means to modify and implement the Plan.

(17) Develop six major units of physical works:

Unit A - Southwest Texas System

Unit B - Northeast Texas System

Unit C - Southeast Texas System

Unit D - Reservoirs to 2020 not included in Units A, B, and C.

Unit E - Water Resources Related Projects

Unit F - Out-of-State import projects.

Description of Proposed Projects

Units A and B are directly related systems described together as the State Water Project, while Units C, D, E, and F are discrete elements of the statewide Plan. These units, phased individually to meet projected requirements, will include the following projects:

State Water Project - Units A and B

The State Water Project is basically a conduit, 980 miles long, which satisfies demands and permits multiple use of water along the route. It extends from the Sulphur River basin, with connections for the Red River and Cypress Creek basins, to the Rio Grande utility canals, through pump stations and the natural channels of the Trinity, Brazos, and Colorado basins along the way.

The origin of the system is in the Sulphur River basin, where water from the Sulphur Bluff I and Naples I and II reservoirs and enlargement of the

Texarkana Reservoir serves as the basic supply for the project. In advanced stages of the project, water will be diverted into the Sulphur basin from the Red River and Cypress Creek basins to augment the supply to satisfy necessary Project needs. By 2020, it is estimated that 2,405,000 acre-feet of water will enter the Project system from these upper source basins.

All of the Sulphur basin water will pass through Cooper Reservoir on its way to the Trinity River. A portion will be diverted for water supply in the Dallas-Fort Worth area, the rest will enter the main channel of the Trinity River through the Forney Reservoir and the East Fork of the Trinity River. An additional benefit will be realized in moving Project water through the Trinity River through amelioration of the undesirable water-quality conditions now existing in the Trinity River below the Dallas-Fort Worth metropolitan area. The water will flow down the Trinity channel for about 70 miles, at which point it is diverted into Richland Reservoir and then Tehuacana Reservoir.

Project water will be diverted from Tehuacana Reservoir through a conduit to the Brazos River and flow for 170 miles to the vicinity of San Felipe. At this location water will be pumped over the divide into the Colorado River. After flowing about 16 miles in the Colorado River channel, the water is again diverted near Garwood to Palmetto Bend. A portion of the Project water can be released to the Colorado to replace water retained in Stacy Reservoir and that diverted from the Colorado River to San Antonio.

Palmetto Bend is the head end of the 190-mile Coastal Aqueduct which conducts water along the Gulf Coast to the lower Rio Grande Valley. It flows through Confluence Reservoir and a line-regulating reservoir, distributing water for irrigation, industrial use, municipal supply on an exchange basis, bays and estuaries, and wildlife refuges. Water from the Guadalupe and San Antonio River basins stored in Cuero, Cibolo, and Goliad Reservoirs will be diverted to the Aqueduct until such time as these waters are needed in the source basin. At selected points along the Aqueduct, three reservoirs--Sinton, Baffin Bay, and Valley--provide system regulation facilities.

Unit A of the State Water Project

Palmetto Bend, (Stages 1 and 2), Cuero (Stages 1 and 2), Cibolo, Goliad, and Confluence Reservoirs; diversion facilities; conveyance facilities and pump stations from the Brazos River to the Lower Rio Grande Valley, and from the Colorado River to the City of San Antonio; re-regulating reservoirs along the conveyance facility; and wholesale distribution facilities for the Coastal Bend and Lower Rio Grande Valley irrigation projects.

Unit B of the State Water Project

Sulphur Bluff (Stage 1), Naples (Stages 1 and 2), Texarkana Enlargement, Pecan Bayou, Franklin County, Titus County, Marshall, Richland Creek, and Tehuacana Creek Reservoirs; diversion of water into and from Cooper, Lake O' The Pines, Lavon and Grapevine Reservoirs; diversion facilities from Red River and Trinity River; pumping plants and conveyance facilities from the Sulphur River, Cypress Creek, and Red River basins to the Trinity River basin and then to the Brazos River basin; and a re-regulating reservoir. Black Cypress Reservoir may be added to this unit when needed.

<u>Texas Water Plan - Units C and D</u>

Unit C of the Texas Water Plan

Toledo Bend Reservoir and Salt-Water Barrier in the Sabine River basin; Blackburn Crossing Enlargement, Rockland and Ponta Reservoirs, and Salt-Water Barrier in the Neches River basin; Livingston, Wallisville, Tennessee Colony and Bedias Reservoirs in the Trinity River basin; Conroe, Cleveland, Humble, Lower East Fork and Lake Creek Reservoirs in the San Jacinto River basin; and conveyance facilities from the lower Sabine and lower Neches River to the Trinity River-Galveston Bay area.

Unit D of the Texas Water Plan

Consists of the following reservoirs by basins:

Red River Basin

Sweetwater, Bois d'Arc, and Big Pine Reservoirs and enlargement of Lake Kemp. Lower McClellan, Lelia Lake Creek, Ringgold, and Barkman Reservoirs are possible additions to meet future needs.

Sulphur River Basin

Sulphur Bluff (Stage 2) Reservoir.

Sabine River Basin

Mineola, Lake Fork, and Kilgore Reservoirs. Cherokee No. 2, Big Sandy, and State Line Reservoirs are future possible additions.

Trinity River Basin

Aubrey, Lakeview, and Little Elkhart Reservoirs and enlargements of Lavon and Bridgeport Reservoirs.

Brazos River Basin

Breckenridge, Miller Creek, De Cordova Bend, Aquilla, Stephenville, North San Gabriel, Laneport, Cameron, Millican, and Navasota No. 2 Reservoirs. The South San Gabriel Reservoir may be added at a future point in time.

Colorado River Basin

Robert Lee, Stacy, Upper Pecan Bayou, Columbus Bend, and Matagorda Reservoirs and replacement of Brownwood Dam. The San Saba, Mason, and Pedernales Reservoirs may be developed as future additions.

Lavaca-Guadalupe Basin

Garcitas Reservoir.

Guadalupe Basin

Ingram, Cloptin Crossing, and Lockhart Reservoirs.

Nueces River Basin

Choke Canyon.

Capital Costs of Units A, B, C, and D

Major water-development facilities are costly, and these costs must be carefully evaluated in terms of the relative benefits accruing as a consequence of development. The following summary shows a total capital cost of the water-development facilities included in the Texas Water Plan.

