DEVELOPMENT OF TEXAS RIVERS

A Water Plan for Texas

Sylvan B. Simpson
Capt – Inf – Res

THE TEXAS PLANNING BOARD
AUSTIN

D E V E L O P M E N T O F T E X A S R I V E R S

A WATER PLAN FOR TEXAS

THE TEXAS PLANNING BOARD

AUSTIN

MARCH, 1938

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ERRATA

Page 54, Line 19: Columbus should read Colorado.

Page 76, Paragraphs: "Measurement of Stream Flow,"
"Ground Water Surveys"
"Topographic Mapping"
"Climatological Data" which first appear on pages 73 and 74 are inadvertently repeated on pages 76 and 77.

Page 106, The second line of the third project should read basis for design.

Page 108, Rio Grande-Pecos project list.

Last item under section 2, which reads "Brazos Island Harbor, Texas: Navigation improvements - $585,000" is a repetition of the third item under Section 2, on page 107.

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ILLUSTRATIONS

INTRODUCTION

Until the last few years the people of Texas have been concerned with water only as it affected their immediate interests and problems. In building irrigation works to use stored water, the possibilities of providing flood control have not always been considered, because such enterprises have usually been financed by private capital, making evaluation of flood control benefits very difficult. In planning for flood protection, the possibilities of power development and the maintenance of low water flow by means of stored water have perhaps been overlooked for the same reason. Too often each of these problems has been regarded as isolated from other possibilities of water development, or has been treated solely in terms of specific localities, with consequent injury to other interests.

It is becoming increasingly apparent that orderless, unintegrated treatment of water problems, however natural and excusable it may have been under pioneer conditions, should no longer be tolerated. This feeling has doubtless been the motivating factor in the creation of various legal authorities and associations in Texas, each organized for the purpose of developing the water resources of some specific watershed or portion thereof. Almost all these organizations have attempted to analyze the water problems within their boundaries and to offer practical solutions, but unfortunately some do not embrace enough of their watersheds to allow full coordination of water uses. To some extent, basin-wide problems are still regarded from a local viewpoint. An inventory of all water problems in each basin and their interlocking aspects has been needed, so that the needs of the whole basin may be satisfied as nearly as possible with the least expense, and without forestalling future developments. Such is the purpose of this state-wide water plan.

Texas has not utilized its water resources to as great an extent as have some other states. In this, Texas may be fortunate since the haphazard growth of water development in other states complicates tremendously the formation of any integrated water plan. Most of the major water developments so far constructed in Texas have been planned with full emphasis given to other related rights and uses.

The economic development of large areas of Texas, hitherto neglected, will depend upon the extent to which surface water can be stored in reservoirs. Further development of other extensive areas depends even now in a great measure on the extent to which the available supply of water can be increased by storing surface water, by pumping from wells, or by other means. The need for controlling floods is evident in almost every river basin in Texas.

The water plan herein presented provides a starting point, from which the orderly development of our rivers may proceed. It is not a fixed plan, for no fixed plan is possible. Future water requirements can seldom be predicted for more than a few years in advance, especially in view of the meagre records of rainfall and stream flow, which have been kept in Texas. Changes in population, land use, and industry can effect pronounced differences in the use and requirements of water, and as to what these changes will be in the distant future, we can only speculate. Moreover, the total supply of surface water and ground water which can be made available for any area can change as a result of natural processes and the use which is made of the watershed surface. For these reasons, any water plan must remain incomplete, no matter how often it is revised. Continuous planning is necessary. Nevertheless, a framework of a state water plan is presented, which can be adjusted, filled in, or

extended to meet changing conditions.

In presenting this water plan, each drainage basin or watershed is treated as a unit, in recognition of the train of connected problems which reaches from the source to the mouth of the river. The plan attempts to keep in mind at all times the interstate character of some of the basins and to treat them accordingly. Statements of problems and recommendations concerning parts of watersheds lying in adjacent states is the result of cooperative effort with the planning boards of other states and with the National Resources Committee.

Since all the projects in a comprehensive water plan cannot be undertaken simultaneously, a program involving priorities is necessary. In general, preference has been given in the present study to investigation projects designed to afford information indispensable for proper action later; to construction projects for which adequate and reliable data are available; to projects involving benefits that exceed costs in relatively high degree; to multiple-purpose projects having relatively high social values for comparatively large numbers of people; to projects of immediate, rather than prospective, urgency; to projects not likely to be delayed by legal and other non-technical complications; to projects which it is believed would fit properly into a comprehensive water plan when it shall have reached a later and more detailed stage; and to projects already authorized by the Congress or now under way.

The application of the foregoing criteria, one by one, to a group of projects in a given area may result in findings not in harmony one with another. Projects of dissimilar character may not be comparable on any satisfactory basis. In the final analysis much depends on the judgment of the investigators responsible for the grouping adopted.

It was found impracticable and undesirable to assign absolute priorities to projects for the state as a whole, for regional groups of drainage basins, or even for individual basins. It was feasible, however, for individual basins and for groups of basins, to classify projects in three broad groups, a procedure deemed adequate for all practical purposes. The groups adopted were as follows:

Group A (immediate) -- Projects which are ready for construction or study and which should be undertaken as soon as possible.

Group B (deferred) -- Projects which, while desirable for immediate construction or study, (a) involve unsolved questions of public policy or (b) can have their priority definitely determined only after additional studies which can not be completed in time for this report or (c) are now obstructed by legal, administrative or other difficulties. Group B also includes projects which should follow Group A in sequence of construction or of study.

Group C (indeterminate) -- Projects which, although included in the plan of development for the basin, should follow Group B in sequence of construction, or whose specific priority in the program is as yet indeterminate.

This plan does not rest upon any assumption as to how the proposed developments should be financed or administered. It is obvious, however, that the effective fulfillment of a comprehensive water plan is contingent upon the effective solution from time to time of the problems of financial and administrative policy.

Preparation of this plan was possible only through the cooperation and sound advice of state and federal agencies concerned with water problems, and with the various organizations created to further water developments in

specific areas. It represents not only the views of local interests and state agencies, but also those federal bodies under whose jurisdiction fall the interstate phases of water resources. Indispensable aid and leadership was given by the National Resources Committee in the appointment of special water consultants of national repute to advise and assist in the assembly and analysis of vast quantities of pertinent material. Without the groundwork which has been laid by Texas river authorities and districts, this proposed plan would lack much of the concreteness which is its dominant characteristic. But for the definite construction projects proposed by these agencies and others, it would become a mere description of Texas rivers and a generalization of its water problems and needs.

In order to show the influence of the various river authorities, districts and associations on the development of Texas watersheds, the boundaries of these organizations have been outlined on the key maps of contiguous basins.

The final assembly and editing of the material presented in this plan was supervised by specially selected basin committees, composed of representatives from all federal and state agencies concerned with such matters and from various basin organizations.

The plan as herein presented has been incorporated into the 1937 report of the National Resources Committee to the President, concerning drainage basin problems of the United States.

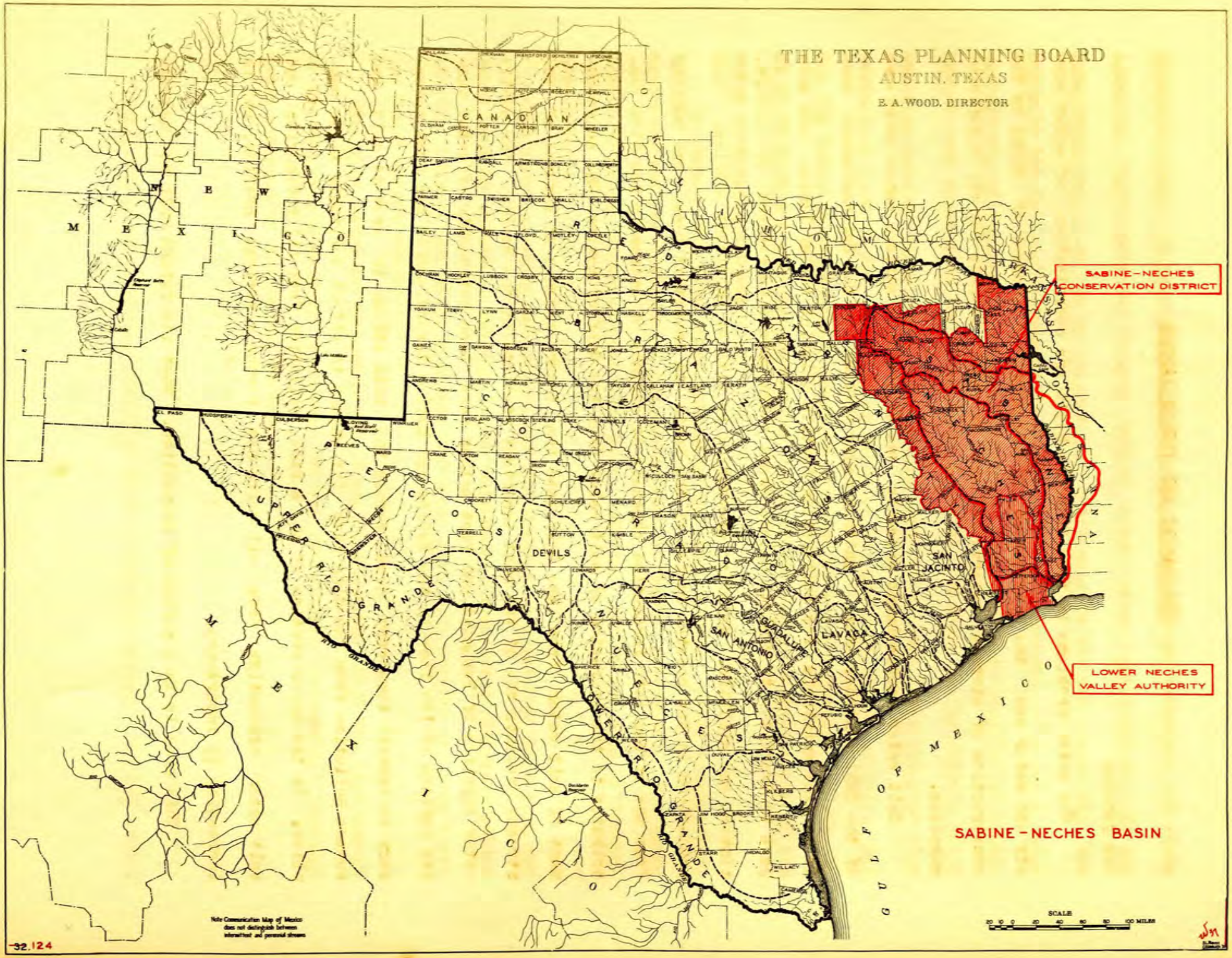
THE SABINE AND NECHES BASINS

THE PROBLEM

The water problems in this drainage basin are coordination of water supply and water use, the elimination of pollution and disposal of waste by the construction of storage reservoirs and by other methods for all beneficial purposes.

Salt water encroachment presents one of the most serious water problems of the Sabine-Neches area. Another major problem in the Sabine-Neches area is to make available for cultivation fertile alluvial valley lands, now subject to overflow, to replace upland areas which should be retired to pasture, timber, and wildlife. Malaria prevention is also an important problem. Rice production in the coastal region of the basin is important here, and pumping from the stream into irrigation channels at periods of extremely low flow contributes to the intrusion of salt water from the Gulf of Mexico. The encroachment of salt water from the Gulf into the lower reaches of several of the streams presents one of the most important problems in the Basin. The public water supplies of Beaumont and Port Arthur have been noticeably affected during periods of low flow in the Sabine and Neches Rivers, and it has been necessary to install temporary dams across the main stream to prevent salt and sewage pollution from receding back far enough to affect seriously these supplies. In the upper portion of the Sabine, pollution from oil refineries and salt water production from oil wells has become a serious problem, and is increasing in importance.

This area is in a period of transition. What its future will be depends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LAVACA
GUADALUPE
SAN ANTONIO
NUECES
RIO GRANDE
DEVILS
SAN JACINTO
MEXICO
GULF OF MEXICO
SCALE
Note: Communication Map of Mexico does not distinguish between international and provincial streams.
-32.124

to a great extent upon proper planning at this time for conservation and judicious use of its water resources. Timber is being cut, pulp mills are coming into the area, flush oil fields are in production, population is increasing, and potentially useful lands have not been developed.

On account of frequent overflow of rich bottomlands, these areas have not been developed to such an extent that major flood damages are as extensive as would otherwise be expected. Erosion is attacking farm lands and cut-over areas.

In this, as in other basins, there is need for systematic collection of basic data on amount and distribution of rainfall, on stream flow, on ground water resources, and for topographic mapping.

A study project to cover both the Sabine and Neches watersheds is under way and should be continued because the time is strategic for sound planning. This project should include topographic mapping, survey and exploration of possible reservoir sites and channel rectification, devising of methods for eliminating oil field, industrial, and municipal pollution, and malaria. This study project should include a determination of the possibilities of hydroelectric power production on these rivers.

A study for flood control which will include consideration of water conservation and water power possibilities is now under way by the U. S. Corps of Engineers. A study for soil conservation and water runoff retardation is now under way by the U. S. Department of Agriculture. Additional funds should be provided to carry on these studies.

GENERAL DESCRIPTION

The rivers of this area drain about 20,000 square miles, 2,700 square

miles in western Louisiana, the balance in East Texas. Average annual rainfall ranges from 40 inches to nearly 60 inches.

The flow of streams varies not only from year to year but also markedly from season to season. The minimum recorded annual discharge near the mouths of the Neches and Sabine rivers has been as low as 16 percent and 21 percent, respectively, of the mean annual discharge at those points. Floods on the main streams, for the most part, overflow the undeveloped plain, and although the flood peaks generally are not high, they are sustained over a longer period of time than in those areas where flood peaks are extreme. On the smaller tributaries the floods are somewhat more flashy, and damage to developed lands is greater than on the main stream.

At the present time the U. S. Geological Survey, in cooperation with the Texas Board of Water Engineers, is maintaining six stream flow stations in the Sabine and Neches basins. A number of additional stations are needed. Only one of the present stations is equipped with a water stage recording instrument. At the others gage-height records are dependent upon local observers.

Extensive drafts are being made on the ground water supplies of this area for farm and city water supply and oil well drilling and refining, particularly in the East Texas oil field. The use of large quantities of ground water for the manufacture of paper pulp will be required in the near future; the construction of one large paper mill in this area in Texas, requiring at least 10,000,000 gallons of ground water a day is already assured. Preliminary ground water surveys have been made in seven counties in Texas by the Texas Board of Water Engineers in cooperation with the U. S. Geological Survey, and W.P.A.; and preliminary reports giving results in five counties have been

published. No extensive ground water surveys have been made in the Louisiana area, although important supplies undoubtedly are available there.

Very little mapping has been done in these basins. Scattered localities have been mapped for flood protection or for reservoirs, but in general, the basin is unmapped. This area is subject to intense storms of long duration, principally from tropical hurricanes. There are now in operation four evaporation stations, and about twenty-seven rainfall stations, one or two of which are equipped with automatic recording gages.

About one fourthof the Sabine-Neches area is now used in crop production, and most of the remainder is in forest or cut-over land. Most of the virgin timber of the upper watershed has been cut. Part of the northern Sabine and Neches River valleys, a rolling country from 250 to 550 feet above sea level, is in crops. Some of this land is so severely eroded that it can no longer be cultivated profitably, and much of the remainder is seriously affected by erosion. One national forest, comprising four purchase areas will ultimately include about one tenth of the timberland, or one million acres. About 200,000 acres will be in federal migratory waterfowl refuges.

The central portions of the Sabine and Neches watersheds are still primarily forest areas. The alluvial valleys have been cut over, but have not been utilized for crops. In the last few years, the central timber area has acquired renewed importance as a possible source of quickly grown pulpwood for paper manufacture. A large pulp mill has been constructed at Houston and is now in operation. This territory is also adapted to tung culture, and a good start has been made to develop this industry.

The remaining part of this area is a strip less than 75 miles wide along

the coast. It is bounded on the south by salt marshes at the edge of the Gulf of Mexico; and on the north, by the forests. Its fertile soil is underlain, in general, by watertight subsoil, making it especially adaptable to rice irrigation.

Oil underlies much of the Sabine-Neches area. The East Texas oil field, on the upper Sabine and Neches tributaries is the world's largest producer, containing more than 24,000 wells. In addition to the oil, the Coastal Plain produces sulphur and salt, each of which has made important contributions to the development of the area. In the central and upper portions of this basin are found iron ore, fuller's earth, lignite, bentonite, salt and other minerals which offer possibilities for future industrial development. Recent new development in the southern Louisiana and southeastern Texas oil fields has increased the oil tonnage on the Intracoastal Canal; and has made Sabine Pass, with its traffic to and from Lake Charles, Orange, Beaumont, and Port Arthur, one of the busiest harbor entrances in the United States.

Refinery wastes and salt water production in the East Texas field discharge into the Sabine River. The Sabine River is now so polluted by salt water as to cause its abandonment as a water supply source immediately below the oil field. Salt water production is now 3.5 million gallons a day and may reach fifteen million gallons daily within three or four years. Portions of the salt water are now being successfully returned to abandoned wells, but other means must be evolved to supplement this procedure.

Population of the Sabine-Neches area in 1930 was 873,000, with 243,000 in cities and towns. The population is increasing very rapidly.

Water supplies for most of the municipalities of this area are obtained

either from deep wells or from small reservoirs constructed to impound the run-off from tributary drainage areas. Beaumont, and Port Arthur are exceptions, using water from the Sabine and Neches Rivers. A fresh-water supply from a protected tributary has been developed for Longview because of salt and oil pollution in the main stream from the East Texas oil field.

RECOMMENDED PLAN

Salt Water Intrusion. As a result of the construction of the deep water navigation channel, salt water has been brought upstream on the Sabine and Neches Rivers to such an extent as to seriously affect the water supplies of Port Arthur and Beaumont on the Neches, and Orange on the Sabine. Water supplies of smaller municipalities in adjacent territory are similarly affected. Rice culture in both the Sabine and Neches basins is seriously hindered, during periods of low stream flow, by these incursions of salt water. At such times, irrigation demand is apt to exceed stream flow.

To meet this situation on the Neches, the Lower Neches Valley Authority has been created by the Legislature, for the purpose of storing flood waters, thereby augmenting the normal flow of the river. Construction of a dam at Rockland on the Neches River about fifty miles above Beaumont is proposed by this agency. This dam would impound about 1,650,000 acre feet, and a gravity canal would extend to Port Arthur, serving the rice fields of Jefferson, Liberty, and Chambers counties, and providing water for municipal and industrial uses. This project has been approved by both the Public Works Administration and the Reconstruction Finance Corporation. Its plans are well beyond the investigational stage and are ready for construction. It is recommended that this project be constructed.

Proposals have been made for the construction of other reservoirs at Magee Bend on the Angelina River, a tributary to the Neches, and at Toledo Bend on the Sabine. These reservoirs would offer a regulated flow for the prevention of pollution and for other purposes. It is recommended that these projects be considered in connection with the basin-wide study being made by the Army Engineers and that their place in the general basin plan be determined.

Waste Disposal. Modern sewage disposal plants are recommended for a number of cities in the basin. In some cases existing plants can be modernized. Extension of sewer mains is needed in some municipalities which have outgrown present systems. Cities should be encouraged to train sewage plant operators and to provide adequate laboratory control and maintenance.

In order to effect a solution to the increasing problem of oil field pollution in the basin, it is recommended that a major study be initiated at once.

Industrial wastes, other than those from the petroleum industry, have not yet created a serious problem in the basin but prospective industrial developments in some sections of the basin indicate that this phase of the problem of stream pollution must be given consideration. Industrial development should be guided and controlled so that by due consideration to such items as plant location, waste treatment processes, available stream flow etc., the serious stream pollution conditions now existing in other sections of the country may be avoided.

Water Supplies. There is a need for improvement and extension of waterworks facilities and for water treatment plants in a number of the smaller municipalities of the area. It is recommended that construction of these be undertaken as soon as possible. The improvement of the water supply for Port

Arthur, Beaumont, and adjacent communities by means of the proposed Rockland project has been discussed.

Malaria Control. Malaria is a problem in this area. There is need for malaria control measures to eliminate present danger. In new projects, particularly where impounded water may create new and prolific mosquito breeding areas, due consideration should be given to this problem so that by providing proper safeguards malaria hazards may be avoided. All mosquito control measures contemplated in this basin should conform to plans approved by the respective state departments of health.

Navigation. The construction of a ship channel from Lake Charles, Louisiana directly to the Gulf of Mexico has been authorized. Such a channel will relieve the congestion at Sabine Pass, and give direct access to the growing oil fields and industrial development of southwest Louisiana. Construction of this channel is recommended.

Flood Control. Floods cause serious damage to health, life, and property in this basin and deter development of some of the most fertile lands. The Corps of Engineers is now making a flood control survey of this area which is being coordinated with studies now being made by other agencies, and funds should be made available for completion of the study.

Drainage. Drainage in the coastal area of this basin is an important problem. It is recommended that adequate drainage systems be installed, where economically feasible, and that due consideration be given to wildlife values within the area.

Hydroelectric Power. Regardless of present economical power development, major dams should incorporate provisions which would permit further future

installations which changed conditions might render the production of hydroelectric power advisable. Funds should be made available for the completion of the survey now being made by the Corps of Engineers as to the feasibility of hydroelectric power generation.

Land Use and Conservation. To reduce silting of stream channels and reservoirs, and destruction of farm lands, it is recommended that a water and soil conservation program be developed for this basin. This program should include retirement of steep and eroded cultivated areas to grass or timber, and the practice of all feasible methods for soil and water conservation applicable to this basin. Additional investigations are needed to determine the specific treatment for individual units of land. Detailed sedimentation surveys should be made for existing reservoirs and preliminary preparations made for such studies on sites of proposed reservoirs.

Wildlife Conservation. The proposed construction of dams and reservoirs for flood control and other purposes on the streams of the Sabine-Neches basin offers a fine opportunity for the development of waterfowl and other wildlife habitat, and their needs should be taken into consideration as far as possible without hazarding the prime purpose for which the construction was planned. The Sabine and Lacassine wildlife refuges in Cameron Parish should be completed.

Measurement of Stream Flow. To obtain needed records of surface runoff and its distribution over the basins, it is recommended that stations now in operation be continued and the equipment improved. It is further recommended that about fourteen stream flow stations be installed in the Sabine-Neches basins and be maintained for sufficient time to give adequate records. As flood

control reservoirs are constructed, it is recommended that additional stream flow stations be installed in connection with these projects to assist in their successful operation.

Ground Water Survey. Preliminary ground water surveys which thus far have covered only a part of the area in Texas and none in Louisiana should be extended to the entire territory. These surveys should be followed by more intensive studies with special reference to the quantity and quality of the ground water supplies that are available for public supply, oil well and oil refinery operations and the manufacture of paper pulp.

Topographic Mapping. The basins should be mapped for flood control, drainage, storage for power, municipal and industrial use, and for ground water investigations.

Climatological Data. To secure additional needed climatological data, it is recommended that there be added to the present facilities at least one automatic recording rainfall station and four standard rainfall stations.

It is further recommended that all of the above hydrologic studies and topographic mapping be done in accordance with approved methods, by competent agencies, and that the results be made readily and promptly available to the public, and periodically published in standard form.

PROJECT LIST - SABINE AND NECHES BASINS

PROJECT	ESTIMATED COST		Authorized by Congress	Authorizing Act	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
GROUP A - IMMEDIATE					
1. Investigation Projects					
Sabine-Neches River Basins, Texas and Louisiana: Study of flood control and conservation of water to devise a plan for water development of the basins.	$ 100,000		Yes	1	Preliminary examination made by Corps of Engineers. Survey reports started.
Portions of Sabine and Neches watersheds, Texas and Louisiana: Detailed conservation survey.	22,000		Yes	Pub. 738	Area to be selected.
Study to devise means for control of stream pollution by salt water from oil wells and refineries.	50,000		No		
Sabine and Neches River Basin in Texas: Topographic mapping of watersheds.	200,000	$ 125,000	No		
Ground water survey of sub-basin.	57,000	115,000	No		To develop ground water to best advantage. Survey to require six years.
Tyler, Hardin, and Polk Counties, Texas: Study of Village Creek reservoir site.	5,000		No		To determine its value in connection with Rockland project, for storage.
Sabine and Neches Basins, Texas: Comprehensive study for elimination and prevention of malaria.	10,000	10,000	No		Continuation of work done in some Texas counties by U.S.P.H.S.
Jasper, Newton, Hardin, Jefferson, and Chambers Counties, Texas: Topographic mapping of Coastal Plain area.	300,000	125,000	No		Portion of control established.

PROJECT LIST - SABINE AND NECHES BASINS

PROJECT	ESTIMATED COST		Authorized By Congress	Authorizing Act	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
1. Investigation Projects (cont.)					
Area study of land use and economic factors to devise plans for needed land retirement and major land and water use adjustment, to insure a proper coordinated land and water utilization program.	$ 50,000	$ 80,000	Yes	Pub. 210 and 738	Extent of study depends upon preliminary surveys now being conducted by the flood control coordinating committee of the U.S.D.A.
2. Construction Projects - General					
Sabine-Neches waterway, Jefferson and Orange Counties, Texas: Channel enlargement from Sabine Pass to Port Arthur, Beaumont, and Orange.		730,000	Yes	3	Funds necessary to complete project.
Tyler Co., Texas: Rockland Dam. Dam and canal for irrigation, municipal, & industrial water supply.	6,000,000	6,000,000	No		Preliminary surveys and reports made.
14 additional stream gaging stations on Sabine and Neches Rivers and tributaries.	19,700		No		Annual operation $7,000.
Lake Charles, La.: Sabine migratory waterfowl development dykes to keep out salt water; buildings and equipment.	200,000				Surveys in progress.
Three additional rainfall and evaporation stations in Sabine and Neches Basins.	820		No		Yearly maintenance $320. In addition to stations now being operated.
Construction of one dam for recreational purposes, including bathhouse, water supply, and sanitation facilities. (Texas National Forests)	22,000		Yes	7	Plans prepared. Annual maintenance $2,000.

PROJECT LIST - SABINE AND NECHES BASINS

PROJECT	ESTIMATED COST		Authorized By Congress	Authorizing Act	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
2. Construction Projects - General (cont.)					
Establishment of two recreational areas in Texas National Forests, involving water supply and sanitation.	$ 4,000		Yes	7	Plans completed. Annual maintenance $600.
Acquisition of 1,000 acres cleared submarginal farm lands in existing National Forests.	6,000		Yes	8,10	Appraisals made.
3. Construction Projects, Municipal Water Supply and Pollution Abatement					
Gladewater, Greggton, Edgewood, Big Sandy, Alba, Quinlan, Royce City, Tex.: Improvements to water supply.	101,000		No		
Troupe, Frankston, Arp, Carthage, Henderson, Overton, Tyler, Kilgore, Grand Saline, and Mineola, Texas: Improvements to water supply.	126,000		No		
Bronson, Lufkin, Alto, Nacogdoches, San Augustine, Appleby, Rusk, Center, Timpson, and Jacksonville, Texas: Improvements to water supply.	102,000		No		
Sour Lake, Silsbee, Woodville, Doucette, Jasper, Colmesneil, Manning, Diboll, Pineland, Hemphill, East Mayfield, Texas: Improvements to water supply.	130,000		No		
Carthage, Arp, Henderson, Overton, Tyler, Kilgore, Longview, Grand Saline, Mineola, Gladewater, Big Sandy, Royce City, Texas: Improvements to sewage system and sewage treatment plants.	230,000		No		

PROJECT LIST - SABINE AND NECHES BASINS

PROJECT	ESTIMATED COST		Authorized By Congress	Authorizing Act	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
3. Construction Projects, Municipal Water Supply and Pollution Abatement (cont.)					
Woodville, Diboll, Pineland, Lufkin, Alto, San Augustine, Rusk, Center, Timpson, Jacksonville, Troupe, Frankston, Texas: Improvements to sewer system and sewage treatment plants.	$ 153,000		No		
Appleby, Garrison, Chandler, Greggton, Edgewood, Alba, Quinlan, Caddo Mills, Emory, Tenaha, Texas: Sewer systems and sewage treatment plants.	200,000		No		
Sour Lake, Nome, Silsbee, Buna, Warren, Kirbyville, Doucette, Jasper, Colmesneil, Corrigan, Manning, Hemphill, East Mayfield, Bronson, Texas: Sewer systems and sewage treatment plants	390,000		No		
Buna, Warren, Corrigan, Chandler, and Emory, Texas: Water supply systems.	125,000		No		
Port Neches, Texas: Sewage treatment plant.	25,000		No		
Port Arthur, Beaumont, Orange, Nacogdoches, Texas: Sewage plant improvements, preliminary treatment.	205,000		No		
Cushing, Texas: Waterworks, sewer system and sewage treatment plant.	60,000		No		Preliminary plans made.
Brownsboro, Garrison, Lindale, Newton, and Tatum, Texas: Water supplies or improvements.	120,000		No		Preliminary plans made.

PROJECT LIST - SABINE AND NECHES BASINS

PROJECT	ESTIMATED COST		Authorized By Congress	Authorizing Act	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
3. Construction Projects, Municipal Water Supply and Pollution Abatement					
Tenaha, Texas: Water supply system.	$ 56,000		No		Preliminary plans made.
Beckville, Caddo Mills, Joaquin, Mt. Enterprise, Texas: Water supply systems.	126,000		No		Preliminary plans made.
Beckville, Texas: Sewer system and treatment plant.	18,000		No		Preliminary plans made.
Newton, Texas: Sewer system.	10,000		No		
Wells, and Nederland, Texas: Additions to water supply.	23,000		No		
GROUP B - DEFERRED					
2. Construction Projects - General					
Acquisition of 5,500 acres of cleared lands now contributing silt to channels in existing national forests.	38,500		Yes	8 10	Examination and appraisals completed.
Planting or reforestation of 400 acres on Texas National Forests.	3,000		Yes	7	Plans prepared.
Drainage on Coastal Plain in Texas	300,000		No		$25,000 annual maintenance required. Depends upon topographic mapping of this area.
3. Construction Projects, Municipal Water Supply and Pollution Abatement					
DeSoto Parish, Mansfield, Louisiana: Sewage treatment plant.	100,000		No		No plans prepared. Estimate of cost preliminary.

PROJECT LIST - SABINE AND NECHES BASINS

PROJECT	ESTIMATED COST		Authorized By Congress	Authorizing Act	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
GROUP C - INDETERMINATE					
Acquisition of 2,000 acres of cleared submarginal farm lands.	$ 14,000		Yes	8,10	Appraisals partially completed.
Planting of 2,400 acres of cleared lands in Texas National Forest.	14,400		Yes	7	Preliminary investigations being made.
Tyler, Hardin, and Polk Counties, Texas: Reservoir on Village Creek for equalizing flow to Rockland project.		Indeterminate	No		Should await results of study in Group A.
Sabine and Neches Basins, Texas: Drainage for control of malaria in selected counties of the basins.	550,000	$ 1,850,000	No		Should await results of malaria study listed in Group A.

THE TRINITY AND SAN JACINTO BASINS

THE PROBLEM

The principal problems of the Trinity and San Jacinto Rivers are the conservation of water for irrigation, flood control, municipal, and industrial uses, prevention of pollution, navigation, and conservation of the soil and native vegetation. In the basins of both the Trinity and San Jacinto Rivers, which are adjacent, problems of sanitation and municipal water supply have been created by the rapid growth of cities. Houston, in the San Jacinto basin, is subject to recurrent floods which cause tremendous damages in the heart of the city and the ship channel area. The industrial development in certain portions of these watersheds has resulted in stream pollution by cheese and milk plants, textile mills, breweries, oil refineries, paper mills, and meat packing plants. There is need for construction of additional storage reservoirs to curb floods and to regulate the streams. Surveys indicate that there is severe soil erosion and excessive runoff, resulting in rapid silting of reservoirs and minor stream channels in these basins. Additional land in the San Jacinto basin can be reclaimed for cultivation by construction of floodways and similar improvements. On the Trinity, a dependable flow for dilution of sewage and the removal of municipal and industrial wastes should be provided. Houston, in the San Jacinto basin, is confronted with the problem of industrial pollution. Navigation of the Houston ship channel is seriously hampered during times of flood by high water velocities. Silt deposits, resulting from these floods, offer a further menace to navigation, and these conditions should be corrected. Additional reservoirs should be constructed to control floods and regulate the flow of the streams in both basins for municipal, industrial, irrigation and

other beneficial uses. Additional levees and drainage are needed; and in the case of Buffalo Bayou, an arm of the San Jacinto River, the possibilities of diversion to other streams in Harris County warrants further study.

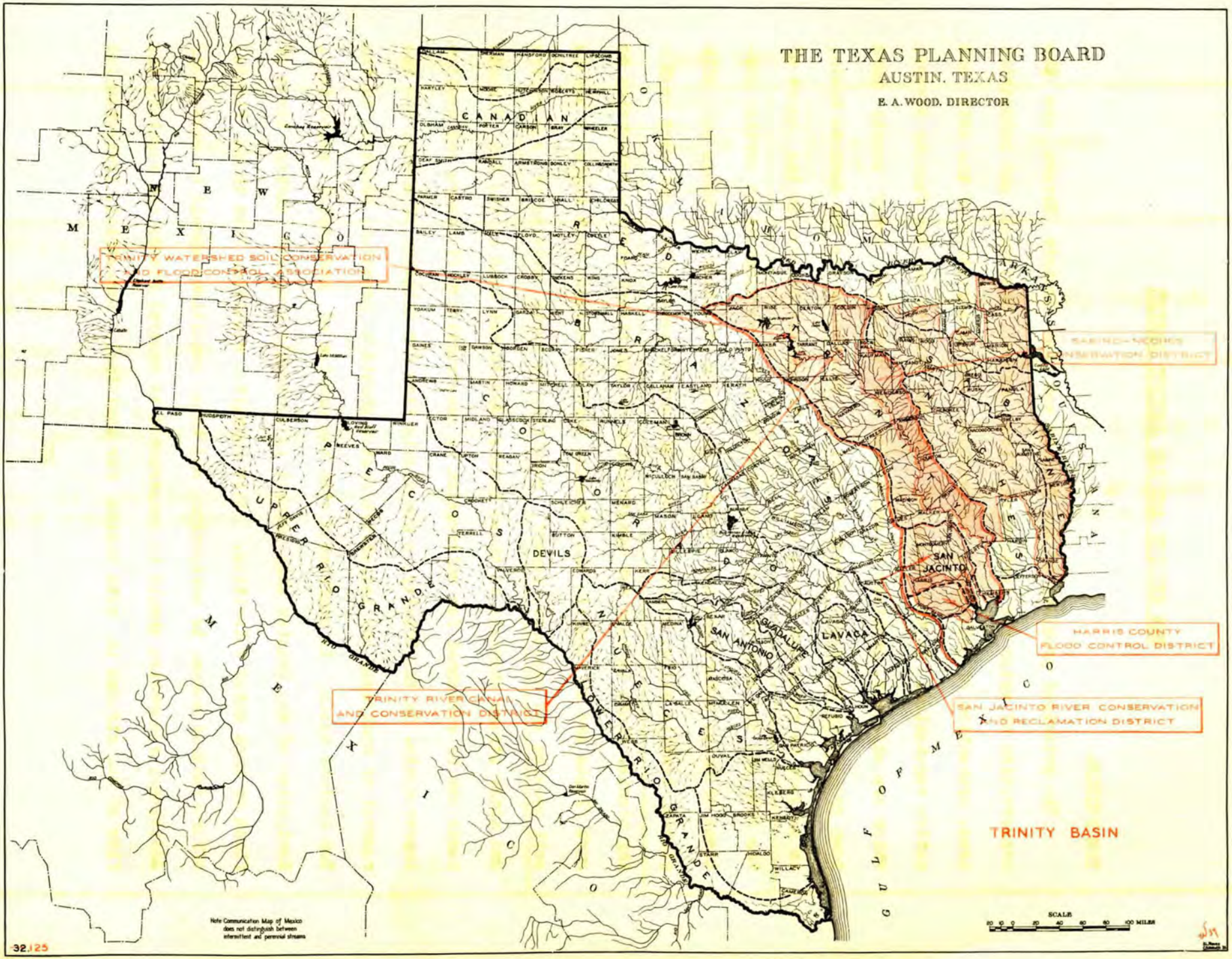
GENERAL DESCRIPTION OF THE BASINS

TRINITY BASIN. The Trinity and San Jacinto basins form an area about seventy miles wide, extending from the northern part of Texas in a general southeasterly direction about 350 miles to Galveston Bay. The principal tributaries of the Trinity drain a fan-shaped, hilly, and partly wooded area. They join the main stream near Dallas. The general character of the terrain changes in the vicinity of Dallas to the Black Waxy Prairie, an area of gently sloping hills with soil of great fertility, especially suited for agricultural purposes.

The commercial forest belt is encountered at Palestine and extends nearly one hundred miles, almost to Galveston Bay. The soil here is generally sandy, and with the exception of the alluvial lands, is not as good for farming as that of the northern section. The San Jacinto River basin lies in the Coastal Plain. It is not, in fact, a part of the Trinity River watershed. Its influence is largely confined to an area some 40 miles wide and 80 miles long, offering problems not related to the Trinity River basin as a whole, and is therefore treated separately in this report.

The population of the northern section of the area is about 900,000, almost evenly divided between the cities of Fort Worth and Dallas and the rural sections. The southern section has a population of about 200,000 with less than 50,000 people living in towns. The Coastal Plain contains 500,000 people, 80 percent living in Houston and Galveston.

Farming is prevalent throughout the area. In the central portion of the


THE TEXAS PLANNING BOARD
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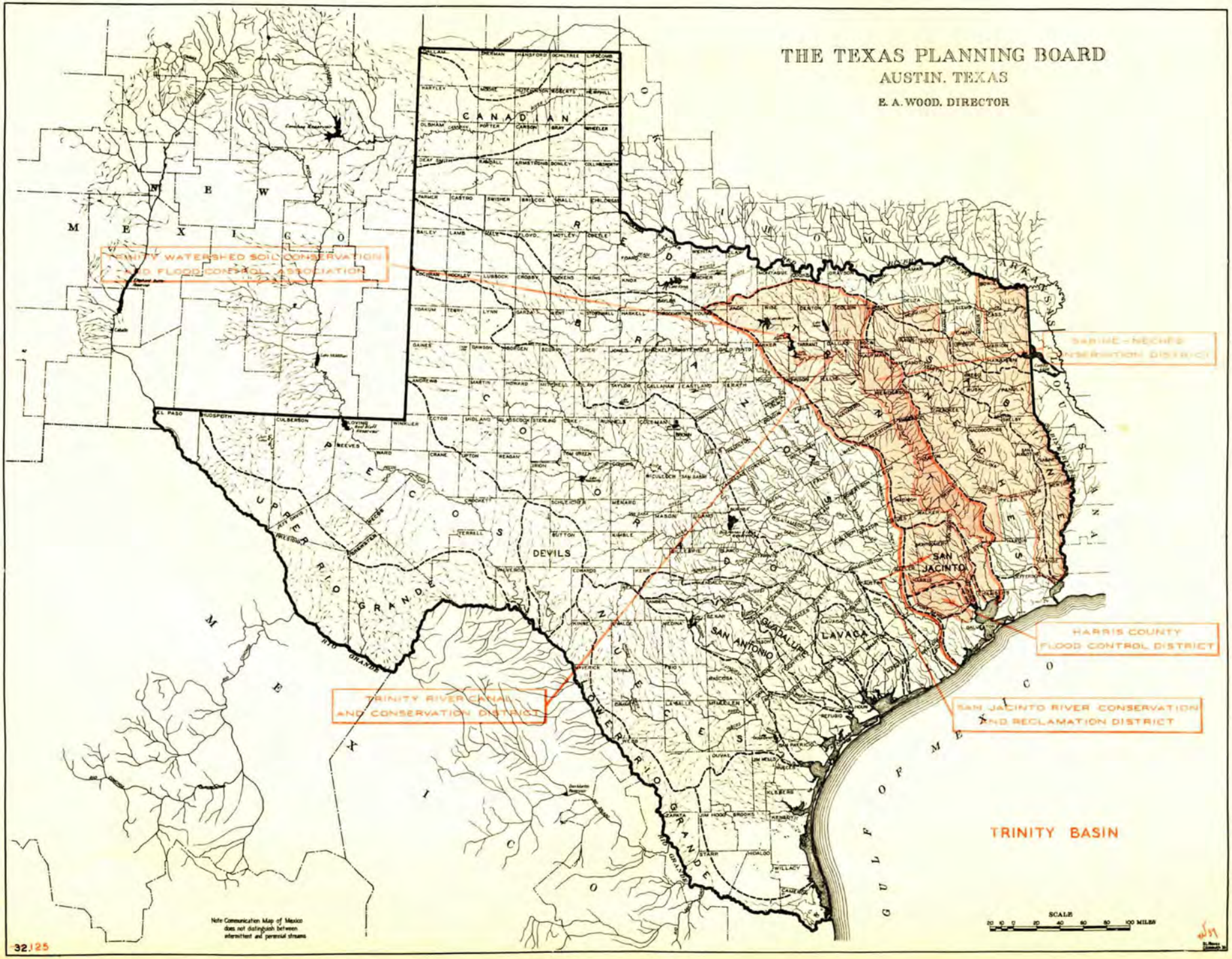
SABINE-NECHES CONSERVATION DISTRICT
HARRIS COUNTY FLOOD CONTROL DISTRICT
TRINITY RIVER CANAL AND CONSERVATION DISTRICT
SAN JACINTO RIVER CONSERVATION AND RECLAMATION DISTRICT
TRINITY BASIN
CANADIAN
RED
BRAZOS
COLORADO
TRINITY
NECHES
SABINE
SAN JACINTO
GUADALUPE
LAVACA
NUECES
DEVILS
UPPER RIO GRANDE
LOWER RIO GRANDE
MEXICO
GULF OF MEXICO
SCALE
Note Communication Map of Mexico does not distinguish between intermittent and perennial streams
32,125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GULF OF MEXICO
MEXICO
SCALE
Note Communication Map of Mexico does not distinguish between intermittent and perennial streams
32125

drainage basin, crops are harvested from about one-half of the land area. Lumbering is an important industry and offers possibilities for future expansion. Clean tilled fields, improperly grazed pastures, and burned-over woodlands contribute materially to severe losses of soil and water in the area above the Coastal Plain. In the Coastal Plain, crops are harvested from only a small part of this land. Petroleum production is a major industry throughout the basin. Other natural resources are salt, iron ore, building materials and lignite.

Mean annual rainfall varies from 30 to 40 inches in the upper part of the Trinity basin and from 40 to 50 inches in the Coastal Plain. Much of this rainfall is frequently concentrated in severe storms which cause large floods.

The average annual stream flow of the Trinity River, near its mouth, is slightly more than 5,000,000 acre feet, but its flow is irregular. During the period of record, 1925 to 1937, it varies from about 750,000 acre feet in 1925 to over 8,000,000 acre feet in 1932. The average daily flow during July, August, and September has been so small that salt water from the Gulf has affected rice culture upstream for a considerable distance.

An intelligent and economical development of the water resources cannot be made without a reliable record of the surface runoff and its distribution over the area. At the present time the United States Geological Survey, in cooperation with the Texas Board of Water Engineers, is maintaining ten stream flow stations in the basin. Some of these stations are not equipped with water-stage recorders, and at others the equipment is becoming old and in need of repair. A number of additional stream flow stations should be installed and maintained for sufficient time to give adequate records. The construction of

flood control reservoirs on the rivers will require the installation of new stations in connection with their operation, as the larger floods will be caused by tropical storms, producing flashy floods of great volume. The successful operation of these reservoirs will depend upon the operators having notice at the earliest possible moment of flood-producing rises in the river. Therefore, stream flow stations used for this purpose should be equipped with instruments capable of transmitting the information for a considerable distance, or arrangements should be made for obtaining telegraph reports directly from the stations.

This area includes Dallas and Fort Worth and the thickly populated adjacent region in which ground-water is a practically indispensable source of water supply. In parts of this region serious questions have been raised as to the permanency of the supply under the present heavy draft from wells. The southern part of the area includes part of the ground-water district to which Houston may have to turn for its ground-water supply. Preliminary studies have been made in three counties in the central part of the basin and in a small part of the area near Houston.

In the Trinity Basin, below Fort Worth and Dallas, only the river channel and narrow strips of adjacent overflow land have been mapped. Above Fort Worth and Dallas, some reservoir sites have been mapped.

In the Trinity-San Jacinto area of about 21,000 square miles, there are now in operation five automatic recording rainfall stations, two evaporation stations, and nineteen standard rainfall stations. The climatic conditions range from coastal, subject to intense storms of long duration, to upland hill country subject to very intense storms of moderate duration.

Local interests of the Trinity basin have expanded, without monetary aid from either State or Federal Government, in excess of fifteen million dollars in the construction of levees and about the same sum for the construction of reservoirs designed for both conservation and flood control purposes. Other millions not so easily segregated have been spent for the amelioration of flood conditions or the prevention of flood damages.

Flood control is important for the entire valley of the Trinity River. Floods affect the bottom lands, reaching to the coast, and are serious around Fort Worth and Dallas and in the adjacent rural area of the Black Waxy Belt, where the greatest amount of development has taken place. Storage reservoirs for control of floods and for municipal water supplies, with a total capacity of 1,943,000 acre feet, have been provided in the headwater tributaries. This storage is equal to about one-quarter of the maximum annual runoff near the mouth of the stream. A reservoir has been recently completed to provide condensing water for a power plant immediately above Dallas. Development of available storage sites for flood control would result in a marked reduction of flood stages at Fort Worth and Dallas. Such development would also have an important bearing on the floodway to be provided by levee construction to reclaim agricultural lands along the valley. The provision of such reservoirs would increase the low-water flow, which would benefit irrigation in the Coastal Plain and provide water for dilution of the effluent from sewage-disposal plants.

Stream pollution, already a major problem, is becoming more serious with the rapid growth of the larger cities. The sewer system of Dallas has lagged behind the increase in population, and there is not enough water in the river at low stages to dilute the sewage sufficiently from the areas of Dallas and

Fort Worth. Final plans have been prepared for the enlargement and modernizing of the Dallas plant, and an allotment of funds of the P.W.A. has been made for this work. The lack of water during low water periods on the upper Trinity accentuates the problem of dilution of the industrial and municipal wastes, and the effect of this pollution upon the Fort Worth and Dallas areas is especially noticeable in the stream from Fort Worth all the way to the Gulf. At irregular intervals water is released from reservoirs above, for the purpose of clearing the channel of sewage, but this results in "black rises." This creates a serious health menace, kills fish, and cause other nuisances throughout the basin.

Smaller municipalities scattered over the basin are also confronted with serious sewage disposal problems. The growth in population and the increased requirements for better sewage treatment have caused many plants to need major remodeling and enlargement.

Water supply for municipal and industrial uses is a problem of major importance. Fort Worth and Dallas have constructed five large reservoirs on the headwaters of the Trinity River for flood control and for the conservation of water for irrigation, industrial, and municipal and other beneficial uses.

SAN JACINTO BASIN. The San Jacinto River watershed embraces an area of some 3,200 square miles, extending over portions of Fort Bend, Waller, Walker, Montgomery, San Jacinto, Liberty, and Harris Counties. A large part of the population is urban, due to the size of Houston, the State's largest city. Principal agricultural products are cattle and dairy products. Rice, cotton, vegetables and produce are also important. Harris County is the State's leading

county in dairy products and fourth in number of cattle. There is considerable petroleum production in the basin. Houston, in Harris County, is the State's largest industrial center and is experiencing a rapid growth.

Mean annual rainfall varies from 40 to 50 inches. The average annual stream flow at the mouth of the San Jacinto is about 1,180,000 acre feet. Its principal tributaries are the East and West Forks, Spring Creek, and Buffalo Bayou. These tributaries extend fan-shaped throughout the San Jacinto watershed, flowing for the most part in an easterly and southeasterly direction.

Buffalo Bayou receives practically all the drainage from streams in Harris County. It flows from west to east, discharging into San Jacinto River, sixteen miles below the Turning Basin of the Houston Ship Channel. From a flood control standpoint, correction of existing conditions on these streams is of major concern to the City of Houston.

Houston was subjected in 1929 and 1935 to devastating floods. In 1929 Houston and the Ship Channel were subjected to serious damage. Heavy rainfall in San Jacinto and Buffalo Bayou watersheds completely closed the ship channel several days by depositing 2,250,000 yards of silt. In 1935, approximately sixteen inches of rain fell within three days over the watershed of Buffalo Bayou and its tributaries, causing a flow far in excess of the capacity of its water courses. The City of Houston is engaged in a demolition project, which will widen an existing bottle neck on the Bayou through the immediate downtown district of Houston, alleviating the spread of flood waters and attendant damage to this immediate section. This project will involve the expenditure of $250,000.

The needs for stream flow records in this basin are quite similar to those

in the Trinity except that one of the major problems in this area will be the rapid development of the water resources for municipal water supply. At the present time, the U. S. Geological Survey, in cooperation with the Texas Board of Water Engineers, is maintaining one station on the West Fork of the San Jacinto River and three stations in the Buffalo Bayou basin. A number of additional stream flow stations should be installed and maintained for sufficient time to give adequate records of the entire area.

This area includes the Houston-Galveston industrial district which depends entirely on ground water for public and industrial water supply. Houston is the largest city in the United States that uses ground water exclusively, and its demands are rapidly increasing. Preliminary ground water studies have been made in five counties in this area, and three preliminary reports based thereon have been issued.

Only that portion of the San Jacinto basin in Harris County has been mapped.

The Harris County Flood Control District was created in 1937 by the Legislature to prepare and execute an economical plan to protect Houston, the port and Harris County from damage by these streams. The San Jacinto River Conservation and Reclamation District, embracing all of the watershed except Harris County, has also been created by the Texas Legislature. Its purposes are similar to those of the Harris County district.

The Corps of Engineers is now engaged in making a survey of Buffalo Bayou for flood control and allied purposes.

The major portion of the population of Galveston and Harris Counties is metropolitan, and the highly industrialized development of this area requires an adequate and constant supply of water. Future industrial development of

this entire area is largely dependent upon maintaining its water supply capacity to meet the increasing demand.

The City of Houston now depends on drilled wells. Whether it shall continue to depend upon this source for its water supply or to rely in whole, or in part, upon surface water supplies is a matter of grave concern. The City of Houston is making an intensive survey of this problem. As a source of surface water supply for Houston, the San Jacinto River basin may offer possibilities, either as supplemental to existing wells, or as a source for all the City's needs. The Trinity River could also be used as an auxiliary source.

The Houston ship channel follows Buffalo Bayou for a distance of sixteen miles, to San Jacinto Bay. Beyond this junction, the ship channel operatesfor some nine miles through San Jacinto Bay which is hardly more than a continuation of the San Jacinto River. Thus the San Jacinto at times of flood also affects navigation on the channel to a serious degree. In times of flood, the high velocity of flow practically closes the Houston ship channel to navigation. Large volumes of silt are deposited in the channel, requiring costly maintenance. The magnitude of losses sustained by the Port of Houston during flood periods on these streams can be visualized when it is remembered that Houston is the fifth largest port in the United States from the standpoint of tonnage.

RECOMMENDED PLAN

TRINITY BASIN.

Stream Pollution. Extension and enlargement of sewage treatment facilities at Dallas should be provided. A recent allotment from the Public Works Administration is expected to provide these improvements. A regulated flow at and

below Fort Worth should be maintained to provide proper dilution for municipal and industrial wastes. A number of towns which have sewage treatment plants are finding them either inadequate or antiquated. The average age of many of the plants is something over twenty years. These plants should be expanded and rehabilitated; when necessary, sewer line extensions should be provided. It is recommended that cities be encouraged to provide trained personnel for sewage plant operation, and to provide better facilities for laboratory control.

Water Supply. It is recommended that the need of many small municipalities for water systems, water plants or improvements be considered and provided for.

Flood Control. The Corps of Engineers is now making a study of the entire watershed for flood control and allied purposes. It is recommended that additional funds be provided to complete this study.

Land Use and Conservation. It is recommended that a soil and water conservation program be planned for this basin to arrest the silting of reservoirs and minor stream channels, and the erosion of farm lands, and that remedial measures be instituted immediately on the watersheds of the White Rock, Lake Dallas, Eagle Mountain, and Bridgeport reservoirs. Detailed sedimentation studies should be made on the Mountain Creek reservoir, and preliminary preparations made for such studies on sites of any proposed reservoirs. The general plan should include provision for necessary changes in land tenure and use, and the application of all types of runoff and erosion control measures which have proved to be effective, economical, and adapted to this basin. A preliminary examination for runoff, water flow retardation and soil erosion prevention on the Trinity watershed has been completed by the U. S. Department of Agriculture. In order to determine definite treatment measures applicable to each land unit,

that there be added to the present facilities one evaporation station, located near the center of the area, and three cooperative Weather Bureau stations.

It is further recommended that all of the above hydrologic studies and topographic mapping be done in standard form by competent agencies, and the results made readily and promptly available to the public, and periodically published in standard form.

SAN JACINTO BASIN.

The San Jacinto watershed presents four major problems: flood control, water supply, navigation, and industrial waste disposal.

Flood Control. The Corps of Engineers has recently completed a survey of the San Jacinto watershed for flood control and allied uses. They have evolved a plan for controlling floods in the City of Houston, which, it is understood, involves several alternate plans. The Harris County Flood Control District has also made plans for this project. It is recommended that immediate steps be taken to remedy present flood hazards at Houston, in accordance with some economical and feasible plan.

Water Supply. The water supply problem of the City of Houston is now under study. It is recommended that these studies be extended and continued. Improvements to water systems of several smaller cities in the basin are recommended. In some cases new systems are needed.

Navigation. Improvements to navigation facilities of the Houston ship channel have been included in the plan for immediate construction. The proposals for flood control works for Houston would include features of assistance to navigation.

Stream Pollution. The rapid growth of Houston and its outlying districts

has given rise to problems of regulating the pollution of streams from industrial waste. A study of this situation is recommended to enable industries to handle their wastes properly and economically. In some cases sewage treatment plants and sewage extensions should be built.

Measurements of Stream Flow. To obtain the necessary records of surface runoff and its distribution over the basin it is recommended that the stations now in operation be continued and equipment improved. It is further recommended that about four new stations be installed and maintained for sufficient time to give adequate records.

Ground Water Survey. Preliminary surveys of ground water conditions which thus far have covered five counties, should be extended to the entire area and should be followed by a continuing program of ground water research to determine the extent of the ground water resources for the rapidly growing city of Houston and its surrounding industrial region.

Topographic Mapping. Only a small portion of the San Jacinto basin is covered by adequate topographic maps. It is recommended that the unmapped portion be mapped for drainage, flood protection, and ground water investigations.

It is further recommended that all the above hydrologic studies and topographic mapping be done in standard form, by competent agencies, and that the results be made readily and promptly available to the public, and periodically published in standard form.

PROJECT LIST - THE TRINITY AND SAN JACINTO BASINS

PROJECT	ESTIMATED COST		Authorized By Congress	Authorizing Act	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
GROUP A - IMMEDIATE 1. Investigation Projects					
Trinity River, Texas: A study of the river and its tributaries for flood control.	$ 100,000		Yes	1	Amount shown to complete study by Corps of Engineers.
Trinity River Basin, Texas: Ground water survey of basin.	69,000	$ 130,000	No		To develop water supplies particularly where present supplies are unsatisfactory and where level is being lowered.
Trinity River Basin, Texas: Study of means for malaria control throughout basin.	5,000	5,000	No		A continuation of work done by USPHS in certain counties in Texas.
Trinity River watershed, Texas: Detailed soil conservation survey of basin.	13,640		No		Preliminary examinations completed. Amount shown required to complete.
Trinity River Basin, Texas: Stream pollution survey.	12,000	15,000	No		To recommend proper treatment of municipal and industrial wastes.
An area study of land use and economic factors to devise plans for needed land retirement and major land and water use adjustments to insure a proper coordinated land and water utilization program.	50,000	77,500	Yes	Pub. 210 and 738	Extent of study dependent upon preliminary surveys now being conducted by Flood Control Coordinating Committee of U.S.D.A.
Detailed survey of woodlands in 10 counties in the cross timbers and sandy lands.	10,000	None	Yes	Pub. 738	
Trinity Basin, Texas: Topographic mapping of overflow areas upstream from the Coastal Plain.	200,000	125,000	No		Sufficient control on main stream is available to begin work at once.

PROJECT LIST - THE TRINITY AND SAN JACINTO BASINS

PROJECT	ESTIMATED COST		Authorized By Congress	Authorizing Act	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
1. Investigation Projects(cont.)					
Montgomery, Liberty, Chambers, and Brazoria Counties, Texas: Topographic mapping of the Coastal Plain area in Trinity Basin.	$ 350,000		No		Harris and Galveston Counties mapped, preliminary plans prepared.
2. Construction Projects - General					
Harris County, Texas: Storage and channel improvement for flood control - City of Houston.	1,000,000	$ 8,000,000			Report prepared by C. of E. Bridge changes and rights-of-way will cost $3,000,000 additional.
Houston, Texas: Ship channel to Galveston Bay, to be dredged to 34 feet in depth, and width increased.		2,164,000	Yes	3	Funds necessary for completion of project.
Galveston channel, Texas: Navigation.		1,430,000	Yes	3	Funds necessary to complete project.
Channel from Galveston Harbor to Texas City: Navigation.		112,000	Yes	3	Funds necessary to complete project.
Channel to Port Bolivar, Texas: Navigation.		102,000	Yes	3	Funds necessary to complete project.
Chocolate Bayou, Texas: Navigation.		8,500	Yes	3	Funds necessary to complete project.
Bastrop Bayou, Texas: Navigation.		10,000	Yes	3	Funds necessary to complete project.
Cedar Bayou, Texas: Navigation.		12,500	Yes	3	Preliminary plans complete.
Twelve additional stream gaging stations on Trinity River and tributaries, and San Jacinto River.	24,500	30,000	No		Cost includes 6 years' operation.
Double Bayou, Texas: Navigation channel.	5,500				Funds necessary to complete project.