Cost of reservoirs in State Water Project	$ 604,000,000
Cost of transfer facilities in State Water Project	460,000,000
Cost of Coastal Aqueduct	220,000,000
Cost of regulating reservoirs	30,000,000
Cost of irrigation distribution systems	250,000,000
Total cost of State Water Project	1,564,000,000
Cost of reservoirs not in State Water Project	1,170,000,000
Total capital cost of Units A, B, C, and D of the Texas Water Plan	$2,734,000,000

Texas Water Plan- Units E and F

Unit E of the Texas Water Plan

Navigation facilities along the coast and to interior locations; flood-control facilities other than reservoirs providing water-supply storage;

hurricane-protection projects; upstream watershed-protection programs; drainage; natural pollution alleviation projects; and phreatophyte control projects.

Unit F of the Texas Water Plan

Includes out-of-state import projects needed to provide water to the High Plains, Trans-Pecos, and El Paso areas.

The studies for the Texas Water Plan have shown conclusively that there is not sufficient surplus water in East Texas in excess of higher priority needs to make it feasible to transport water from those sources for irrigation in West Texas. Therefore, we must look elsewhere for water to supply the irrigation requirements of that portion of Texas lying generally west of 99° west longitude.

The future water needs of West Texas are so large and so urgent that, if the State is to continue to grow economically, water must be brought in within 15 years from outside sources, such as the Missouri River, Mississippi River or possibly, the Columbia River, or ultimately, sources farther to the North. Studies by consulting engineers have shown that surplus water resources are available and that it would be physically feasible to import substantial quantities of water to meet these demands.

It is obvious that Texas could not "go it alone" to import water; the cost would be far too great. Any importation plan for West Texas, to be feasible, must be part of some larger regional plan for conservation and redistribution of water resources. It is entirely possible that other States or areas would benefit from certain regional plans.

The future economic well-being and growth of West Texas will be very largely dependent upon the availability of adequate irrigation water supplies, which can only be provided by importation from sources outside the State of Texas.

Table 2.--Construction costs and capacities of proposed reservoir development*

River basin	Reservoir	Storage capacity in thousands of acre-feet				Construction cost in millions of dollars
		Flood control	Conser- vation	Sediment	Total	
Red	Sweetwater	0	33.0	16.9	49.9	4.2
	Timber Creek	0	12.0	1.0	13.0	2.3
	Bois d'Arc	73.1	92.5	13.9	179.5	13.9
	Big Pine	54.7	77.9	6.0	138.6	10.0
	Pecan Bayou	0	369.8	13.5	383.3	16.6
	Lake Kemp modification	200.0	245.8	80.2	526.0	7.1
Sulphur	Cooper	127.5	273.0	9.3	409.8	18.0
	Sulphur Bluff I	0	548.2	87.2	635.4	31.2
	Naples I	454.7	1,466.5	135.8	2,057.0	74.9
	Naples II	701.7	2,220.0	190.0	3,111.7	41.9
	Texarkana modification	1,687.7	802.9	125.8	2,616.4	13.0
Cypress	Franklin County	0	71.8	1.2	73.0	3.5
	Titus County	132.8	287.0	2.9	422.7	12.0
	Lake O' the Pines modification	461.2	377.1	3.8	842.1	5.9
	Marshall	0	775.0	7.3	782.3	25.1
Sabine	Mineola	668.8	167.1	11.0	846.9	49.5
	Lake Fork	357.6	498.8	18.9	875.3	45.9
	Kilgore No. 2	0	14.0	1.0	15.0	2.0
Neches	Blackburn Crossing enlargement	0	401.4	8.6	410.0	12.3
	Ponta	649.2	810.0	25.4	1,484.6	51.8
	Rockland	1,440.5	1,787.9	58.9	3,287.3	84.5
Trinity	Bridgeport modification	0	396.1	37.0	433.1	3.0
	Aubrey	258.3	603.8	37.8	899.9	34.1
	Lakeview	136.7	306.4	45.6	488.7	31.8
	Richland Creek	0	1,000.0	135.5	1,135.5	30.0
	Tehuacana Creek	0	374.0	33.5	407.5	19.7
	Tennessee Colony	2,144.3	1,032.5	190.0	3,366.8	137.1
	Bedias	0	488.0	16.7	504.7	25.2
	Wallisville	0	46.7	12.4	59.1	16.3
	Lavon modification	275.6	380.0	92.6	748.2	31.4
San Jacinto	Cleveland	0	479.8	4.2	484.0	18.7
	Lower East Fork	0	330.7	7.3	338.0	35.1
	Lake Creek	0	200.0	6.0	206.0	15.0
	Humble	0	511.0	15.0	526.0	60.0
Brazos	Millers Creek	0	17.5	8.0	25.5	5.4
	Breckenridge	0	550.0	67.0	617.0	19.6
	De Cordova Bend	0	105.4	44.6	150.0	15.0
	Stephenville	0	40.6	10.9	51.5	2.5
	Aquilla Creek	111.5	59.7	28.1	199.3	23.6
	North San Gabriel	87.7	36.1	7.0	130.8	14.1
	Laneport	130.1	91.9	22.2	244.2	32.2
	Cameron	0	1,200.0	18.0	1,218.0	32.5
	Navasota No. 2	550.7	1,315.4	69.5	1,935.6	61.1
	Millican	359.0	1,125.8	72.0	1,556.8	58.6
Colorado	Robert Lee	0	454.8	34.0	488.8	12.8
	Stacy	659.3	650.0	50.0	1,359.3	26.4
	Upper Pecan Bayou	102.7	93.5	10.1	206.3	10.5
	Columbus Bend	481.7	395.2	88.1	965.0	44.2
	Matagorda	0	61.4	28.6	90.0	31.3
	Brownwood replacement	0	133.2	10.2	143.4	7.3
Lavaca	Palmetto Bend	0	230.0	55.0	285.0	51.0
	Garcitas	0	63.0	4.0	67.0	22.0
Guadalupe	Ingram	36.4	53.5	.5	90.4	8.5
	Cloptin Crossing	107.0	146.8	3.2	257.0	14.5
	Lockhart	0	59.9	9.5	69.4	5.0
	Cuero (I and II)	843.0	2,816.0	50.0	3,709.0	117.5
	Confluence	0	406.0	33.0	439.0	63.0
San Antonio	Cibolo	218.0	172.0	28.0	418.0	26.5
	Goliad	702.0	958.0	42.0	1,702.0	50.5
Nueces	Choke Canyon	0	686.0	14.0	700.0	31.9