PROJECT LIST - THE TRINITY AND SAN JACINTO BASINS

PROJECT	ESTIMATED COST		Authorized By Congress	Authorizing Act	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
2. Construction Projects - General (cont.)					
Trinity Basin, Texas: Additional rainfall and evaporation stations in basin.	$ 1,030		No		Present stations are too few in number and too widely scattered to yield adequate data. Yearly maintenance $330.
Wise, Montague, and Jack Counties, Texas: Land utilization project, prevention of silting, reducing flood hazards, conservation of soil and water, and correction of other maladjustments in land use.	125,000	$ 325,000	Yes	Pub. 210	Detailed conservation surveys, land classification maps and other investigations by Farm Security Administration.
Collin and Dallas Counties, Texas: Runoff and water flow retardation and soil erosion prevention on watershed of White Rock Lake.	100,000	300,000	Yes	Pub. 46	Detailed conservation surveys have been made of entire watershed.
Denton County, Texas: Runoff and water flow retardation and soil erosion prevention on watershed of Lake Dallas.	250,000	1,750,000	Yes	Pub. 46	Detailed conservation surveys have been made on small parts of watershed.
Application of soil and water conservation measures on watershed of Bridgeport, Eagle Mountain, and Lake Worth reservoirs.	500,000	3,000,000	Yes	Pub. 46	
3. Construction Projects, Municipal Water Supply and Pollution Abatement					
Terrell, Springtown, Roanoke, Aubrey, Valley View, Sunset, Gunter, Texas: Improvements and additions to water supply.	47,000		No		
Galveston, Texas City, and La Porte, Texas: Sewage treatment plants and additions to water supplies.	172,000		No		

PROJECT LIST - THE TRINITY AND SAN JACINTO BASINS

PROJECT	FIRST YEAR	BALANCE TO COMPLETE	Authorized By Congress	Authorizing Act	REMARKS
3. Construction Projects, Municipal Water Supply and Pollution Abatement					
South Houston, Brookshire, Anahuac, Daisetta, Buffalo, Grapeland, Streetman, Dawson, Maypearl, Texas: Improvements and additions to water supply.	$ 88,000		No		
Sugar Land, Humble, Lancaster, Waxahachie, Grapevine, Pilot Point, Texas: Improvements to sewage treatment plants.	50,000		No		
Dickinson, Webster, Spring, Willis, Shepherd, Cold Springs, Shiro, Midway, Richland, Texas: Waterworks systems.	173,000		No		
Celina, Sanger, Tioga, Gainesville, Whitesboro, Tex. Additions to water supply and sewage treatment plants.	59,000		No		
Garland, Carrollton, Plano, Wylie, Lewisville, Frisco, Farmersville, McKinney, Bridgeport, Decatur, Denton, Jacksboro, Texas: Additions to water supply and sewage treatment plants.	178,000		No		
Alvarado, Kemp, Venus, Midlothian, Mansfield, Ferris, Kaufman, Forney, Grand Prairie, Arlington, Mesquite, Rockwall, Texas: Additions to water supply and sewage treatment plants.	176,000		No		
Groveton, Crockett, Elkhart, Fairfield, Palestine. Wortham, Hubbard, Corsicana, Kerens, Trinidad, Italy, Ennis, Mabank, Texas: Additions to water supply and sewage treatment plants.	194,000		No		

PROJECT LIST - THE TRINITY AND SAN JACINTO BASINS

PROJECT	ESTIMATED COST		Authorized By Congress	Authorizing Act	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
3. Construction Projects, Municipal Water Supply and Pollution Abatement					
Angleton, Alvin, Pasadena, Goose Creek, Pelly, Waller, Dayton, Conroe, Huntsville, Livingston, Trinity, Madisonville, Texas: Additions to water supply and sewage treatment plants.	$ 220,000		No		
Midway, Buffalo, Grapeland, Streetman, Richland, Handley, Springtown, Aubrey, Valley View, Sunset, Gunter, Texas: Sewer systems and sewage treatment plants.	227,000		No		
Dickinson, Webster, South Houston, Brookshire, Cold Springs, Anahuac, Spring, Daisetta, Willis, Shepherd, Texas: Sewer systems and sewage treatment plants.	179,000		No		
Malakoff, Texas: Sewer system and additions to water supply.	30,000		No		
Trinidad and Baytown, Texas: Improvements and additions to water supply and sewage treatment plants.	65,000		No		
Galena Park, Texas: Sewer system.	20,000		No		
Springtown and Goodrich, Texas: Improvements to water supply.	26,000		No		
Houston, Texas: Water system improvements.	1,000,000		No		Preliminary plans made.
Highland Park, Texas: Water system improvements.	285,000		No		Preliminary plans made.

PROJECT LIST - THE TRINITY AND SAN JACINTO BASINS

PROJECT	ESTIMATED COST		Authorized By Congress	Authorizing Act	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
3. Construction Projects, Municipal Water Supply and Pollution Abatement					
Eustace, Grapevine, Lancaster, Pilot Point, Prosper, Rhome, Texas: Waterworks improvements.	$ 133,000		No		Preliminary plans made.
Centerville, Mesquite, Oakwood, Texas: Waterworks and sewer system improvements.	121,000		No		Preliminary plans made.
Jewett, Texas: Sewage treatment plant.	16,000		No		Preliminary plans made.
Blue Ridge, Texas: Waterworks system.	29,000		No		Preliminary plans made.
Alvord, Athens, Rice, Texas: Waterworks and sewer system improvements.	203,000		No		Preliminary plans made.
Bryson, Dawson, Normangee, Roanoke, Seagoville, Texas: Sewer systems.	145,000		No		Preliminary plans made.
Waxahachie, Tex.: Water supply reservoir and pipeline.	273,000		No		Preliminary plans made.
GROUP B - DEFERRED					
2. Construction Projects - General					
Trinity Basin, Texas: Drainage on Coastal Plain.	350,000		No		Should await results of study. Annual maintenance $25,000.

THE BRAZOS AND COLORADO RIVER BASINS

THE PROBLEM

The most important water problems in the Colorado and Brazos River Basins are the control of floods and the conservation of water for varied needed purposes. The Buchanan and Inks Dams have been completed and will store 1,000,000 acre feet of water. The Marshall Ford Dam is under construction, and it is expected that a fourth dam at Austin will be under construction during 1938. It is also expected that the Possum Kingdom Dam on the Brazos will be under construction during the same year. Such reservoirs will retain flood waters and release them to provide an increased seasonal and more uniform normal flow for the benefit of irrigators and other water users. Soil and water conservation measures on the lands are needed as a protection against erosion and will minimize drouth hazards on farms and ranches, and may also prolong the life of reservoirs and stabilize spring and stream flow. Various water supply and sewerage projects are needed in the Basin. In the South High Plains, development of underground water supplies is needed. Conservation of water for irrigation and other purposes in the area below the Cap Rock is important. The native purity of the waters of these streams should be rigidly protected by adequate sewage treatment. The Corps of Engineers is making a survey of both the Brazos and Colorado Basins, excluding the Possum Kingdom Dam, for navigation, flood control, and allied purposes.

GENERAL DESCRIPTION

The drainage basins of the Brazos and Colorado Rivers, considered together

here, have an area of more than 83,000 square miles. They cover a district about 600 miles long and as much as 250 miles wide. These basins are divided physiographically into five major subsections in which the varying physical conditions have considerable bearing on the feasibility of flood control and water conservation measures in the entire basin.

The section of highest elevation is the South High Plains, at an average altitude of 4,000 feet. This section is the southernmost extension of the Great Plains and is 16,000 square miles in extent. It is surrounded on three sides by the Cap Rock, a prominent escarpment. To the north is the Texas Panhandle.

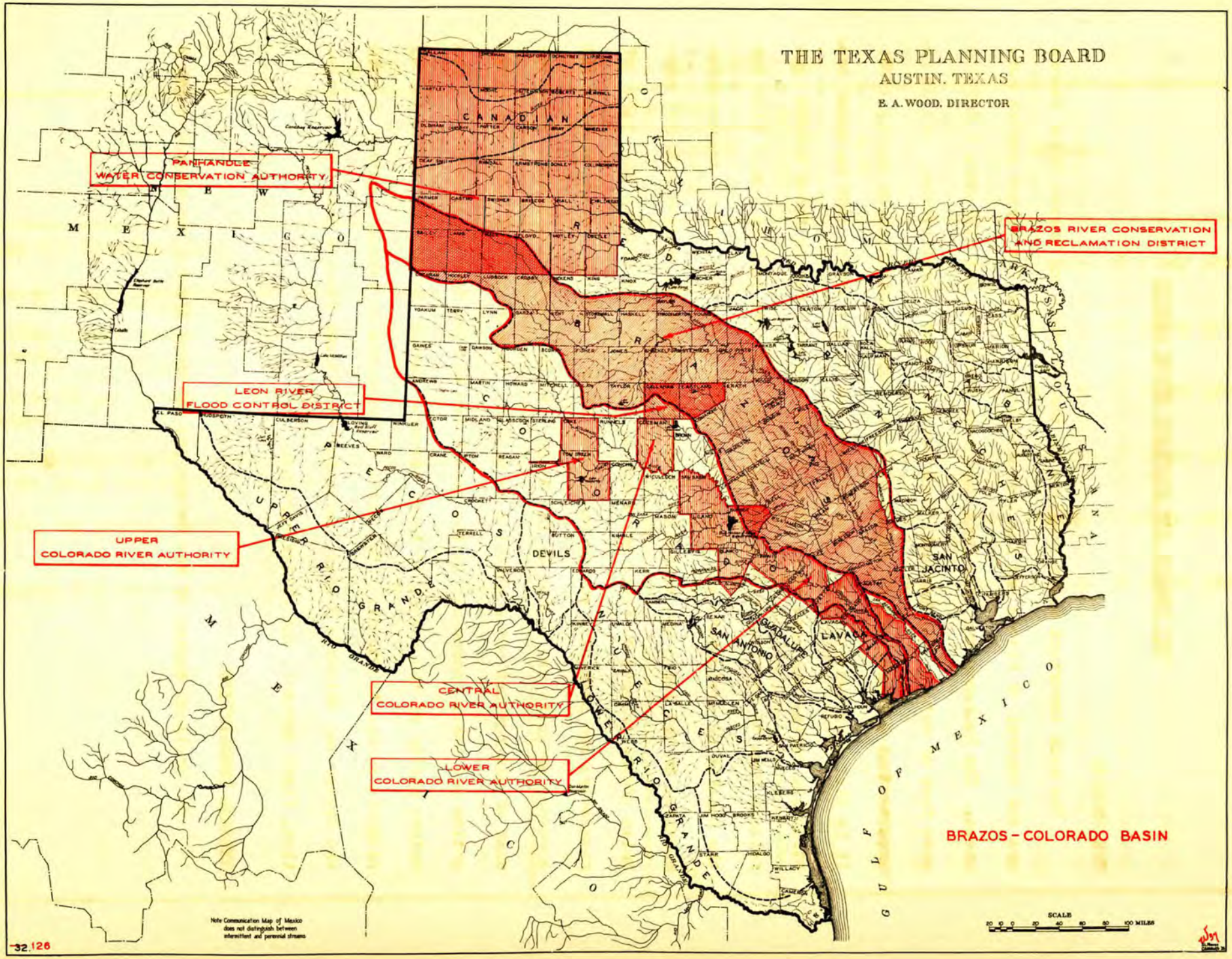
Southeast of the High Plains is the Edwards Plateau, the second subsection, largely made up of rough and stony lands, used chiefly for grazing. Its area is 21,000 square miles.

The third sub-region comprises the rolling plain, north of the Colorado River and extending east from the Cap Rock to the line of 25-inch annual rainfall, with an area of approximately 14,000 square miles. This region consists of rolling valleys with gentle slopes ranging in some places to rough hills.

The fourth zone is the rolling and timbered country which includes the Grand Prairie and lies east of the 25-inch rainfall line and above the Balcones Escarpment. It is known as the Canyon section and has an area of some 17,000 square miles.

The fifth zone, with an area of 15,000 square miles, lies below the Balcones Escarpment and extends to the Gulf of Mexico. It is composed of the blackland prairie and the coastal plain, a zone of partly timbered strip plains intervening.

The population of the basins was 1,345,000 in 1930. The section west of the 25-inch rainfall line was settled much more recently than the eastern


THE TEXAS PLANNING BOARD
AUSTIN, TEXAS
E. A. WOOD, DIRECTOR
PANHANDLE WATER CONSERVATION AUTHORITY
BRAZOS RIVER CONSERVATION AND RECLAMATION DISTRICT
LEON RIVER FLOOD CONTROL DISTRICT
UPPER COLORADO RIVER AUTHORITY
CENTRAL COLORADO RIVER AUTHORITY
LOWER COLORADO RIVER AUTHORITY
CANADIAN
BRAZOS
COLORADO
DEVILS
SAN JACINTO
GUADALUPE
SAN ANTONIO
LAVACA
NUECES
RIO GRANDE
MEXICO
GULF OF MEXICO
BRAZOS - COLORADO BASIN
SCALE
20 10 0 20 40 60 80 100 MILES
Note Communication Map of Mexico does not distinguish between intermittent and perennial streams
32.126

section. In 1900 the humid eastern half of the basins contained 830,000 rural inhabitants. The semiarid western half reported 102,000 in the same year. In 1930 the eastern half had 811,000 rural inhabitants, practically the same as in 1900. The western half, on the other hand, reported 392,000 rural inhabitants. The larger cities are just below the Balcones escarpment. They are Austin on the Colorado River and Waco on the Brazos River. Each city had about 53,000 population in 1930. The next largest city in the Basin is San Angelo, which is situated above the Balcones fault zone, at the confluence of the Concho and the Colorado. It has a population of 30,000.

Prior to 1910 the South High Plains was, for the most part, ranch country. Farmers, penetrating from the northeast corner, where rainfall is heaviest, now have obtained about one-third of the total area. In 1910 there were about 4,000 ranch and farm units. In 1935 there were 23,000 ranches and farms. Crops were harvested in 1935 from 2,500,000 acres, or about 17 percent of the land. The most important crops are cotton and grain sorghum, the latter an important livestock feed. Irrigation from wells is increasing rapidly. The principal use of the underground water supply, however, still is for domestic and stock watering purposes.

On the rolling plain dry farming is competing with grazing. Irrigation is successfully practiced in the Colorado and Brazos River valleys. To insure crop production during drouth years and increase crop yields in years of average rainfall, water conservation measures are essential on farm and grazing lands. Control of erosion will be effected by the application of these measures. Three counties have been listed as drouth areas for four of the last six years.

In the canyon section crops were harvested in 1935 from 785,000 acres, or about 7 percent of the area, while below the Balcones Escarpment crops were harvested from 300,000 acres or about one-quarter of the area of this black prairie and coastal section. Continuous and heavy grazing of range land and lack of conservation measures on cultivated lands have resulted in greatly increased runoff and contributed to the high silt content of streams. A preliminary estimate made by the Corps of Engineers indicates an annual load of suspended silt in the Brazos River at Waco of about 19,000,000 tons. The Lake Waco reservoir has silted 19.78 percent of its capacity in six years and the small Austin reservoir on the Colorado River has silted nearly full. In 1936, 85,000 acres were irrigated for rice on the lower Colorado River, and about 35,000 acres on the lower Brazos.

Aside from agriculture, the oil industry is the chief economic activity. Oil is being produced in all sections of the area. Large sulphur mines are also located in this area.

Precipitation in the South High Plains varies from 20 inches in the upper Brazos valley to 14 inches at the southwestern edge in New Mexico. Rainfall in the rolling plain zone is erratic and comes in intense localized storms. The average rainfall in this zone is about 22 inches, but the rain actually received in any one year may drop as low as 11 inches or rise as high as 35 inches.

Both rivers have a number of important tributaries. Those of the Brazos rise in the Grand Prairie region and enter the main stream both above and below the Balcones escarpment. The principal tributaries of the Colorado rise in the Edwards Plateau and flow easterly to join that river above the

escarpment. These tributaries, like the main streams, are subject to large flood flow.

At the point of entrance into the humid portion of the drainage basins the flow of the rivers is flashy. The average annual flow at the escarpment on each of these rivers is about two million acre feet. The rivers attain large size only when they enter the humid zone at the 25-inch rainfall line. Below this line they have carved deep canyons.

Flood control is an important problem in the Colorado and Brazos River Basins. It is, however, so interconnected with power, irrigation, soil and water conservation problems that it will be necessary to consider them together. Devastating floods originate largely in the canyon section of the rivers above the Balcones fault, as well as in the broken escarpment of the Concho above San Angelo and other tributaries of the Colorado River above the deep canyon section. The fault, where it crosses the basins is marked by a prominent escarpment. The steep and bare slopes of the canyon areas cause rapid runoff, resulting in high floods of short duration. The floods originating below the Balcones fault are not so severe because of the smaller drainage areas, the nearly flat terrain, substantial vegetal cover, and rather absorptive soils.

From Austin to LaGrange, about 60 miles downstream, the Colorado overflows infrequently since it is confined between high banks. From LaGrange to the mouth of the river, the banks are lower, and a large acreage of fertile and highly productive agricultural land is subject to overflow. Since 1900, twenty-four floods have occurred. The combined losses are estimated at more than $78,000,000. The largest measured flood occurred in June, 1935, when the peak flow at Austin reached nearly 500,000 cubic feet per second. Damages

totaled about $13,000,000. The 1869 flood is known to have been higher.

In September, 1936, a flood of major consequence occurred on the Concho River at San Angelo and on the Colorado above the deep canyon section. The estimated damages were $5,000,000, the major portion of which occurred on the Concho at San Angelo.

On the Brazos River, three outstanding floods have occurred during the last twenty-four years; one on the main stream in 1913, when 177 lives were lost and property damage amounted to more than $3,000,000; one in 1921, originating on Little River, principal tributary of the Brazos, which resulting in 164 deaths and damages amounting to approximately $13,000,000; and one in 1936 when the highest flood crest at Waco was reached, amounting to 246,000 second feet. Damages resulting from this flood amounted to approximately $8,000,000. Since 1913, the number of lives lost is 346 and the estimated damage has been $37,000,000. About 1,000,000 acres of fertile and highly productive bottom land along the main river and the tributaries below Waco are subject to overflow.

Irrigation in the Colorado and Brazos River basins below the Cap Rock is dependent upon the conservation and regulation of the water supplies to supplement deficient precipitation.

On the Colorado River in Wharton, Colorado, and Matagorda Counties, deficiencies occur at times for the irrigation of rice. This situation will be relieved to a considerable extent by the operation of the reservoirs being constructed by the Lower Colorado River Authority. The United States Bureau of Reclamation has investigated a project in this area which would involve the rehabilitation of the present pumping plants or the construction of a low

diversion dam and gravity canal.

In a large part of this area, ground water is the most economical and convenient source of water supply for domestic, public, industrial, and irrigation purposes. This is particularly true in the High Plains, the Balcones fault zone of south central Texas and the Coastal Plain. Preliminary ground water surveys by the Texas Board of Water Engineers, in cooperation with the U. S. Geological Survey and Works Progress Administration, have been completed or are in progress in twenty-three counties of this area. The high fluoride content in many places renders the water questionable as drinking water unless practical means can be found for fluoride removal. In Coleman County, and some adjoining territory the original and extremely limited underground water supply is practically exhausted, and in some instances pollution is caused by drilling shallow oil fields. This and silting of creek water holes has developed a very serious problem for permanent supply of water for domestic, farm, livestock, and municipal purposes.

Waco, formerly dependent upon artesian and well water, has been forced by deficiency in these supplies to develop an impounded surface supply from a tributary of the Brazos. Austin uses the Colorado River as its source of water supply, without storage. The water supply systems of both these cities have suffered severe flood damage. There is need for water projects for a number of other municipalities in the area, but some of the projects proposed may require additional study.

The Lower Colorado Authority, organized by special State legislation, embraces the territory along the Colorado River from San Saba River to the Gulf. This Authority recently has completed construction of the Buchanan and

Inks Dams on the Colorado River above Austin. These dams will provide reservoirs with an aggregate capacity of about 1,100,000 acre feet, including 95,000 acre feet of super-storage. These reservoirs will be used for the generation of electrical energy and for incidental flood control. The Marshall Ford Dam, which will provide a reservoir with a capacity of 583,000 acre feet, primarily for flood control, is being constructed about 15 miles above Austin for the Authority by the U. S. Bureau of Reclamation. Outlets are being provided in the Marshall Ford Dam which will permit the future installation of hydroelectric generating units as the need for additional power in the territory develops. The dam has been so designed that it can be raised to provide additional capacity which the Bureau estimates will be required to control adequately the flood flows originating above it.

It is understood that the Lower Colorado River Authority is to reconstruct the old Austin Dam situated immediately above Austin, which failed several years ago. This dam will be used to regulate water released from Marshall Ford Dam for generation of power and other beneficial use below.

An investigation has been made by the Reclamation Department of Texas and the U. S. Bureau of Reclamation with respect to a proposed system of levees between Columbus and the mouth of the river. The required height and extent of the levees will depend upon the ultimate capacity of Marshall Ford reservoir.

Central Colorado River Authority, created under legislative act, covers Coleman County where both surface and ground water supplies are deficient. This Authority proposes the construction of a number of small reservoirs to conserve water for domestic, farm, livestock, and municipal purposes.

A number of the smaller ponds and reservoirs have been built by the

Authority, but three larger reservoirs, of an aggregate capacity of 17,000 acre feet are still needed.

The Upper Colorado River Authority covering the counties of Coke and Tom Green proposes a project to irrigate 50,000 acres of land in the vicinity of Tennyson. The Brown County Water Control and Improvement District has in preliminary stages an irrigation project, partially financed with federal funds, of approximately 10,000 acres on Pecan Bayou, a tributary of the Colorado.

The entire watershed of the Brazos River in Texas is included in the Brazos River Conservation and Reclamation District created by a special State legislative act in 1929. Both the Leon River Flood Control District and the Panhandle Water Conservation Authority cover portions of the Brazos River Basin.

The Brazos River Conservation and Reclamation District is investigating thirteen reservoirs in the Brazos River basin proposed for flood control and regulation of water for other purposes. An allotment of $4,500,000 has been made to start the construction of the first unit of the proposed system of the Possum Kingdom Dam on the main stream of the Brazos River above Waco.

In addition to the studies and activities of the above agencies the Corps of Engineers is making a study of the Brazos and Colorado River basins for flood control and allied purposes. This study will include the entire area of both basins except the area between Austin and the Buchanan Dam and the Possum Kingdom Dam in the Brazos basin.

An intelligent and economical development of the water resources cannot be made without a reliable record of the surface runoff and its distribution over the area. At the present time the U. S. Geological Survey, in cooperation with the Texas Board of Water Engineers, is maintaining thirty-six stream flow

stations in the two basins. Some of these stations are not equipped with water-stage recorders and at others the equipment is becoming old and in need of repair. A number of additional stream flow stations should be installed and maintained for sufficient time to give adequate records. The construction of flood control reservoirs on the rivers will require the installation of new stations in connection with their operation, as the larger floods will be caused by tropical storms, producing flashy floods of great volume. The successful operation of these reservoirs will depend upon the operators having notice at the earliest possible moment of flood-producing rises in the river. Therefore, stream flow stations used for this purpose should be equipped with instruments capable of transmitting the information for a considerable distance, or arrangements should be made for obtaining telegraph reports directly from the stations.

Topographic mapping is needed for proper development of these basins. In the lower reaches of the rivers, the mapping done is confined to the river channel and a small strip of adjacent overflow land. In the middle and upper reaches, west of 97° longitude, the bulk of the mapping was done before 1896 and, judged by present day standards, is reconnaissance work. With the exception of the thirteen dams and reservoirs under investigation by the Brazos River Conservation and Reclamation District no reservoir or dam site has been surveyed and mapped accurately enough for actual construction in the Brazos River Basin. By far the greater number of potential reservoir sites have not been sufficiently mapped to permit a determination of their values. In the upland section where mapping is needed for ground water surveys and for soil conservation, practically no adequate maps are in existence.

These watersheds cover about 86,000 square miles, which may be divided into a coastal zone subject to tropical storms of high intensity and comparatively long duration, a central zone subject to some very intense storms of moderate duration and a western zone subject to intense storms of short duration, and with high evaporation. At present there are in these basins only two automatic recording rainfall gauges, six evaporation stations, and 84 standard rainfall stations.

RECOMMENDED PLAN:

A logical plan of water development for the Colorado River will include the provision of flood control reservoirs between Austin and the 25-inch-annual rainfall line; the construction of reservoirs for flood control and conservation of water for irrigation, domestic and industrial requirements above the 25-inch-annual-rainfall line; the construction of an adequate levee system between Columbus and the mouth of the river; the provision of pumping plants and canals for irrigation in the coastal region; and the development of ground water, principally in the High Plains area. The project under construction by the Lower Colorado River Authority embraces a part of such a major plan.

In the Brazos River basin a system of reservoirs to control floods and levee construction below Waco is important. Some of the reservoirs can be designed, constructed, and operated to generate electrical energy and to provide irrigation water in the coastal region during periods of low flow. In this basin the plan being developed by the Brazos River Conservation and Reclamation District will constitute a major part of such comprehensive plan for the development of the water supplies of the basin.

It is recommended funds be provided for the completion of the comprehensive

study now being made by the Corps of Engineers of both the Colorado and Brazos River Basins.

Flood Control. As the next step in the development of the Colorado River, insofar as flood control is concerned, the Marshall Ford Dam should be raised. Funds should be provided for this purpose.

Bureau engineers have made comprehensive studies and reports on the type and occurrence of Colorado River floods, and of the relative values of the low and high dams with respect to flood damages, auxiliary flood protection works for the reduction of overflow below Columbus; irrigation benefits, and power production.

Colorado River floods with the low and high dams are estimated as follows:

Frequency	Maximum Discharge With Dam Under Construction	With High Dam
5 year	Below 100,000 S.F.	Below 100,000 S.F.
25 "	" 165,000 S.F.	" 100,000 S.F.
100 "	" 333,000 S.F.	" 100,000 S.F.
500 "	" 490,000 S.F.	" 188,000 S.F.
1000 "	" 593,000 S.F.	" 257,000 S.F.
Maximum	" 820,000 S.F.	" 505,000 S.F.

Costs and benefits of the low and high dams compare as follows:

Costs:		
Low Dam	$ 14,677,000	
High Dam	27,507,000	
Increased Cost		$ 12,830,000
Benefits:		
Reduction in cost of flood protection levees below Columbus		2,000,000
Reduction in flood damage capitalized at 5%		7,600,000
Valuation of increased irrigation supplies		1,600,000
Valuation of increased power output		5,300,000
Increased Benefits		$ 16,500,000

The indicated difference in levee costs below Columbus will not provide equal protection with the high and low dams, but will avoid overflow with the frequent moderate floods which the low dam will not control. The reduction in flood damage is based on past property values and will increase as the region develops.

As the irrigation and power benefits would be repaid through sale of water and power, the net cost for securing adequate flood control would be $5,930,000. The alternative flood damage capitalized at 5 percent will far exceed this sum with present and future property values.

Even though complete control of floods at Austin may be accomplished by Buchanan and Marshall Ford Dams, floods originating below Austin will at times cause overflow because of the smaller channel and lower gradient. Levees will be required between Columbus and the mouth of the river. Funds should be provided for the construction of these levees, the amount of funds required being dependent upon the ultimate height to which the Marshall Ford Dam is constructed.

The provision of flood control projects above the Buchanan reservoir should await the completion of the studies now underway by the Corps of Engineers. A special study should be made to determine proper means for protecting the towns of Brady and San Angelo in the Columbus River basin and Waco in the Brazos River basin against flood damage.

The Brazos River Conservation and Reclamation District is rapidly completing its study of the thirteen proposed reservoirs in the Brazos River basin. As soon as the study of the basin is completed by this agency and by the Corps of Engineers, funds should be provided for the construction of those reservoirs which the studies indicate to be an essential part of the major plan for

controlling and regulating for beneficial uses the waters of this basin.

Irrigation. A comprehensive system of reservoirs should be provided on the tributaries of the Colorado River above the Buchanan reservoir for the control of floods and the conservation of water for irrigation and other purposes.

The three larger reservoirs proposed by the Central Colorado River Authority of Coleman County should be constructed. These reservoirs, in addition to conserving water for use locally in that county, will decrease to some extent the flood flows in the main stream. A program of small dam construction is now under way by the Authority.

If and when economically justified, funds should be provided for the project proposed by the U. S. Bureau of Reclamation for the rehabilitation of the pumping plants or the construction of a diversion dam and gravity canal in the coastal area of the Colorado River.

Hydroelectric Power. In the Colorado River basin additional dams can be constructed between the Marshall Ford and Inks reservoirs to develop the complete head of the river between Austin and the Buchanan reservoir for the generation of power if and when this construction is warranted by the demand for power.

Several of the flood control reservoirs proposed by the Brazos River Conservation and Reclamation District can be utilized for the development of electrical energy as the need arises.

Domestic Water Supply, Sewer Systems, and Sewage Treatment Plants which are needed in a number of the smaller municipalities in the basins should be constructed. Better and more economic operation of the existing plants is recommended.

Navigation. The Corps of Engineers is now making a survey of navigation in the Brazos and Colorado Rivers.

Land Use and Conservation. A plan that will provide for the most effective utilization of rainfall on agricultural lands and at the same time prevent the continued progress of soil erosion and stream and reservoir sedimentation should be prepared for this basin, including needed adjustments in land tenure and use. Immediate treatment of the watershed of Lake Waco is recommended. On agricultural lands in the upper and semi-arid portion of this basin, treatment measures should be planned to hold as much of the rainfall as possible in place. In the remainder of the basin, protective measures should be designed primarily to retard runoff and prevent soil erosion. In order to determine the needed treatment of individual land units, additional investigations and surveys should be made. Sedimentation surveys should be made on the Buchanan and Inks reservoirs and preliminary preparations made for such studies on the sites of the Marshall Ford, Possum Kingdom, and any other proposed reservoirs. The State Board of Water Engineers and the U. S. Department of Agriculture have carried on silt investigations on the Brazos and Colorado Rivers for some years, and have much data on hand.

Wildlife Conservation. Consideration should be given to the needs of migratory waterfowl and other wildlife and of public recreational use in the development of the various projects in the basin; this use, however, being secondary to the use of the areas for irrigation or other purposes for which the projects were originally constructed.

Measurement of Stream Flow. To obtain a record of the surface runoff and its distribution over the basins, it is recommended that the stations now in

operation be continued and the equipment improved. It is further recommended that about thirty new stream flow stations be installed and maintained for sufficient time to give adequate records. As the flood control reservoirs are constructed, it is recommended that additional stream flow stations be installed in connection with these projects to assist in their successful operation and that these stations be equipped with instruments capable of transmitting the information for a considerable distance.

Ground Water Studies should be extended to the entire area and should be followed by more intensive investigations, including test drilling, to determine the extent and limitations of the available ground water supplies.

Topographic Surveys on the lower reaches of the rivers should be extended away from the streams for drainage and flood control. These will also be of value for ground water investigations. In the middle and upper reaches, surveys should cover the possible reservoir sites on the main streams and tributaries and the adjacent land which should receive soil conservation. In those sections where ground water investigations are needed, mapping should be adequate for that purpose.

Climatological Data. Because of the wide diversity in climatic conditions, the present stations are inadequate to provide the required basic data. It is recommended that there be installed in the basins seven automatic recording rainfall stations, four evaporation stations, and fourteen standard rainfall stations.