* Does not include salt-water barriers

Table 3.--Preliminary staging of reservoir construction, 1967 - 2020

1967 - 1979	1980 - 1990	1990 - 2020
Cooper	Richland	Sweetwater
Cuero I & II	Tehuacana	Naples I & II
Goliad	Ingram	Texarkana Modification
Palmetto Bend	Mineola	Pecan Bayou
Cibolo	Lake Fork (Sabine)	Marshall
Confluence	Stacy	Bedias
Aubrey	Sulphur Bluff I	Cameron
Lakeview	Choke Canyon	Big Pine
Columbus Bend	Miller Creek	Upper Pecan Bayou
Garcitas	Rockland	Ponta
Stephenville		Cleveland
Cloptin Crossing		Humble
Aquilla Creek		Lower East Fork
Millican		Lake Creek
Brownwood Replacement		Navasota No. 2
Lockhart		Matagorda
Breckenridge		Franklin County
Bois d'Arc		Titus County--Staging dependent on navigation.
Lake O' the Pines Modification		
Kilgore No. 2		
Timber Creek		

Already Scheduled for Construction

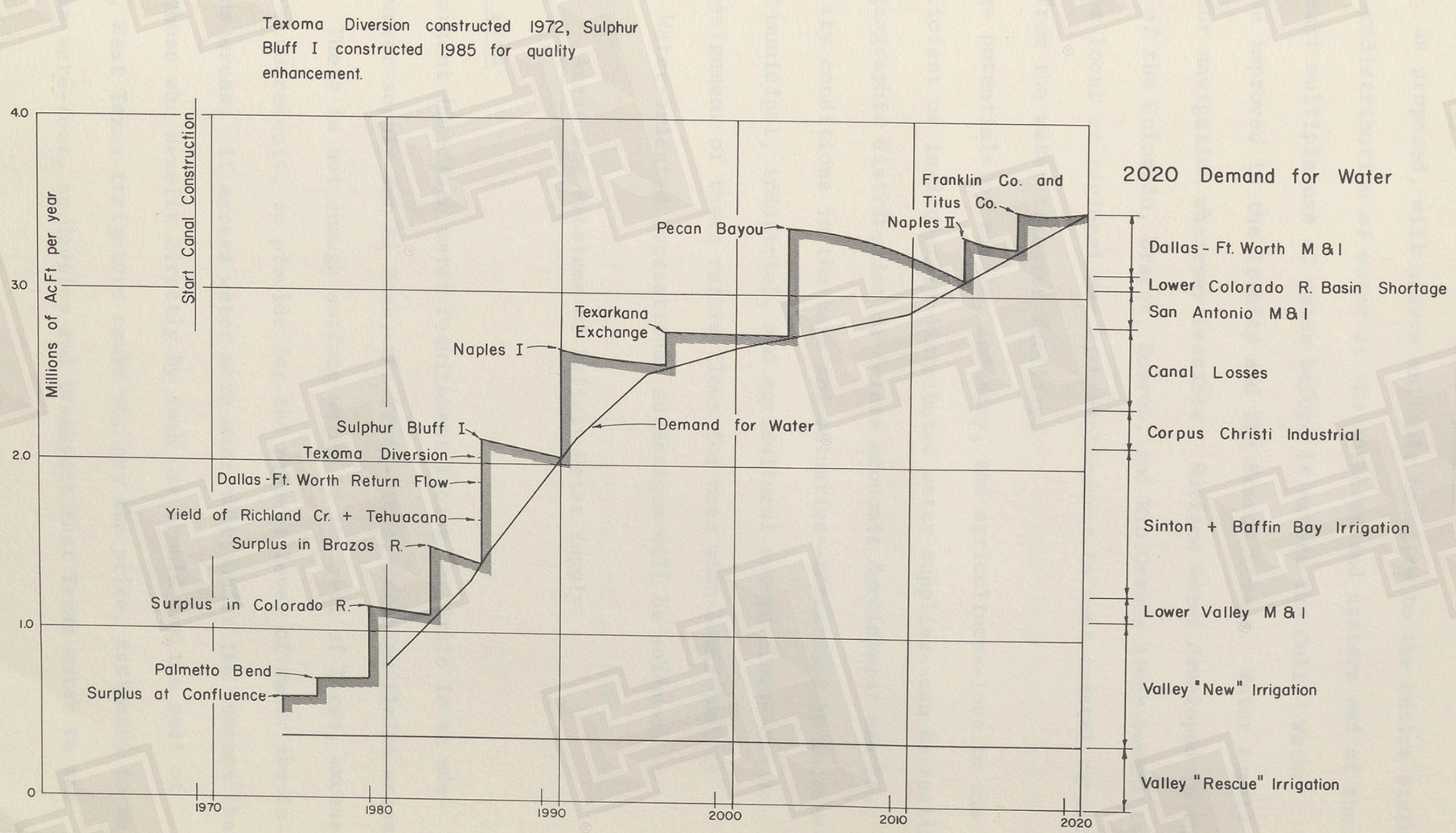
Bridgeport Modification
Lavon Modification
Blackburn Crossing Enlargement
North San Gabriel
Laneport
Wallisville
De Cordova Bend
Robert Lee
Lake Kemp Modification

Tennessee Colony - Authorized, possibly early construction for flood control.

Figure 4A

STAGED DEMAND AND CONSTRUCTION

Texas Water Development Board



Benefits to Entire State

The Plan, as proposed, will assure multiple benefits to the entire State. Beginning the redistribution of water at the northern and eastern end of the State will permit multiple use of water before it enters the Gulf. Water quality will be improved in the Trinity and the Brazos Rivers. Water supply is available for navigation wherever feasible. Surface water developed in the upper reaches of the Colorado, Brazos, Nueces, and Rio Grande River basins can be retained for local or regional use with replacement to meet coastal requirements coming from the water transfer facility.

Long range potentials of cities, industry, and agriculture--lost to the State with deficient or inadequately distributed water supplies--can be realized. Satisfactory geographic distribution of future economic development can be assured. Quality conditions in the bays and estuaries--threatened by increasing volumes of municipal, industrial, and agricultural return flows--can be protected by assignment of these return flows for uses with lower quality requirements. Water-oriented recreational advantages will be enhanced.

Areas and Problems of Deficit Water Supply

The West Texas Area

The most urgent immediate water requirement facing the State is an adequate surface-water supply for El Paso, the Trans-Pecos, and High Plains areas of West Texas. There is not enough surface water in the rest of Texas, excess to foreseeable requirements, to provide for the present level of water use in these West Texas areas. If excess water were available, under the concept that each user and those who benefit directly by such use should pay the cost of water delivery, West Texas irrigators could not pay the price, estimated to be at least $168 an acre-foot, to develop and transport East Texas water to the west.

The Plan recognizes that all Texans, not just those in the west, have a vital interest in sharing the continued and expanding contribution of West Texas, through its irrigated agriculture, and its unique culture and environment, to the State's economy. The Plan proposes the following specific actions to aid in meeting the water needs of this area:

(1) Active and vigorous leadership at the State level in proposals before the Congress for inclusion of West Texas in regional plans for the movement of water from northwestern United States, or from the Mississippi and Missouri Rivers, to the West Texas area, and participation by the Texas Water Development Board in development and financing of such plans.

(2) State financial participation in carefully designed recharge projects to increase the storage in the underground waterbearing formations which supply the West Texas area. State financial assistance for playa lake modification to conserve and utilize these 36,000 shallow depressions as storage facilties.

(3) Establishing an office of the Texas Water Development Board in West Texas, adequately staffed with able personnel to assist in the wide range of research, data-collection programs, improved water-application studies, and continuing technical and economical analyses, required to assure the optimum conservation and utilization of available water supplies.

(4) State financial participation with local and Federal agencies in a modern, large-volume inland desalination plant to provide additional municipal and industrial water supply.

(5) Continued exploration of the economic feasibility of import of water from in-state sources for municipal and industrial purposes as specific unforeseen needs are projected.

(6) Intensified efforts to improve surface-water quality in the upper reaches of the Red, Brazos, and Colorado Rivers to permit multiple uses.

The San Antonio Area

The principal water supply to San Antonio is a complex underground-water formation called the Edwards Aquifer. In addition to supplying the municipal, industrial, and military installation water requirements of the city of San Antonio, and of other municipal areas in southwest Texas, the Edwards supplies irrigation development west (and south) of San Antonio, and supports the spring flow from San Marcos Springs and Comal Springs at New Braunfels.

There is tremendous value to the State in maintaining underground hydrologic conditions required to assure the flow from Comal and San Marcos Springs. The flow of these springs not only provides significant recreational opportunities, but, also, the pool receiving the flows of San Marcos Springs has developed a fascinating ecology of flora and fauna, which is a tourist attraction and a scientific treasure. Its loss would be irreparable.

Additionally, the city of San Antonio uses water from the Edwards aquifer to enhance the flow of the San Antonio River through the city. There is exceptional value to the entire State in the excellent use which the city is making of the flow of the river, and the Texas Water Plan contemplates the continuance of the aesthetic and real values derived from a firm supply of clean water for this purpose.

Increasing water requirements in the area served from this ground-water source makes it essential that additional supplies of water be provided to meet all of these needs. Supplemental water could come from the Nueces River and its tributaries, the Guadalupe River, and the Blanco River. When these have been committed to their capacity, the next dependable source of supply is the Colorado River.

The Plan proposes that the State, in cooperation with local agencies in the area overlying the Edwards aquifer, develop an integrated supply and distribution system, utilizing water from the Colorado and Nueces River basins, the yield from Cloptin Crossing Reservoir, a portion of the yield from Canyon Reservoir (if this becomes available), and the yield from the Edwards aquifer in excess of that required to maintain adequate spring flows. Such a system will produce greater benefits than is possible if these sources are developed and managed individually.

The Lower Rio Grande Valley

This semi-tropical four-county area, including Cameron, Willacy, Hidalgo, and Starr counties, produces citrus and other fruits, cotton, and vegetables. In 1964, approximately 824,000 acres of land were irrigated with water from the Rio Grande. However, the distribution of the United States share of Rio Grande water allocated to irrigation has been altered by a recent district court decision fixing water rights below Falcon Dam. A decision may not be final until after an appeal is considered.

Dependable volumes of Rio Grande water are available to irrigate no more than 650,000 acres below Falcon Dam, or approximately 174,000 fewer acres of land than is presently irrigated.

Studies indicate that there is about 1.4 million acres of potentially profitable irrigation land in this lower Valley area. The development of any portion of this acreage, in excess of the 650,000 acres which can be dependably served by the Rio Grande, would require water from another source.

In making a reality of the multiple use of water concept, the Plan proposes that water transported through, and return flows to the State Water Project, be used for irrigation in the Valley area as its final reuse. Full utilization of this water will require early action by the many water districts, water-supply systems and water users in the area to form organizations with sufficient authority and geographic area to contract for delivered water and to assume responsibility for the repayment of capital costs incurred in bringing water to the area.

Water Quality

Water-quality management is an essential part of the Texas Water Plan. Of special concern is water quality in the reservoirs and transfer facilities of the system, the requirements for clean water for municipal and other uses including recreation, and the effect of increased waste discharges on downstream uses and fish and wildlife.

The Plan has taken full advantage of the large volume of water which will return to the streams as the result of the increased uses arising from municipal, industrial, and agricultural growth. These return flows have been included with the total water resources available for additional uses.

Present treatment levels will be inadequate for projected future volumes from municipal and industrial waste water treatment plants. Selective collection and treatment of certain wastes to remove undesirable constituents, including germs, bacteria and viruses and other objectionable or undesirable constituents, will be necessary.

The Plan suggests means to improve quality conditions in the Red, Trinity, and Brazos Rivers, to lessen the load of pollutants entering the bays and estuaries, and to assure municipal water supplies of high quality into the next century throughout the State. The Plan proposes the participation of the State in financing mounting costs of waste treatment and disposal. Studies made as part of the planning program indicate that capital costs alone of the facilities required to serve the 21 major metropolitan areas of the State will reach almost a billion dollars ($971,000,000) by 1990.