All of the above hydrologic studies and topographic mapping should be done in accordance with approved methods, by competent agencies, and the results made readily and promptly available to the public, and periodically published in standard form.

PROJECT LIST - THE BRAZOS AND COLORADO BASINS

PROJECT	ESTIMATED COST		Authorized By Congress	Authorizing Act	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
GROUP A - IMMEDIATE 1. Investigation Projects					
Brazos River and tributaries, Texas: Survey for flood control, irrigation, navigation and reclamation.		$ 125,000	Yes		Study now under way by C. of E. Balance required to complete.
Ground water survey of Brazos basin, Texas.	$ 116,500	213,000	No		To make thorough study of ground water resources of Basin. To correlate a similar work already done in a few counties. Six year program.
Brazos Basin, Texas: Malaria control study.	2,100	4,400	No		Comprehensive study of drainage problems for malaria control in affected areas.
Waco, Texas: Study to devise methods for flood protection for city of Waco.	15,000	25,000	No		
Brazos Basin, Texas: Stream pollution study.	12,500	10,000	No		Survey of means for prevention of municipal and industrial pollution.
Brazos River, Texas: Study of flood control by means of levees, also topographic mapping for the lower Brazos.	175,000		No		Plans for study made.
Colorado River and tributaries, Texas: Study for development of basin for flood control, navigation, and allied purposes.	100,000		Yes		Study now under way by C. of E. Amt. given necessary to complete.
Colorado River Basin, Texas: Ground water survey.	101,000	180,500	No		A thorough study of ground water resources of the basin for agricultural and urban use. Six year program.

PROJECT LIST - THE BRAZOS AND COLORADO BASINS

PROJECT	ESTIMATED COST		Authorized By Congress	Authorizing Act	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
1. Investigation Projects (cont.)					
Colorado Basin, Texas: Stream pollution study.	$ 12,500	$ 10,000	No		Study of means for prevention of municipal and industrial pollution.
Colorado Basin, Texas: Malaria control study.	2,800	5,700	No		Comprehensive study of drainage problems for malaria control in effected areas.
Brady, Texas: Study for flood protection of city.	2,000	3,000	No		Excessive flood damages suffered frequently.
San Angelo, Texas: Study for flood protection.	15,000	35,000	No		
Colorado River, Texas: Edwards Plateau Soil Conservation project to determine applicable conservation measures.	80,000	120,000	Yes	Pub. 46	Area to be selected.
Colorado River, Texas: Detailed sedimentation survey of Buchanan reservoir.	22,900		Yes	Pub. 738	
Brazos and Colorado Basins, Texas, between Cap Rock and 25-inch rainfall line; Land utilization study of present land and water use, and problems, adjustments needed, and measures or procedures required to carry out recommended adjustments.	100,000	115,000	Yes	Pub. 210	Study of land use and economic phases dependent upon preliminary surveys already under way or contemplated by the Flood Control Coordinating Committee of the U.S.D.A.
Brazos and Colorado Basins, Texas: Detailed woodlands survey in 25 counties.	10,000	5,000	Yes	Pub. 738	
Portions of Brazos and Colorado Basins, Texas: Detailed conservation survey.	10,000	9,720	Yes	Pub. 738	Areas to be selected.

PROJECT LIST - THE BRAZOS AND COLORADO BASINS

PROJECT	ESTIMATED COST		Authorized By Congress	Authorizing Act	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
GROUP A - IMMEDIATE 2. Construction Projects - General					
Palo Pinto County, Texas: Possum Kingdom Dam for flood control and power.		$ 4,500,000	Yes		Amount needed to complete.
Sixteen additional stream gaging stations in Brazos River Basin.	$ 17,000		No		In addition to stations already operating. Annual operation $7,200.
Brazos Basin, Texas: Additional rainfall and evaporation stations to augment existing facilities.	3,160		No		Present stations are too few in number and too widely scattered to yield adequate data. Annual operation $1260
Martin, Dickens, and Garza Counties, Texas: Drouth area conservation project to conserve soil and water in place.	300,000	2,700,000	Yes	Pub. 46	Detailed conservation surveys have been made on soil areas common to the watershed.
Bosque River, Texas: Lake Waco soil conservation project, to conserve soil and water in place.	300,000	2,200,000	Yes	Pub. 46	Detailed surveys 40 percent complete.
Bailey County, Texas: Muleshoe migratory waterfowl refuge.	50,100		Yes	MBCA	
Breckenridge Dam in Throckmorton County.	5,000,000		No		Preliminary plans complete.
Seymour Dam in Stonewall County.	4,700,000		No		Preliminary plans complete.
Turkey Creek Dam in Palo Pinto County.	2,800,000		No		Preliminary plans complete.
Inspiration Point Dam in Palo Pinto County.	2,800,000		No		Preliminary plans complete.

PROJECT LIST - THE BRAZOS AND COLORADO BASINS

PROJECT	ESTIMATED COST		Authorized By Congress	Authorizing Act	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
2. Construction Projects - General (cont.)					
Cordova Bend Dam in Hood County.	$ 2,950,000		No		Preliminary plans complete.
Bee Mountain Dam in Bosque County.	4,500,000		No		Preliminary plans complete.
Whitney Dam in Bosque County.	4,600,000		No		Preliminary plans complete.
Lampasas Dam in Bell County.	2,500,000		No		Preliminary plans complete.
Leon Dam in Bell County.	3,500,000		No		Preliminary plans complete.
Navasota Dam in Madison-Brazos Counties.	2,700,000		No		Preliminary plans complete.
San Gabriel (North Fork) Dam in Williamson County.	1,900,000		No		Preliminary plans complete.
San Gabriel (South Fork) Dam in Williamson County.	2,600,000		No		Preliminary plans complete.
Marshall Ford, Texas: Marshall Ford Dam to be raised to provide extra capacity for flood control, power, and irrigation.	8,000,000	$ 11,678,000	Yes		Low dam under construction. Preliminary plans and estimates complete for high dam. Cost given is amount required to complete high dam, in addition to funds already available.
Coleman, Texas: Central Colorado River Authority project: Three small reservoirs for domestic, stock, and irrigation uses.	567,000		No		Preliminary plans made.
Lower Colorado River, Texas: Levees and channel improvements for flood control.	3,200,000		No		Field investigations completed. Preliminary plans now being made.
Colorado River Basin, Texas: Nine additional stream gaging stations in Basin.	9,300		No		In addition to stations already operating. Annual operation $4,000.

PROJECT LIST - THE BRAZOS AND COLORADO BASINS

PROJECT:	ESTIMATED COST		Authorized By Congress	Authorizing Act	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
2. Construction Projects - General					
Upper Colorado River, Texas: Upper Colorado River Authority project near Tennyson. Reservoirs and canals for irrigation.	$ 7,000,000		No		Preliminary plans made and project needed, but cost excessive.
Colorado Basin, Texas: Additional rainfall and evaporation stations to augment existing facilities.	5,380		No		Present stations are too few in number and too widely scattered to yield adequate data. Annual operation $2,180.
Brownwood, Texas: Gates for spillway of Brownwood reservoir to control floods on Pecan Bayou and Colorado River.	300,000		No		Preliminary plans made. Subject to check by survey now under way by C of E.
3. Construction Projects, Municipal Water Supply and Pollution Abatement					
Kosse, Texas: Water supply from wells, sewer system, and sewage treatment plant.	58,000		No		Preliminary plans complete.
Aspermont, Benjamin, Calvert, Hempstead, Lexington, Soudan, and Tenuacana, Texas: Water supply and sewage systems.	200,000		No		Preliminary plans complete.
Hamlin, Texas: Additional water filters and improvements.	145,000		No		Preliminary plans complete. Requires further study.
Round Rock, Texas: Sewer system and sewage treatment plant.	47,000		No		Preliminary plans complete.
Abilene, Texas: Domestic water supply improvements.		$ 214,000			Under construction. Amount shown necessary to complete.

PROJECT LIST - THE BRAZOS AND COLORADO BASINS

PROJECT	ESTIMATED COST		Authorized By Congress	Authorizing Act	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
3. Construction Projects, Municipal Water Supply and Pollution Abatement					
Hempstead, Texas: Sewer system.	$ 60,000		No		
Rochester, Stamford, Putnam, Strawn, Graford, Lometa, Desdemona, McGregor, Moody, Brazoria, Mart, Whitney, West Columbia, Texas: Sewer systems and sewage disposal plants.	220,000		No		
Rogers, Thorndale, Marquez, Brenham, Amherst, Clton, Halo Center, and Hermleigh, Texas: Sewer systems and sewage treatment plants.	187,000		No		
Mt. Calm, Stamford, Putnam, Texas: Water treatment plants.	40,000		No		
Bartlett, Cameron, Slaton, Post, Spur, Palo Pinto, Freeport, Mt. Calm, Hamlin, Texas: Sewage treatment plants.	140,000		No		
Belton, Holland, Granger, Coolidge, Marlin, Rosebud, Rockdale, Caldwell, Teague, Groesbeck, Texas: Additions to water supply systems and sewage treatment plants.	150,000		No		
Franklin, Hearne, Bryan, Navasota, Bellville, and Littlefield, Texas: Additions to water supply and sewage treatment plants.	100,000		No		

PROJECT LIST - THE BRAZOS AND COLORADO BASINS

PROJECT	ESTIMATED COST		Authorized By Congress Authorizing Act		REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
3. Construction Projects, Municipal Water Supply and Pollution Abatement (cont.)					
Crosbyton, Rotan, Roby, Roscoe, Sweetwater, Merkel, Munday, Knox City, Texas: Additions to water supply and sewage treatment plants.	$ 133,000		No		
Haskell, Anson, Moran, Albany, Baird, Rising Star, Olney, Abilene, Newcastle, Texas: Additions to water supply and sewage treatment plants.	136,000		No		
Graham, Ranger, Eastland, Cisco, Gorman, Comanche, Hamilton, Lampasas, Texas: Additions to water supply and sewage treatment plants.	155,000		No		
DeLeon, Mineral Wells, Weatherford, Granbury, Glenrose, Meridian, Hico, Gatesville, Killeen, Georgetown, Cleburne, Hillsboro, Clifton, Waco, Richmond, and Rosenburg, Texas: Additions to water supply and sewage treatment plants.	340,000		No		
Bartlett, Cameron, Thorndale, Marquez, Somerville, Brenham, Amherst, Olton, Hale Center, Slaton, and Post, Texas: Improvements and additions to water supply and treatment.	144,000		No		
Spur, Hermleigh, Rochester, Strawn, Graford, and Palo Pinto, Texas: Improvements and additions to water supply and treatment.	41,000		No		

PROJECT LIST - THE BRAZOS AND COLORADO BASINS

PROJECT	ESTIMATED COST		Authorized By Congress	Authorizing Act	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
3. Construction Projects, Municipal Water Supply and Pollution Abatement					
Lometa, Desdemona, Whitney, McGregor, Moody, West Columbia, Brazoria, and Freeport, Texas: Improvements and additions to water supply and treatment.	$ 126,000		No		
Jayton and Crosbyton, Texas: Water treatment plants and improvements to water supply and sewage treatment plant.	18,000		No		
Eastland, Texas: Dam, reservoir, and treatment plant for water supply on Leon River.	528,000		No		Present city supply is subject to shortages.
Eldorado, Texas: Waterworks and sewer system including treatment plant.	105,000		No		Preliminary plans made.
Elgin, Texas: Water supply improvements.	13,000		No		Preliminary plans made.
Winters, Texas: Dam, pumping equipment and treatment plant for domestic water supply.	84,000		No		Preliminary plans made. Requires re-study.
Bangs, Texas: New filtration galleries and pumps for water supply, and sewerage system.	31,000		No		Preliminary plans made. Requires re-study.
Big Spring, Texas: Water supply reservoir, pipe line, tanks, and filter plant.	500,000		No		Preliminary plans made.
Hobbs and New Hobbs, New Mexico: Sewer system and sewage treatment plant.	159,000		No		Preliminary plans made.

PROJECT LIST - THE BRAZOS AND COLORADO BASINS

PROJECT	ESTIMATED COST		Authorized By Congress	Authorizing Act	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
3. Construction Projects, Municipal Water Supply and Pollution Abatement					
Colorado, Texas: Reservoir, filtration plant, pipe line and pump station for water supply.	$ 184,000		No		Preliminary plans made. Requires re-study on account of high cost.
Smithville, Texas: Deep well, surface reservoir, elevated tank and distribution system for water supply.	185,000		No		Preliminary plans made. Requires re-study on account of high cost.
Miles, Eden, Burnett, Marble Falls, Westbrook, Texas: Sewer systems and sewage treatment plants.	35,000		No		
Bastrop, Robert Lee, Seminole, Seagraves, Sterling City, Coahoma, Bronte, Texas: Sewer systems and sewage treatment plants.	163,000		No		
Robert Lee, Texas: Water treatment plant.	12,000		No		
Smithville, Santa Anna, Eagle Lake, Wharton, Texas: Sewage treatment plants.	63,000		No		
Austin, LaGrange, Weimar, Texas: Additions to water supply systems and sewage treatment plants.	102,000		No		
Columbus, Levelland, Brownfield, Midland, Odessa, Tahoka, Lamesa, Texas: Additions to water supply systems and sewage treatment plants.	115,000		No		

PROJECT LIST - THE BRAZOS AND COLORADO BASINS

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
3. Construction Projects, Municipal Water Supply and Pollution Abatement (cont.)					
Stanton, Big Lake, Snyder, Mertzon, Loraine, and Ballinger, Texas: Additions to water supply systems and sewage treatment plants.	$ 100,000		No		
Coleman, Junction, Cross Plains, Brownwood, Richland Springs, Brady, Mason, Texas: Additions to water supply systems and sewage treatment plants.	44,000		No		
San Saba, Llano, Fredericksburg, Goldthwaite, Texas: Additions to water supply systems and sewage treatment plants.	62,000		No		
Bay City, Texas: Sewage treatment plant.	30,000		No		
Bastrop, Seminole, Seagraves, Texas: Improvements and additions to water supply and treatment.	39,000		No		
Sterling City, Coahoma, Westbrook, Bronte, Miles, Eden, Santa Anna, Texas: Improvements and additions to water supply and treatment.	49,000		No		
Burnett, Marble Falls, Eagle Lake, Wharton, Texas: Improvements and additions to water supply and treatment.	64,000		No		
Palacios, Texas: Improvements to water supply and sewage treatment plant.	30,000		No		

PROJECT LIST - THE BRAZOS AND COLORADO BASINS

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
GROUP B - DEFERRED					
2. Construction Projects, General					
Bell County, Texas: Lampasas reservoir.		$ 1,355,000	No		Under study. Cost estimate approx.
Bell County, Texas: Leon reservoir.		2,382,000	No		Under study. Cost estimate approx.
Madison County, Texas: Navasota reservoir.		2,143,000	No		Under study. Cost estimate approx.
Stephens County, Texas: Breckenridge reservoir.		2,385,000	No		Under study. Cost estimate approx.
Matagorda County, Texas: Matagorda migratory waterfowl refuge.	$ 50,000	25,000	Yes	MBCA	
GROUP C - INDETERMINATE					
Lower Brazos River, Texas: Levee construction and channel improvement for flood control.		15,594,000	No		Estimate of cost approximate. Brazos District and Corps of Engineers are cooperating in study.
Freeport Harbor, Texas: Extension of 30-foot channel	9,000		Yes		Preliminary plans made by C. of E.
Forty reservoirs on Brazos River and tributaries for conservation, flood control, irrigation, urban supply, and power.		Indet.	No		Should await results of study listed in Group A. Does not include reservoirs in program of Brazos Conservation District.
Waco, Texas: Flood protection for City of Waco.		Indet.	No		Depends on results of study listed in Group A.
Brazos River, Texas: Migratory waterfowl refuges.		Indet.	Yes	MBCA	

PROJECT LIST - THE BRAZOS AND COLORADO BASINS

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
GROUP C - INDETERMINATE (cont.)					
Brazos River Basin, Texas: Drainage of lowlands and swamps to eliminate malaria.		$ 230,000	No		Should await results of study project in Group A.
Matagorda, Wharton, and Colorado Counties, Texas: Pumping plants and canals for irrigation system to utilize regulated flows made available by reservoirs.		3,000,000	No		Preliminary surveys now under way by U. S. Bureau of Reclamation.
Colorado Basin, Texas: 28 reservoirs on Colorado River and tributaries for water conservation, for flood control, irrigation, urban supply, and power.		Indet.	No		Should await results of study project in Group A.
Brady, Texas: Flood protection for City of Brady.		Indet.	No		Depends upon results of study project in Group A.
Colorado Basin, Texas: Drainage of swamps and lowlands to eliminate malaria.	$ 645,000		No		Should await results of study project in Group A.
Colorado River, Texas: Migratory wildfowl refuges.		Indet.	Yes	MBCA	
Brown County, Texas: Brown County Water Improvement District project near Brownwood, Texas: Outlet canal from reservoir for irrigation and domestic water supply.	1,000,000		No		Preliminary plans made and project needed but cost excessive.
San Angelo, Texas: Flood protection.		Indet.	No		Should await results of study in Group A.

THE GUADALUPE RIVER BASIN

THE PROBLEM

The most important water problems in the Guadalupe River basin are the control of floods and the conservation of water for all useful purposes. The major single problem of the Guadalupe and San Antonio Rivers is that presented by floods.

The pollution of the San Antonio River has been protested by practically all the counties from the Gulf to San Antonio, and a study should be made to determine the extent of pollution and to make suitable recommendations.

Surveys show that erosion is sufficiently serious to indicate a need for soil and water conservation measures to prevent silting of existing and proposed reservoirs. Land utilization studies of the basin are proposed to assist in devising methods of improving the vegetative cover and bringing about proper land use, which would contribute to the control of floods.

A study of ground water should be made.

GENERAL DESCRIPTION

These drainage basins, including the Lavaca, Guadalupe, and San Antonio Rivers and several minor coastal streams are in southeastern Texas, and extend from the Edwards Plateau to the Gulf of Mexico. They have an area of about 13,000 square miles. North of the Balcones Escarpment, which is the southerly boundary of the Edwards Plateau, these rivers are typical mountain streams with headwaters at an altitude of about 2,300 feet. From the Balcones Escarpment the San Antonio and Guadalupe Rivers descend through a rolling and prairie country for a distance of about 150 miles.

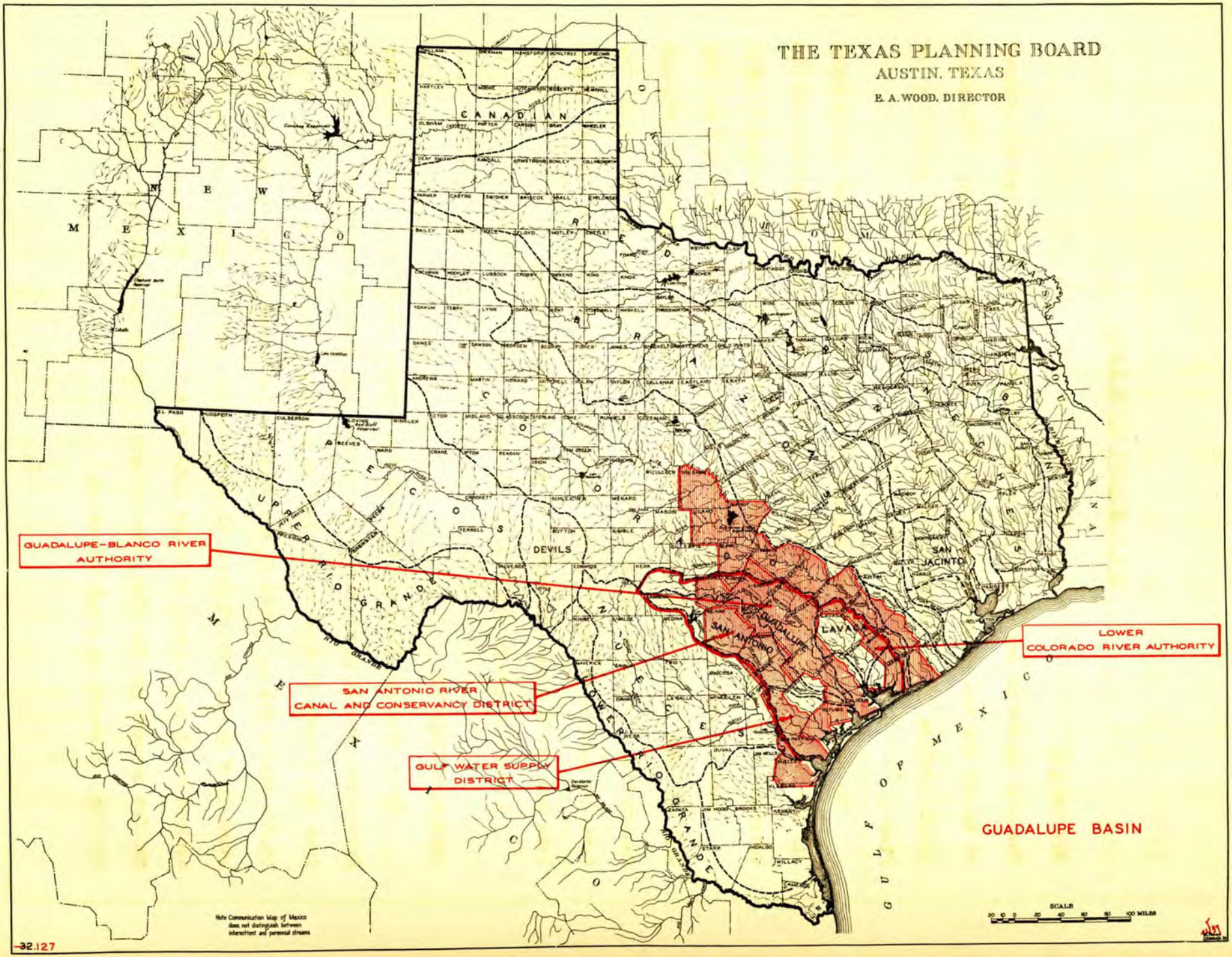
The population of the area is about 555,000 with 30,000 on the Edwards Plateau. Below the escarpment the density of population is about 50 per square mile. Half the population is urban. San Antonio, the principal city, is the industrial, commercial, and transportation center of the region. Oil and gas are produced in several counties.

Quarries for production of crushed limestone and material for cement manufacture are situated along the Balcones fault, and large gravel and sand plants are in operation at Victoria. Other industries scattered through the basin are cotton ginning, cottonseed oil extraction, cotton textiles, brick, hydrate of lime, ice, dairying, and flour milling. Health resorts on the upper Guadalupe bring many seasonal visitors into the region.

In the upper section of the water basin in the Edwards Plateau, cattle, sheep, and goat ranching is the main type of farming. In the lower section of the basin in the Coastal Plain, cotton farming is predominant. In 1935, approximately 2,500,000 acres in the basin were used for crops, or about 27 percent of the land. About 52 percent of the land in 1935 was in pasture, 9 percent being plowable pasture, and 43 percent being woodland pasture.

Agricultural and livestock products include wool and mohair from the Edwards Plateau, poultry and dairy products, raw cotton, pecans, corn, and beef cattle in the Coastal Plain section. Irrigation in the area has been practiced since 1730, but in the lower portion of the basin has been affected by the fact that rainfall in some years is adequate for crop production.

The line of 25-inch average annual rainfall crosses the upper Guadalupe and the valley of the Medina, the main tributary of the San Antonio watershed, above its junction with the latter stream. Below the Edwards Plateau the San Antonio and Guadalupe Rivers receive large additional supplies from springs


THE TEXAS PLANNING BOARD
AUSTIN, TEXAS
E. A. WOOD, DIRECTOR
GUADALUPE-BLANCO RIVER AUTHORITY
SAN ANTONIO RIVER CANAL AND CONSERVANCY DISTRICT
GULF WATER SUPPLY DISTRICT
LOWER COLORADO RIVER AUTHORITY
GUADALUPE BASIN
CANADIAN
DEVILS
SAN JACINTO
GUADALUPE
SAN ANTONIO
LAVACA
RIO GRANDE
GULF OF MEXICO
SCALE
Note Communication Map of Mexico does not distinguish between intermittent and perennial streams
-32.127

having their sources in the plateau. The flow of the San Marcos and New Braunfels springs averages 457 cubic feet per second, or enough to supply nearly one-third of the water consumption of New York City. San Antonio is supplied with water from wells tapping the underground flow. This area is subject to great variation in total annual rainfall. On the Guadalupe River at New Braunfels, the 39-year average rainfall has been 30 inches, with a minimum of 13 inches and a maximum of 60 inches.

Power is produced by twenty-three hydroelectric plants with a total installed capacity of 20,500 kilowatts on the Guadalupe, Comal, and San Marcos Rivers. The cost of production of power by steam, using local oil and gas for fuel, is low and obviously a factor in further development of water power. Most of the hydroelectric energy is consumed within the area, chiefly at San Antonio.

This area is subject to frequent floods, one of the most disastrous of which occurred in 1936. Improper range management coupled with shallow soils and steep slopes accentuate runoff, which contributes materially to floods. Straight-row culture, overgrazing, and lack of soil and water conservation measures amplify the rapidity and volume of runoff from this section. The Corps of Engineers recommended in a "308" report a plan for the conservation and development of the waters of the Guadalupe River for navigation, water power development, flood control, and irrigation. The plan covered the Guadalupe only and due to recent floods appears inadequate to provide complete flood control.

The Corps of Engineers is now making a preliminary examination and survey of the Lavaca and Navidad Rivers for navigation and flood control. The Guadalupe River Authority is making studies and is proposing irrigation, development of

hydroelectric power, and conservation of water for flood control, industrial, and domestic uses.

This rather thickly settled portion of the State is served by a large number of antiquated sewage treatment plants, the pollution from which is especially noticeable because of the normal clear water, most of which originates from springs. These rivers are used for swimming and for drinking water supplies by campers as well as by residents along the banks. Oyster beds and important shellfish areas are located at the mouths of these rivers in the bay. Pollution of these areas by sewage should be eliminated.

A number of the communities obtain their supplies of water from deep wells or springs. Numerous water-supply projects have been completed in these basins with Public Works Administration loans and grants, and others are under consideration. Some malaria exists in the Coastal region of the basin.

Measurements of Stream Flow. An intelligent and economical development of the water resources cannot be made without a reliable record of the surface runoff and its distribution over the area. At the present time the U. S. Geological Survey, in cooperation with the Texas Board of Water Engineers, is maintaining only nine stream flow stations in the basin. Some of the equipment at these stations is becoming old and in need of repair. A number of additional stream flow stations should be installed and maintained for sufficient time to give adequate records. The construction of flood control reservoirs will require the installation of new stations in connection with their operation, as the larger floods will be caused by tropical storms, producing flashy floods of great volume. The successful operation of these reservoirs will depend upon the operators having notice at the earliest possible moment of flood-producing

rises in the river. Therefore, stream flow stations used for this purpose should be equipped with instruments capable of transmitting the information for a considerable distance, or arrangements should be made for obtaining telegraph reports directly from the stations.

Ground Water Surveys. This area includes some of the largest springs in the Southwestern part of the United States, representing large present and potential sources of supply for public, industrial, and irrigation purposes. It is important to determine the interrelationship between the springs and deep wells of the area in order that the springs may be protected from depletion. Preliminary ground-water surveys have been completed or are in progress in four counties.

Topographic Mapping. Practically the only topographic mapping so far done is on the upper reaches, and covers a few of the possible reservoir sites. Maps of the river channel and narrow strips of adjacent overflow lands have been made in the lower reaches.

Climatological Data. The Guadalupe basin of about 7,000 square miles extends from the hilly section of the Edwards Plateau, with very intense rainfalls of moderate duration down to the coastal area with intense rains of long duration. In this area are now one automatic recording rainfall gauge, 2 evaporation stations, and 23 standard rainfall stations.

RECOMMENDED PLAN

The Corps of Engineers, in its "308" report, suggested a long-range plan for the development of the Guadalupe River, as follows:

1. Construction of seven run-of-the-river power projects between Gonzales and Victoria.

2. Construction of the Canyon Reservoir.

3. Construction of the Wimberly Reservoir.

4. Construction of levees.

5. Construction of a navigation project. Victoria to Gonzales.

It is suggested that the Canyon reservoir will be economically justified when the head of the river below is fully developed for power, but that it is not justified with the present installations. Besides controlling floods, the Wimberly reservoir will afford 31,000 acre feet of water for irrigation purposes during the crop season. The potential savings on transportation charges through the use of an improved river for navigation do not appear to justify such a project at this time. Consequently, power developments should not be delayed, but licenses for such dams between Victoria and Gonzales should be granted only for such sites as can be fitted into a navigation project and should contain a provision for a right-of-way through the power site for navigation purposes.

Since the above plan was submitted, an unprecedented flood in 1936, below the Canyon and Wimberly sites, caused damages in excess of $2,000,000. Consequently, a revision of the above plan and a flood control study of the entire basin is recommended.

It is recommended that the study now under way by the Corps of Engineers of the Lavaca and Navidad Rivers be extended to include the entire basin and that it be expanded in scope to include conservation of water for irrigation, generation of electric energy, and industrial and municipal uses; and that the

study being made by the Guadalupe River Authority be coordinated with the Corps of Engineers' study. It is recommended funds be made available for this study.

Stream Pollution. It is recommended the antiquated sewage treatment plants of the area be rehabilitated or reconstructed. Better operation and maintenance of existing plants is recommended.

Malaria Control and Prevention should be given consideration.

Water Supply. Many of the domestic water supply plants of the smaller towns of the basin should be reconstructed or extended.

Land Use and Conservation. A long-time program of water and soil conservation should be planned for this basin for the retardation of runoff and the prevention of erosion, including all effective and economical measures which are known to be applicable. Consideration should be given to needed changes in land tenure and methods of use, with particular attention to the problem of improving range cover in the upper third of the Basin, lying in the Edwards Plateau. Additional surveys and investigations will be needed to make possible the preparation of a detailed plan for each land ownership unit. Sedimentation studies should be made of existing reservoirs, and preliminary preparations made for such studies on sites for proposed reservoirs.