Bays and Estuaries

Because it recognized the presently unsatifactory condition of the bays and estuaries along the Texas Gulf Coast, and their steadily increasing value, the Board authorized and financed a study of possible structural, hydraulic, and operating modifications of the bay systems. The aim is the preservation and enhancement of the bay habitat and fisheries.

Deterioration in bay water quality results from the increased volume of pollutants entering the bays from metropolitan growth and expanded coastal irrigation, and the concurrent decrease of fresh inflow from rivers because of upstream reservoirs.

The largest and most complex tidal estuary along the Texas shore of the Gulf of Mexico is the Galveston Bay system. This bay area provides nursery grounds for over 80 percent of the poundage of fish products from the Gulf of Mexico adjacent to the Texas coast.

A specific and comprehensive study is being initiated in the Galveston Bay area by the Texas Water Pollution Control Board to be conducted cooperatively by State, local, and Federal government entities, universities, and local organizations having direct interests in the Galveston Bay system. The objective will be to develop information on the physical, hydrologic, chemical, biological, and economic characteristics of the system. The study will develop information required to achieve the recreation potential of the bay area, to guide general land use patterns around the bay system, and to define the economic relationships between the water resource and anticipated use. Its ultimate objective is the development of a land and water resource management plan for the Galveston Bay system and its surrounding area, which will be of use as a model in the successful management of the other bay systems on the Gulf Coast.

The Texas Water Plan, in addition to furthering these intensive studies, proposes the following in the bay areas:

(1) To use to the fullest Gulf water in order to minimize the needs for fresh water for preservation of the bay environment.

(2) To reduce pollution by treatment of wastes, and to improve bay circulation and distribution of Gulf water interchange, thus assisting the bays in assimilation of municipal, industrial, and agricultural return flows.

(3) To achieve the maximum benefits from the minimum fresh water, by designed and controlled releases to selected spawning and nursery grounds for aquatic life.

(4) To give further consideration to the future of commercial oystering in San Antonio and Guadalupe Bays.

(5) To recommend responsible control of hydraulic dredge spoils in order to protect corrective and improvement investments.

(6) To design and construct Gulf inlets on the basis of adequate basic data to assure the uninhibited inflow of adequate supplies of Gulf water.

SCHEDULE

Hearings and Plan Modification

The Texas Water Plan will be presented in two parts: (1) a state planning report, now complete in draft form, proposing the overall distribution of the water of the State; and (2) detailed preliminary basin plans for each of the river and coastal basins in the State. This permits the presentation of detailed information developed for each of the river basins in hearings which will begin the last week in June, 1966, and continue through the last week of August, 1966. For each of these hearings there will be presented to the people of each region a detailed summary of the Texas Water Plan, what it will mean to the basin, and what it will mean to the State as a whole. Approximately three hearings a week will be held, or a total of twenty-seven at places scattered across the State in accordance with the following schedule:

Basin	City	Date
Sabine	Longview Orange	June 20, 1966 June 22
Sulphur	Sulphur Springs	June 28
Cypress	Mount Pleasant	June 29
Lower Red River	Paris	July 1
Neches	Nacogdoches	July 6
Neches, Neches-Trinity	Beaumont	July 8
Trinity	Arlington	July 11
Trinity, Neches-Trinity and Trinity-San Jacinto	Liberty	July 13
San Jacinto	Conroe	July 15
Brazos	Abilene Waco	July 18 July 20
Brazos, San Jacinto-Brazos and Brazos-Colorado	Richmond	July 22

Basin	City	Date
Colorado (Upper)	Odessa	July 25, 1966
Colorado (Lower)	Austin	July 27
Colorado, Brazos-Colorado, and Colorado-Lavaca	Bay City	July 29
Guadalupe	New Braunfels	August 1
Guadalupe, and Lavaca-Guadalupe	Victoria	August 3
Lavaca, Colorado-Lavaca, and Lavaca-Guadalupe	Edna	August 5
San Antonio	San Antonio	August 8
San Antonio, San Antonio-Nueces	Goliad	August 10
Nueces	Carrizo Springs	August 12
San Antonio-Nueces, Nueces, and Nueces-Rio Grande	Corpus Christi	August 16
Rio Grande and Nueces-Rio Grande	Laredo	August 18
Upper Red River	Wichita Falls	August 22
High Plains and Canadian River	Amarillo	August 24
High Plains	Lubbock	August 26

From information presented in the basin hearings, necessary modifications will be made in the individual basin plans, and in the Texas Water Plan during September and October, 1966.

Texas Water Rights Commission

After modification and completion, the Plan must then be tentatively adopted by the Texas Water Development Board, and referred to the Texas Water Rights Commission for a hearing to determine that water rights are adequately protected and that the Plan takes into account modes and procedures for the equitable adjustment of water rights affected by the Plan. When the Water Rights Commission has satisfied itself that the Plan meets these objectives, it will certify that fact to the Texas Water Development Board, and the Board may then finally adopt the Plan.

Texas Water Development Board Action

Following adoption of the Plan by the Water Development Board, it will be printed in final form for presentation to the Governor and to the Legislature, and for distribution to the people of Texas. While the Texas Water Plan does not require formal adoption by the Texas Legislature, it will make recommendations for statutory changes to secure its implementation in the years ahead. On its completion and adoption by the Board, and enactment by the Legislature of necessary statutory changes, the Plan can become a flexible guide to the development of the State's water resources into the next century.

THE PLAN A BEGINNING--NOT AN END

Implementation

The Texas Water Plan will have real substance as it is translated into reality through the construction of reservoirs, conveyance systems, and water-distribution facilities, but its implementation does not depend alone on engineering design and construction. Many complex legal and economic considerations must be resolved before the Plan takes form in physical works. Growth and change throughout the State will require constant evaluation, restudy, and Plan modification.

Legal Problems

Legal considerations affecting implementation of the Plan require objective analysis within the framework of the rambling, and not always consistent, body of water law developed historically within the State.

An effective procedure for the administrative adjudication of water rights is essential.

Water permits and certified filings in the present listings must be reviewed and evaluated quantitatively by the Texas Water Rights Commission for State administrative purposes and to meet needs of detailed project planning.

In Texas, remaining prime reservoir sites are few and must be preserved. The Texas Water Plan has been carefully designed to propose development of these sites to coincide chronologically with water-supply needs. This is the least costly, and most efficient and orderly procedure. If these sites are lost through other development--either to urban encroachment or through less than optimum reservoir construction--then the fabric of the entire Plan may be threatened.

Water-quality protection in the streams and bays and estuaries is a major challenge. If, through planned use and reservoir development, the flow in rivers is completely controlled, there may be insufficient water available to dilute wastes adequately, even after the highest feasible degree of treatment. Solutions to the ensuing water quality problems are expensive, and may not be possible within our present legal framework. Statewide or regionwide systems may be needed to collect and transport noxious or toxic wastes from throughout the State by closed canal, by pipeline, or by other means to the coast and thence to the open sea for disposal. Or they may be disposed into deep wells, into permeable formations far below the earth's surface, or into caverns excavated in salt formations.

A modification of the State's taxing structure may be required in the form of taxing waste dischargers on the basis of the incremental load of waste products added to the receiving streams for disposal, in the form of providing a subsidy to waste producers who find alternatives to water quality degradation, or by a tax supported fund accumulated to develop and support disposal systems which avoid or eliminate burdens upon the assimilative capacity of surface streams.

Under the Federal Water Pollution Control Act of 1965, if the states do not protect the water quality in their streams individually, the Federal government has the authority to do so. Governor Connally has accepted the obligation that Texas will take the necessary steps to establish stream quality criteria, and to assure their effective application. The Texas Water Plan assumes the continued coordination of water development with water quality protection measures.

Under Texas law, ground waters are specifically excluded from management as public waters. Within the Texas Water Plan, however, an overall objective is the proper management of the total water resource of the State. In pursuit of this objective, the Plan recognizes that management of ground water resources continues to be a local responsibility. The need for such local management is limited to those areas where special conditions require it. That view does not, however, lessen the importance of local control. It increases both the importance and the responsibility of that control in those areas where it is needed. In some areas it will mean that the State must expect local agencies to develop a coordinated use of ground water with any proposed surface water importation. Without assurances of such coordinated management, the State could not justify, even on an interim basis, committing financial resources accumulated from all areas of the State to meet the water needs of a particular area.

In Texas there are more than 500 water districts and river authorities, ranging widely in character, in size, in legal authorization, and in the vigor with which they conduct their activities. Cities and counties throughout the State have a vital interest in water development. In the event of conflicts between these various governmental units which affect the implementation of the Water Plan, some legal or institutional modification of the authorization to overlapping governmental entities may become essential.

At the same time, adequate and orderly implementation of the Plan requires viable, properly related local units of government to assure retail distribution of available water.

Economic Studies

Detailed and comprehensive economic studies in greater depth than those made in preparing the Plan must be conducted as a part of the implementation of the Water Plan. The relative costs and benefits of supplying water to meet specific requirements throughout the State must be analyzed. All of the complex factors which affect a valid determination of water-supply costs, and the price which should be paid for water by the users must be determined.

Feasibility Studies

Before construction can actually begin on the physical works proposed in the Plan, detailed engineering and economic feasibility studies of the individual projects must be completed. Investigations conducted as a part of the planning program indicate the feasibility of the multiple-use of water within the framework of the proposed system, but the detailed analysis of the individual units must be the subject of further studies.

Water-Permit Hearings

Permit applications for elements of the Plan will be submitted to the Texas Water Rights Commission at appropriate future times as feasibility studies and the need for these elements become apparent. These studies must assure adequate consideration of all then existing water rights. The Water Rights Commission will hold public hearings on these applications and proposed projects.

State Staff Requirements

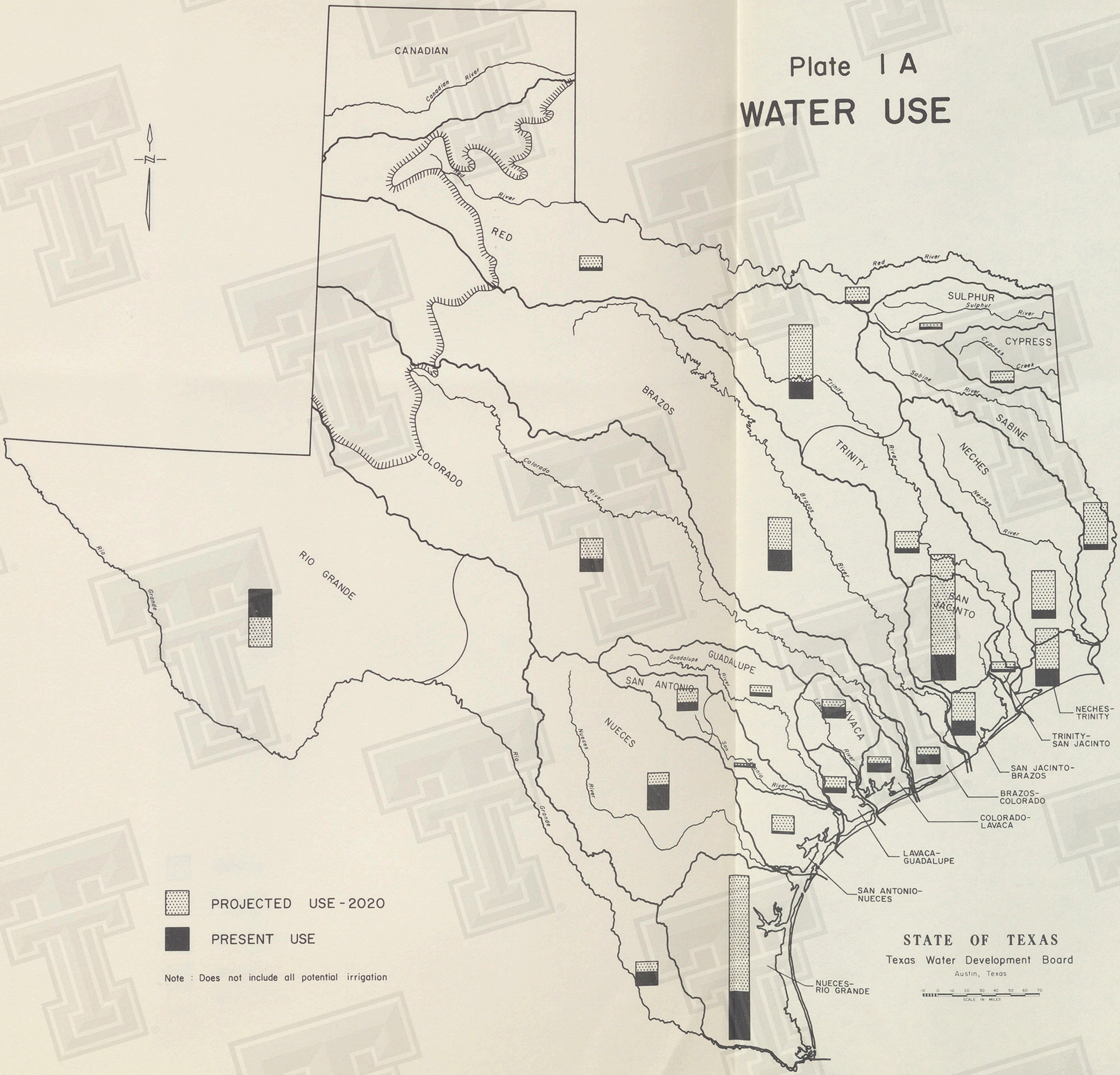
Texans talk of exercising their local and State governmental responsibilities. Such exercise at competent levels is costly. State leadership has been demonstrated in preparing a Plan. State responsibility will be realized only when water requirements are fulfilled as the State believes is wise.