Measurements of Stream Flow. An intelligent and economical development of the water resources cannot be made without a reliable record of the surface runoff and its distribution over the area. At the present time the U. S. Geological Survey, in cooperation with the Texas Board of Water Engineers, is maintaining only nine stream flow stations in the basin. Some of the equipment at these stations is becoming old and in need of repair. A number of additional stream flow stations should be installed and maintained for sufficient time to

give adequate records. The construction of flood control reservoirs will require the installation of new stations in connection with their operation, as the larger floods will be caused by tropical storms, producing flashy floods of great volume. The successful operation of these reservoirs will depend upon the operators having notice at the earliest possible moment of flood-producing rises in the river. Therefore, stream flow stations used for this purpose should be equipped with instruments capable of transmitting the information for a considerable distence, or arrangements should be made for obtaining telegraph reports directly from the stations.

Ground Water Surveys. This area includes some of the largest springs in the southwestern part of the United States, representing large present and potential sources of supply for public, industrial, and irrigation purposes. It is important to determine the interrelationship between the springs and deep wells of the area in order that the springs may be protected from depletion. Preliminary ground water surveys have been completed or are in progress in four counties.

Topographic Mapping. Practically the only topographic mapping so far done is on the upper reaches, and covers a few of the possible reservoir sites. Maps of the river channel and narrow strips of adjacent overflow lands have been made in the lower reaches.

Climatological Data. The Guadalupe basin of about 7,000 square miles extends from the hilly section of the Edwards Plateau, with very intense rainfalls of moderate duration down to the coastal area with intense rains of long duration. In this area are now one automatic recording rainfall gauge, 2 evaporation stations, and 23 standard rainfall stations.

Wildlife Conservation. Flood control and water conservation projects

within the Guadalupe watershed will offer excellent opportunities for wildlife development, and the needs of wildlife should be taken into consideration in carrying out these projects. The Aransas wildlife refuge in Aransas County should be completed.

Measurements of Stream Flow. To obtain a record of the surface runoff and its distribution over the basin, it is recommended that the stations now in operation be continued and the equipment improved. It is further recommended that about nine additional stream flow stations be installed and maintained for sufficient time to give adequate records. As the flood control reservoirs are constructed, it is recommended that additional stream flow stations be installed in connection with these projects to assist in their successful operation, and that these stations be equipped with instruments capable of transmitting the information for a considerable distance to the operators.

Ground Water Surveys. The preliminary ground water studies now in progress should be extended to the entire area and should be followed by extensive detailed studies in parts of the area to determine how much pumping from wells can be carried out without depleting the flow of the large springs.

Topographic Mapping. It is recommended that the lower river basin be mapped for flood control, drainage, and ground water investigation, that the middle reaches, along the Balcones Escarpment be mapped for reservoir sites and ground water investigations and that the upper reaches be mapped for reservoir sites, erosion control and ground water investigation.

Climatological Data. To serve this area, it is recommended that there be added one automatic recording rainfall station, one evaporation station, and two standard rainfall stations.

PROJECT LIST - THE GUADALUPE RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
GROUP A - IMMEDIATE					
1. Investigation Projects					
Study of coordinated utilization of the water resources of the Guadalupe and San Antonio basins for flood control, water power, irrigation, navigation.	$ 200,000		No		Continuation and extension of study made by Corps of Engineers.
Ground water survey of Guadalupe Basin.	41,000	$ 100,000	No		To develop ground water to best advantage, particularly in those areas where supplies are unsatisfactory.
Upper Guadalupe Basin, Texas: Topographic mapping of upper reaches of Basin.	50,000	150,000	No		To assist in solving flood problems of this Basin.
Guadalupe Basin in Coastal Plain, Texas: Topographic mapping of Coastal Plain area for drainage and flood control.	125,000	300,000	No		
Guadalupe Basin, Texas: Study of drainage problems to eliminate malaria in Basin.	5,000	5,000	No		
Stream pollution study.	10,000	10,000			To assist in controlling stream pollution by investigation of procedures and recommendations regarding treatment.
Portions of the Guadalupe, Lavaca, and San Antonio River watersheds, Texas: Detailed conservation survey.	5,040		Yes	Pub. 738	Area to be selected.

All of the above Hydrologic Studies and Topographic Mapping should be done in accordance with approved methods, by competent agencies, and the results made readily and promptly available to the public, and periodically published in standard form.

PROJECT LIST - THE GUADALUPE RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
1. Investigation Projects (cont.)					
Entire Guadalupe Basin, Texas: Area study, land utilization, involving study of economic factors, present land and water use and problems, adjustments needed, to assist in devising measures or procedures required to carry out recommended adjustments.	$ 65,000		Yes	Pub. 210 and 738	Study of land use and economic phases dependent upon preliminary surveys already under way or contemplated by the Flood Control Coordinating Committee of the USDA.
2. Construction Projects - General					
Channel from Pass Cavallo to Port Lavaca, Texas: navigation.		$ 116,874	Yes	1	Funds necessary for completion of projects.
Guadalupe River, Texas: Twelve additional gaging stations on Guadalupe River and tributaries.	13,600		No		Present stations not sufficient to cover area. Annual operation $5,200.
Guadalupe River and tributaries, Texas: Additional rainfall and evaporation stations.	1,100		No		Present stations too few in number and too widely scattered to yield adequate data. Annual operation $620.
Aransas County, Texas: Aransas migratory waterfowl refuge.	40,000	20,000	Yes	MBCA	
3. Construction Projects - Municipal Water Supply and Pollution Abatement					
Cuero, Victoria, Goliad, Refugio, Woodsboro, Edna, El Campo, Port Lavaca, Austwell, Seadrift, Palacios, Texas: Improvements to sewage treatment plants.	133,000				
Blanco and Stockdale, Texas: Water supply systems.	50,000				

PROJECT LIST - THE GUADALUPE RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
3. Construction Projects - Municipal Water Supply and Pollution Abatement (cont.)					
New Braunfels, San Marcos, Seguin, Nixon, Kenedy, Runge, Yorktown, Luling, Lockhart, Waelder, Gonzales, Hallettsville, Yoakum, Texas: Improvements to sewage treatment plants.	$ 192,000				
Refugio, Woodsboro, Edna, El Campo, Port Lavaca, Austwell, Seadrift, Palacios, Texas: Water supply improvements.	75,000				
Bandera, New Braunfels, Floresville, Kenedy, Luling, Lockhart, Waelder, Gonzales, Hallettsville, Yoakum, Cuero, Victoria, Texas: Water supply improvements.	147,000				
Blanco, Boerne, Floresville, Stockdale, Kyle, Bandera, Texas: Sewer systems and sewage treatment plants.	160,000				
Victoria, Texas: Waterworks.	74,000		No		Preliminary plans made.
Ganado, Texas: Waterworks and sewer system.	54,000		No		Preliminary plans made.
Kyle, Texas: Waterworks.	38,000		No		Preliminary plans made.
Rockport, Texas: Sewer system and treatment plant.	40,000		No		Preliminary plans made.

PROJECT LIST - THE GUADALUPE RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
GROUP C - INDETERMINATE					
Canyon reservoir on Guadalupe River.		$ 2,600,000	No		Depends on study in Group A.
Wimberly reservoir on Blanco River.		4,800,000	No		Depends on study in Group A.
Levees on Guadalupe River.		235,000	No		Depends on study in Group A.
Reservoirs on Guadalupe and tributaries for flood control, irrigation, urban supply, and power.			No		Depends on results of study project in Group A.
Falls City irrigation project.			No		Depends on results of study project in Group A.
Guadalupe Basin, Texas: Drainage of marshland in selected counties of the Basin for elimination of malaria.		450,000	No		Should await results of study in Group A.

THE NUECES RIVER BASIN

THE PROBLEM

The economic necessity exists in the Nueces River Basin, to conserve for irrigation the water now wasted by damaging floods. During the past decade, the hydrostatic head of the ground water supply, upon which the Winter Garden District largely depends for irrigation through artesian and pumped wells, has steadily fallen. Large areas of formerly highly productive lands now lie fallow or in pasturage, due to failure of artesian flow or increased pumping costs. To rehabilitate and maintain farm values, whose products from these fertile lands form the larger part of the earning power of this section of Texas, is the urgent need of the Nueces River Basin. Several communities need new or better assurance of their domestic water supplies. The progress of erosion on the agricultural and grazing lands indicates that soil and water conservation measures are needed to reduce further sedimentation damage to reservoirs and other stream improvements.

GENERAL DESCRIPTION

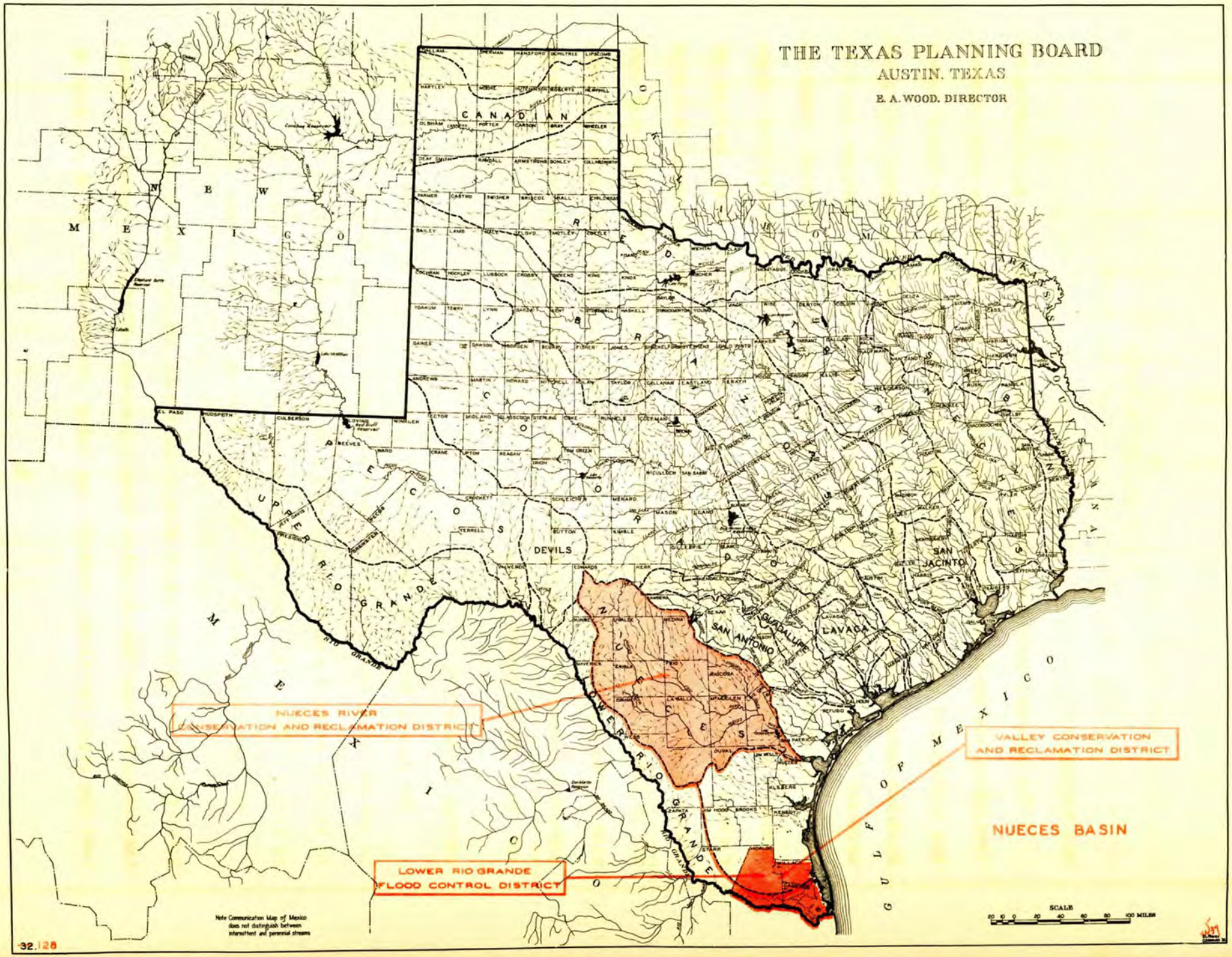
The Nueces River and its tributaries drain an area of 16,500 square miles in extent and discharge into the Gulf of Mexico at Corpus Christi. The Basin as treated in this report also includes an area of coastal lowlands about half as large. With its longest tributary, the river is 366 miles in length.

The headwaters are in the Edwards Plateau at a maximum altitude of 2,100 feet - a region of steep slopes and little cover. From the plateau the land drops in less than 40 miles through canyons affording a number of excellent dam sites for flood control and water conservation, to an altitude of

about 1,000 feet in the region of the Balcones fault. Below this fault lies the outcrop of the Carrizo sandstone, a belt three to six miles in width. Through this faulted and porous zone much seepage is lost into underground channels, estimated by the U.S.G.S. at more than 150,000 acre feet annually. The problem here is to bring the water from above the fault zone to irrigable lands below without excessive seepage loss; however, much of this seepage passes into the Edwards limestone.

The soils in the Winter Garden area are thinner and relatively more drought resisting than the Blackland prairie soil found in the humid regions of the Coastal Plain. There is little alluvial soil. Only a small part of the area is in crop production at present, and of this, about half is irrigated. 1,600,000 acres, (or about 11 percent of the Nueces Basin), were used for crops in 1935. About one fifth of the land, or 3,000,000 acres, is in the rocky hill country above, or in divides, just below the Balcones fault, and classified as woodland pasture. The remainder of the Basin is now generally devoted to grazing, but the major portion consists of tillable and fertile lands.

The irrigated lands comprised about 38,000 acres, in 1930, lying immediately below the Carrizo sandstone outcrop in an area commonly called the Winter Garden. Citrus fruit culture on irrigated lands in the Winter Garden District, is successful and growing in importance. Flax growing has been successfully demonstrated. Spinach and onion raising and all truck farming is highly productive, and the Texas State Experimental Station near Carrizo Springs is working on new crops adaptable to this area. The final conditioning and fattening of livestock has been successfully demonstrated by field feeding of alfalfa and small grains grown under irrigation methods, and is a potential use of new irrigated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NUECES RIVER CONSERVATION AND RECLAMATION DISTRICT
VALLEY CONSERVATION AND RECLAMATION DISTRICT
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NUECES BASIN
SCALE
Note Communication Map of Mexico does not distinguish between intermittent and perennial streams
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lands in conjunction with the vast areas of range grazing lands adjacent thereto.

The dry farming country near Corpus Christi produces vegetables and a large amount of cotton.

The total population of the Nueces drainage basin in 1930 was 250,000, an average density of 10 per square mile. About one quarter was urban. Corpus Christi, a deep water port, the largest city in the watershed, has grown since 1935 from 28,000 to more than 50,000 population. San Antonio, situated just outside the watershed, is the metropolis for the region.

Along the coast an important navigation improvement, the Intracoastal Canal, has been authorized by Congress as far as the Port of Corpus Christi. Its completion will increase the importance of that port, which will then be the western terminus of a system of barge canals, serving the Gulf coast west of the Mississippi River, and will be an important factor in the shipping facilities of the Nueces River Basin.

During recent years oil production has grown to major importance throughout the Basin. There is a sulphur mine, west of San Diego and rock asphalt is mined in the area west of Uvalde, supplying the southwestern market of street and highway construction. An alkali plant has recently been put into operation at Corpus Christi. Two major operators are planning meat packing plants at Corpus Christi, this development awaiting only the assurance of an adequate water supply.

The Basin is in the sub-humid zone; annual precipitation rangesfrom 20 to 30 inches. Extremes in annual precipitation range from 8 to 45 inches. The Spring (April, May, and June) and Fall (September and October) are the seasons of maximum rainfall, with fairly even distribution of rainfall but insufficient

for growing crops, throughout the balance of the year. Runoff is highly variable, some of the streams being dry at times. The average annual discharge of the Nueces River and its tributaries at Three Rivers is about 600,000 acre feet; the minimum annual flow is 2.1 percent of the maximum.

The two major problems of this Basin are the control of floods and the conservation of water for irrigation. Some of the most intense rains ever recorded in the United States have centered over the headwaters of the Nueces Basin. Because of such storms and scantily covered slopes, flood discharges are among the highest in the United States, in proportion to the drainage area.

The magnitude of the flood control problem may be visualized by considering the greater of two floods that occurred in the basin in 1935. In June of that year there was a peak flow estimated at more than 660,000 cubic feet per second from a drainage area of 400 square miles. Depths of 32.4 feet at Cotulla and 44.7 feet at Three Rivers were recorded. The damage was estimated at about $10,000,000. The lower end of the Basin, with its almost flat slopes and poor natural drainage, has experienced flood waters as much as eight miles in width, covering this agricultural land to a depth of several feet.

There is more agricultural land adaptable to irrigation, under subtropical climatic conditions, than can be supplied by the water now available. The marked variation in annual stream flow and the prospect of seepage losses in the Balcones fault and the Carrizo sand zone, have so far prevented the utilization of any great amount of the surface water for irrigation. About 27,000 acres in the Winter Garden region are irrigated from wells; the average annual withdrawal of water — 20,000 acre feet — exceeds the recharge rate, thus producing the present critical situation.

Generally speaking, this basin approaches an ideal setup as a water conservation project, being endowed by nature with climate and soils which produce abundantly a variety of crops and lacking only the regularity of sufficient rainfall. Its northern areas are relatively high in elevation; and over rocky and broken country, intense rainfall occurs during short rainy seasons. Great concentrations of runoff sweep down through the Nueces River and its tributaries, causing great damage, and is lost to utiliterian purposes. The conservation of these waters behind storage dams and their transfer to the fertile lands in the Coastal Plain below, will bring about the development so vitally needed in this Basin.

Construction plans are ready for storage reservoirs at three locations. As the result of private engineering initiative, construction of the Cotulla Dam was started. Engineering reports are available covering several other locations. The definite reality of the economic need for water control and development in this basin is evidenced by the fact that in the decade 1920-1930 the citizenship of the Basin expended over $300,000 in engineering investigations for conservation and flood control projects. These isolated projects, however, do not consider the Basin as a coordinated whole.

The Nueces River Conservation and Reclamation District, organized under Texas law, also has made a preliminary study and is continuing its investigation. The Corps of Engineers has made a preliminary examination of the watershed and has begun a detailed survey for flood control and allied purposes. On the foundation provided by these studies, a plan for these improvements will be devised. The results of these basin-wide studies will determine the amount of water available, proper means for its control, the lands to which it can be applied

with maximum benefit and the cost and nature of flood control measures with full consideration given to proper coordination between flood control and irrigation. The detailed studies and plans by private interests of the several irrigation projects within the District will be included in the present study for coordination with the flood control program.

A dependable water supply for some municipalities in this basin is an urgent problem. Most of the communities obtain their supply from underground sources. Corpus Christi, however, gets its supply from the Nueces River, impounding the water at the La Fruta Dam. Improvements to this system are now under construction. Improvements are proposed in the water supply systems of several smaller communities.

An intelligent and economical development of the water resources can not be made without a reliable record of the surface runoff and its distribution over the area. The determination of large water losses by seepage in the faulted areas is of major importance. The U. S. Geological Survey, in cooperation with the Texas Board of Water Engineers, is maintaining only eight stream flow stations in the Basin. Some of these are not equipped with water-stage recorders and at others the equipment is becoming old and in need of repair. Additional stations should be installed and maintained for sufficient time to give adequate records. When large reservoirs are constructed in the Basin, additional stations will be needed to assist in the proper regulation of the flashy floods produced by tropical storms.

In this area the relation between ground water inflow to the streams and seepage losses into the underground reservoirs from the streams is exceedingly complicated, and it is impossible to evaluate the water resources of the area

without adequate understanding of ground water conditions. Ground water surveys have been made by the Texas Board of Water Engineers, in cooperation with the U. S. Geological Survey, or are in progress in seven counties, and several reports have been published dealing with the ground water supplies including the supply available for the winter garden district, which is famous for its production of winter vegetables.

Very little mapping has been done in this basin. Some of the known reservoir sites have been mapped for investigation, but not for construction. A small amount of reconnaissance mapping has been done on the upper reaches.

In this basin of about 18,000 square miles occur some of the most intense storms and highest peak floods known in the United States. A basin of great potential value, it is poorly supplied with climatological stations. The present list comprises one automatic recording rainfall station, one evaporation station and 23 standard rainfall stations.

RECOMMENDED PLAN

Flood Control and Irrigation. It is recommended that funds be provided to complete the study of the basin now under way by the Corps of Engineers.

Ground Water Survey. It is recommended that funds be provided to complete the ground water studies of the basin. Proper legislation, which is in process of preparation, to provide for the administration of the use of ground water supplies should be enacted.

Domestic Water Supply. The improvements proposed to the water supply system of several of the towns should be made.

Stream Pollution. Sewage treatment plants proposed for many of the towns of the basin should be constructed.

Irrigation as a means of disposal of sewage probably would be practicable in this area and would tend to keep the streams free from pollution.

Land Use and Conservation. The development and application of a complete coordinated plan of water and soil conservation is needed to reduce runoff and control erosion in the Nueces Basin. Such a program should include all methods and practices which can be effectively and economically applied in this area. Recommended changes in land tenure and use should give special consideration to the treatment of pasture land, comprising the greater portion of the Basin. Additional farm reservoirs for stock water supply should be built, where soil conditions make this feasible, to facilitate the practice of controlled grazing, which is essential to the improvement of range cover. Further surveys and investigations are recommended to make possible the formulation of specific plans for the treatment of individual land units. Preliminary preparations should be made for sedimentation studies on the sites of the Cotulla and other proposed reservoirs.

Wildlife Conservation. Wintering and migrating waterfowl and other wildlife will be definitely aided by the proposed flood control and water conservation projects on the Nueces watershed, and wherever it is possible without interfering with the original purpose of the project, consideration should be given to the needs of wildlife in developing the area.

Measurement of Stream Flow. To obtain the necessary records of surface runoff and its distribution over the Basin as well as seepage losses, it is recommended that the stations now in operation be continued and the equipment improved. It is further recommended that about nine additional stations be installed and maintained for sufficient time to give adequate records. When

flood control reservoirs are constructed, it is recommended that additional stations be installed in connection with these projects to assist in the proper regulation of flood waters.

Ground Water Survey. Extensive ground water surveys have been made in this area, but much more remains to be done and moreover the investigation should be a continuing one. Preliminary ground water surveys should be made in all parts of the area that have not been covered heretofore and the analytical quantitative studies should be continued.

Topographic Mapping. It is recommended that the lower reaches be mapped for flood control, and in some localities, for drainage. The middle and upper reaches should have maps made of reservoir sites. Along the Balcones Escarpment maps should be made for ground water investigation. In the area known as the "Winter Garden" in Uvalde, Maverick, Zavala and Dimmit Counties, adequate maps should be prepared at an early date to aid in ground water surveys including possibilities of artificial recharge.

Climatological Data. To secure the added necessary records, it is recommended that there be installed and maintained 2 automatic recording rainfall gauges, one evaporation station, and 4 standard rainfall stations, and that those now in operation be continued.

It is recommended that all of the above hydrologic studies and topographic mapping be done in accordance with approved methods, by competent agencies, and that the results be made readily and promptly available to the public, and periodically published in standard form.

PROJECT LIST - THE NUECES RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
GROUP A - IMMEDIATE 1. Investigation Projects					
Nueces River and tributaries, Texas: Survey for flood control and allied purposes.	$ 125,000		Yes		Now under way by Corps of Engineers. Amount necessary to complete.
Nueces Basin, Texas: Ground water survey of basin.	37,000	$ 95,000	No		To develop ground water to best advantage, particularly in those areas where supplies are unsatisfactory.
Lower Nueces Basin, Texas: Topographic mapping -- all of Nueces, Jim Wells, Kenedy, and Kleberg Counties.	50,000	200,000	No		Control already established in Nueces County. Work can begin at once.
Nueces Basin, Texas: Malaria control study.	5,000	5,000	No		Comprehensive study of drainage problems throughout basin.
Portion of Frio River watershed, Texas: Field application of soil and water conservation measures.	80,000	120,000	Yes	Pub. 46	Area to be selected.
Portions of Nueces River, San Fernando and Los Olmos Creek watersheds, Texas: Detailed conservation survey.	11,600		Yes	Pub. 738	Area to be selected.
Nueces Basin, Texas: An area study of land use and economic factors to assist in devising plans for needed land retirement and major land and water use adjustments to insure a proper coordinated land and water utilization program.	30,000	50,000	Yes	Pub. 210 and 738	Study of land use and economic phases dependent upon preliminary surveys already under way or contemplated by Flood Control Coordinating Committee of the U. S. Dept. of Agriculture.

PROJECT LIST - THE NUECES RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
2. Construction Projects - General					
Sabine River to Corpus Christi, Texas: Intracoastal waterway. Navigation.		$ 4,900,000	Yes	3	Funds necessary to complete project.
Port Aransas, Texas: Navigation.		333,430	Yes	3	Funds necessary to complete project.
Additional rainfall and evaporation stations in sub-basin.	$ 2,340		No		Present stations are too few in number to yield adequate data.
Eight additional stream gaging stations in Nueces basin.	12,700		No		Present gaging stations do not cover enough territory. Annual operation $3,400.
La Salle and McMullen Counties, Texas: Fowlerton project. Irrigation reservoir and canal.		2,500,000	No		Preliminary study completed.
Zavalla County, Texas: No. 2 project. Irrigation, reservoirs, and lined canal.		5,000,000	No		Preliminary study completed.
La Salle County, Texas: Cotulla project, irrigation, reservoir, and lined canal.		5,800,000	No		Preliminary study completed.
Uvalde County, Texas: Shut-in project, Frio River, irrigation, reservoir, and lined canal.		3,500,000	No		Preliminary study completed.
Nine reservoirs on Nueces River and tributaries for conservation, irrigation, flood control, and urban supply.		Indet.	No		Preliminary study completed.

PROJECT LIST - THE NUECES RIVER BASIN

PROJECT	ESTIMATED COST				REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
3. Construction Projects, Municipal Water Supply and Pollution Abatement					
Beeville, Alice, Falfurrias, Bishop, Sinton, Taft, Robstown, Texas: Sewage treatment plant improvements.	$ 134,000				
Uvalde, Asherton, Catarina, Sabinal, Pearsall, Dilley, Cotulla: Sewage treatment plant improvements.	46,000				
Hondo, LaPryor, Encinal, Poteet, Jourdanton, Devine, Christine, Hebbronville, Three Rivers, Mathis, Odem, Sabinal, Texas: Sewer system and treatment plants.	305,000				
Three Rivers, Beeville, Kingsville, Bishop, Mathis, Sinton, Taft, Robstown, Crystal City, LaPryor, Rock Springs, Uvalde, Hondo, Encinal, Poteet, Jourdanton, Christine, Hebbronville, Alice, Carrizo Springs, San Diego, Fowlerton, Texas: Improvements to water supply.	574,000				
Woodsboro, Benavides, Texas: Water and sewer systems.	162,000		No		
Freer, Texas: Water supply system.	30,000		No		
GROUP C - INDETERMINATE					
Malaria control project: Construction of main and lateral ditches. Nueces River Basin.	350,000	$ 725,000	No		Should await results of study project in Group A.

THE LOWER RIO GRANDE AND PECOS BASINS

THE PROBLEM

The prime necessity, so far as the Lower Rio Grande Basin is concerned, is a treaty with Mexico covering division and control of the waters of the Rio Grande below Fort Quitman, and providing for the construction and operation of reservoirs on the main stream which is the international boundary. For the Basin as a whole, the major problems are conservation of water for irrigation, as well as the control of floods. A comprehensive drainage system for the irrigated area in the Lower Valley is an immediate and vital need.

Despite the fact that an average of about 4,500,000 acre feet of unused flood waters flow annually from the Rio Grande into the Gulf of Mexico, Texas irrigators who are dependent on the stream for a livelihood suffer losses at times because at low flow the supply of water is insufficient. Furthermore, the water supply is being depleted by extensive increases in upstream uses particularly in Mexico, as well as to some extent on the American side. Studies of actual and potential water requirements on the United States side of the Lower Rio Grande, because of the complexity and international aspect of the problem, should be continued but should not delay treaty negotiations.

An interstate problem exists on the Pecos River, the meager waters of which are being used in both New Mexico and Texas. Negotiation of an interstate compact covering this stream is essential and should be completed expeditiously so that use of the waters of the Pecos may be stabilized and the maximum benefit obtained.

Other needs in these watersheds involve local problems of domestic supply, irrigation supplies from wells, and the control of erosion and rehabilitation,

protection, and management of watershed lands.

Studies of ground water resources in both the Lower Rio Grande and Pecos Basins are necessary.