The Plan is a "flexible guide" subject to continuing evaluation and, when appropriate, to modification. Continuing supporting programs to accumulate massive amounts of data on water uses, streamflow, water quality, costs, and analyses and interpretation of these data in relation to needed projects will be vital.

The Plan will not become a physical reality, operated in the best interests of the State, without strong, competent, active State water agencies to direct its development, to supervise its operation and maintenance, and to guide the course of the complicated interrelationship of State, local, and Federal governmental units.

A wide range of interdependent disciplines must be represented on the staffs of the State's water agencies--engineers, economists, chemists, geologists, lawyers, financial experts--and all of these disciplines represented by highly trained, highly skilled individuals. State level competence must equal or exceed that of local and Federal counterparts. Any other course will dissipate the momentum already gained; and the State will either relinquish the direction of water development, or water development to achieve statewide goals will not occur at all.

Plate I A
WATER USE



STATE OF TEXAS
Texas Water Development Board
Austin, Texas

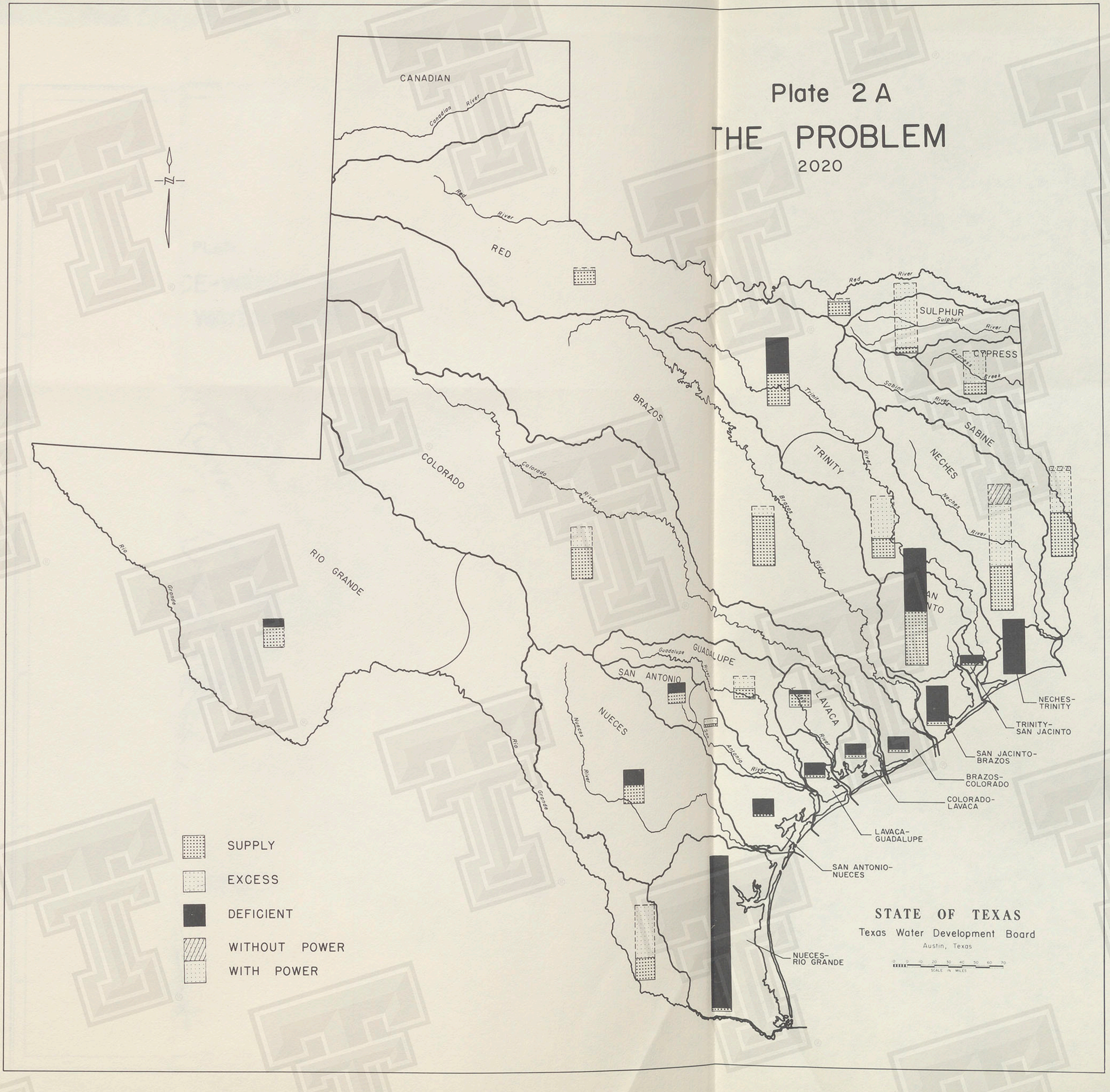


Plate 2A
THE PROBLEM
2020
CANADIAN
Canadian River
Red River
RED