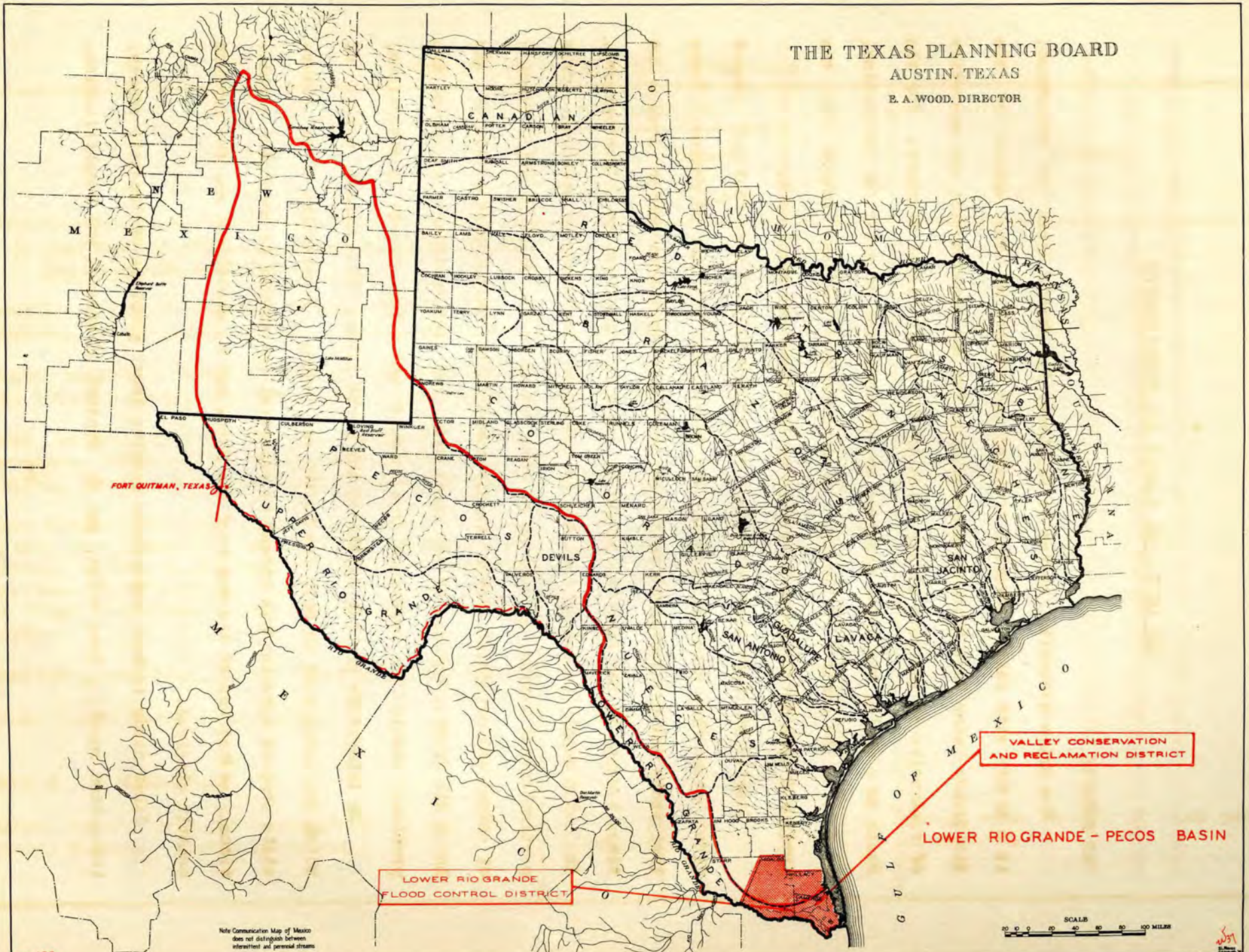
GENERAL DESCRIPTION

The Rio Grande, the boundary for 1,300 miles between the United States and Mexico, drains an area below Fort Quitman nearly as large as the State of California. More than half of this area is in Mexico. About 70 percent of the water in the Lower Rio Grande originates south of the boundary. From Fort Quitman to its junction with the Devils River near Del Rio, a distance of some 570 miles, the Rio Grande flows through a mountainous section with small isolated valleys. From Del Rio, at an altitude of 950 feet, to Penitas, which lies 800 feet lower, the Rio Grande traverses nearly 400 miles of rough broken country with narrow valleys and broad areas of tablelands. The Lower Rio Grande Valley, as opposed to the lower basin as here defined, extends from Penitas to the Gulf of Mexico, a distance of 175 miles by the river but only 70 miles in a straight line. This area is a broad fan-shaped coastal plain.

At infrequent intervals the low flow of the Rio Grande in its lower valley is insufficient to supply irrigation demands. At other times there are great floods which result in overflows. Floodways on both sides of the river are being provided to relieve the flood conditions and to carry excess water to the Gulf.

In the Rio Grande Basin below Fort Quitman, there are about 1,100,000 acres in existing irrigation projects on the Texas side of the river of which about 470,000 acres are now being irrigated. There are other large areas which are susceptible to irrigation.

While the concern here is with that part of the Lower Rio Grande Basin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GUADALUPE
LAVACA
SAN ANTONIO
MEXICO
GULF OF MEXICO
FORT QUITMAN, TEXAS
VALLEY CONSERVATION AND RECLAMATION DISTRICT
LOWER RIO GRANDE - PECOS BASIN
LOWER RIO GRANDE FLOOD CONTROL DISTRICT
Note: Communication Map of Mexico does not distinguish between intermittent and perennial streams
SCALE
20 10 0 20 40 60 80 100 MILES

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within the United States, that which lies in Mexico cannot be ignored. Three important tributaries enter the Lower Rio Grande from the Mexican side on which extensive developments are being made. There is sufficient arable land on either the American or Mexican side of the Rio Grande to require all the waters of the stream in its development. Construction of large-scale irrigation projects on the Mexican side has proceeded less rapidly than in Texas, but construction is now increasing rapidly.

The Pecos River, a tributary of the Rio Grande, drains an area about equal to that of Kentucky. This river and its chief tributaries rise in mountainous areas in New Mexico, principally in National Forests, at elevations varying from 7,500 feet to more than 13,000 feet. Between the mountains and the river below Santa Rosa, New Mexico are mesas and plains, having grass vegetation with some shrubs and trees. Scattered flood plain areas along the Pecos and its tributaries constitute the irrigated lands. The main stream may become dry in places each summer; however, during the same period when torrential rains are common, disastrous floods may occur.

The normal flow of the river and its tributaries disappears from place to place in river bed sands, reappearing in part farther down stream. The Pecos, from Sheffield, Texas to its junction with the Rio Grande, below Langtry, and the Devils River from Ozona, Texas to its junction with the Rio Grande above Del Rio, flow through rough, canyon country.

Below high mountain altitudes, the Lower Rio Grande-Pecos Basin is semi-arid. The precipitation undoubtedly amounts to as much as 35 inches and more annually in the high mountains and reaches an average annual of about 25 inches near the Gulf of Mexico, but in the greater part of the basin it ranges from

less than 10 to about 16 inches.

The soils are generally absorptive, but due to the rolling to mountainous topography, thin vegetative cover and lack of soil and water conserving practices, much of the rainfall is lost during the more intense rains.

The present population of the Lower Rio Grande-Pecos area in the United States is more than 450,000, of which 200,000 are urban. About 275,000 live in the Lower Rio Grande Valley. Practically all crops are the result of irrigation. In the vast area where dry farming is not practicable and where water is not available for irrigation, encompassing all the central part of the basin, stock raising is the chief industry. In addition to agriculture, the chief industries of the basin are the canning of fruits, fruit juices, and vegetables, the production of oil, gas and other minerals and the refining of oil. Crops produced by irrigation in the Lower Rio Grande Basin are of wide variety, including citrus, winter vegetables, cotton, corn and feedstuffs, the latter being desirable to supplement uncertain pasturage and is generally regarded as of considerable importance in the regional economy.

About 210,000 acres are irrigated in the Pecos Valley which supports 120,000 people. Wells and springs provide for the irrigation of a substantial area. Principal crops produced by irrigation are cotton, alfalfa, vegetables, and fruit. Stock raising is an important industry in this basin.

Toyah Creek, a main tributary of the Pecos furnishes the principal water supply for the Reeves County Water Improvement District Number One in the vicinity of the towns of Balmorhea and Saragosa. This project and adjoining irrigated areas include 12,000 acres of cultivated land at the foothill of the Davis Mountains. A reservoir of 7,000 acre feet capacity, constructed in 1915 has been

silted to approximately one-half its capacity. The use of water for irrigation in this area dates back to about 1840.

Soil erosion has become a major problem in the Lower Rio Grande-Pecos Basin. Summer rains often of cloudburst intensity convey immense quantities of mud and debris to drainageways. Spring flows from rain and melting snow in the mountains tend to move these channel deposits and cause bank erosion. Silt deposits increase the cost of maintenance of irrigation systems, and are a menace to reservoirs. Any remedy for silting must include control of the silt at its origin. The restoration of native vegetation, which affords natural protection against accelerated runoff, erosion, and silting, is a major consideration. Watershed management is required to reduce silting, insure maximum surface and ground supply, reduce the flood hazard, and maintain the forest, range and farm resources of the basin in a state of maximum productivity.

Measurements of stream flow are essential for the intelligent and economical development of the water resources. At the present time the International Boundary Commission - United States and Mexico are maintaining thirty-five stations along the Rio Grande and near the mouth of all tributaries of importance. Also, the U. S. Geological Survey, in cooperation with the Texas Board of Water Engineers, is maintaining five stations on tributary streams.

The ground water area in this basin includes the great springs of Balmorhea and Fort Stockton, a large shallow ground water area in Reeves, Pecos and Ward Counties near Pecos, the Roswell artesian and shallow ground water area in New Mexico, and other smaller shallow ground water areas which can be pumped for irrigation. Some work has been done by the U. S. Geological Survey, in cooperation with the Texas Board of Water Engineers, in the vicinity of Balmorhea

and Fort Stockton and Pecos, and preliminary reports have been released, giving the most important results of these studies.

Present mapping includes the mountainous area west of the Pecos and a small portion near the coast. The International Boundary Commission makes continual surveys of the river channel and its changes. The Pecos is practically unmapped.

Within this vast area of some 21,000 square miles in Texas alone, there are at present only 3 automatic recording rainfall gauges, 3 evaporation stations, and 19 standard rainfall stations. Nine counties have no meteorological stations, and thirteen have but one each. Climatic conditions range from the almost arid region west of the Pecos to the semi-tropical area near the coast. Increasing use of water for irrigation and the probability of the construction of reservoirs on the Rio Grande make the installation of additional meteorological stations imperative.

RECOMMENDED PLAN

Control of the Lower Rio Grande and diversion of its waters are complicated by the fact that the river is the international boundary from Fort Quitman to the Gulf, which makes national allocation of water a treaty matter. It is recommended that a treaty be made between the governments of the United States and Mexico to provide for equitable division of the waters, and/or that reservoirs be constructed on the main stream to conserve flood waters and make these waters available for all beneficial uses. Ample factual information is now available upon which to base a treaty.

A study project is recommended for the Rio Grande below Fort Quitman to include a determination of actual and potential water requirements on the United States side of the river; a study of land drainage requirements; a study of

stream pollution and means for its abatement; and other allied matters. It is recommended that funds be made available for these projects.

The proper use of the water of the Pecos River is necessary for the development of the semi-arid areas through which it flows. The use of such water is complicated by reason of the river's interstate character. Consequently, all phases of the use of water from the Pecos are being considered by a Commission as a basis for a proposed compact between Texas and New Mexico. It is recommended that additional funds be provided to enable this Commission to complete its work.

Irrigation. To meet irrigation needs of the Lower Rio Grande Valley, the International Boundary Commission has proposed the construction of three reservoirs, two above and one below Laredo. The generation of a substantial block of hydroelectric power will be made possible by these dams. It is recommended that the Salineno and El Jardin dams be constructed as soon as possible. The construction of the Big Bend dam should be deferred, pending a determination of the future supply of water which may be controlled.

Lake McMillan on the Pecos River, which has been the main supply for the Carlsbad irrigation project, has been silted and is leaky, making necessary the construction of the Alamagorda dam. Lining of the canals to reduce seepage losses should be completed.

It is recommended that the capacity of Toyah Creek reservoir be restored by raising the present dam to increase water height three feet. It is also recommended that studies be made for an additional reservoir to store the flood waters of this creek.

Municipal Supplies. Municipal water supplies in the Lower Rio Grande

Valley come from the river itself, usually by way of some irrigation canal. In the Pecos Valley municipal supplies are obtained largely from wells and springs. Improvement of waterworks should be made in many of the towns in the entire basin.

Pollution. Sewage facilities are lacking in about half the communities of the basin. Plans are being prepared which provide for sanitary systems and disposal plants in several of these towns, and it is recommended that these be built as plans are completed.

Drainage. Consideration should be given to adequate land drainage to prevent water logging and the spread of malaria.

Land Use and Conservation. A comprehensive watershed management program should be prepared to include basin-wide application of soil and water conservation practices on forest, range, and other lands. It must necessarily be based upon and implemented by adequate surveys, investigations, and the technical supervision of land use through the cooperation of local, state and federal agencies. In addition, silt retention and runoff retardation works on slopes and in small drainageways, and bank control structures on streams, is needed in places, both to supplement the control afforded by a protective ground cover of vegetation, and to counteract the effect of disturbances resulting from modern improvements, such as highways. Works undertaken in this program will be subject to statutory regulations. A preliminary survey for flood control and erosion control in the basin of the Rio Grande and Pecos rivers above their junction has been authorized by Congress and should be undertaken promptly.

Wildlife Conservation. Consideration should be given to the establishment of supplemental wildlife refuges on the more favorable of the proposed reservoirs along the stretches and tributaries of the Rio Grande in Texas, provided

that the use of such water for wildlife will not interfere with its use for irrigation or other primary purposes.

Flood Control. Through formal agreement with Mexico for flood control in the Rio Grande delta, each nation is constructing flood control works within its territory in accordance with a joint plan. Completion of levees and floodways along the Rio Grande near Brownsville is recommended to protect the large investment in the delta area on the Texas side. A complete study and construction of flood control measures is recommended for the Pecos River Basin for the protection of cities, irrigation systems, and highways.

Measurements of Stream Flow. It is recommended that the stations now in operation be continued and the equipment be improved when needed. It is further recommended that about four additional stations be installed and maintained, for sufficient time to give adequate records. When flood control reservoirs are constructed, it is recommended that additional stations be installed in connection with these projects to assist with the proper regulation of the flow.

Ground Water Survey. The preliminary ground water surveys in this area in the vicinity of Fort Stockton, Balmorhea and Pecos should be extended to the entire area and should be followed by more intensive studies to reach a conclusion as to whether pumping from wells will deplete the discharge of the large springs, and to evaluate the ground water supplies available in other parts of the area for farm, municipal, and irrigation purposes.

Topographic Mapping. The Rio Grande being an international boundary, mapping should, if practicable, be correlated across the stream. It is recommended that the main stream be mapped in those areas where appear suitable

locations for reservoirs, or for irrigation; that the unmapped portions of the irrigated area in Hidalgo and Willacy Counties, Texas, be mapped for drainage, and that areas where ground water investigations are recommended be mapped for that purpose. It is further recommended that the irrigated sections of the Pecos be mapped for drainage, and that areas where ground water investigations are recommended be mapped for that purpose.

Climatological Data. It is recommended that there be installed and maintained 3 automatic recording rainfall stations, 5 evaporation stations, and 29 standard rainfall stations, and that those stations now in operation be continued.

It is further recommended that all of the above hydrologic studies and topographic mapping be done in accordance with approved methods by competent agencies and that the results be made readily and promptly available to the public, and periodically published in standard form.

PROJECT LIST - RIO GRANDE AND PECOS BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
GROUP A - IMMEDIATE					
1. Investigation Projects					
Study of water uses and water supply in Texas along the Lower Rio Grande below Fort Quitman.	$ 200,000		No		Factual data now on hand should be supplemented and extended in cooperation with the State of Texas.
Study to determine interstate phases of the Pecos River and the facts in regard to the water supply and uses which will form a basis for the compact negotiations between New Mexico and Texas.	150,000		No		Estimated cost approximate.
Study of lower valley of the Rio Grande to form basin for design of needed drainage system, including topographic mapping, water table, and seepage investigation.	100,000	$ 100,000	No		High water table, due to seepage and other causes is damaging large areas. Most of the mapping has been completed.
Pecos River and tributaries, Texas: Study of this basin for conservation and use of water for irrigation, flood protection, and power.	20,000	80,000	No		Large possibilities for water use, but no detailed information available.
Toyah Lake, Texas: Study project.	1,500				Study to determine value of this lake as an adjunct to Red Bluff reservoir.
Lower Rio Grande and Pecos Basins, Texas: Ground water surveys.	75,000	120,000	No		To develop ground water to best advantage.
Malaria control study.	10,000	10,000	No		Comprehensive study of drainage problems for malaria control throughout the lower Rio Grande and Pecos basins.

PROJECT LIST - RIO GRANDE AND PECOS BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
1. Investigation Projects (cont.)					
Lower Rio Grande and Pecos Basin, Texas: Area study land utilization, involving study of present land and water use and problems, adjustments needed to assist in devising measures and procedures required to carry out recommended adjustments.	$ 35,000	$ 145,000	Yes	Pub. 210 and 738	Study of land and economic phases dependent upon preliminary surveys already under way or contemplated by Flood Control Coordinating Committee of the U. S. Dept. of Agriculture.
Lower Rio Grande and Pecos Basins, Texas: Stream pollution study.	8,000	8,000	No		To study stream pollution and efficiency of municipal and industrial waste treatment.
2. Construction Projects, General					
Lower Rio Grande-Pecos basins, Texas: Four additional stream gaging stations.	5,400		No		Needed to give more complete records. Annual operation $2,000.
Lower Rio Grande-Pecos Basins, Texas: Additional rainfall and evaporation stations.	5,800				Present stations too widely scattered to yield reliable data. Annual operation $2,690.
Lower Rio Grande Basin, Texas: Channel to Port of Brownsville and Port Isabel.		585,000			Deepening of existing channels and easing of certain curves.
Lower Rio Grande Valley of Texas: Flood control by levees and floodways.	1,250,000	1,725,000	Yes		Levees and floodways more than two-thirds completed.
Rio Grande, 35 miles above Rio Grande City -- Salineno Dam: Flood control, irrigation, and power.	1,000,000	5,000,000	No		International agreement necessary. Plans in process of preparation.

PROJECT LIST - RIO GRANDE AND PECOS BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
2. Construction Projects, General (cont.)					
Rio Grande, 50 miles above Laredo: El Jardin Dam: Flood control, irrigation, and power.	$ 2,000,000	$ 8,000,000	No		International agreement necessary. Plans in process of preparation.
Harlingen, Texas: Completion of light-draft channel between Port Isabel and Harlingen.	200,000	100,000			Plans completed.
Brazos Island Harbor, Texas: Navigation improvements		585,000	Yes		Funds necessary for completion of work.
3. Construction Projects, Municipal Water Supply and Pollution Abatement					
Barstow and Rankin, Texas: Water supply system or improvements.	91,000		No		Plans completed.
Santa Rosa and Fort Sumner, New Mexico: Replacement of old sewer system.	95,000		No		Preliminary plans complete.
Presidio and Hebbronville, Texas: Waterworks system.	125,000		No		Preliminary plans made.
Sierra Blanca and Pecos, Texas: Sewerage systems.	120,000		No		Preliminary plans made.
La Feria and Quemado: Waterworks & sewerage systems.	72,000		No		Preliminary plans complete.
Valentine, Texas: Waterworks system.	40,000		No		Preliminary plans made.
Port Isabel, Texas: Water treatment plant.	22,000				
Port Isabel, Texas: Sewer system and sewage treatment plant.	50,000				

PROJECT LIST - RIO GRANDE AND PECOS BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
3. Construction Projects, Municipal Water Supply and Pollution Abatement (cont.)					
Mirando City, Texas: Water system improvements and sewer system and sewage treatment plant.	$ 47,000				
Hidalgo, Texas: Sewer systems and sewage treatment plant.	27,000				
Edcouch, Texas: Water purification treatment and sewer system.	45,000				
Lyford, Texas: Water supply improvements and sewer system.	30,000				
Rio Hondo, Texas: Sewer system and sewage treatment plant.	35,000				
Raymondville, Texas: Water supply improvements.	8,000				
Brackettville, Texas: Water purification treatment additions.	3,000				
Alpine, Texas: Additions to water supply and sewage treatment.	18,000				
Del Rio, Texas: Water purification treatment.	10,000				
Marfa, Texas: Additional water supply.	10,000				
Sanderson, Texas: Additional water supply.	10,000				

PROJECT LIST - RIO GRANDE AND PECOS BASINS

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
3. Construction Projects, Municipal Water Supply and Pollution Abatement (cont.)					
Pecos, Texas: Additional water supply.	$ 10,000				
Rio Grande City, Texas: Sewer system and sewage treatment plant.	60,000				
Roma, Texas: Water and sewer systems.	50,000				
Eagle Pass, Harlingen, Laredo, Brownsville, Pharr, Mission, Edinburg, Weslaco, Donna, McAllen, San Juan, Mercedes, San Benito: Sewage treatment plants or extensions.	178,000				
GROUP B - DEFERRED					
2. Construction Projects, General					
Rio Grande, Big Bend area: Big Bend dam, flood control, irrigation, and power.		Indet.	No		International agreement necessary. Plans being prepared.
Presidio County, Texas: Demonstration area in representative portion of Rio Grande. Pecos Basin water conservation practices.	50,000	$ 200,000	Yes		Contingent upon passage of adequate enabling acts by the Texas Legislature.
Cameron County, Texas: Brownsville migratory waterfowl refuge.		75,000	Yes	MBCA	
Pecos River Basin in Texas: Land management and watershed treatment of 1,000 square miles of critical area.	100,000	1,700,000	Yes	4 & 6	

PROJECT LIST - RIO GRANDE AND PECOS BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
GROUP C - INDETERMINATE					
Extension of light-draft channel between Port Isabel and Harlingen to within 3 miles of Mercedes.	$ 150,000		No		Preliminary plans complete.
Nueces, Kleberg, Kenedy, Willacy, and Cameron Counties, Texas: Extension of Intracoastal Canal from Corpus Christi to Port Isabel.		Indet.	No		Being studied by Corps of Engineers, U. S. Army.
Toyah Lake, Texas: Toyah Lake project in conjunction with Red Bluff reservoir.		Indet.	No		Should await results of study listed in Group A.
Lower Rio Grande and Pecos Basins, Texas: 43 reservoirs for conservation of water for irrigation, power, flood control, and stock water.		Indet.	No		Should await results of study listed in Group A.
Lower Rio Grande and Pecos Basins, Texas: Drainage of swamp and lowlands for malaria control.		$ 1,275,000	No		Should await results of basin study listed in Group A.
Lower Rio Grande and Pecos Basins, Texas: Supplemental wildlife refuge on future reservoirs.		Indet.	Yes	MBCA	

THE UPPER RED RIVER BASIN

SYNOPSIS

A long-range water plan for the basin of the Red River above Denison, Texas will have as its principal purpose the conservation of water for all beneficial purposes and concurrent flood control. Numerous reservoirs will be needed, ranging from one-tenth acre ponds for farm stock through larger ranch tanks, reservoirs for small cities, to a few major projects for irrigation and flood control.

The coordinated water plan is developed around a proposal for construction of reservoirs on each of the principal streams of the basin as the best means of developing and operating the water resources to meet the greatest need and for the most reasonable use.

Principal uses of the water resources include irrigation for general crops, and particularly for orchards and other special production in the drier western watershed; domestic water supply; stream flow regulation to decrease floods and augment low water flow for sanitary purposes; power development; industrial consumption; recreation; and wildlife conservation.

The recommended plan should preserve to beneficial users the title to the waters and to the several states the administration of the program for the benefit of their citizens. Each project is a unit in the integrated plan for the basin as a whole.

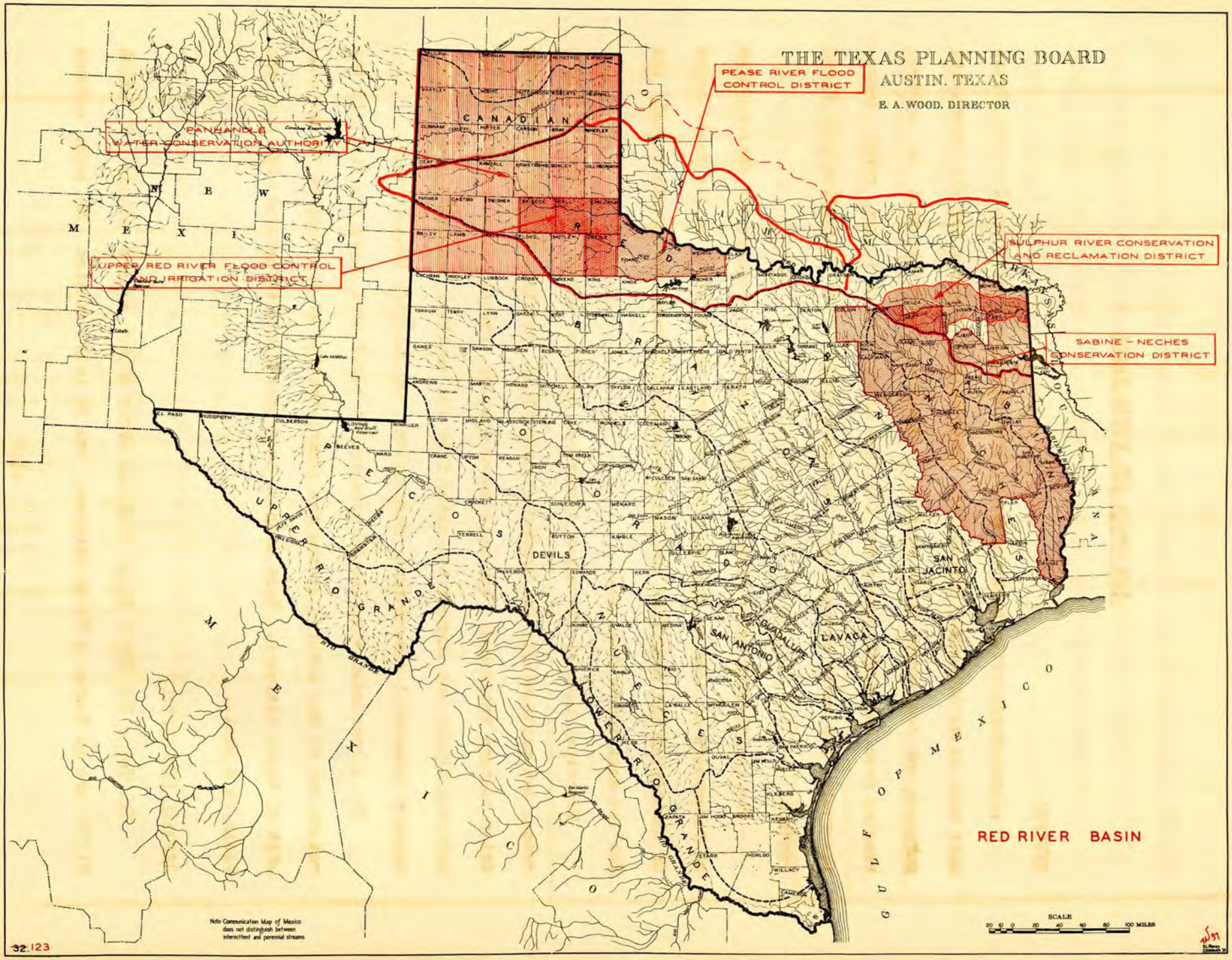
GENERAL DESCRIPTION

The Upper Red River Basin contains about 30,500 square miles, of which 21,700 are in Texas, 8,750 in Oklahoma, and 50 in New Mexico. The basin extends

from the mouth of the Washita River to the headwaters at the Texas-New Mexico boundary line. The principal tributaries are the Wichita, Little Wichita, Pease, Prairie Dog Town Fork, Salt Fork, North Fork (principal tributaries are Elm and Elk Rivers), Cache and Beaver Rivers.

The Red River headwaters rise in the High Plains section of the Texas Panhandle at an altitude of about 4,000 feet. The plains slope gently and smoothly eastward about 10 feet per mile to an abrupt escarpment several hundred feet high. The escarpment is a belt of "bad lands." Underlying the plains, Tertiary formations, approximately 400 feet thick, are the source of underground water for local rural and urban water supplies, and for irrigation. About 7,000 acres are irrigated from shallow wells and are intensively cultivated. Rapid development of shallow well irrigation has occurred the past two years, stimulated by the recent sustained drouth and by improved power and pumping systems including the program of rural electrification. The average annual precipitation on the High Plains ranges from 15 inches at the headwaters to 22 inches near the Cap Rock. The growing season is from 185 to 210 days. Large acreages are dry-farmed, and much land is used for grazing. Cotton, grains, alfalfa, vegetables, livestock, dairy products, poultry and eggs are produced. Oil and gas are found in this area. Overgrazing has seriously reduced the vegetative cover. As a result of these conditions, erosion has been accelerated.

The Red River Basin, east of the escarpment, is in the rolling plains section of Texas and Oklahoma. Many streams have cut deep valleys with nearly flat bottoms. The inter-stream uplands have been eroded into rounded hills. The precipitation ranges from 22 inches in the High Plains to 38 inches at Denison. Many varieties of crops are produced in the eastern part.


THE TEXAS PLANNING BOARD
AUSTIN, TEXAS
E. A. WOOD, DIRECTOR
PEASE RIVER FLOOD CONTROL DISTRICT
PANHANDLE WATER CONSERVATION AUTHORITY
UPPER RED RIVER FLOOD CONTROL AND IRRIGATION DISTRICT
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COLORADO
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SULPHUR
SAN JACINTO
LAVACA
GUADALUPE
SAN ANTONIO
NUECES
RIO GRANDE
PECOS
DEVILS
UPPER RIO GRANDE
LOWER RIO GRANDE
MEXICO
GULF OF MEXICO
RED RIVER BASIN
SCALE
20 10 0 20 40 60 80 100 MILES
Note Communication Map of Mexico does not distinguish between intermittent and perennial streams
32.123

Specialization in cotton, wheat or alfalfa, and cattle is general in the West. Oil, gas, asphalt, gypsum, lime, and glass sand are mineral resources utilized in various localities. Cotton-oil mills, flour mills, oil refineries, clay products, cement and plaster manufactures are important. There are consumer goods factories in the larger cities, chiefly in Wichita Falls, which has a population of 43,700. Other cities are trade and railroad centers. They include: Vernon 9,200, Electra 6,700, Quanah 4,500, and Childress 7,100, in Texas; and Lawton 12,000, Altus 8,400, Duncan 8,300, Elk City 5,600, and Hobart 4,900, in Oklahoma.

The Wichita Mountains along the northern divide are rugged, rising from 500 to 1,500 feet above the surrounding plains. They are wooded and provide an excellent setting for wildlife conservation, and recreation.

The total population of the Upper Red River Basin is about 640,000, of which about 50,000 are in the High Plains. Of the 590,000 in the rolling plains, 315,000 are in Texas and 275,000 are in Oklahoma. The agricultural and mineral resources of the Basin have not been fully utilized. The future development of the Basin can be greatly facilitated by insuring adequate and safe water supplies for rural, urban, and industrial uses.

Records of precipitation and stream flow are inadequate. The only stream flow record of sufficient length to be of much value for the whole Basin is at Denison, Texas where gauge readings have been observed since 1906 and discharge measurements made since 1923. For the 13-year period, 1923-1936, the average annual runoff was 3,670,000 acre feet, and for the 31-year period, 1906-1936, the average annual runoff is estimated to have been about 4,400,000 acre feet. Records of stream flow for periods of 10 years or less have been obtained at a few other points.

Underground water is found in the Tertiary sands of the High Plains in relatively large quantities at depths of from 50 to 400 feet. It is now subjected to heavy withdrawals both for municipal water supply and for irrigation. Studies on the effect of these withdrawals on the water table, now underway, should be enlarged and continued. In certain parts of this area storage of surface water for underground water recharge may be feasible. Over a large part of this section, underground water contains a considerable amount of fluoride which makes it undesirable as a drinking water supply for children. A high mineral content generally makes underground water below the escarpment unsatisfactory for municipal supply. In this area, therefore, a development of the surface water resources is particularly important.

On the Texas side of the basin, sewage wastes from 83 percent of the urban population above Denison is served by some form of treatment, and works for complete treatment of sewage serve about 70 percent. On the Oklahoma side, the proportions are about the same. However, a number of the cities use only primary settling or unsatisfactory and inefficient septic tank treatment. The discharge of raw sewage by certain of the cities, inadequate partial treatment of the sewage of others, and apparently a failure to operate some of the better plants to best advantage, combine to create a serious sanitary problem which is critically aggravated in periods of extremely low flow.

There are few satisfactory recreational facilities in the area, the principal ones resulting chiefly from the use of existing reservoir lakes, such as Lakes Lawtonka, Altus, and Kemp. An area of 20,000 acres has been purchased with state and federal funds and is being developed as a state park. A dam is in the process of completion, which will inundate 9,800 acres in Carter and Love

Counties, Oklahoma. This is known as Lake Murray. The Biological Survey has recently completed more than fifty concrete dams within the Wichita Preserve.

RECOMMENDED PLAN

Water Supply. In the High Plains section there appears to be ample ground water for urban use. Further studies to determine practical means for fluoride removal are needed. In the central section of the Basin, both ground and surface waters require softening to be thoroughly satisfactory for home and industrial use. The high cost of operation of softening plants has kept most of the smaller towns from installing them. Many municipal supplies are taken from surface waters. Stream beds in this area are frequently dry in summer, and many municipal supplies have been very low during the recent years of drouth. The cities of Crowell and Electra in Texas have been forced, at times, to import water by rail for considerable periods. Several of the large cities have developed reliable surface supplies through storage. The development of storage water for the supply of other cities is needed, and in certain instances this should be worked out as part of a combined water development program, involving irrigation, some measure of flood flow correction, and improvement of low water flows for sanitary purposes.

Pollution. Because of the low summer flow in the streams, sewage wastes in this area should be treated by methods considered suitable by the State health authorities. Many cities depend upon surface runoff for urban water supply. For this reason, adequate facilities for treatment of sewage and industrial wastes, as well as provisions for proper plant operation, are necessary. Proper sanitary conditions can be brought about only by increasing the dry-

weather stream flow so treatment plant effluents may be suitably diluted; providing that adequate treatment plants for domestic and industrial wastes are installed; and further provided, that technical supervision of operation can be secured. In some instances an augmentation of low flows can be worked out to advantage in connection with the storage of water for other purposes.

Attention should also be given to the possibility of utilizing irrigation practices for final disposal of sewage as a conservation measure in line with the satisfactory results obtained in numerous western areas where this has been carried out. Further study on the subject of irrigation should prove worthwhile.

There is some pollution from oil field wastes, particularly from brine. Before drilling, bonds should be required of operators to provide funds for capping abandoned wells that are flowing salt water. In most sewage and industrial waste treatment plants, the chief problem is the matter of providing proper plant operation and attention. An educational program designed to foster better operating methods and greater interest in the problem of stream pollution on the part of operating officials should be provided.

To control stream pollution in interstate streams, compacts between the States under the supervision of their respective State agencies is necessary in order to adequately regulate domestic and industrial waste discharge.

Flood Control. An extensive study of flood flow in the streams of the Red River has been made by the Corps of Engineers in connection with the "308" reports. Studies were directed primarily to correction of floods in the Red River below Denison, and to reduction of the effect of Red River flood peaks on Mississippi River floods. However, this study contained an analysis of flood flows and flood damages on the Red River above Denison and on certain of the

tributaries, with a finding that the expense involved in flood protection, either by levees or by levees and detention reservoirs, was greatly in excess of apparent benefits. Protection from moderate floods may be warranted when the lands in the overflow areas are more highly developed. A re-study is required of flood characteristics of the whole Upper Red River Basin, including the possibilities of introducing a reasonable measure of protection into multiple-purpose projects. A study now in progress by the Corps of Engineers, U. S. Army, will in part provide this information but should be extended to include such parts of the Basin as have not been included.

Irrigation. Irrigation of a supplemental type is needed by a large acreage of fertile agricultural land. Experience with small operations, and on the Wichita project, where supplemental water has been applied shows that the increase in crop values is very large. About two acre feet per annum of water per acre is required. About 35,000 acres are now being irrigated in the Wichita Basin, and it is likely that this acreage will be increased.

Studies have been made of similar developments on the Pease River with a reservoir at Crowell to serve about 75,000 acres below that point and on the main stream in Hall and Briscoe Counties, on the Little Wichita in Archer County, on the Tierra Blanca in Randall County, all in Texas. Congress has authorized a survey by the Corps of Engineers for the development of the entire Pease Basin. There is a proposal on the North and Salt Forks in Oklahoma involving interconnected reservoirs which would supply supplemental water for 160,000 acres. The Bureau of Reclamation and the Corps of Engineers have recently (September, 1937) resurveyed North Fork reservoir to serve as a flood control, irrigation, municipal water supply, and stream flow regulation project. All of

these proposed projects may serve multiple purposes and should be restudied with this in view.

Studies for subsistence irrigation on Indian lands are under way and have proceeded far enough to begin construction.

Water Power. The Corps of Engineers has completed a study of a proposed development at Denison for which hydroelectric power is one of the important items, but a report has not been released. A project for the development of hydroelectric power at Lake Kemp on the Wichita River seems feasible in the event that the water supply is not needed for irrigation of additional land, but the project requires further study.

Soil Conservation. The streams in the eastern and central part of this Basin have a high silt content, and soil erosion is serious over a considerable part of the area below the High Plains escarpment. There is need for better soil conservation practice in this part of the Basin to hold water on the soil and to reduce silting of reservoirs.

Recreation and Wildlife. Studies should be initiated to determine wildlife and recreational facilities of the region.

Sanitation and Disease Control. Experience indicates the importance of giving consideration to the matter of malaria control.

PROJECT LIST - UPPER RED RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
GROUP A - IMMEDIATE 1. Investigation Projects					
Collection of basic hydrologic data in Oklahoma, including meteorologic and stream flow records.	$ 25,000		No		15 additional stream gaging stations included. $7500 annual maintenance.
Study and survey of stream pollution in Texas and Oklahoma. Chemical and biological analyses of surface water to determine extent and seriousness of pollution. Should include fluoride analyses.	25,000	$ 125,000	No		6 yr. program: Texas, $15,000 per yr. Oklahoma, $10,000 per year.
Study of reservoirs throughout the sub-basin in Oklahoma and Texas to determine the most warrantable system for water supply, supplemental irrigation, and flow regulation, including a study of methods to minimize silting in reservoirs.	400,000	100,000	Yes	Pub. 738	This study needed for full development of the basin. This study may indicate the desirability of altering the proposed Denison project. Reservoir projects in Groups B and C are also dependent on this study.
Upper Red River Basin in Texas: Thorough study of ground water resources of the basin by mapping present development and studying ground water hydrology and geology over a period of years. Test drilling and geophysical work to be done in undeveloped areas.	56,500	87,500	No		6 year study.
Preliminary conservation and range surveys: To determine the applicability of various water retention structures and moisture conservation practices through mapping of erosion conditions, soil types, slopes and land cover.	40,000	35,000	No		3 year program.

PROJECT LIST - UPPER RED RIVER BASIN

PROJECT	ESTIMATED COST				REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
1. Investigation Projects (cont.)					
Upper Red River Basin in Texas: Eight additional stream gaging stations and 6 rainfall and evaporation stations.	$ 17,140	$ 25,500	No		In addition to present facilities; cost provides for six years operation after construction.
Study to determine warrantable satisfactory methods for minimizing salt pollution throughout the basin.	5,000	10,000	No		
2. Construction Projects, General.					
Wichita Falls, Texas: Drainage of irrigated land.	200,000	145,000	No		Preliminary plans made.
North Fork Altus Project: Dam and distribution system for supplemental irrigation with concurrent flood control benefits incidental to irrigation.	2,000,000	2,500,000	No		Survey completed by Bureau of Reclamation.
Otter Creek at Mountain Park, Oklahoma: Dam and reservoir for urban water supply, irrigation, flow regulation.	432,000		No		
Subsistence irrigation projects for Comanche, Chickasaw and other Indians in the Kiowa and Five Tribes jurisdiction in Oklahoma, north of the Red River. Water supply from wells, springs and streams tributary to the Red River.	20,000		No		
Carter, Cotton, Jefferson, Love, and Marshall Counties, Oklahoma; Cooke, Grayson, Hall, Montague, and Wichita Counties, Texas: Malaria control.	200,000		No		

PROJECT LIST - UPPER RED RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
2. Construction Projects, General (cont.)					
Sealing of abandoned mines, drill holes, and abandoned wells on Indian, public, and private lands in Oklahoma.	$ 50,000	$ 250,000	No		6 year program. Abandoned wells on private property are those not claimed as to ownership and for which responsibility cannot be fixed.
Construction of 35 reservoirs in Oklahoma for stock water.	175,000		No		Estimate assumes $5000 per reservoir.
Wichita Falls, Texas: Drainage of irrigated land.	200,000	145,000	No		Preliminary plans made.
3. Construction Projects, Municipal Water Supply and Pollution Abatement					
Erick, Indianhoma, Texola, Rocky, Sentinel, Duncan, Belleview, and Hastings, Oklahoma; Iowa Park and Wheeler, Texas: Water supply and/or improvements.	307,000		No		
Wichita Falls, Texas: Water supply, 5 miles of 42 inch pipe line, and treatment plant to improve quality of water.	1,000,000	500,000	No		Preliminary plans made.
Claude, Leflors, Nocona, and Petrolia, Texas: Water supply and sewer systems.	238,000		No		
Clarendon, Dimmitt, Hedley, Henrietta, St. Joseph, Shamrock, and Vernon, Texas: Sewage treatment plants	214,000		No		Additional treatment needed.
Archer City, Childress, Crowell, Electra, Henrietta, and Holliday, Texas: Water treatment plants.	200,000		No		All towns have surface supplies which are unsatisfactorily treated.

PROJECT LIST - UPPER RED RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
3. Construction Projects, Municipal Water Supply and Pollution Abatement (cont.)					
Belleview, Happy, Holliday, and Muenster, Texas: Sewer systems and sewage treatment.	$ 145,000		No		
Wichita Falls, Canyon, Childress, Bowie, Wellington, Burkburnett, Tulia, and Iowa Park, Texas: Additional sewage treatment.	235,000		No		All towns have only primary treatment or are overloaded.
Altus, Apache, Comanche, Davidson, Devol, Eldorado, Fletcher, Grandfield, Hollis, Mangum, Marietta, Ringling, Ryan, Sayre, Temple, Tipton, Walters, and Waurika, Oklahoma: Construction of sewage treatment plants or improvements to existing plants.	223,000		No		
GROUP B - DEFERRED					
2. Construction Projects, General					
Baylor County, Texas: Lake Kemp power plant, installation of 1400 KW operating capacity to make use of water now wasted.	170,000		No		Project dependent on agreement of water users not to expand acreage under irrigation and on analyses of flow during recent dry years.
Parmer County, Texas: Dam on Friona Draw for flood control and flow regulation for benefit of town of Friona and Paloduro Canyon Park.	40,000		No		

PROJECT LIST - UPPER RED RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
2. Construction Projects, General (cont.)					Construction should follow findings of study in Group A. Reservoir construction program must include soil conservation program on watershed to prevent loss of capacity through silting. Failure of present municipal supply demands increased facilities for several cities.
Pease River at Crowell, Texas: Dam and reservoir for urban water supply, irrigation, flow regulation.	$2,000,000	$ 2,059,000	No		
3. Construction Projects, Municipal Water Supply and Pollution Abatement					
Canyon, Harrold, Matador, and Pottsboro, Texas: Water supply system or improvements.	216,000				
GROUP C - INDETERMINATE					
Little Wichita at Scotland, Texas: Dam and reservoir for urban water supply, irrigation, flow regulation.	473,000		No		Construction should follow findings of Group A study.
Red River at Davidson, Oklahoma: Dam and reservoir for urban water supply, irrigation, flow regulation.	1,000,000	2,835,000	No		Construction should follow findings of Group A study.
Salt Fork at Mangum, Oklahoma: Dam and reservoir for urban water supply, irrigation, flow regulation.	500,000	581,000	No		Construction should follow findings of Group A study.
East Cache Creek: Reservoir and 2 reservoirs on Beaver Creek.	1,000,000	2,200,000	No		Construction should follow findings of Group A study.

PROJECT LIST - UPPER RED RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
GROUP C - INDETERMINATE (cont.)					
Navajo Reservoir on North Fork: Dam and reservoir for urban water supply, irrigation, and flow regulation.	$1,000,000	$ 2,000,000	No		Construction should follow findings of Group A study.
Oklahoma and Texas: Irrigation of lands in upper basin in connection with construction of dams and reservoirs recommended elsewhere.	2,000,000	8,000,000	No		Approximately 200,000 acres available for irrigation.
Hardeman, Foard, Wilbarger, Randall, Deaf Smith, Gray, Hall, Briscoe and Grayson Counties, Texas: Dams and reservoirs for urban water supply, irrigation, and flow regulation.		Indet.	No		These reservoir sites have been reported by Texas Board of Water Engineers and in some cases reconnaissance investigations have been made. Construction should follow the results of the study of Group A.
Paducah, Texas: Water supply from wells and 30 miles of 10 inch pipe line.	350,000		No		

THE LOWER RED RIVER BASIN

THE PROBLEM

Floods in the lower Red River Basin inundate at frequent intervals valuable agricultural land. To provide complete protection probably is not warranted but protection from minor overflows would enhance the value of these lands and would contribute other benefits.

GENERAL DESCRIPTION

The lower Red River Basin includes the drainage of the Red River from the mouth of the Washita, just upstream from Denison, Texas, to the edge of the Mississippi River lowlands in the vicinity of Alexandria, Louisiana, a stream distance of 638 miles. The basin includes some 27,500 square miles, of which 4,500 are in Arkansas, 8,150 in Oklahoma, 9,450 in Texas, and 5,400 in Louisiana.

The tributaries entering from the North, the Blue, Boggy, Kiamichi, and Little Rivers, rise in the Arbuckle, Kiamichi, and Ouachita Mountains. The upper and middle parts of their courses have steep gradients. Their lower courses are in the border of the Coastal Plain where they have developed broad fertile flood plains. Their basins include 9,040 square miles, much of which is rugged, with rocky, poor soils, and is generally forested. The annual revenue from lumber and allied products of this area in Oklahoma is approximately $4,500,000. In the Northwest coal is mined from extensive reserves. Some oil and gas have been produced in the upper Boggy and Blue Basins. Granite and marble are quarried at several places.

The Sulphur and Cypress Rivers in Texas, and the Dorcheat Bayou in Louisiana are tributaries in the lower or southern part of the Basin. They lie in

the Gulf Coastal Plains. Their headwater altitudes are about 500 feet and the altitudes of their mouths about 150 feet. They have meandering channels and sluggish flow. The topography of their basins is gently rolling. The soils of the valleys are fine-textured and very fertile, but this bottom land is subject to frequent flooding. Much of the Red River bottom land area in Arkansas, Texas, and Louisiana is protected from minor floods by small levees, but further protection is required for their full development. Farming, cattle raising, and lumbering are important activities. The bottomlands are generally wooded with oaks, gum, cypress, and other species. Several new oil fields of importance have been recently developed in this region, notably the Talco field in Titus County, Texas, the Fitz and Jessie pools in Oklahoma, and the Rhodessa field in Texas, Arkansas, and Louisiana. Adequate protection from floods would greatly enhance the value and productivity of the lands.

In the extreme southern parts of the Red River Basin below Shreveport, much of the bottoms is swampy, although some land has been reclaimed by levees. The interstream uplands are generally farmed where the soils are fertile, and are in pine forests where the soils are sandy. Cotton, fruits, nuts, and vegetables are raised on a commercial scale.

The mean annual temperature is about 63°. The January mean is 50°, and the July mean is 77°. The growing season ranges from 250 days in the southeast to 230 days in the northwest. The Basin is humid with a normal annual rainfall varying from 38 inches to 50 inches. The poorly drained valleys afford widespread breeding places for mosquitoes.

The total population of the Basin is about 1,081,500, of which about 474,500 are in Texas, 313,900 in Louisiana, 156,600 in Oklahoma, and 136,500

in Arkansas. In the Coastal Plains there are several important cities, including Shreveport with 76,600 population, Alexandria, 23,000, and Nachitoches, 4,500, in Louisiana; Texarkana, 27,300, in Arkansas and Texas; Marshall, 17,000, Sherman, 15,700, Paris, 15,600, and Denison, 13,800, in Texas; Hope, 6,000 in Arkansas; and Durant, 7,400, and Hugo, 5,300, in Oklahoma.

Throughout the lower Red River Basin the main stream traverses a rather wide overflow plain having a sandy channel of from 1,000 to 1,500 feet wide. The slope of the stream averages about one foot per mile in the upper part and less than six inches per mile in the lower portion. Low water flows range from 150 cubic feet per second at Denison, to 720 at Garland City. Flood flows at Denison are estimated to have exceeded 450,000 cubic feet per second, and at Shreveport, 250,000 cubic feet per second.

RECOMMENDED PLAN

To a great degree the recommended plan for this area is based on the construction of reservoirs as the best means for developing the water resources for the greatest need and the most reasonable use:

1. For domestic and municipal water supply.
2. For production of steam, manufacturing purposes, sanitary conditions, and flood control.
3. For power development, recreation, subsistence irrigation, fisheries, and other uses.

The recommended plan is based on preserving to the State the title to the waters and the administration by the several states of the water resources to the benefit of the citizens, and each project is an integral part of the plan for the entire drainage basin of the Red River.

Flood Control. The best plan for flood control in this State involves

the construction of storage reservoirs with the assistance of levees and channel rectification, so far as necessary. Other benefits resulting from these reservoirs would go far toward justifying their construction from an economic viewpoint. Additional investigations are required.

Navigation. Extensive studies by the Corps of Engineers for developing reliable year-round navigation on the Red River indicate a cost for such a project far in excess of the benefits. A new study of navigation possibilities from Jefferson to Shreveport and thence to the mouth of the Red River has been authorized, and after development or study of reservoirs a further study is desirable for navigation to Denison.

Hydroelectric Power. For the streams flowing out of the Kiamichi Mountains and from the southwestern slope of the Ouachita Mountains, water storage for power may possibly be worked into a multiple-purpose program. A recent study conducted by The Texas Planning Board showed that ample markets exist in Texas for all the power which can be generated by the Denison project. Doubtless, other markets exist in Oklahoma. The cost of power production on the Kiamichi and at the Eagletown and Yashoo sites on the Mountain Fork of the Little River appears to be sufficiently low to justify further consideration, particularly in connection with the storage of water for multiple uses. These projects are further justified in connection with the manufacture of paper, in view of the fact that all the natural resources necessary are present. Chemurgic and mineral products could also be produced in this area. Further studies on the main stream and tributaries are recommended.

Drainage of agricultural lands in the Oklahoma and Texas sections of the Basin is not extensive. In Arkansas and Louisiana, however, most of the land included in levee districts has been drained. In Arkansas 135,000 acres are in

drainage districts. Most of the districts have been in financial difficulties, and the facilities are commonly in a state of disrepair. Extensive rehabilitation of the drainage and levee structures is recommended.

To the extent that fertile lands in the Basin are relieved of frequent flooding and their productivity correspondingly increased, further installation of land drainage may be justified.

Water Supply. In the Oklahoma section of this Basin, eleven of the cities, generally the larger ones, depend on surface water supply. Nine use underground water. Surface waters are generally soft, but are subject to serious pollution at some places. In Arkansas, Nashville uses surface water, Texarkana surface water in part, and all other towns underground water. The underground water supply in parts of this area has been found to be inadequate, but comparatively little is known regarding the underground water resources. Mt. Pleasant and other cities are seeking additional water supplies in Texas. In addition to Texarkana, Sulphur Springs and several other cities use surface water. Still other cities use underground water. A thorough study of underground water resources for the whole area is recommended.

Rural water supply has not been a serious problem, except that in parts of Oklahoma and Texas, water for domestic and stock consumption has been inadequate during dry summers. Construction of small reservoirs for stock watering is suggested.

Pollution. Both sewer systems and sewage treatment facilities are inadequate, and stream pollution results. Further pollution of both surface and ground water is resulting from recent oil developments in the Basin. This stream pollution can only be overcome by increasing the minimum stream flow so

that effluents may be sufficiently diluted; by the installation of adequate treatment plants for domestic and industrial wastes; and through proper operation of these plants. To control stream pollution in interstate streams, compacts between the states, under the supervision of their respective state agencies, is necessary in order to regulate domestic and industrial waste discharge.

Recreation. There is a serious lack of water areas for recreational purposes. Caddo Lake, on lower Cypress Creek, with about 32,000 acres, is used for recreational purposes, as are many of the oxbow lakes along the Red River, particularly in Arkansas. The construction of reservoirs in the Basin would provide recreational opportunities.

Malaria Control. Malaria is one of the great problems in this area, and proper studies should be made with regard to tying in the proposed irrigation, land drainage, and storage projects with the problem of malaria control.

PROJECT LIST - LOWER RED RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
GROUP A - IMMEDIATE 1. Investigation Projects					
Arkansas, Louisiana, Oklahoma, and Texas: Blue River, Boggy Creek, Kiamichi River, Little River, Sulphur River, Cypress Creek, Bayou Bodcau, and Bayou Dorcheat: Study of reservoirs for partial flood control in connection with water power.	$ 300,000	$ 100,000	No		Studies should give consideration to the malaria problem.
Survey for flood control and other benefits on Red River in Arkansas: Investigation of existing conditions, including such levees and drainage works as are already constructed along 174 miles of Red River and the merit of improving these conditions.	44,500		Yes	Pub. 738	Ratio of cost to benefits indicates that the making of a survey is justified. This survey will provide information useful in study project.
Survey for flood control and other benefits on Sulphur River in Texas and Arkansas: Investigation of Sulphur River and its major tributaries, including existing conditions of levees, river channels and drainage structures and the study of the merit of improving these conditions.	22,000		Yes	Pub. 738	Ratio of cost to benefits indicates that the making of a survey is justified. This survey will provide information useful in study project.
Survey of Little River and its tributary Cossatot River in Arkansas for flood control and other benefits: Investigation of existing flood conditions and the making of such surveys and studies as are required to develop plans for flood control and other benefits.	27,000		Yes	Pub. 738	Ratio of cost to benefits indicates that the making of a survey is justified. This survey will provide information useful in study project.

PROJECT LIST - LOWER RED RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
1. Investigation Projects (cont.)					
Preliminary examination of Walnut Bayou, Arkansas: Will consist of a public hearing to develop the views of local interests, the compilation of descriptive data, a study of such data to determine the merits of making further surveys, and the preparation of a report on the results of the examination.	$ 2,000		Yes	H. R. 7646 75th Cong.	
Survey for study of navigation possibilities on Cypress Creek and Red River: Survey of the channel for navigation purposes from Jefferson, Texas to Shreveport, Louisiana by way of the Jefferson-Shreveport waterway thence to the mouth of the Red River, including the advisability of water supply reservoirs on Cypress and Black Cypress Rivers above the head of navigation.	50,000		Yes	H.R. 7051 75th Cong.	
Study of reservoir possibility at Denison, Texas as related to other tributary reservoir possibilities in both the upper and lower basins for power and flood control.	50,000				Review of studies now completed after completion of other reservoir studies.
Pollution survey in Arkansas, Louisiana, Oklahoma, and Texas.	40,000	$ 80,000			3 year program.
Fannin and Hunt Counties, Texas; Miller and Sevier Counties, Arkansas: Study of small water conservation projects.	15,000				Assume $10,000 for Texas Counties; assume $5,000 for Arkansas Counties, for summer supply in areas lacking adequate ground water.

PROJECT LIST - LOWER RED RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
1. Investigation Projects (cont.)					
Installation and operation of stream gaging stations in Oklahoma and Arkansas.	$ 20,000				$8,000 annual operation cost.
Stream gaging program in Texas portion of Lower Red River: Additional gaging stations.	5,600				Present stream flow records are scattered and inadequate; good records are necessary for intelligent study of basin. $8,000 annual operation cost.
Four rainfall and evaporation stations in Texas part of Lower Red River Basin.	3,000				At present, an insufficient number of stations are in operation in the basin to determine variations in rainfall and evaporation.
Study to determine warrantable bank erosion control measures in entire basin.	30,000	$ 70,000			
Survey of water supply in Arkansas.	5,000	15,000			Four year program.
Rehabilitation survey of drainage districts to determine needs and make recommendations.	2,000				
Central Red River Basin, Oklahoma and Texas: Investigative study to determine runoff retardation measures applicable to low quality scrub oak woodlands.	7,500	2,500			Could be started in 1938 and finished in 1939. Importance of scrubby woodlands in watershed protection warrants a detailed survey to develop practicable remedies and improvement measures.
Ground water survey of Lower Red River basin in Texas: Thorough study of ground water resources.	36,000	60,000			3 year program.

PROJECT LIST - LOWER RED RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
2. Construction Projects, General.					Subject to findings of studies. Detailed plans in preparation. In view of the high malaria incidence in this area, this project should be given priority since this drainage work is a necessary preliminary to the securing of adequate local, community drainage.
DeSoto, Natchitoches, and Red River Parishes, La.: Enlargement of drainage channels through Bayou Pierre and Bayou Pierre Lake from Bayou Wincey to the north at Grand Ecore for protection against headwater floods.	$ 300,000		Yes	Pub. 738	
Arkansas, Louisiana, Texas, and Oklahoma: Malaria control.	300,000	$ 700,000			
Caddo Parish, Louisiana: Wallace Lake Dam for storage of floodwaters to improve protection of population and lands below.	400,000		Yes	Pub. 738	
Caddo Parish, Louisiana: Twelve Mile Bayou: 5-mile levee along east bank of Twelve Mile Bayou, north of Shreveport. Includes drainage structures. To protect against headwater overflows.	150,000	350,000			$150,000 work under contract; $350,000 needed to complete.
LeFlore County, Oklahoma: Construction of dam and lake with attendant recreation area 12 miles southwest of Heavener, Oklahoma on Bohannon Creek.	40,000		Yes		Plans complete. This project will provide needed recreation for the people of Poteau, Heavener, Mena and other smaller towns.
Winn and Natchitoches Parishes, Louisiana: 2 recreation areas with attendant water supply and sanitation facilities, 1 each in Kisatchie and Catahoula Divisions of the Kisatchie National Forest.	9,000		Yes		This project will provide needed recreation facilities for Winnfield, Alexandria, Natchitoches and surroundings. Plans completed.