Red River
SULPHUR
Sulphur River
CYPRESS
Cypress Creek
Sabine River
SABINE
BRAZOS
TRINITY
Trinity River
NECHES
Neches River
COLORADO
Colorado River
Brazos River
RIO GRANDE
Rio Grande
GUADALUPE
Guadalupe
SAN ANTONIO
San Antonio River
NUECES
Nueces River
LAVACA
NECHES-TRINITY
TRINITY-SAN JACINTO
SAN JACINTO-BRAZOS
BRAZOS-COLORADO
COLORADO-LAVACA
LAVACA-GUADALUPE
SAN ANTONIO-NUECES
NUECES-RIO GRANDE
SUPPLY
EXCESS
DEFICIENT
WITHOUT POWER
WITH POWER
STATE OF TEXAS
Texas Water Development Board
Austin, Texas
SCALE IN MILES

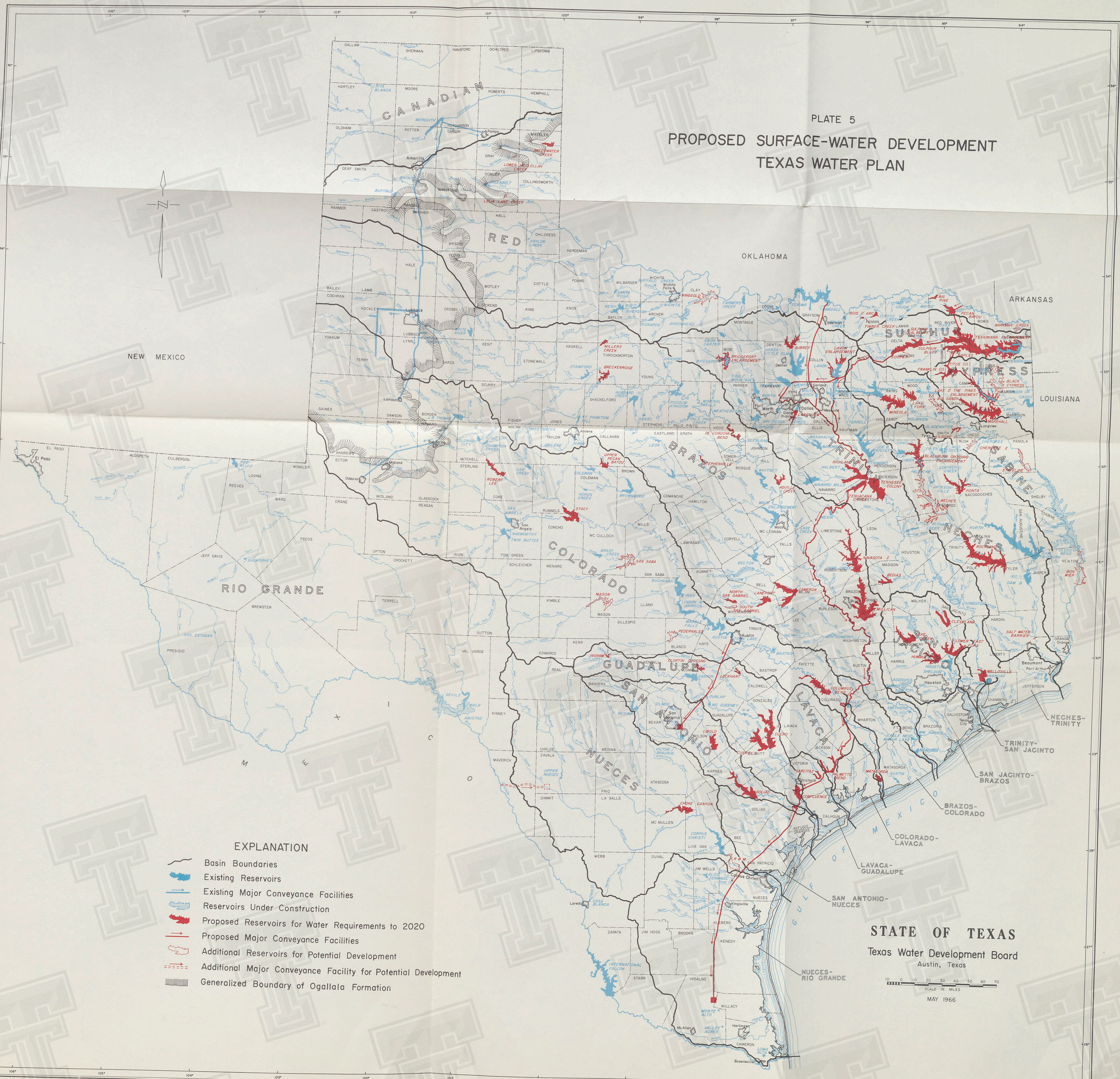


PLATE 5
PROPOSED SURFACE-WATER DEVELOPMENT
TEXAS WATER PLAN
EXPLANATION
Basin Boundaries
Existing Reservoirs
Existing Major Conveyance Facilities
Reservoirs Under Construction
Proposed Reservoirs for Water Requirements to 2020
Proposed Major Conveyance Facilities
Additional Reservoirs for Potential Development
Additional Major Conveyance Facility for Potential Development
Generalized Boundary of Ogallala Formation
STATE OF TEXAS
Texas Water Development Board
Austin, Texas
SCALE IN MILES
MAY 1966
NEW MEXICO
OKLAHOMA
ARKANSAS
LOUISIANA
MEXICO
GULF OF MEXICO
CANADIAN
RED
SULPHUR
CYPRESS
SABINE
NECHES
TRINITY
SAN JACINTO
BRAZOS
COLORADO
GUADALUPE
SAN ANTONIO
LAVACA
NUECES
RIO GRANDE
NECHES-TRINITY
TRINITY-SAN JACINTO
SAN JACINTO-BRAZOS
BRAZOS-COLORADO
COLORADO-LAVACA
LAVACA-GUADALUPE
SAN ANTONIO-NUECES
NUECES-RIO GRANDE