PROJECT LIST - LOWER RED RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
2. Construction Projects, General (cont.)					For summer supply in areas lacking adequate ground water. Atoka, Choctaw and Pushmataha projects have had $32,200 spent on them. Estimate here given includes $102,500 to finish these three projects.
Atoka, Bryan, Choctaw, Coal, Johnston, McCurtain, and Pushmataha Counties, Oklahoma: Small water conservation projects.	$ 302,500		No		
Red River Parish, below Shreveport, Louisiana: Raising, enlarging, and extending existing levee system to improve flood protection.	180,000		Yes	Pub. 738	Subject to findings of studies.
3. Construction Projects, Municipal Water Supply and Pollution Abatement					
Cove, Dierks, Foreman, Fulton, Garland, Horatio, Lockesburg, McNeill, Mineral Springs, Stamps, and Washington, Arkansas; Bells, Savoy, and Lone Oak, Texas: Sewer systems.	373,000		No		
Ashdown, DeQueen, Hope, Lewisville, Magnolia, Nashville, and Texarkana, Arkansas; Avery, Blossom, Gilmer, New Boston, and Waskom, Texas; Barksdale Field, and Shreveport, Louisiana; Ada, Idabel, and Antlers, Oklahoma: Sewer systems and sewage treatment plants or improvements to existing facilities.	534,000		No		
Atoka, Caddo, Coalgate, Hugo, Pittsburg, Talihina, Oklahoma: Sewer systems and sewage treatment plants.	105,000		No		
Mt. Pleasant, Texas: Improvements to sewage treatment plant.	21,000		No		

PROJECT LIST - LOWER RED RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
3. Construction Projects, Municipal Water Supply and Pollution Abatement (cont.)					
Cumby, DeKalb, Denison, Honey Grove, Hughes Springs, Linden, Mount Vernon, Sulphur Springs, Bogota, Atlanta, Celeste, Clarksville, Commerce, Cooper, Deport, Greenville, Ladonia, Leonard, Naples, Sherman, Whitewright, Winnsboro, and Wolfe City, Texas: Sewage treatment plants.	$ 647,000		No		
Cove, Fulton, Garland, Horatio, McNeil, Washington, Arkansas: Water supply systems.	167,000		No		
Ashdown, De Queen, Dierks, Foreman, Hope, Lewisville, Magnolia, and Stamps, Arkansas: Repair waterworks.	133,000		No		
Clarksville, Honey Grove, Linden, Jefferson, Bonham, Whitewright, Celeste, Texas: Enlargement of water production systems to provide peak and future demands.	105,000		No		
Greenville, Wolfe City, Deport, Texas: Water treatment plants.	85,000		No		
Commerce, Cooper, Dodd City, Ector, Hallsville, Mt. Pleasant, Sherman, Trenton, Waskom, Texas; Atoka, Antlers, Coalgate, Hugo, Stonewall, Oklahoma; Robeline, Louisiana: Water supplies or improvements.	626,000		No		Preliminary plans made.
Pittsburg, Talihina, Oklahoma: Water supplies and improvements.	22,000		No		

PROJECT LIST - LOWER RED RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
3. Construction Projects, Municipal Water Supply and Pollution Abatement (cont.)					
Atlanta, Daingerfield, Detroit, Omaha, Pecan Gap, Pittsburg, Texarkana, Texas: Water supply and sewer systems, or improvements to existing systems.	$ 941,000		No		Preliminary plans made.
GROUP B - DEFERRED					
2. Construction Projects, General					
Red River at Denison, Texas: Dam and reservoir for flood control and power.	15,000,000	$ 25,000,000			Value of power combined with flood control benefits makes this project feasible. Pending the conclusions of the Corps of Engineers' study completed but not yet released.
Bossier Parish, Louisiana: Alternate reservoir project instead of authorized (Pub. 738) Bayou Bodcau diversion floodway project involving levees and ditches to carry waters of Bayou Bodcau and Cypress Bayou to Red River. For protection against headwater floods.	1,000,000	893,000	No		Costs to be obtained from Chief of Engineers' office in Washington; figures given are those for diversion floodway; Louisiana State's reservoir costs about same.
Small water conservation projects in 2 counties in Texas and 2 counties in Arkansas.	200,000		No		Locations and plans dependent on study project in Group A.
Caddo Parish, Louisiana: Black Bayou Dam and Reservoir.	125,000		Yes	Pub. 738	
Bienville Parish, Louisiana: Construction of earth-filled dam across Bayou Dorcheat, for restoration of Lake Bistineau for fish and game preserve.	71,000				Plans for future work should include provision for avoidance of malaria hazards. Present situation a matter of concern to Louisiana Board of Health.

PROJECT LIST - LOWER RED RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
2. Construction Projects, General (cont.)					
Sulphur River, Texas: Channel improvement for flood control.	$ 600,000	$ 685,000	No		Subject to restudy as to possible inclusion of reservoirs in plan of flood control. Authorized survey under way.
Bois d'Arc Creek, Texas: Channel improvement for flood control.	25,000				
Natchitoches Parish, Louisiana: Extension of levee on right bank of Red River.			No		Louisiana State's original estimate $410,000; $300,000 needed to complete
3. Construction Projects, Municipal Water Supply and Pollution Abatement					
Ada, Oklahoma: Water softening plant.	50,000		No		
Dexter and Pottsboro, Texas: Water supply.	20,000		No		

PROJECT LIST - LOWER RED RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
GROUP C - INDETERMINATE					
Hugo, Kiamichi River; Bossier, Bodcau Bayou; Caddo Lake, Cypress Creek; Darden, Sulphur River; Eagletown, and Yashoo, Mountain Fork River; Idabel, Little River; McGee, Muddy Boggy Creek; Sandy Creek, Blue River; Springhill, Dorcheat Bayou; and Tupelo, Clear Boggy Creek: Flood control and power reservoirs.	$5,000,000	$15,000,000	No		To be restudied in connection with study project. Plans should include provisions for the avoidance of malaria hazards.
Delta County Levee Improvement District No. 2, Texas: Levees and channel improvements.	25,000		No		Should await results of studies of Group A. Preliminary plans made.
Hopkins County Levee Improvement District No. 4, Texas: Levees.	100,000		No		Should await results of studies of Group A. Preliminary plans made.
Lamar County Levee Improvement District No. 3, Texas: Levees and channel improvements.	71,000		No		Should await results of studies of Group A. Preliminary plans made.
Black Bayou in Caddo Parish, Louisiana: Construct 18-mile levee along east bank of Black Bayou and Jefferson Canal. Includes drainage structures. To protect against headwater overflows.	125,000		No		Preliminary plans made. Should await results of Studies of Group A.

PROJECT LIST - LOWER RED RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
GROUP C - INDETERMINATE (cont.)					
Dams for water conservation in Miller and Sevier Counties, Arkansas.	$ 8,000		No		
Drainage in Lafayette and Little River Counties, Arkansas.	16,600		No		
Fraser Creek Reservoir, Texas.		Indet.	No		

THE CANADIAN RIVER BASIN

The Basin of the Canadian River is made up of the basins of the twin streams, the North and South Canadian Rivers. These streams are erratic, and their regulation for all beneficial uses is the most important problem in the Basin.

GENERAL DESCRIPTION

The Basin of the Canadian River includes the northeastern corner of New Mexico, the northern part of the Texas Panhandle, most of the Oklahoma Panhandle, and a strip through the middle of Oklahoma nearly to the eastern boundary. The area is 47,500 square miles, of which 16,066 are in New Mexico, 13,372 in Texas, and 18,062 in Oklahoma.

The Basin is drained by two streams, the North Canadian and South Canadian Rivers. For one hundred miles they are separated by a distance of only ten to twenty miles. They join forty miles above the junction of the Canadian and Arkansas Rivers.

The South Canadian Basin is larger and hydrologically more important, though perhaps less populous than its neighbor. No important tributaries enter the South Canadian east of Major Long's Creek, which joins it about forty miles east of the New Mexico-Texas line, until Little River is reached. This enters the main stream 110 miles from its mouth. The drainage area of the South Canadian is 30,650 square miles, with 15,200 in New Mexico, 8,800 in Texas, and 6,650 in Oklahoma. The total length of the river is 900 miles.

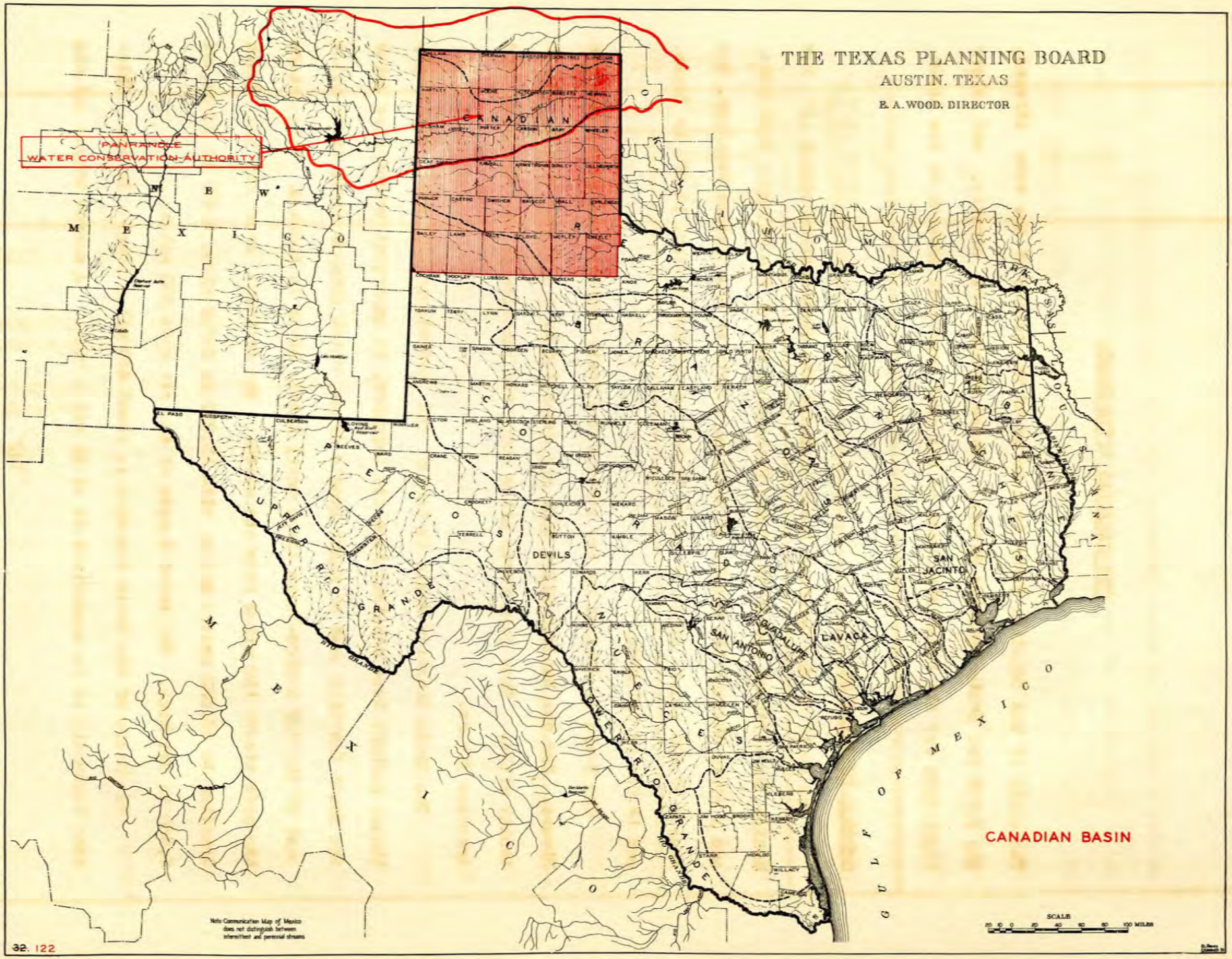
The Basin of the North Canadian is about 460 miles long. In the Oklahoma Panhandle it is approximately sixty miles wide. A narrow tongue extends

50 miles into New Mexico. East from the hundredth meridian, the basin narrows rapidly from 50 miles to 12 or 15, a width it maintains for one hundred miles before expanding into a crude oval, approximately 60 by 100 miles, near its eastern end. About 30 miles east of the Texas line Wolf Creek joins the main stream. Deep Fork, the most important tributary draining 2,540 square miles, joins about 15 miles above the mouth. The North Canadian drains 16,850 square miles, of which 866 are in New Mexico, 4,572 in Texas, and 11,412 in Oklahoma.

The South Canadian originates in a network of snow-fed streams, rising high upon the eastern slope of the Sangre de Christo range in New Mexico. Part of the drainage area rises above 12,000 feet altitude. The tributary streams fall rapidly until the plains area is reached, but thereafter the gradient is less. At the mouth, the altitude is 450 feet.

Most of the river channel in eastern New Mexico and across Texas lies in a broad canyon from 300 to 600 feet below the level of the "Llano Estacado." Throughout Oklahoma the river occupies a wide meandering channel.

The North Canadian rises in the plateau region of northeastern New Mexico at an altitude of about 6,500 feet. It falls rapidly for 65 miles to 4,600 feet at the New Mexico-Oklahoma line. The fall is comparatively rapid for the next 165 miles. The river flows the entire length of the Oklahoma Panhandle. In that distance it receives no important tributaries from the North. Coldwater Creek, with a drainage area of 1,870 square miles, Paloduro Creek with 1,660, and Wolf Creek with 1,660, enter from the South. Throughout the eastern section the river flows very near to the north edge of its basin, the channel being in places, not more than three or four miles from the divide which separates the North Canadian from that of the Cimarron River. The channel of the North


THE TEXAS PLANNING BOARD
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LOWER RIO GRANDE
NUECES
SAN JACINTO
GUADALUPE
SAN ANTONIO
LAVACA
MEXICO
GULF OF MEXICO
CANADIAN BASIN
SCALE
Note: Communication Map of Mexico does not distinguish between intermittent and perennial streams

Canadian is some two hundred feet higher than that of the Cimarron, and from 50 to 100 feet above that of the South Canadian.

The population of the Canadian Basin is 982,000, of which nearly 800,000 are in Oklahoma, a little more than a hundred thousand in Texas, and 82,000 in New Mexico. The urban population is 48.5 percent of the total in Oklahoma, about 50 percent in Texas, and in New Mexico, about 26.6 percent.

In Oklahoma the percentage of land in farms increases from 77 in the eastern part of the basin to 96 in the Panhandle. The cropped area, however, is greatest in the vicinity of Oklahoma City, where it is 50 percent of the total, as compared with 22 percent in the extreme east and 27 percent in the western end of the Panhandle.

The land included in the basin in Texas is used for the production of wheat, corn, oats, barley, grain sorghums, and for the grazing of livestock.

In the New Mexico area there were 69,811 acres under irrigation in 1931, and a much large acreage in dry farming.

The industrial activities of the Canadian Basin are those connected with the production of oil, coal, and natural gas, natural gasoline, and carbon black. Coal is produced near the eastern end of the basin in Oklahoma, and at Dawson, New Mexico, in the extreme northwest corner. The Amarillo gas field in Texas is one of the most important in the United States. Petroleum and natural gas are produced in central and eastern Oklahoma. The Texas Panhandle is possibly the most important single area in the country for the production of natural gasoline and carbon black; the area also contains over three thousand producing oil wells. There is a helium gas extraction plant in this area.

Average annual precipitation is about 26 inches in the mountains at the

West. It decreases toward the East to a minimum of about 15 inches at Taylor Springs, New Mexico, some 85 miles west of the New Mexico-Texas line. It then increases at a fairly uniform rate to 42 inches at the mouth of the river. Throughout the basin more than 60 percent of the rainfall occurs in the five months May to September, though it tends to be more evenly distributed in eastern Oklahoma.

Stream flow in the upper basin is erratic. At Logan, New Mexico, which commands 64 percent of the total drainage area of that State, the average annual discharge of the South Canadian River is about 325,000 acre feet. The maximum was 685,628 in 1914 and of this 313,568 were discharged in the month of August. The minimum was 48,362 in 1934 when two thirds of the total came in May and June. Although 1910 was the year of minimum precipitation, the discharge of the river was 391,890 acre feet, 20 percent more than the average. In the record period of 168 months there were five months in which there was no discharge whatever at Logan, New Mexico. There are no stream gaging stations within the Canadian Basins in Texas. At Calvin, Oklahoma 105 miles from the mouth of the river and 565 miles below Logan, there are discharge records for only four years, 1906 and 1928-1930. The drainage area above this station is 2.56 times that above Logan. The average annual discharge of the South Canadian at this point is about 1,540,000 acre feet, nearly five times the average at Logan. The maximum, 1929, is 15 percent above the average, and the minimum, 1928, is 20 percent below. So far as may be concluded from so short a record, the annual average is less variable at Calvin than at Logan. The distribution through the year, however, is as irregular and uncertain.

The description of precipitation distribution applies as well to the

North Canadian, but since its basin does not extend into the high mountain area, it does not profit from the greater rainfall of the high altitudes.

The greatest flood of record on the North Canadian was in October, 1923. The maximum discharge at Woodward, Oklahoma was estimated at 90,000 cubic feet per second on October 12. At El Reno, Oklahoma, the maximum was 80,000 cubic feet per second on October 15.

Minimum flows are as important as flood discharges, particularly if the streams are to be relied upon to carry off sewage effluents and industrial wastes, and to furnish municipal and industrial water supplies. Both the South Canadian and North Canadian Rivers have gone virtually dry. In 1930 the discharge of the South Canadian at Calvin was only 45 cubic feet per second for twelve consecutive days in April, and was zero for several periods of a week or more in July, August, September, and October. On the North Canadian at Woodward, the minimum was 5 cubic feet per second in August and 2 in September of 1929. In 1930 it dropped to 1 cubic foot per second in August. At Wetumka, less than 100 miles above the mouth of the river, the discharge dropped to 67 cubic feet per second in September and October, 1929. However, gage readings are not always reliable to ascertain the low flow of this stream; zero readings of the gages are from 1 to 4 feet above the stream bed, and the sandy channels frequently shift, leaving the gage removed from the low flow channel.

RECOMMENDED PLAN

Irrigation. Irrigation is of first importance in the New Mexico, Texas, and western Oklahoma portions of this basin. A number of existing systems in New Mexico are in need of improvement or extensions. The Conchas Reservoir on

the South Canadian is under construction. It will provide a water supply adequate for the irrigation of 45,000 acres in New Mexico. Detailed plans for a canal and distribution system to serve these lands have been made by the Bureau of Reclamation, and the project has been authorized by Congress; the Arch Hurley Conservancy District has been organized under the required statutory provisions. A portion of the water from the Conchas Reservoir, if available, might be utilized in Texas and Oklahoma for such useful purposes as may be determined to be economically feasible.

On the North Canadian River about 10,000 acres in Texas and Beaver Counties, Oklahoma, can be irrigated with water to be stored in the Optima Reservoir, and about 20,000 acres in Woodward County can be served from the Fort Supply Reservoir. Construction of both reservoirs has been authorized by the Congress, and initial funds have been allocated for the construction of the Fort Supply project. A study should be made of the necessary distribution system.

Flood Control. Flood control is of importance on the streams of this basin, particularly on the lower reaches. Many suggested reservoir sites have been studied by the Corps of Engineers, which concluded that the preventable damage would not justify the cost of construction. Some of these reservoirs, however, may be made to serve more than one purpose. The further studies now in progress, and other studies to be made, should be carried out so as to develop the best multiple use of the projects. In certain areas detailed studies have been made in the past year which are reflected in the project lists. In other areas supplemental studies of possible multiple use should be made.

One quarter of the South Canadian drainage area is above the Conchas Reservoir. This reservoir will contribute to the mitigation of severity of floods on the lower stream. There are other sites for storage available in Texas, which should be further investigated for their flood control possibilities of the upper half of the South Canadian drainage area.

In the North Canadian, the Optima Reservoir in Texas County, Oklahoma and the Fort Supply Reservoir on Wolf Creek will serve for flood control and for irrigation, or municipal and industrial water supplies, as well as to maintain a suitable dry season flow for sanitation in the river. Both have been authorized by the Congress. The Optima Reservoir on the North Canadian has a drainage area of 2,560 square miles and a proposed capacity of 77,500 acre feet. The Fort Supply Reservoir is tentatively planned for a capacity of 208,000 acre feet, of which 108,000 would be allocated to flood control, and 100,000 for other beneficial uses; of this amount 90,000 acre feet may be reserved as a supplemental water supply for Oklahoma City. The Fort Supply Reservoir has a tributary drainage of 1,665 square miles on Wolf Creek, the most productive tributary of the upper river. It is 130 miles downstream from the Optima.

A third reservoir in this system will be necessary in order to maintain an adequate dry season flow. An alternate for the El Reno project has been proposed at Canton to control floods on the lower river, and to insure a sufficient ultimate water supply for Oklahoma City.

Reservoirs on Coldwater, Paloduro, and Wolf Creeks, in Texas, should be studied for flood control and other uses.

The Deep Fork will require flood protection by works entirely independent

of those on the main river. This stream has a drainage area of 2,640 square miles lying in a region where the precipitation averages 36 inches annually. The Corps of Engineers has studied the proposed Okmulgee Reservoir, which has a drainage area of 2,146 square miles, a storage capacity of 400,000 acrefeet, and would protect an area of 42,850 acres.

The Eufaula Reservoir, which has been proposed for flood control, would be located below the mouth of the North Canadian and would control the entire drainage area of both rivers. Although situated in the Canadian Basin, its benefits would accrue only to the lower Arkansas and to the Mississippi.

Small Reservoirs. Small reservoirs, chiefly to supply stock water, are desirable improvements in the western part of the basin, but no specific projects have been listed. Reservoirs to supply water for irrigation should be constructed wherever economically convenient. Water for this purpose is highly desirable, and if it is available, will add materially to the agricultural stability and economic balance of the area.

Conservation of Water at Source. The conservation of water by soil conservation methods, where it falls, is of importance in this basin where the soil erodes easily and the precipitation is relatively low. The holding of a small proportion of the rain at the point where it falls will greatly increase the amount of water available for plant production.

Stream Pollution. Stream pollution is of first importance in the lower end of the basin. Few towns have complete treatment for municipal wastes, and oil field wastes and salt brines discharge into the stream. A number of sewage treatment plants are needed. Better sanitary conditions can be brought about by increasing the dry season stream flow so that effluents may be suit-

ably diluted, by providing adequate treatment plants for domestic and industrial wastes, and by providing proper operation of these plants by trained operators. To control stream pollution, an interstate compact between the State Health Departments would be helpful in regulating domestic and industrial waste discharges.

Water Supply. Water supplies are known to be inadequate in many towns and cities, but detailed information is not available. The largest and most important water supply problem is that of Oklahoma City. In order to insure adequate supply for the future, the city desires to obtain reserve storage of 100,000 acre feet.

Ground Water. Drought conditions of the past five years in Kansas and Oklahoma have raised serious questions regarding the maintenance of the farm population in the basins of the upper Arkansas and the Cimarron Rivers. These conditions might be improved by the establishment of irrigated tracts for subsistence crops to supplement cash income. The extent to which such tracts may be established safely cannot be determined until adequate ground water studies have been completed. These studies should include a determination of the extent of suitable water areas, the depth and type of aquifers, the amount of draw-down relative to accurately measured pumping, the rate of recharge, and the determination of a safe amount of withdrawal. These demonstrational projects could be undertaken immediately to show what crops can be grown under irrigation in western Kansas and Oklahoma, and to determine the best methods of handling such crops. Such demonstrational projects should be under the direction of the land-grant colleges and the Department of Agriculture, and should not be initiated until it has been shown that the states can and are prepared to protect the available ground water from overdraft.

PROJECT LIST - THE CANADIAN RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
GROUP A - IMMEDIATE 1. Investigation Projects					
Study of methods of disposing of salt water in the oil fields in the Canadian River basin in Oklahoma and Texas.	$ 10,000	$ 40,000	No		Five year study. Program contemplated.
Big Bend flats on South Canadian River in Dewey County, Oklahoma: Preliminary study of diversion dam and system for irrigating 25,000 acres.	5,000		No		
Canadian River Basin: Investigation of ground water supply for rural and urban needs throughout basin.	20,000	80,000	No		Five year program contemplated. Continuation of work begun by Texas Board of Water Engineers, New Mexico State Engineer and Oklahoma Division of Water Resources.
Canadian River Basin: Further studies of water use and control throughout basin.	50,000	50,000	No		Preliminary investigations by Corps of Engineers have been authorized for South Canadian in Oklahoma and for the North Canadian.
Mustang, Rabbit's Ear, Paloduro and Wolf Creeks in Texas: Preliminary investigation of reservoir sites for storing water for irrigation.	20,000		No		Several localities need water for irrigation.
Study of possibilities of irrigation systems corollary to Optima and Fort Supply reservoirs in Texas and in Beaver and Woodward Counties, Oklahoma.	50,000		No		

PROJECT LIST - THE CANADIAN RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
2. Construction Projects, General					
Canadian River Basin: Establishment and maintenance of stream gaging, precipitation and evaporation stations; silt observation stations and observation wells; and the correlation and analyses of the data obtained therefrom.	$ 30,000	$ 35,000	No		Additional data collection is as urgently necessary in the basin as any other studied heretofore.
Woodward County, Oklahoma: Fort Supply Reservoir on Wolf Creek for flood correction and storage.	1,000,000	1,585,000	Yes	Pub. 738	
La Cueva, New Mexico: Earth fill dam on the Mora River for retention of flood waters for irrigation.	476,000		No		Plans complete; core drillings have been made. Authorized for construction under WPA program, allocation not made; estimated cost covers dam and irrigation system.
Texas County, Oklahoma: Optima Reservoir on Beaver River for flood correction and storage.	1,000,000	530,000	Yes	Pub. 738	Further investigation in progress.
Colfax County, New Mexico: Completion of Miami Dam to insure cultivation of about 6,500 acres of fertile farm lands.	60,000				Preliminary plans and surveys made. Approximately $50,000 already spent by farmer's development company.
Clayton, New Mexico: Storage reservoir to augment urban water supply.	176,000				Authorized for construction under WPA program; allocation not made.
Quay and San Miguel Counties, New Mexico: Canal and lateral system on Conchas irrigation project, to irrigate 45,000 acres in vicinity of Tucumcari.	2,500,000	5,655,000			Detailed surveys have been made; funds for first year have been allocated by WPA.

PROJECT LIST - THE CANADIAN RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
2. Construction Projects, General (cont.)					
Cimarron, Harper and Texas Counties, Oklahoma: Wells near Boise City, Guyman, and LaVerne for irrigation purposes.	$ 50,000				Preliminary plans made.
Woodward County, Oklahoma: Reservoir and water mains for irrigating nurseries and for fire protection at field station of Bureau of Plant Industry.	50,000				Present water supply inadequate. Sketch plans have been completed.
Mora County, New Mexico: Improvement of Colmar irrigation system.	23,000		No		Plans completed.
Colfax County, New Mexico: Dam and reservoir at Maxwell site for storage of waste water and for irrigation purposes.	23,000		No		Plans completed.
Mora County, New Mexico: Eradication of malaria mosquito breeding areas by fill and drainage.	32,000		No		
Lincoln County, Oklahoma: Drainage for farm lands.	72,000		No		
Hughes County, Oklahoma: Drainage for farm lands.	84,000		No		
Colfax County, New Mexico: Repair and raise height of Springer Ditch Reservoir for irrigation of 6,000 acres under existing right.	55,000				Plans prepared. Approved for construction under WPA program.
Tucumcari, New Mexico: Conchas Dam and Reservoir for flood control, irrigation and water supply.	1,000,000	$ 3,750,000	Yes	Pub. 738	$4,750,000 estimate is amount required to complete project which is under construction.

PROJECT LIST - THE CANADIAN RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
2. Construction Projects, General (cont.)					
Demonstration project of use of well water for subsistence farming by installation of deep wells and irrigation system for 20 acre plots.	$ 20,000		No		Estimate assumes two projects in Oklahoma at $10,000 each. Withdrawal of water to be subject to adequate State control.
3. Construction Projects, Municipal Water Supply and Pollution Abatement					
Oklahoma City, Oklahoma: Improvements to supplement present water supply.	1,000,000		No		Cost of these improvements included in estimate for Fort Supply Reservoir
Shawnee, Oklahoma: Sewage treatment plant.	250,000				No treatment facilities at present.
Allen, Beaver, Blanchard, Depew, Eufaula, Gage, Haileyville, Hartshorne, Konawa, McAlester, McLoud, Morris, Norman, Purcell, Seminole, Shattuck, Stratford, Thomas, Watonga, Weleetka, and Woodward, Oklahoma; Roy, New Mexico; Borger, Canadian, Dumas, Perryton, Stinnett, Stratford, Texline, Whitedeer, Texas: Improvements to sewer systems and sewage treatment plants.	660,000				
Ada, Chandler, Jones City, Oklahoma: Improvements to sewer systems and sewage treatment plants.	210,000				
McAlester, Oklahoma: Water supply improvements.	193,000				
Oklahoma City, Oklahoma: Improvements to sewage disposal plant.	800,000				Preliminary plans made, after study by a board of consulting engineers.

PROJECT LIST - THE CANADIAN RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
3. Construction Projects, Municipal Water Supply and Pollution Abatement (cont.)					
Oklahoma City, Oklahoma: Improvements to city water system, including extension to purification, improvements at Lake Overholser Reservoir, and improvements to distribution system.	$1,000,000	$ 1,000,000			Preliminary plans made; no major improvement to system since 1923.
GROUP B - DEFERRED					
2. Construction Projects, General					
Colfax County, New Mexico: Improvement to Colfax Irrigation District.	75,000		No		Preliminary plans made.
Blaine County, Oklahoma: Reservoir on North Canadian for flood control and storage of water.	1,000,000	5,032,000	No		Estimate is approximate. Report on selection of exact site in preparation by Corps of Engineers.
Potter County or Hutchinson County, Texas: Flood protection reservoir at Amarillo site or Borger site on Canadian River.	1,000,000	3,325,000	No		Contingent upon whether Conchas Reservoir (now under construction) can give satisfactory flood protection without the additional reservoir.
Union County, New Mexico: Earth-fill dam at Claphan site for flood protection and irrigation; also 5 miles of canal.	100,000		No		Plans nearing completion.

PROJECT LIST - THE CANADIAN RIVER BASIN

PROJECT	ESTIMATED COST		AUTHORIZED BY CONGRESS	AUTHORIZING ACT	REMARKS
	FIRST YEAR	BALANCE TO COMPLETE			
2. Construction Projects, General (cont.)					
Colfax County, New Mexico: Reservoir on Urraca Creek, 10 miles west of Springer for furnishing supplemental water for irrigation of 1,500 acres.	$ 20,000		No		Plans prepared.
3. Construction Projects, Municipal Water Supply and Pollution Abatement					
Greenfield, Indianola, Morris, Okfuskee, Wetumka, Oklahoma: Water supply improvements.	251,000		No		
Borger and Dalhart, Texas: Water supply.	915,000		No		
GROUP C - INDETERMINATE					Further studies necessary including consideration of smaller reservoir at this site and study of other smaller reservoirs upstream. Cost estimate is for Okmulgee reservoir as studied in "308" report.
Okmulgee County, Oklahoma: Flood protection reservoir on Deep Fork River.	1,000,000	4,260,000	No		
Union County, New Mexico: Water control of Ute Creek for flood control and water conservation.	200,000		No		Plans in preparation.
Union County, New Mexico: Dam and storage reservoir at Greenville for flood protection.	100,000		No		Preliminary plans prepared.
Union County, New Mexico: Dam at Tramperos site for flood protection and storage.	300,000		No		Plans nearing completion.

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